Inter-signal/frequency biases and their meaning for multi-constellation multi-frequency processing

TECHNISCHE UNIVERSITÄT DARMSTADT

M. Becker, E. Schönemann, T. Springer, F. Dilssner, W. Enderle and R. Zandbergen

Introduction

In the recent years, GPS only dual-frequency GNSS receivers are increasingly developing into multi-constellation, multi-frequency receivers. This development poses a new set of technical challenges. A key factor for precise GNSS applications is the stability of observation-system induced inter-frequency/signal delays (USDs) for code (UCDs) and phase (UPDs). If estimated from GNSS tracking data, unmodelled effects (antenna delays, atmosphere, multipath) alias into the USD parameters.

Sources of bias variations

Even in the case of temperature-stabilised environments, the internal receiver temperature may not remain constant in time. Moreover, the internal receiver temperature is influenced by internal receiver heating as, for example, caused by the Central Processing Unit (CPU). Figure 1 shows an example for the impact of file download on the internal receiver temperature.

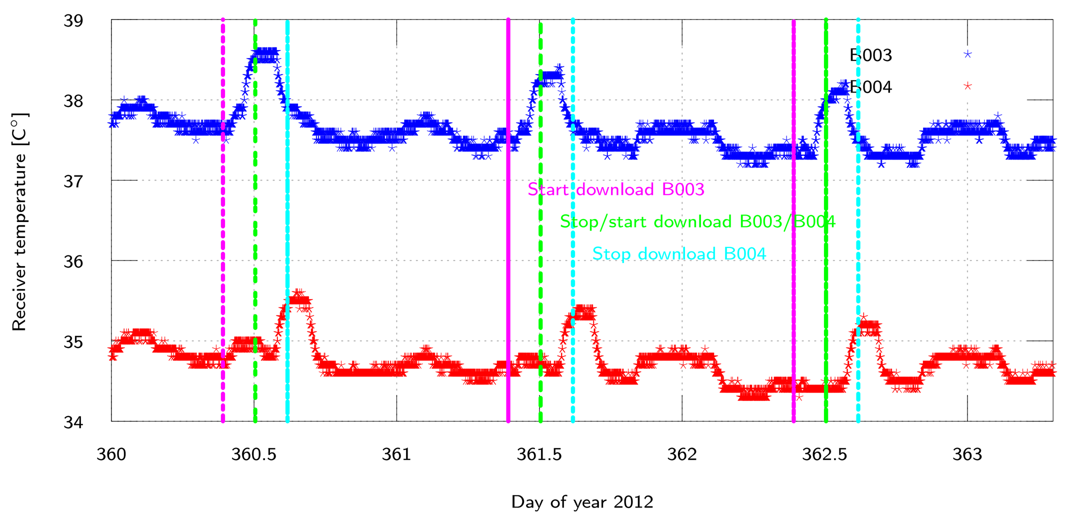

Figure 1: Impact of receiver load on the internal temperature.

It is clearly recognisable that the internal receiver temperature increases during the file download by approximately 1 C°. This example shows that even in a temperature-controlled environment the internal receiver temperature can vary as a consequence of changes in the CPU load.

To demonstrate the impact of such receiver temperature variations on the USDs, five different receivers of three different types (A001/A002, B003/B004, C005) were exposed to a strong temperature change. The test receivers were connected to a GNSS signal generator via a signal splitter. This setup ensures equal input signals, free of atmospheric, multipath and antenna delays. The differential code biases (DCBs) appeared to be insensitive to temperature changes for all tested receivers. A different behaviour was observed for the phase observations. Figure 2 depicts the differential phase residuals (L2/L5 vs. L1) of all receivers with reference to the internal receiver temperature.

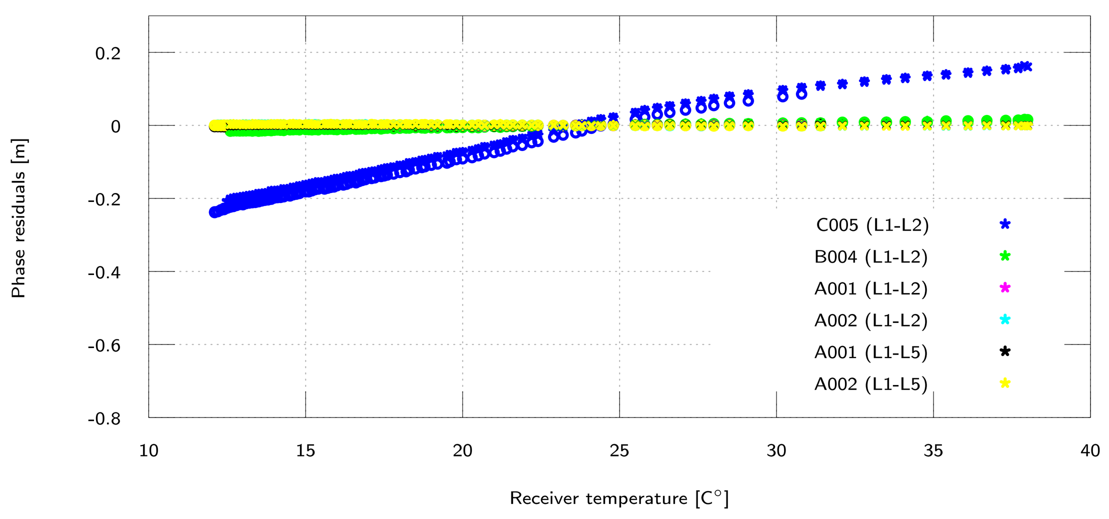

Figure 2: Temperature behaviour of relative receiver phase delays.

It becomes obvious that, for some receivers, the differential phase delays show significant drift rates up to 17 $mm/C°$, whereas, for others, they remain constant.

In fact, the observation-system comprises more components than the receiver itself (environment, antenna, cables, splitter, receiver). Therefore, the experiments were extended to real observations in a natural environment. The basic prerequisite for this experiments were identical atmospheric conditions for all receivers. This was ensured by a zero-/short-baseline setup for the test receivers. Under this condition, it was possible to determine relative DCB differences to a reference receiver (here: A001).

Different test scenarios were run to show the relative DCB behaviour as a response to changes in the environment, for different antennas or receiver settings. A brief overview on the different scenarios run is given in table 2.

SC	Description
1	baseline
2	multipath mitigation
3	baseline
4-8	environment + antennas

Table 1: Scenario descriptions.

Figure 3 shows the DCB differences against the reference receiver.

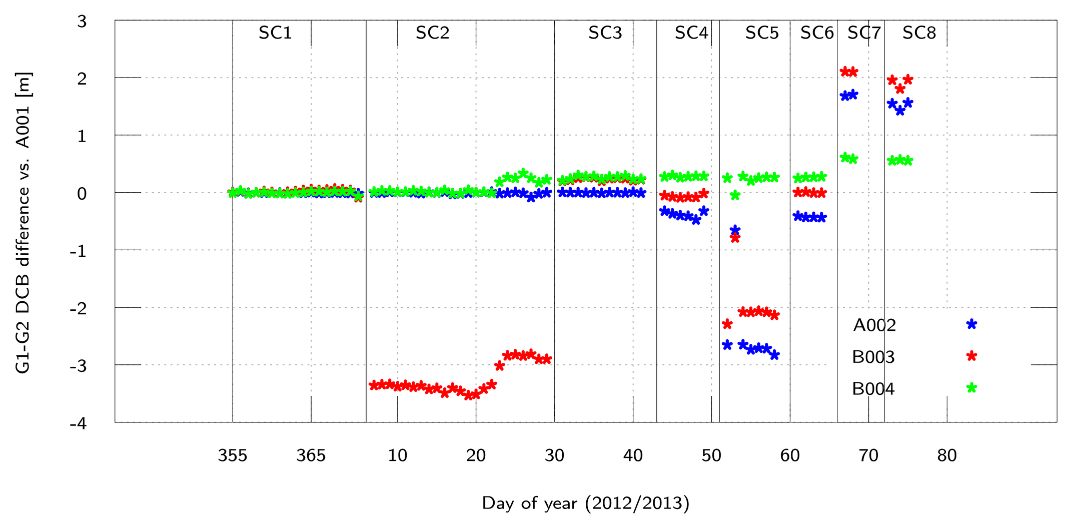

Figure 3: Stability of receiver dependent DCBs.

The experiments demonstrated constant daily DCBs estimates for unchanged scenarios (hardware, environment, settings).

Impact of signal delays and their variations on the processing

Considering the observation weighting (code vs. phase) and the missing absolute reference of phase measurements (float ambiguities), the constant code delays are decisive for the realisation of the absolute clock and ionosphere level. Different solutions exist for the handling of these delays making them uncritical for most applications.

Significantly more important are variations in the differential phase delays. For the analysis of the results from the temperature experiments, three different dual-frequency scenarios were set up (table 2).

SC	Description
PAI	ionosphere free PPP
PAR	raw observation PPP (ionosphere estimated)
RER	PPP waiving on iono. handling

Table 2: PPP scenarios

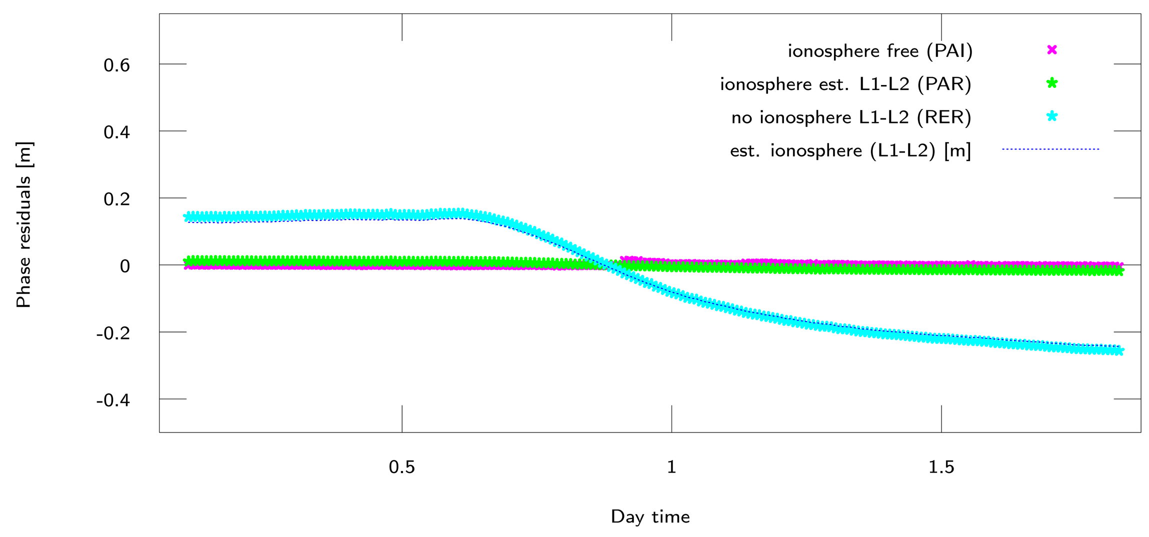

Figure 4: Impact of differential UPD drifts on adjusted phase observations.

Figure 4 shows that in the case of dual-frequency observations differential phase drifts can be absorbed by the ionosphere correction and the clock offset estimate (not displayed). This, in turn, affects the adjusted code observations (figure 5).

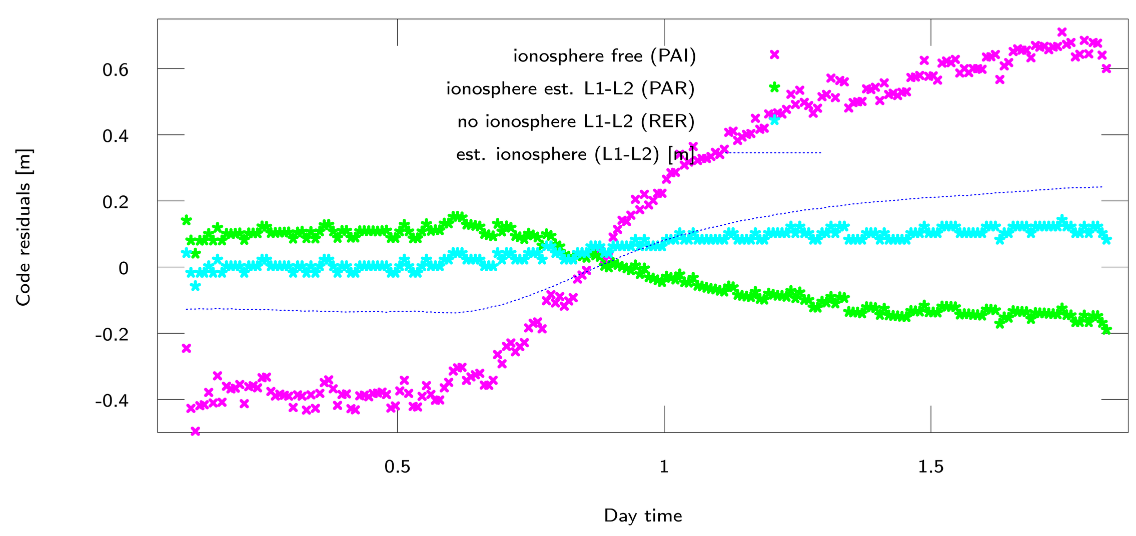

Figure 5: Impact of differential UPD drifts on adjusted code observations.

It shows that the required adaption of clock offset and ionosphere corrections influences the adjusted code observation.

In the case of raw observation based PPP the code residuals show the characteristics of the actual delay variations, induced by the phase observations. For ionosphere free code residuals the effect is amplified.

In the case of observations on more than two frequencies or from different GNSS, total absorption of differential delay variations is not possible. This allows to uncover hidden effects, but at the same time requires stable differential UPDs to ensure a consistent processing of all observables. An example showing satellite phase bias instabilities is given in figure 6. It shows the raw phase-observation residuals for L1, L2 and L5 to satellite GPS62 of a global 87 station network estimation. The systematic pattern in L5 is caused by differential phase bias variations in the satellite. If it is in the size as detected here, triple frequency observations are not usable for precise applications. In general the lumped effect of satellite and receiver phase biases plus other unmodelled effects may show up in any of the residuals L1, L2 or L5 alternatively. It is determined by the relative weighting of the observables.

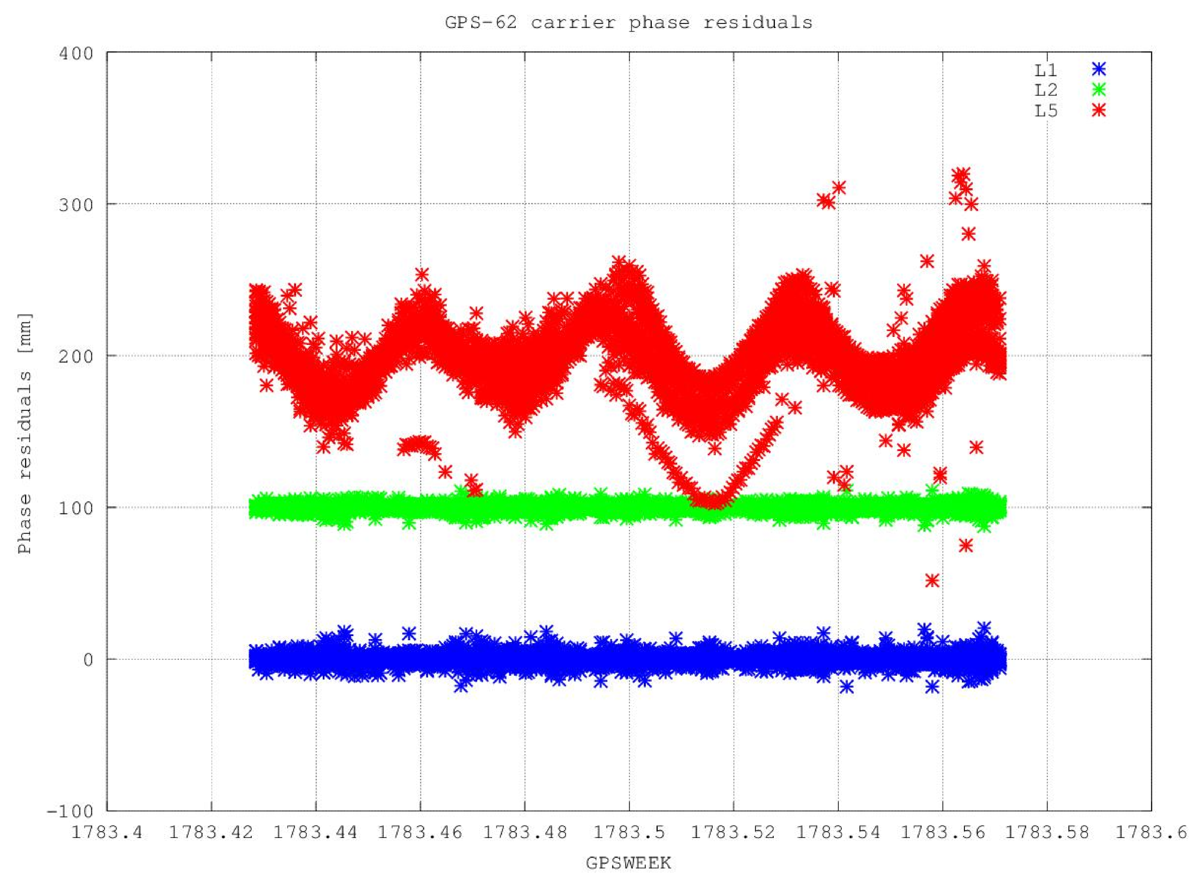

Figure 6: Raw Observation Residuals for GPS-62, DOY 71, 2014, 87 Stations.

Because of the existing correlation between UPDs, clock offsets and ionospheric estimates, the stability of UPDs is of particular importance for precise timing applications and ionospheric research.

Conclusions

- Receivers showed constant DCBs for unchanged setups.
- Modifications in the setup causes the DCBs to change (Meters, for active multipath mitigation (some rec.) or antenna changes).
- CPU load can cause the receiver temperature to change.
- Differential phase delay drifts (L1-L2) up to 17 $mm/C°$ were shown for individual receivers.
- For dual-frequency point positioning exclusively interested in coordinates, delay variations are of minor importance.
- Triple Frequency raw analysis reveals that uncalibrated delays in satellite and receiver seriously deteriorate the solutions in the several cm-range.
- Stability of differential delays is essential for timing or multi-frequency/GNSS applications.

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Institut für Geodäsie
Franziska-Braun-Straße 7
64287 Darmstadt
✉ becker@psg.tu-darmstadt.de

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