From Past to Present: Investigating Retrofitted GPS Antennas for Multi-GNSS Functionality

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Introduction

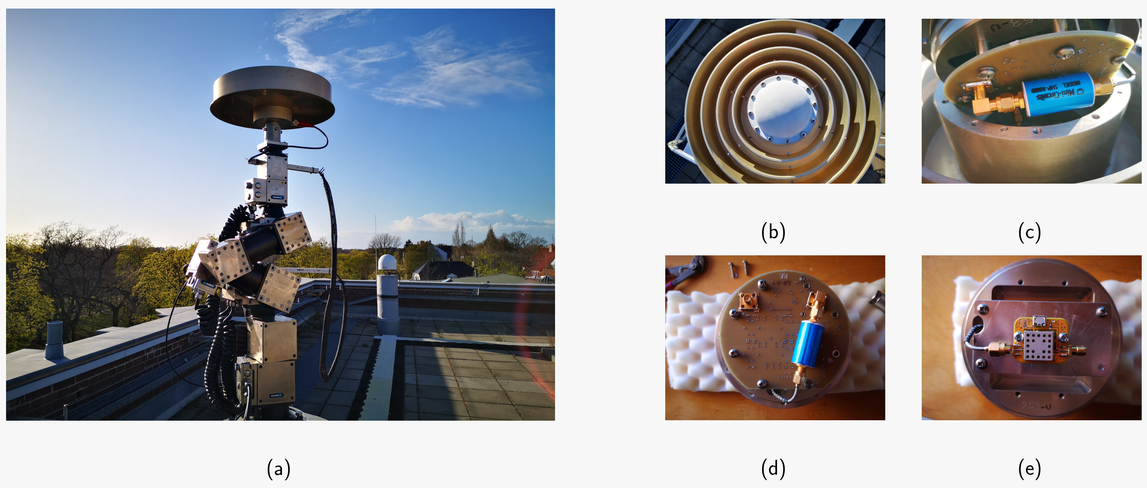
Challenge and scope of study

- Older geodetic-quality antennas with effective multipath reduction but outdated Low Noise Amplifiers (LNAs) limit the access to observations of new systems, frequencies, and modulations.
- Retrofitting: integration of hardware upgrade into existing antenna design for the transition from pure GPS-only to multi-GNSS.
- Previous *IGS master antenna* based on multiple calibrations of two specific antennas (#393 and #404) with more than 40 sets each (Schmid et al., 2015).

Research question

- How do changes of internal components gets physically detectable?
- Do these changes significantly alter the antenna's reception capabilities?
- How to assess the impact on observable data and derived position results?

Retrofitting - upgrading an AOAD/M_T

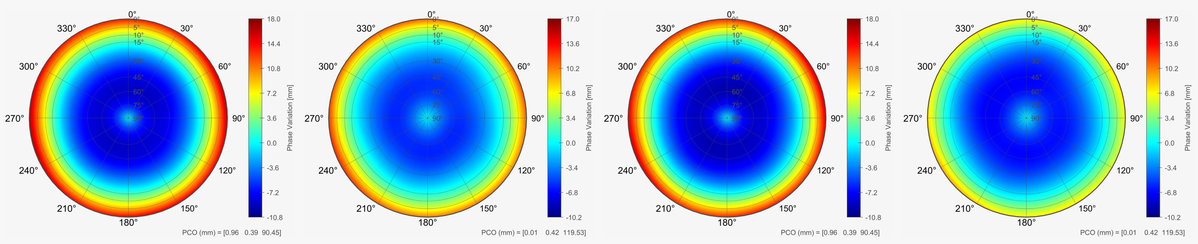


(a) (b) (c) (d) (e)

Figure 1: Calibration of retrofitted GPS antenna for multi GNSS, (a) calibration setup at the IfE facility, (b) top-view of dissembled antenna, (c,d) original 12 VDC LNA of AOAD/MT antenna, (e) new multi GNSS LNA.

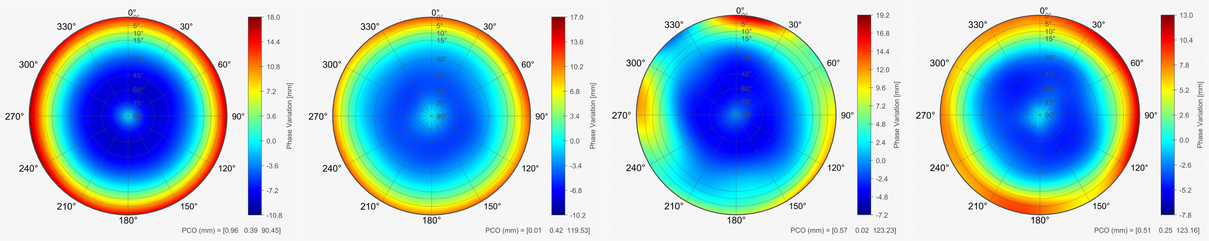
- The upgraded antenna is named `AOAD/M-T_RFI_GL, NONE`, where `RFI` stands for retrofit interior, and `GL` indicates GPIO Labs (manufacturer of the LNA).
- New LNA offers pre-filtering, a bias tee, and support for GPS L1 to L5, Galileo, Glonass, BeiDou, and Navic with 25dB gain.
- At IfE, antennas from GFZ have been evaluated (#317, #354) and compared to IGS type-mean and original data of previous IGS master antenna (#404).

Calibration results for #317 (original and upgrade)



(a) GPS L1 (b) GPS L2 (c) Glonass L2 (d) Glonass L2

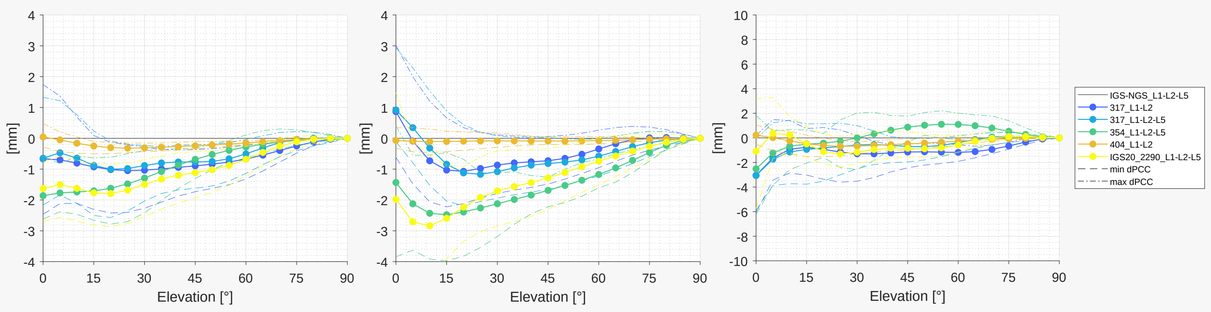
Figure 2: Calibration Results of legacy systems and frequencies of AOAD/M_T NONE (serial number: #317).



(a) GPS L1 (b) GPS L2 (c) Galileo E5 (d) Galileo E8

Figure 3: Calibration results of retro-fitted AOAD/M-T_RFI_GL NONE for selected systems and frequencies (serial number: #317).

Comparisons on observation domain



(a) GPS L1 (b) GPS L2 (c) GPS IF-LC (L1/L2)

Figure 4: Comparison of differential phase center corrections (ΔPCC) of upgraded (317-L1-L2-L5) and original (317-L1-L2) LNA at antenna #317 with antennas #404 (AOAD/M_T, NONE) and #354 (AOAD/M_T_RFI_GL, NONE) as well as published type means from NGS (IGS-NGS-L1-L2-L5) and IGS (IGS20_2290_L1-L2-L5). For differentiation, the ΔPCC for all antennas are referred to the phase centre offset (PCO) of the first antenna.

Statistics and scalar measures

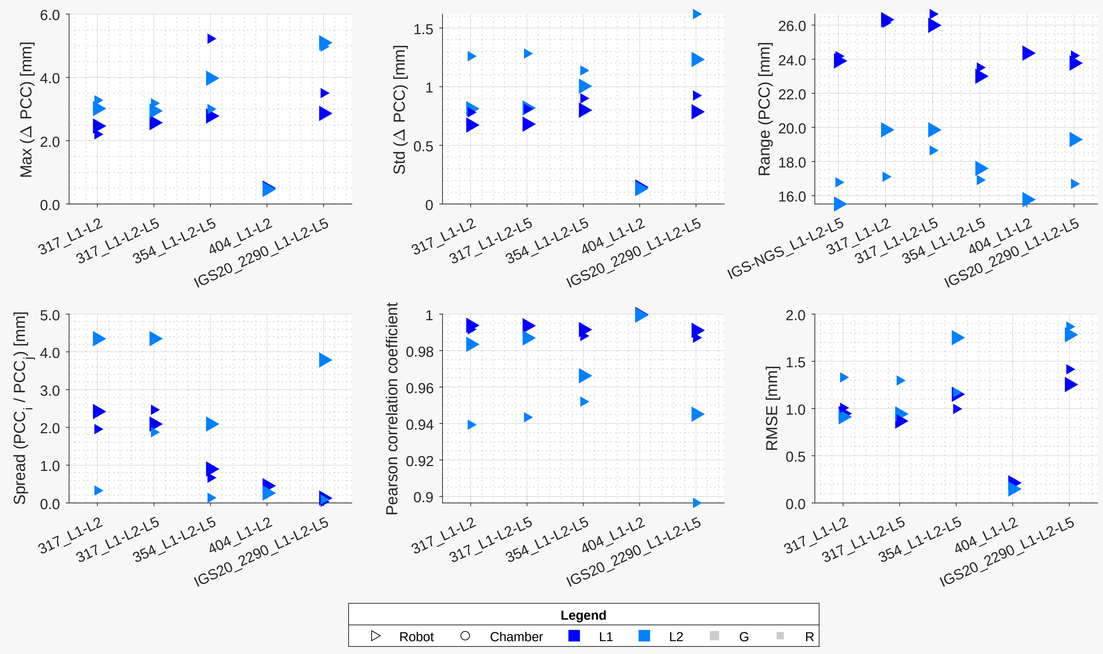


Figure 5: Scalar metrics (Kersten et al., 2022) facilitate the verification of the impact of LNA modifications on phase center corrections for both legacy frequencies and new systems and frequencies at upgraded antennas.

Position domain

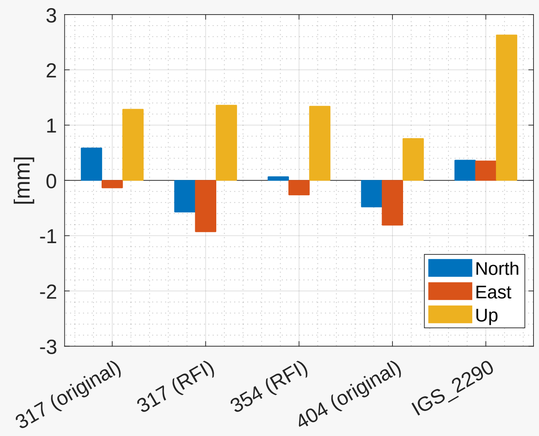
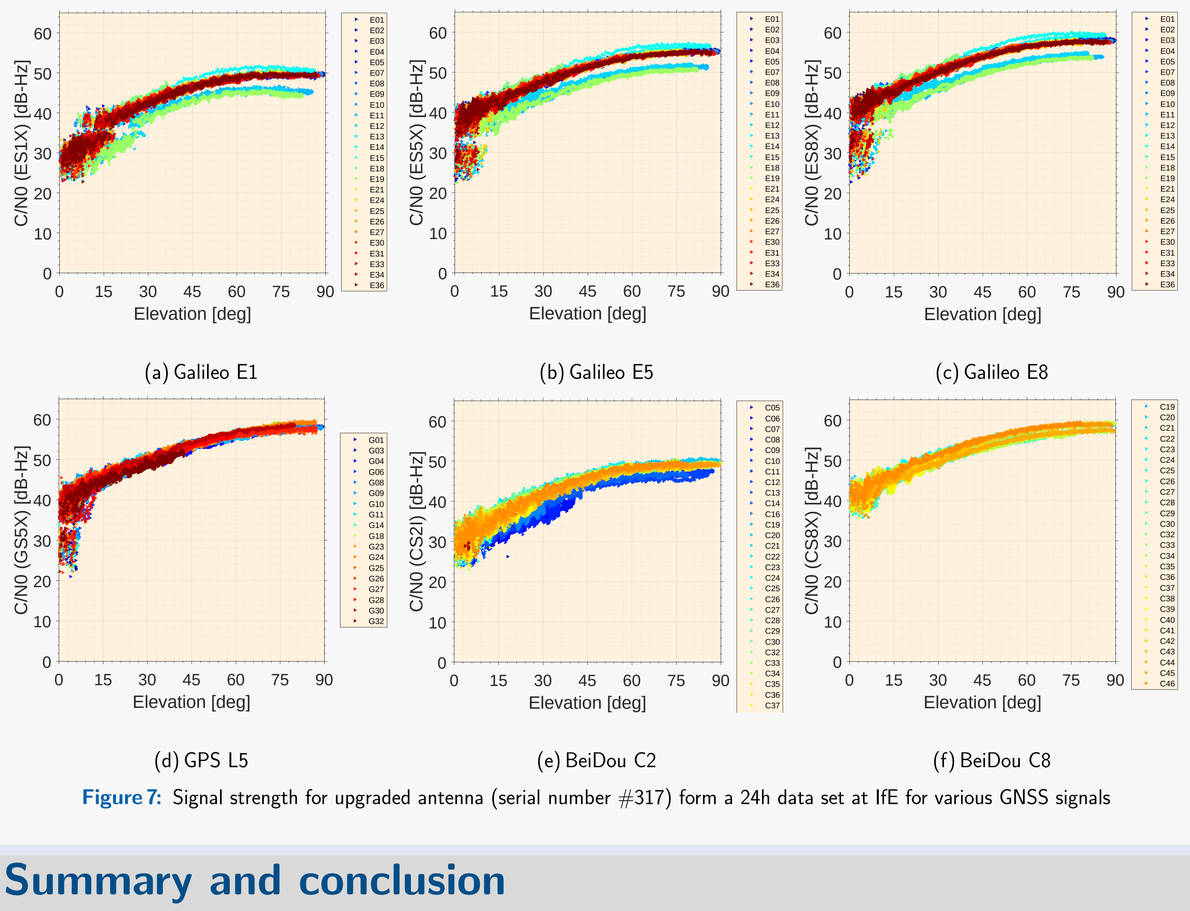


Figure 6: Position deviations w.r.t. AOAD/M-T NONE (IGS_2290)

Assessing PCC effects for changed LNA

- Analytical approach (Kröger et al., 2022), ionosphere free LC (G01/G02), mid latitudes, 24h
- Differences w.r.t. AOAD/M_T NONE type mean (original PCCs)
- Original LNA and upgrade show minimal deviations among each other (cf. #317, #354 in Fig. 1)

Observation domain



(a) Galileo E1 (b) Galileo E5 (c) Galileo E8

(d) GPS L5 (e) BeiDou C2 (f) BeiDou C8

Figure 7: Signal strength for upgraded antenna (serial number #317) form a 24h data set at IfE for various GNSS signals

Summary and conclusion

- Upgrading existing GPS-only JPL choke ring antennas is beneficial for multi-GNSS compatibility.
- Differences were found between antennas #317 and #354, further calibration of additional models is needed for deeper insights.

References

Kersten, T., J. Kröger, and S. Schön (2022). "Comparison concept and quality metrics for GNSS antenna calibrations". In: *Journal of Geodesy* 96.7. DOI: 10.1007/s00190-022-01635-8.

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