Precise Point Positioning for characterization of GPS L5 biases using M-GEX data

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Introduction

The latest generation GPS-IIF satellites transmit the new civil signal on the L5 frequency (1176.42 MHz), in addition to the legacy signals on L1 (1575.42 MHz) and L2 (1227.6 MHz). The benefits of the third frequency include better reliability and redundancy for navigation users. Additionally, for applications that require the utmost accuracy, triple-frequency Precise Point Positioning (PPP) can be performed. The purpose of this work is to demonstrate how to integrate the new L5 pseudorange and phase observables in the traditional L1/L2 PPP, which at the same time will allow us to estimate adequately relevant biases of the new signals.

L5 tracking network: the Multi-GNSS Experiment

Following the on-going GNSS systems modernization, IGS has recently started the Multi-GNSS experiment (MGEX), which aims at providing the scientific community with observation data from all the new generation GNSS satellites, using state-of-the-art ground station technology. The following map shows the geographical distribution of the M-GEX stations; almost all of them provide adequate tracking of GPS L5, which shares the same carrier frequency as Galileo E5a.

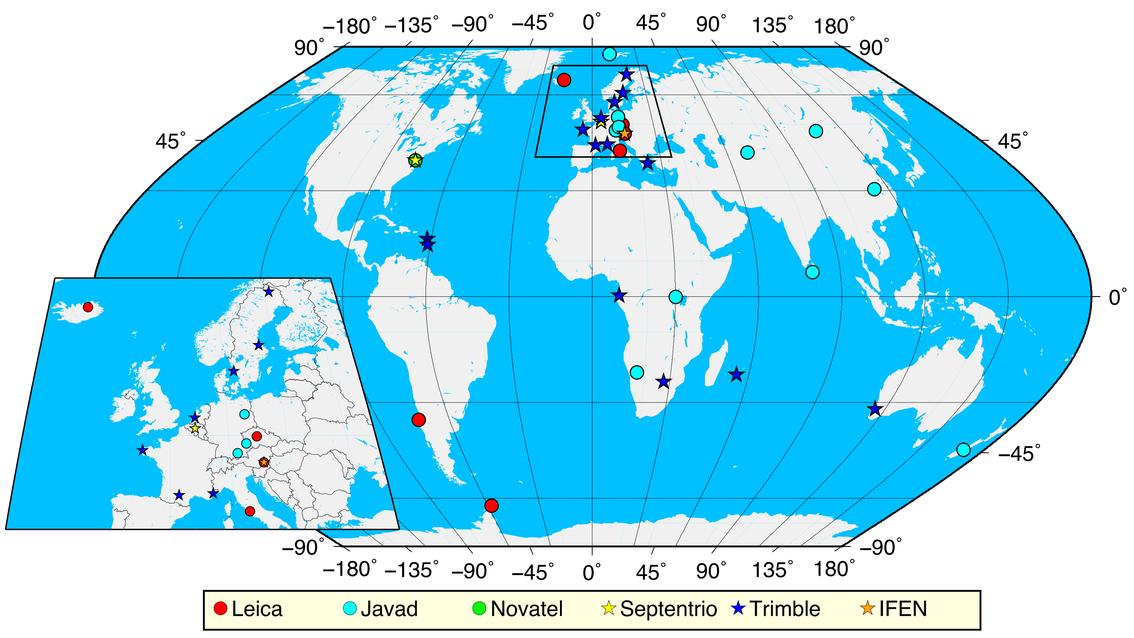

Figure 1 – Geographical distribution of stations in the M-GEX network

Receiver brand	Receiver Model	Number of stations	GPS Rinex3 observables available (pseudorange/phase)								
			L1 (1575.42 MHz)		L2 (1227.6 MHz)					L5 (1176.42 MHz)	
			C1C/L1C	C1W/L1W	C2D/L2D	C2L/L2L	C2P/L2P	C2W/L2W	C2X/C2X	C5Q/L5Q	C5X/L5X
Trimble	NETR9	14	•					•	•		•
Javad	Delta G3T	11	•	•				•	•		•
	JPS Legacy	1	•				•				
Leica	GRX1200+GNSS	4	•					•	•		•
	GR10/GR25+	2	•					•	•		•
Septentrio	POLARX4	2	•	•		•		•		•	
Novatel	OEM6	1	•		•					•	
IFEN	SX_NSR_RT_800	1	•		•				•		•

Table 1 – Receivers installed in the M-GEX network and GPS observables delivered in RINEX3 format (observables used in this study are marked with •)

Triple Frequency Precise Point Positioning

In the estimation process, the ionosphere-free linear combination is computed, with the following well-known generic formulation for 2 given frequencies:

$$S_{ij} = \frac{1}{f_i^2 - f_j^2}(f_i^2 S_i - f_j^2 S_j) \qquad S = \{P(code), L(phase)\}$$

The L1/L2 and L1/L5 ionosphere-free observables, and their simplified observation equations used in PPP, for a given satellite *k*, are as follows:

$$L_1/L_2 \begin{cases} P_{12}^k = \rho^k + m^k T + c(\delta t - \delta t^k) + \varepsilon_{P_{12}}^k \\ L_{12}^k = \rho^k + m^k T + c(\delta t - \delta t^k) + A_{12}^k + \varepsilon_{L_{12}^k} \end{cases}$$

$$L_1/L_5 \begin{cases} P_{15}^k = \rho^k + m^k T + c(\delta t - \delta t^k) + B_{15}^k + \varepsilon_{P_{15}}^k \\ L_{15}^k = \rho^k + m^k T + c(\delta t - \delta t^k) + B_{15}^k + A_{15}^k + \varepsilon_{L_{15}^k} \end{cases}$$

- Geometric distance
- Tropospheric Delay
- Receiver clock bias
- Satellite clock bias
- Inter-frequency bias
- Carrier Phase ambiguity
- Measurement noise

Inter-frequency code biases

Using IGS Final Orbit and Clock product [1], L1/L2 and L1/L5 ionosphere-free observations are fed into a kinematic PPP engine, that is capable of estimating the inter-frequency biases B_{15}. These biases are very stable over time (figure 2), but show significant differences among different stations and receiver models (figure 3).

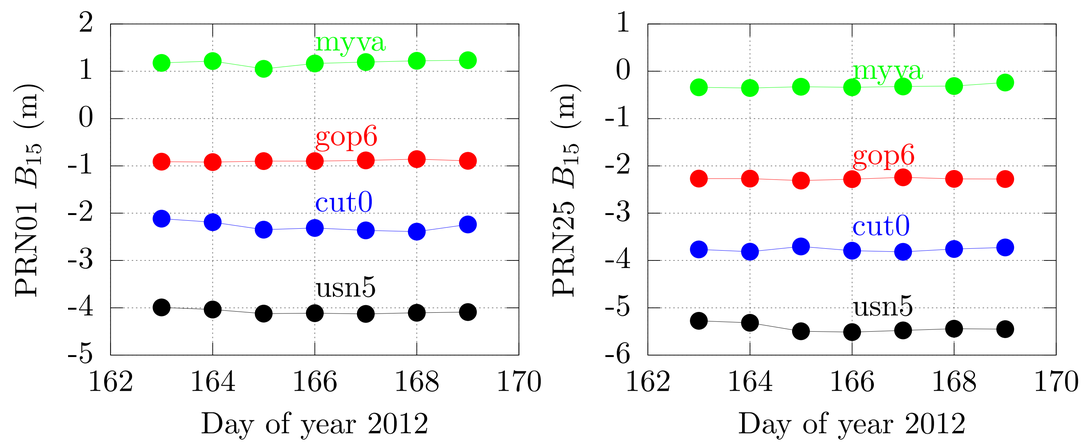

Figure 2 – Daily inter-frequency biases estimates for several M-GEX stations

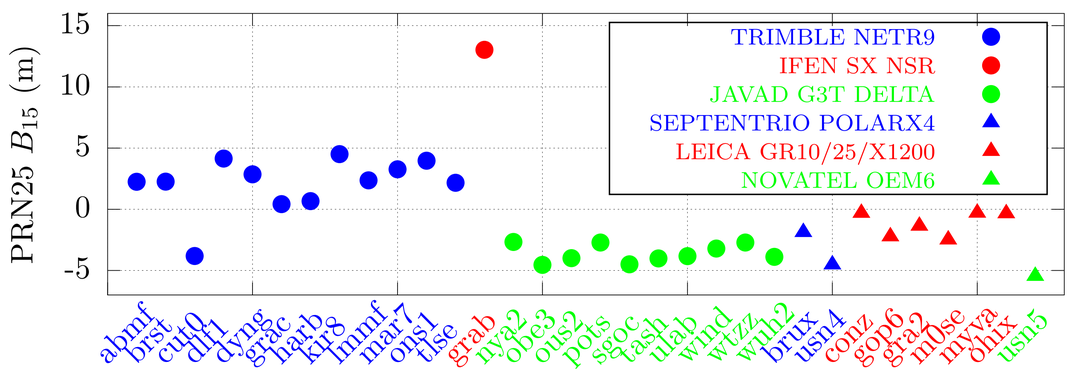

Figure 3 – Inter-frequency biases for M-GEX stations (DOY 12168)

The L5 phase anomaly

It was first presented in [2] that the L5 carrier phase of SVN-62 (PRN25) has an abnormal performance, likely due to thermal effects on the satellite. This analysis can be also performed now using M-GEX stations, and can be extended to the second IIF satellite SVN-63 (PRN01). Figure 4 shows the phase residuals in the PPP processing for the two IIF satellites. The phase anomaly can be clearly noticed in the L1/L5 phase residuals, in which a clear signal can be observed because the constant phase ambiguity term A_{15} cannot absorb the time-variant phase anomaly present in both IIF satellites.

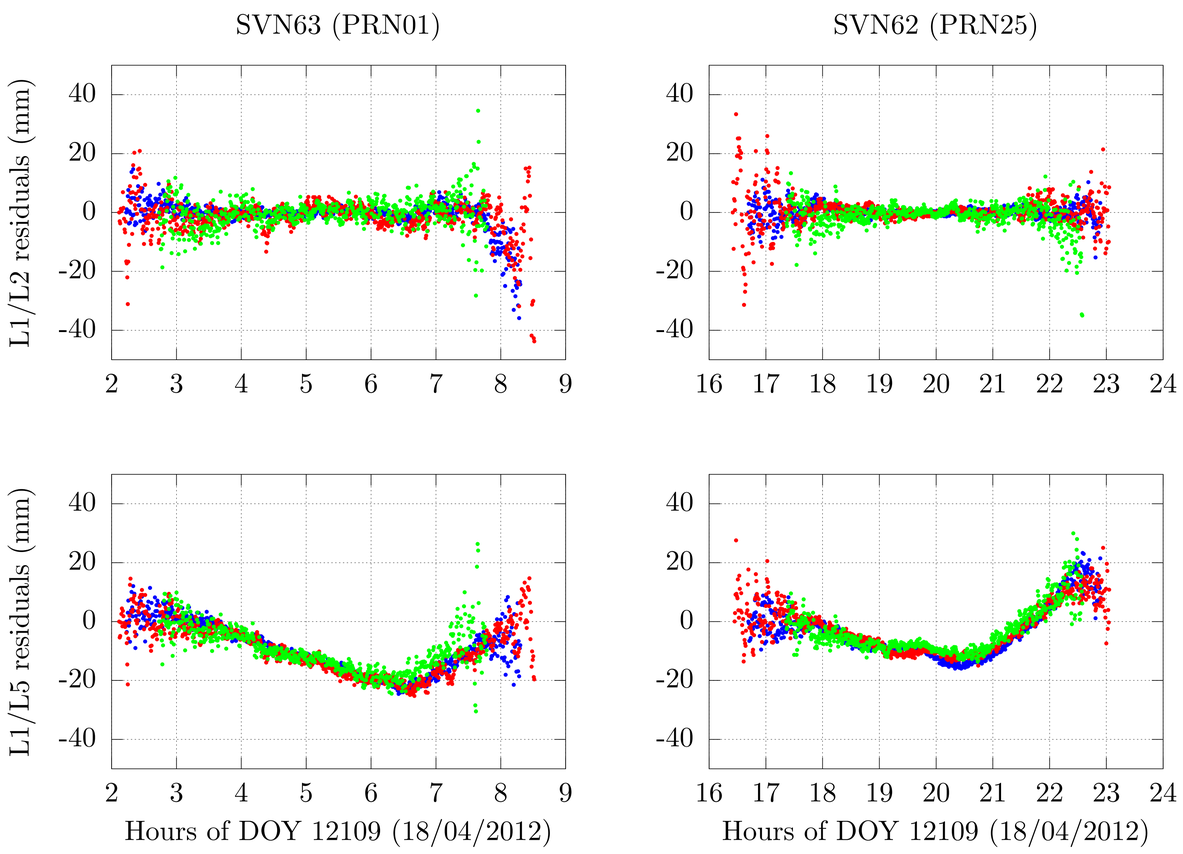

Figure 4 – PPP Phase Residuals for stations tlse, brux and ons1. The L5 phase anomaly is clearly present in the L1/L5 residuals

References

[1] Kouba, J. (2009). A guide to using International GNSS Service (IGS) products. *Available at http://igscb. jpl. nasa. gov/components/usage*

[2] Montenbruck, O., Hugentobler, U., Dach, R., Steigenberger, P., & Hauschild, A. (2011). Apparent clock variations of the Block IIF-1 (SVN62) GPS satellite. *GPS Solutions*, *1*. doi:10.1007/s10291-011-0232-x