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An alternative method for determining GPS receiver biases

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Introduction

Precise Point Positioning (PPP) with undifferenced phase measurements in comparison to traditional differential approaches is highly attractive, since the effort on the user side can be reduced to minimum, e.g. no reference stations are needed. The quality of the obtained position solutions is comparable to those obtained from differential approaches.

Receiver phase biases (RPB) are one of the most limiting factors for PPP, due to the high correlation with the ambiguities during the estimation process, [Laurichesse et al., 2009]. Furthermore, [Wang and Gao, 2007] showed that RPBs are very complex to model since they can change completely by a loss of lock (LL).

This contribution presents an alternative method to estimate RPBs for carrier phase of different GPS/GNSS receivers and signals w.r.t. a reference receiver. Receiver phase biases are estimated on a zero baseline and in combination with a very stable and precise clock (H-Maser).

Approach and Concept

- Based on receiver-to-receiver single differences ($\Delta\Phi^j_{A,B}$) per satellite j and satellite arc resp.

$$\Delta\Phi^j_{A,B} = \underbrace{c(\delta t_A - \delta t_B)}_{\text{constant per switch-on \& freq dependent}} + \underbrace{\lambda(N^j_A - N^j_B)}_{\text{constant per satellite arc}} + \underbrace{d^j_{\Phi,A} - d^j_{\Phi,B}}_{\text{constant \& frequency dependent}} .$$

- Eliminate and reduce most of GNSS error terms by using a zero baseline and a common clock approach (ultra stable H-Maser, refer to set-up in Figure 1).
- Remove potential drifts and quadratic terms (temperature effects) and separate:
  1. differential receiver clock error $c\Delta\delta t_{AB}$,
  2. differential ambiguity term $\lambda\Delta N^j_{AB}$.
- Estimate the initial inter-frequency receiver phase bias (RPB) (L_2-L_1) $\Delta d^j_{\Phi_{AB}}$.

Methodology and Experiment

Set-up of complete data-set

- Zero baseline with Leica AX1202GG Antenna.
- Common clock scenario with ultra stable H-Maser to reduce variations of receivers internal oscillator.
- Continuous dataset for 5 days (DOY359-363, 2008) without switching off any receiver.

Abbrev.	Receiver	Signal
JAV1/2	Javad Legacy	L1C, L2P
GTR1/2	DiCom GTR50	L1P, L2P
LEI1/2	Leica GRX1200GG Pro	L1C, L2P
TRS1/2	Trimble NetRS	L1P, L2P

Table 1 : Abbreviations during experiment.

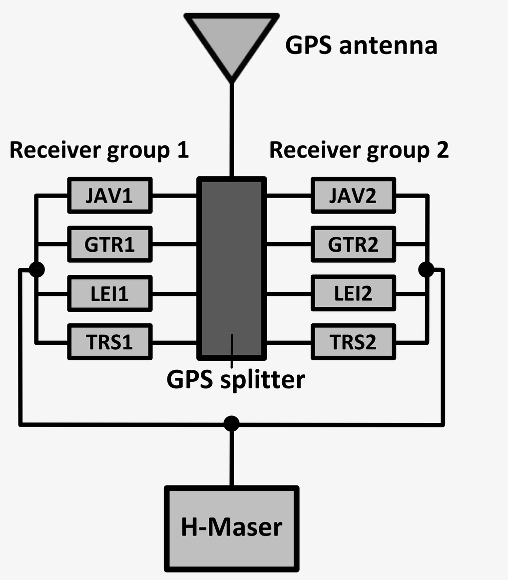
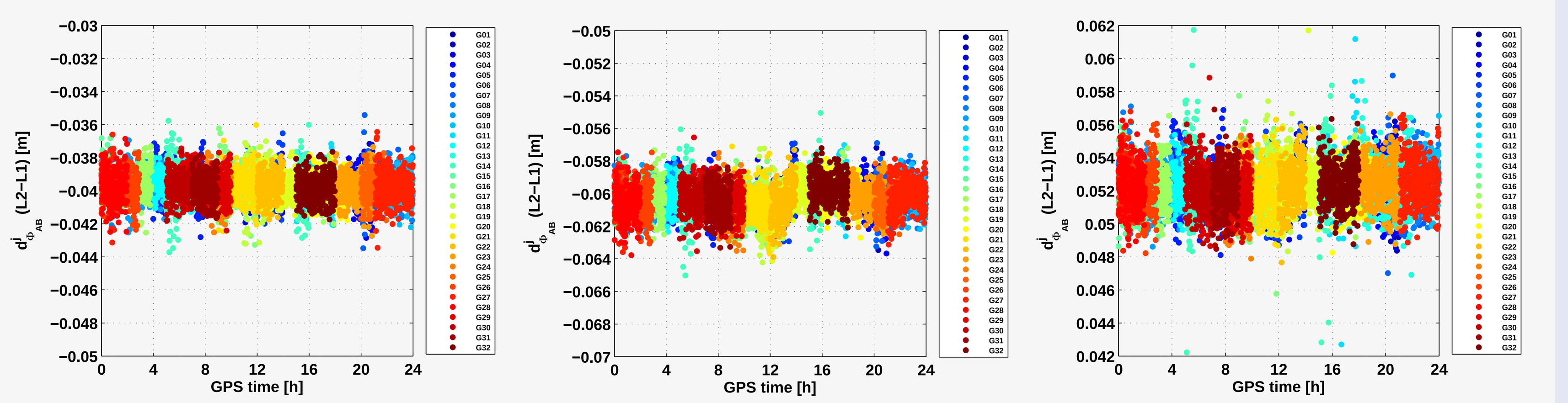


Figure 1 : Zero baseline set-up for determination of initial inter-frequency receiver phase biases (RPBs).

Processing of selected combinations

- Selected baselines refer to JAV1 as reference.
- Detection and correction of cycle slips.
- Fixing integer valued ambiguities.



(a) JAV2-JAV1 (b) LEI1-JAV1 (c) TRS1-JAV1

Figure 2 : Daily batches of inter-frequency RPB observables, selected configurations for DOY359, 2008.

Receiver Phase Bias (RPB) Determination

Implementation of two strategies to test the Concept:

Least Squares Adjustment (LSA): Estimate RPBs with individual receiver clock error for each satellite arc.

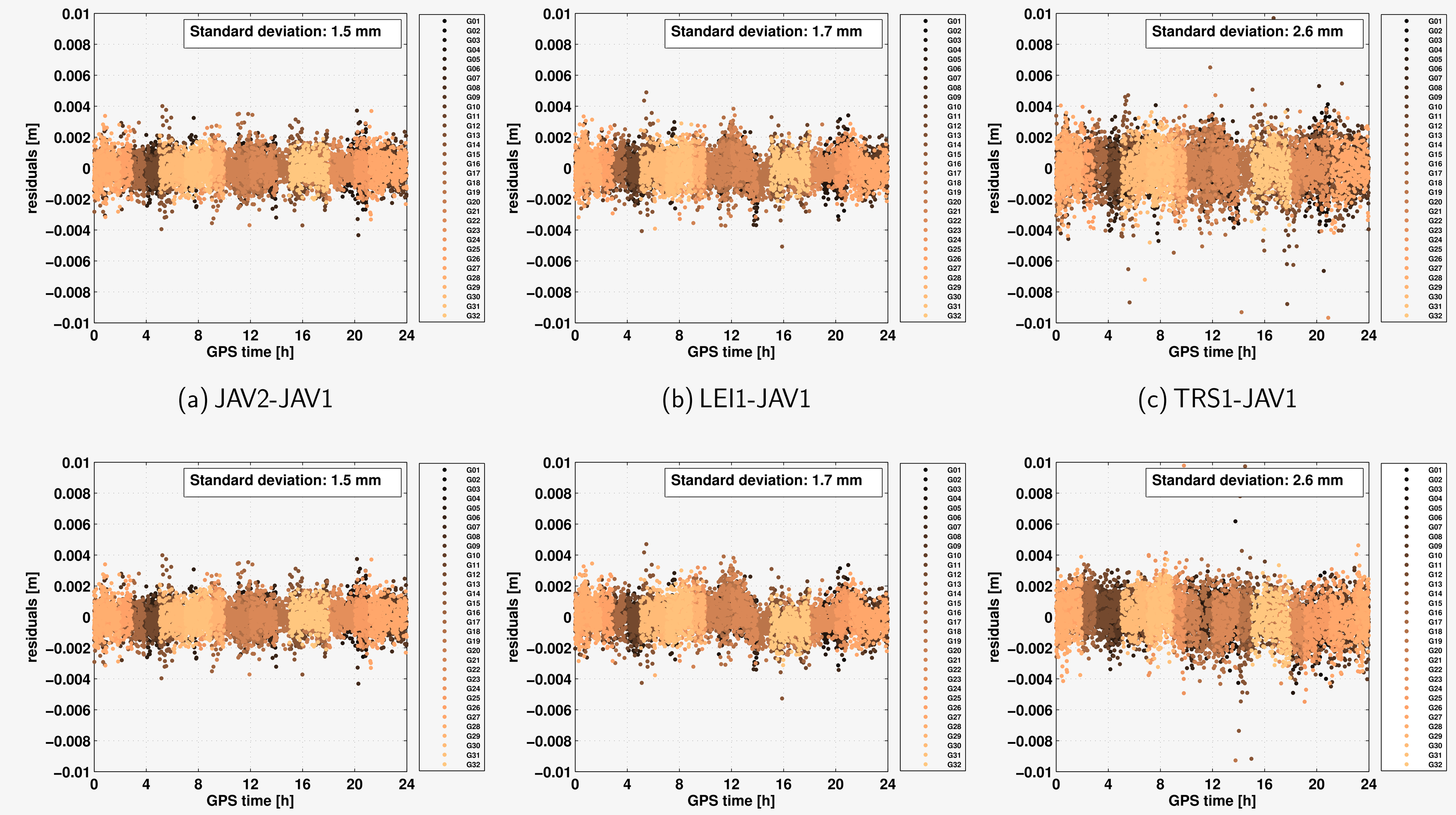
Sequential Least Squares Adjustment (S-LSA): Accumulate normal equation system (NEQS) to calculate one unique receiver clock error for all satellite arcs.

- Both strategies succeed and lead to the same results as well as same residuals.

Daily solutions

lfd. No.	DOY	L2-L1 Bias $\Delta d^j_{\Phi_{AB}}$ JAV2-JAV1 [m]	LEI1-JAV1 [m]	TRS1-JAV1 [m]	TRS2-JAV1 [m]
1	359	-0.040	-0.060	+0.052	+0.029
2	360	-0.040	-0.059	+0.053	+0.030
3	361	-0.040	-0.057	+0.054	+0.030
4	362	-0.041	-0.056	+0.055	+0.030
5	363	-0.042	-0.054	+0.054	+0.029

Table 2 : Estimated inter-frequency receiver phase biases for selected receiver combinations and five days.



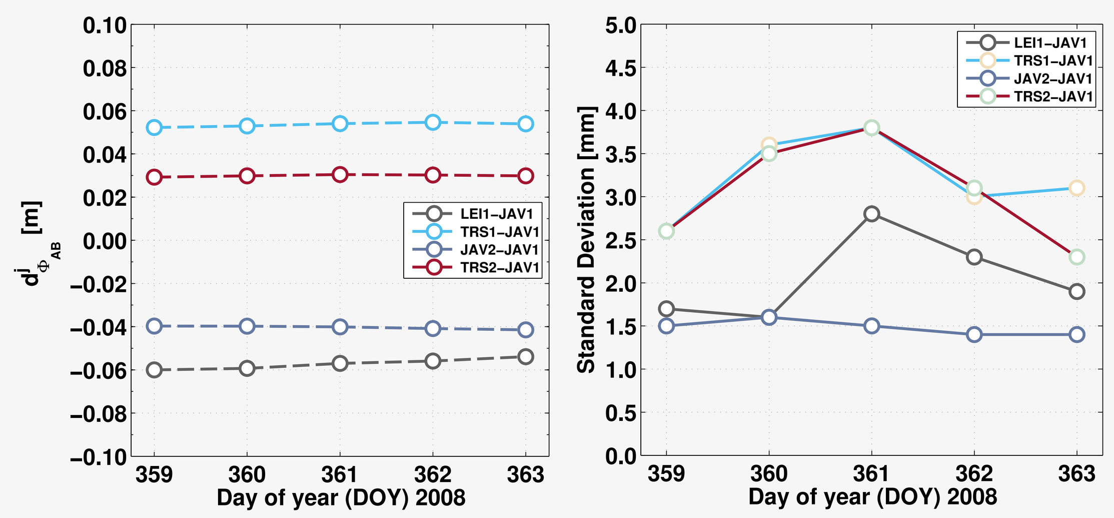
(a) JAV2-JAV1 (b) LEI1-JAV1 (c) TRS1-JAV1

(d) JAV2-JAV1 (e) LEI1-JAV1 (f) TRS1-JAV1

Figure 3 : Residuals of estimated inter-frequency RPBs of DOY359 for selected combinations using least squares adjustment (LSA), shown in (a-c) and sequential least squares (S-LSA), shown in (d-f).

Repeatability of daily solutions

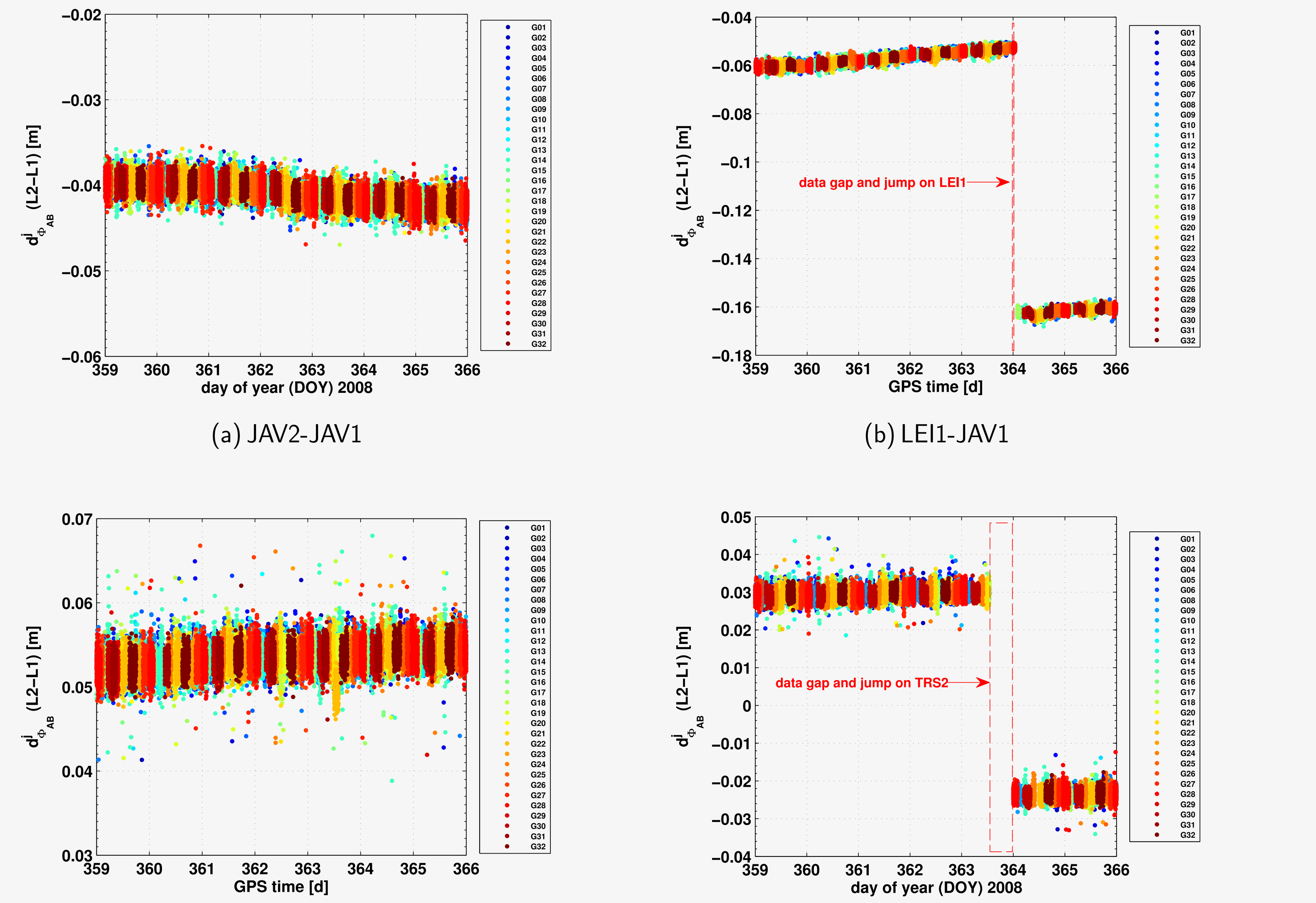
- Initial inter-frequency RPBs are stable for DOY359-363 within the precision of carrier phase observation. ($\approx$ 2 mm)
- Magnitudes for standard deviation of residuals in the range of 1.5 - 3.8 mm.
- Unexpected drift for combination LEI1-JAV1.



(a) (b)

Figure 4 : Receiver phase biases (RPBs) for selected receiver combinations (a) and standard deviations of estimated RPBs (b).

Stability over one week



(a) JAV2-JAV1 (b) LEI1-JAV1

(c) TRS1-JAV1 (d) TRS2-JAV1

Figure 5 : Stability of inter-frequency RPBs for seven days and selected combinations.

Conclusions and Further Work

Conclusions

- Concept verified to estimate inter-frequency RPBs in daily batches.
- Estimated values are repeatable (refer to Figure 4(a)) and magnitudes are below 2 mm.
- Standard deviations of each daily batch solution in the range of 1.5 - 2.5 mm for JAV1-JAV2 and LEI1-JAV1 as well as 2.5 - 3.8 mm for JAV1-TRS1/2 combination

Challenges

- Stability for more than one day strongly depends on environment (temperature, etc.), as shown in Figure 5.
- Unknown internal receiver implementation; challenging for handling complete loss of lock (LL) (refer to Figure 5(b), 5(d)), change of initial RPBs as well as tracking loop parameters.
- Tracking behavior (e.g. L2C/L2P tracking problem) and correct signal assignment.

Further Work

- Concept of estimating complete set of RPBs (model with several rank defects, modeling unique system).
- Further knowledge of receiver technology to correctly verify and determine RPBs.
- Test Concept with extended data set and additional tests (tracking loops, etc.).
- Use calibrated *GPS timing receiver* (known delays and receiver clock) for RPB calibration .

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