Implementation of PPP-based Time Transfer: GAPSTT

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1. Introduction

The International GPS Service (IGS) commitment in providing quality data and products for the GNSS community, has supported the development of the technique called Precise Point Positioning (PPP) due to the availability of orbit and clock products. The PPP technique proved to be not only a technique to determine positions from a single geodetic receiver, but, more than that, it also proved to be an incredible tool for remote time and frequency comparisons of atomic timescales and oscillators. This work discusses implementation and validation of the in-house UNB PPP software GPS Analysis and Positioning Software (GAPS) as a tool for time transfer.

2. Using Geodetic Receivers for Time and Frequency Transfer

Precise timing is the heart of managing the flow of information around the globe and to improve the precise time, the time community is always looking for reliable, robust and inexpensive ways of managing time to be used in synchronized systems.

As we have different options of geodetic receiver for timing, we also have different measurements and modeling techniques. In this work, we are modelling the GNSS observations using the method called PPP. This method in the time and frequency community is classified as an all-in-view time technique for clock comparisons.
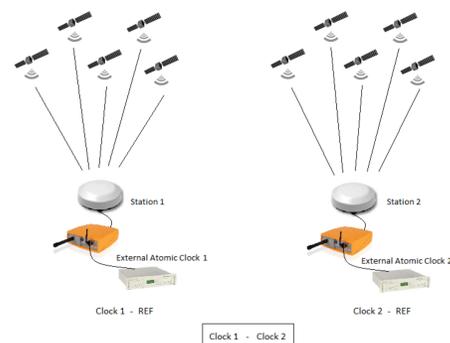

Fig. 1: All-in-view time and transfer method for clock comparisons.

According to Petit and Jiand, [2004], the principle of AV is very simple: two stations (time laboratories) collect all the GNSS observations in view, but instead of using the GPS time scale as reference, they use the IGS products as reference. Then, to perform the two clock comparison, a simple difference between the two clocks is needed. See the figure 1.

3. Improvements, implementation and updates

- **Solid Earth Tides** - GAPS has been updated to apply the earth tides corrections based on the IERS (International Earth Rotation and Reference Systems Services) 2010 conventions.
- **Ocean Tide Loading** (OTL) - OTL was implemented to apply the displacements to all the IGS stations automatically using the FES2004 model. The user also has the option to apply corrections to different stations and using other preferable models.

- **IGS rapid products** - GAPS has been modified to process observation files using both IGS final and rapid products.
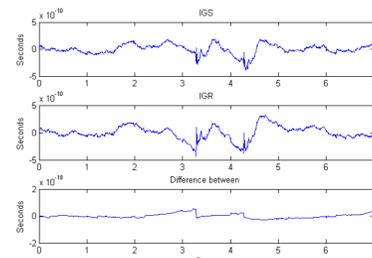

Fig. 2: Comparisons between station clocks estimated with IGS and IGR.

- **Internal delays** - GAPS was update to apply the internal constant delay values such as: the receiver, antenna and antenna cable delays and the delay between the external clock and the receiver clock must be apply as a constant, following the equation 1.

$$\Delta T_d = [154^2 \times INT_{P1} - 120^2 \times INT_{P2}] \div 9316 + [CAB_D - REF_D] \quad (2)$$

where ΔT_d is the total delay, INT_{P1} and INT_{P2} ae the receiver and antenna delays for P1 and P2 observable, CAB_D is the antenna cable delay, REF_D is the delay between the external clock and the internal receiver clock, and the coefficients [152^2], [120^2], and [9316] are due to the ratio of the two GPS frequencies.

- **Day-Boundary-Discontinuity** – Guyennon et al [2009] presents the problem called day-boundary-discontinuity. The IGS products are made available in daily solution files. A daily solution causes a discontinuity of the phase ambiguities through the midnight epoch, from one day to the following one. See the figure 2.
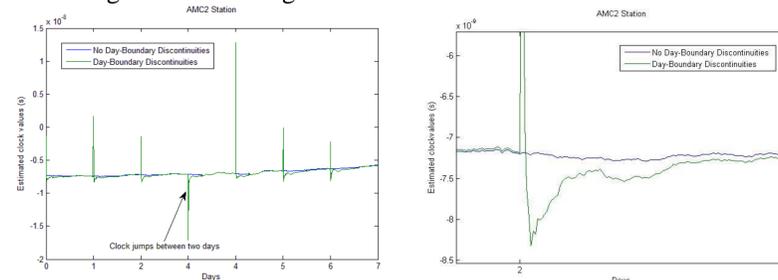

Fig. 3: Estimated clock comparison between a batch solution and day-by-day

		Max Value	Min Value	Mean	median	Standard Deviation
AMC2	batch solution	-5.72560E-09	-7.46150E-09	-6.90500E-09	-7.09960E-09	4.66290E-10
	day-by-day solution	1.28180E-08	-1.71360E-08	-7.00540E-09	-7.11880E-09	7.71220E-10
BREW	batch solution	2.57140E-10	-4.83870E-10	7.90170E-11	6.64380E-12	1.05560E-10
	day-by-day solution	1.81750E-08	-9.22450E-09	1.90580E-10	-7.89950E-13	5.94430E-10
IENG	batch solution	3.61110E-08	3.48200E-08	3.52170E-08	3.51410E-08	3.14240E-10
	day-by-day solution	4.28480E-08	2.96090E-08	3.54290E-08	3.53720E-08	6.55830E-10

Table 1: Statistics comparison between batch solution and day-by-day solution

- **CGGTTS output files** – GAPS has been update to generate output files following the CGGTTS (CCTF Group on GNSS Time Transfer Standards) format for PPP time transfer.

4. Automatic process to perform the clock comparisons (link), frequency stability analysis and GAPSTT interface
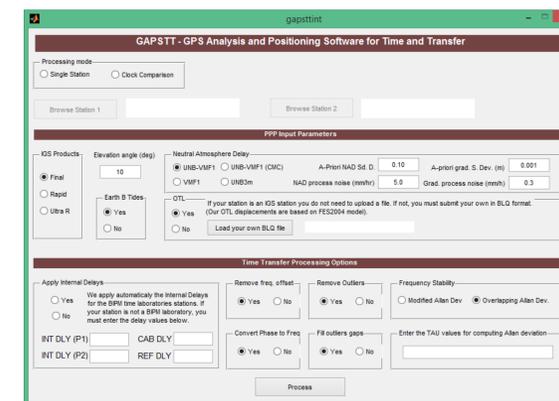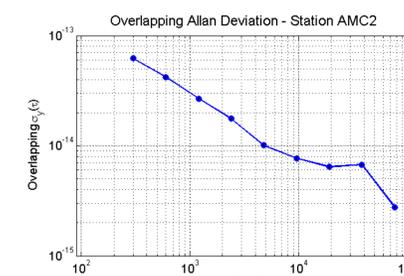

Fig. 4: GAPSTT interface

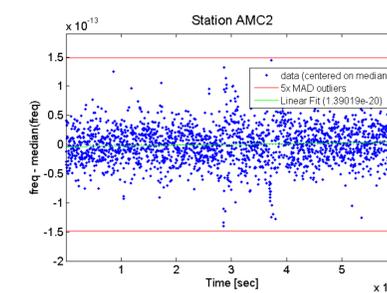Fig. 5: Stability Frequency analysis plot by GAPSTT

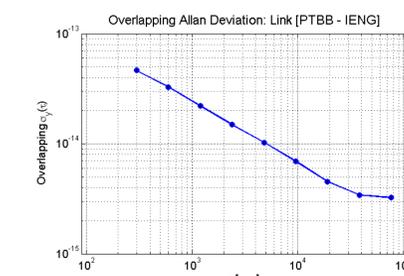Fig. 6: Outliers detection by GAPSTT

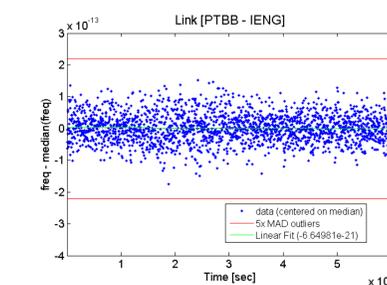Fig. 7: Stability Frequency analysis plot by GAPSTT

Fig. 8: Outliers detection by GAPSTT

References:

Guyennon, N., G. Cerretto, P. Tavella, F. Lahaye, "Further Characterization of the Time Transfer Capabilities of Precise Point Positioning (PPP): The Sliding Batch procedure", IEEE Trans. Ultrason. Ferroelectr. and Freq. Control, Vol. 56, No. 8, pp. 1634-1641, August, 2009.

G. Petit, Z. Jiang, "Precise Point Positioning for TAI computation". Bureau International des Poids et Mesures (BIPM), (2009).