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# Current Research Activities at the IfE Antenna Calibration Facility

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## Variation of the Code-Phase by GNSS Antennae?

- Variations of the Carrier-Phase Center are known and can be calibrated in the field using the *Hannover Concept of absolute Antenna Calibration*
- The current findings at Institut für Erdmessung (IfE) suggest that
  - Variation of Code-Phase (GDV) exits and *can* degrade the accuracy of code based applications (i.e. landing approaches, time and frequency transfer)
  - magnitude of GDV depends on individual antenna design
  - GDV *can be* azimuth and elevation dependent
  - Variations of the Code-Phase are specific for the used frequency / signal

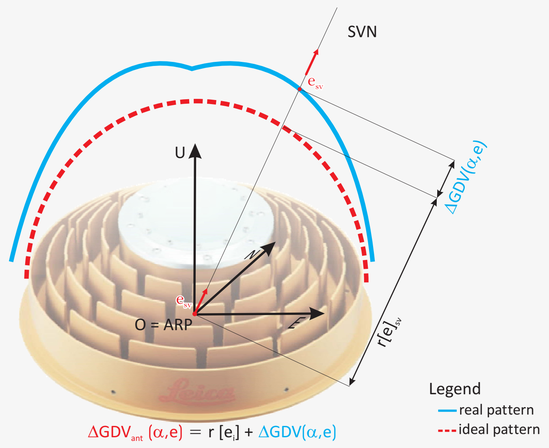



**Fig. 1:** Principles of Code-Phase Variation w.r.t. antenna body frame.

## Analysing the Variation of the Code-Phase

### Setup for Analysis

- static setup on a short baseline
- identical receiver and common clock with
- several antenna with different Code-Phase Variation properties
- duration of 5 hours @ 1 Hz sampling rate

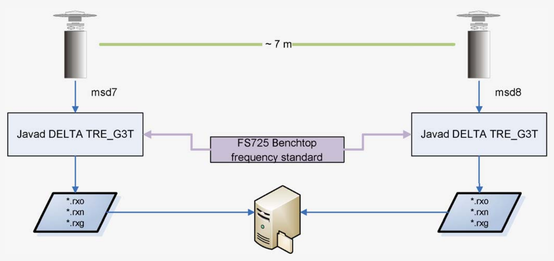
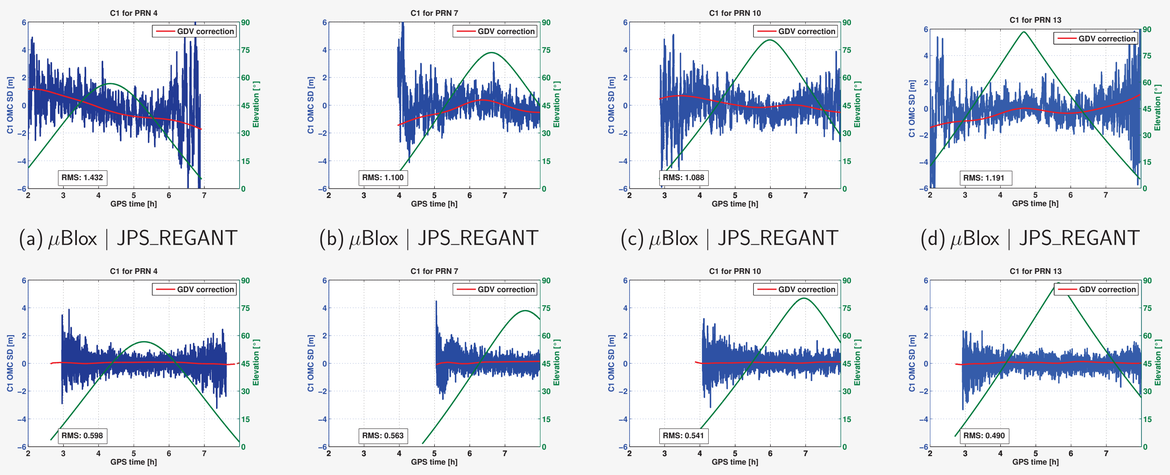



**Fig. 2:** Static analysis at the Laboratory Network at the IfE rooftop.

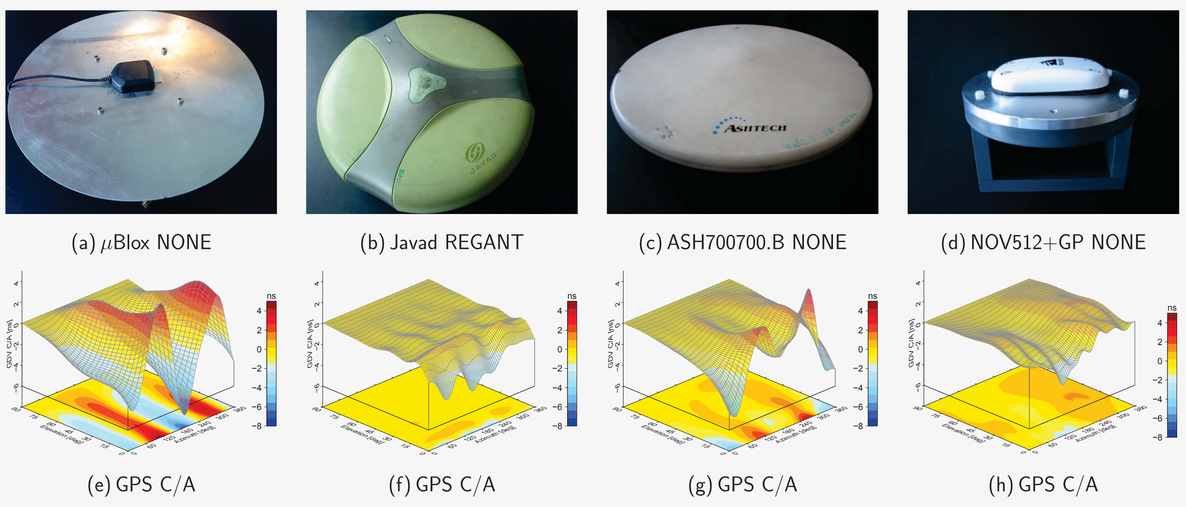



(a) $\mu$Blox | JPS_REGANT (b) $\mu$Blox | JPS_REGANT (c) $\mu$Blox | JPS_REGANT (d) $\mu$Blox | JPS_REGANT

(e) TRM59900.00 | LEIAR25.R3 (f) TRM59900.00 | LEIAR25.R3 (g) TRM59900.00 | LEIAR25.R3 (h) TRM59900.00 | LEIAR25.R3

**Fig. 3:** Observed Minus Computed (OMC) Inter-Station Single Differences (SD) for a short baseline in common clock mode. The configuration in (a-d) shows obvisouly a systematic effect that varies. This is not true in the configuration (e-h).

## Experimental Results for GPS C/A Code-Phase Variation

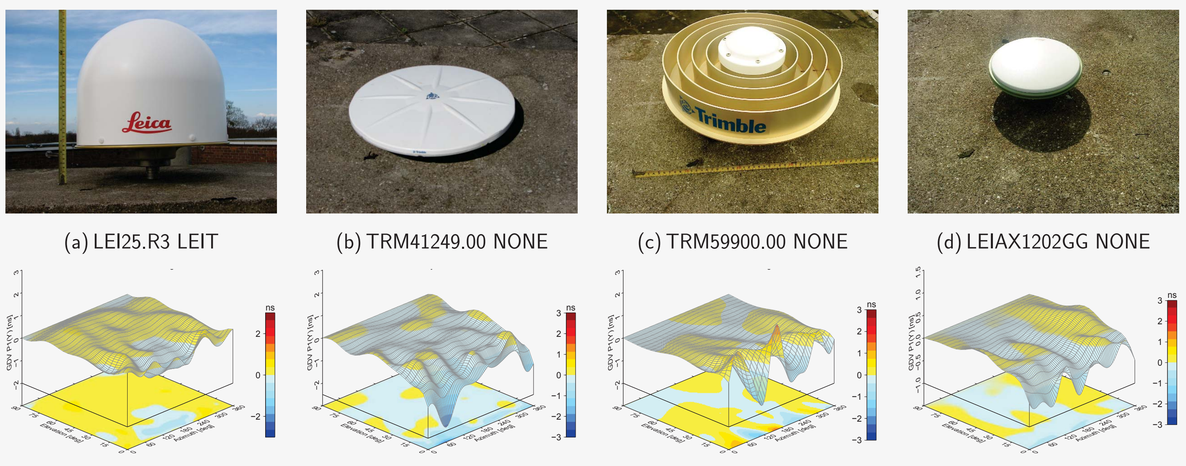



(a) $\mu$Blox NONE (b) Javad REGANT (c) ASH700700.B NONE (d) NOV512+GP NONE

(e) GPS C/A (f) GPS C/A (g) GPS C/A (h) GPS C/A

**Fig. 4:** Determined GDV for several antenna for the C/A Code, 1 ns ≅ 0.30 m.

## Experimental Results for GPS P1 and GPS P2 Code-Phase Variation



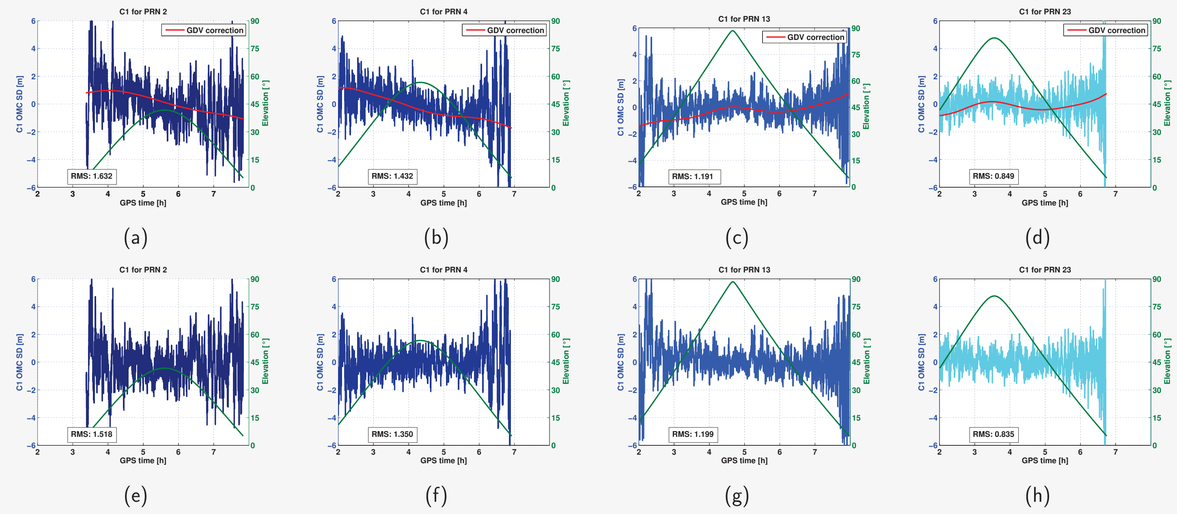

(a) LEI25.R3 LEIT (b) TRM41249.00 NONE (c) TRM59900.00 NONE (d) LEIAX1202GG NONE

(e) GPS P1 (f) GPS P1 (g) GPS P1 (h) GPS P1

(i) GPS P2 (j) GPS P2 (k) GPS P2 (l) GPS P2

**Fig. 5:** Determined GDV for several antenna and different frequencies as well as signals, 1 ns ≅ 0.30 m.

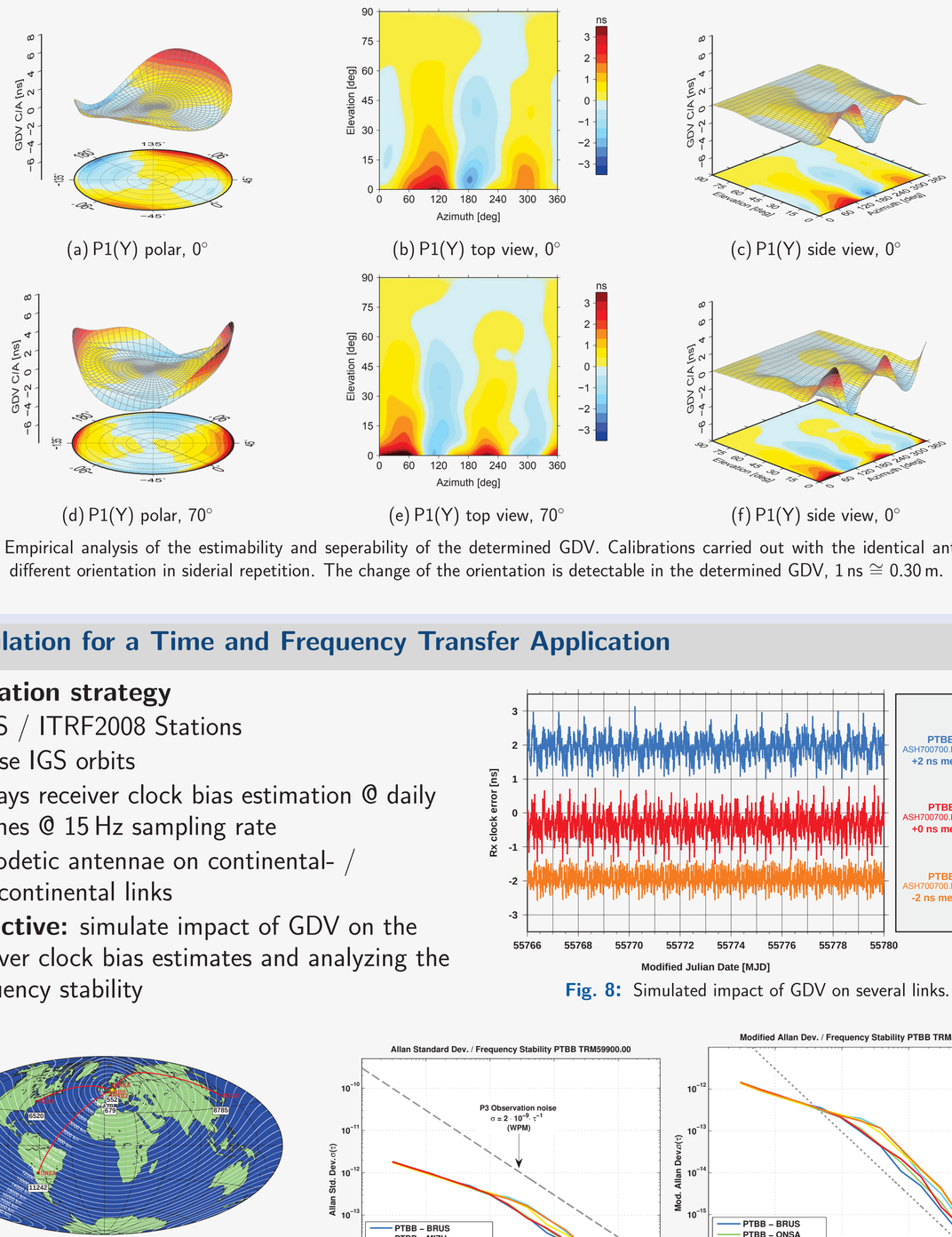
## Verification of determined Code-Phase Variations




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

(e) (f) (g) (h)

**Fig. 6:** Applying the determined Code-Phase Center Variation as corrections along the line-of-sight of the OMC SD for every Satellite, visible on the short baseline from Figure 2.




(a) P1(Y) polar, 0° (b) P1(Y) top view, 0° (c) P1(Y) side view, 0°

(d) P1(Y) polar, 70° (e) P1(Y) top view, 70° (f) P1(Y) side view, 0°

**Fig. 7:** Empirical analysis of the estimability and seperability of the determined GDV. Calibrations carried out with the identical antenna but different orientation in siderial repetition. The change of the orientation is detectable in the determined GDV, 1 ns ≅ 0.30 m.

## Simulation for a Time and Frequency Transfer Application

### Simulation strategy

- 7 IGS / ITRF2008 Stations
- precise IGS orbits
- 14 days receiver clock bias estimation @ daily batches @ 15 Hz sampling rate
- 4 geodetic antennae on continental- / intercontinental links
- **objective:** simulate impact of GDV on the receiver clock bias estimates and analyzing the frequency stability



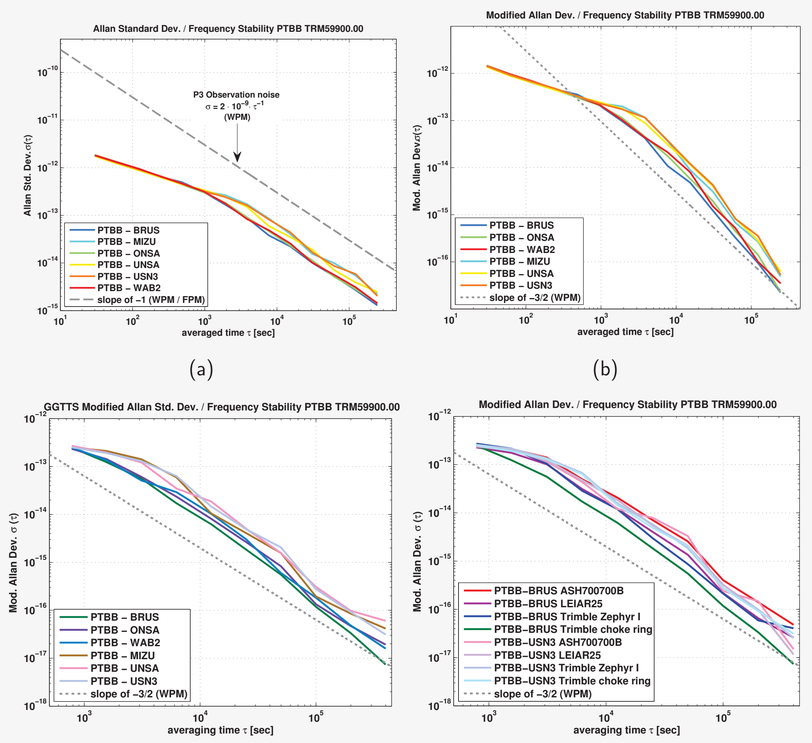

**Fig. 8:** Simulated impact of GDV on several links.




**Fig. 9:** Distribution of used stations.

### Findings

- GDV introduce offset in code based time comparison of 0.4 - 0.5 ns
- for *geodetic antennae* GDV with low magnitude detected
- on long links magnitudes due to different satellite geometry and GDV property
- impact is below the P3 observation noise (cf. Figure 10(a))
- GDV introduce a white noise process (cf. Figure 10(b))




(a) (b)

(c) (d)

**Fig. 10:** Frequency stability of several links equipped with identical antenna (a-b) and CGGTTS formatted time series for different antennae (c-d).

## Conclusions and further challenges

- GDV currently not a limiting factor for code based time and frequency comparison
- new signal generations (E5a,b, AltBOC) will decrease code noise and GDV *may* become an issue

### References

**Kersten, Tobias et al. (2012)**. On the Impact of Group Delay Variations on GNSS Time and Frequency Transfer. In: *Proceedings of the 26th European Frequency and Time Forum (EFTF)*, April 24.-26. 2012, Gothenburg, Sweden, 8p.

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