CCTF 2015: Report of the Royal Observatory of Belgium

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Clocks and Time scales:

The Precise Time Facility (PTF) of the Royal Observatory of Belgium (ROB) contains presently 4 Cesium clocks HP5071A, one with standard tubes (since 1995), and three with High Perf. Tubes (since 2012), and one active H-maser CH1-75A (since 2006). UTC(ORB) is generated from the CH1-75A frequency, steered weekly upon the rapid UTC values. Due to an important maser failure, UTC(ORB) was generated by a Cesium clock between 07-2013 and 06-2015.

The behavior of UTC(ORB) with respect to UTC is shown in Figure1.

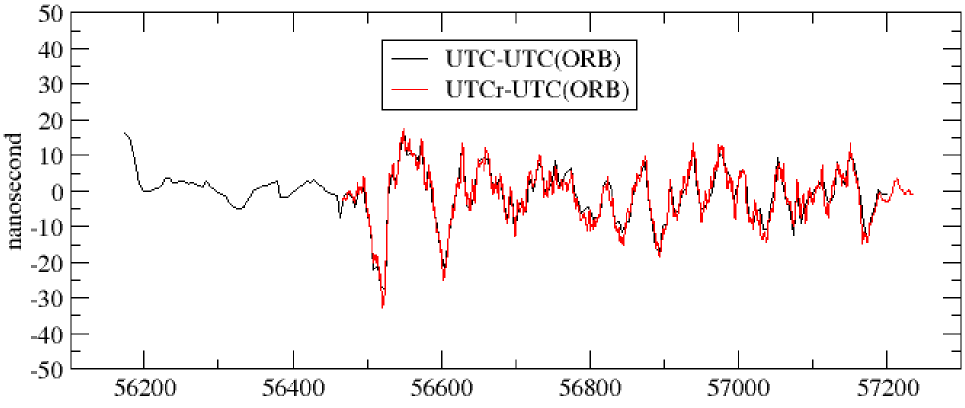
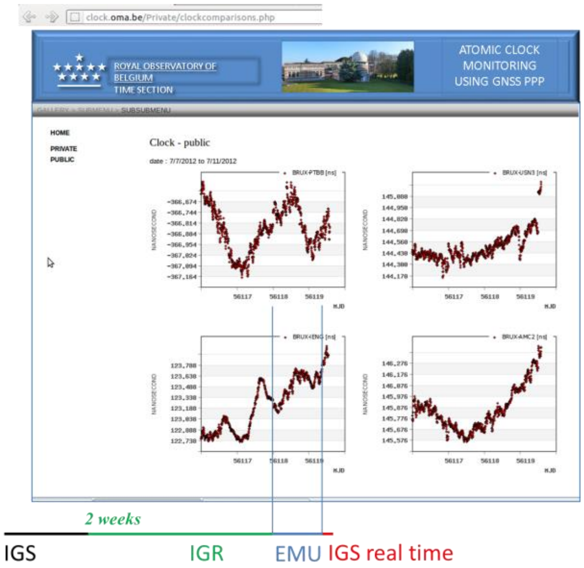


Figure 1. UTC-UTC(ORB) from 2012.7 to 2012.6

- The station BRUX, used for the ling of ORB with TAI, was calibrated in August 2012 using the traveling GTR50 receiver from BIPM. An inconsistence of 3 ns on both P1 and P2 was found with respect to the previous calibrations. A further exercise was done with OP, and still different HW delays were found, more in agreement with previous calibrations. The uncertainty on the BRUX HW delays is therefore quite large presently.

- UTC(ORB) is continuously monitored also by a comparison with other UTC(k) using PPP and the real-time orbits and clocks provided by the IGS. It was shown that this allows a detection of any clock jump larger than 1.5 ns with a latency of some minutes after the end of the hour (see [3]). The clock comparisons are available on a web page as shown in Figure 2.



clock.oma.be/Private/clockcomparisons.php

ROYAL OBSERVATORY OF BELGIUM
TIME SECTION

ATOMIC CLOCK MONITORING USING GNSS PPP

GALLERY > SUBMENU > SUBSUBMENU

HOME
PRIVATE
PUBLIC

Clock - public

date : 7/7/2012 to 7/11/2012

Figure 2. Web page with PPP clock comparisons

Participation to the Galileo Activities

- ORB was collaborating with 5 European time laboratories to form the "Time Validation Facility" for Galileo, the European Global Navigation Satellite System. The ORB team is responsible for the validation and calibration of the UTC and GGTO information broadcasted in the navigation message of the Galileo satellites.

GNSS time and frequency transfer

- The R2CGGTTS software version 6 was built, allowing the use of GPS+GLONASS+Galileo for time transfer in the official format CGTTS from raw data in the RINEX 3.0 format. First results of dual-frequency Galileo time transfer were obtained: the Galileo solution is about 15% more precise than the GPS solution thanks to the Galileo frequencies giving a smaller noise increase in the dual-frequency ionosphere-free combination. Figure 3 shows the residuals as a function of the elevation.

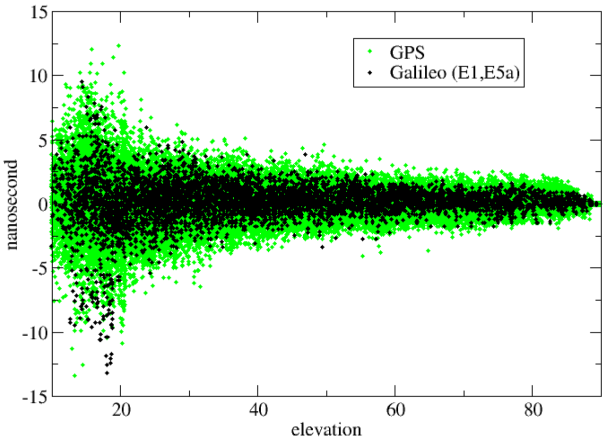
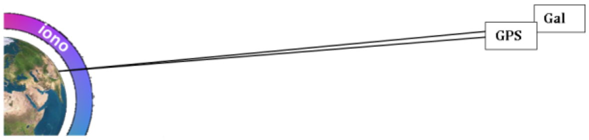


Figure 3. Dispersion of the time transfer results between Brussels and Turin, as a function of the satellite elevation.

At ORB we developed an original technique for the calibration of a GNSS station for the Galileo signals, once the HW delays of GPS signals are known [5]. Considering that the code E1 has the same delay as GPS P1, the hardware delays on E5a and E5b can be retrieved from the measurements of the ionospheric delays suffered by the signals of a Galileo and a GPS satellite appearing at the same time in the same direction. This delay on L1 must be the same for both. It can be determined from the combination of (P1,P2) for GPS and the combination of (E1,E5a,b) for Galileo, after correction of the satellite and station hardware delays. As the only unknown in the equality I1(GPS)=I1(Galileo) is the hardware delay on E5(a or b), this latter can be determined. Figure 4 presents the results obtained for the delay in E5a obtained from the ionospheric measurements of GPS and Galileo using different cut-off for the angular separation between the GPS and the Galileo satellite for a given receiver.



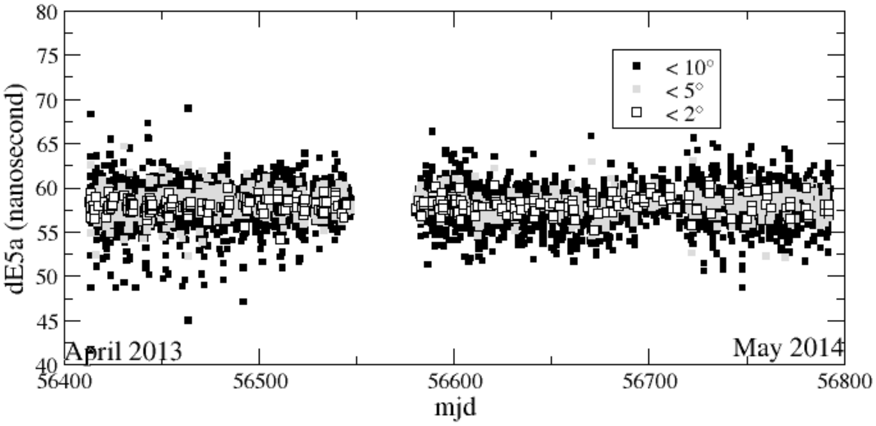


Fig. 4. Results for the E5a hardware delay obtained with satellites GPS and Galileo in view with an angular separation lower than 10, 4, 2 degrees**.**

The method was furthermore validated using the GPS satellites transmitting in L5 (Fig. 5). The ionospheric delay can then be determined from the combination of (L1,L2) or (L1,L5) which gives access to the hardware delays of L5 signals, once the hardware delays are known for L1 and L2. As GPS C5 and Galileo E5a have exactly the same frequency and the same modulation, we should retrieve exactly the same hardware delay for C5 than for E5a. The results are shown in Figure 5, for different period of times. Our computation indeed needs the TGD between C1 and C5, which has been provided experimentally in the GPS CNAV message. As the CNAV transmission was still in validation phase at the time of this experiment, this can explain the small differences we had between the results obtained with the different satellites. This validation is nonetheless really promising as when using the results of May 2014 and June 2014 and ignoring the PRN 01 results which seem really problematic, the hardware delay of C_5 is found in very good agreement with the result obtained for Galileo E_{5a}.

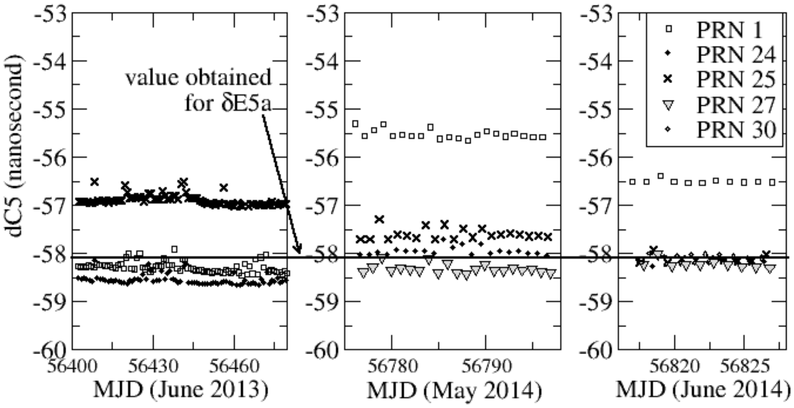


Figure 9. Results for δC5 for the station BRUX obtained with five Block-IIF GPS satellites. Each point corresponds to the average of measurements above 65 degrees during a pass of the satellite.

- ORB started the study of calibrating GLONASS time transfer, and arrived to the conclusion that only link calibrations can be used for GLONASS (no single station calibration). A first experience was realized in May 2013 in collaboration with the Paris Observatory (OP) for the link OP-BRUX, using our station ZTB3 (receiver+antenna+cable) sent to OP for two weeks for calibration of the GLONASS channels. The results (Figure 5) showed a difference of 2 ns pic to peak between the solutions based on calibrated GPS and GLONASS data, and the solution using only GPS calibration for both GPS and GLONASS [14].

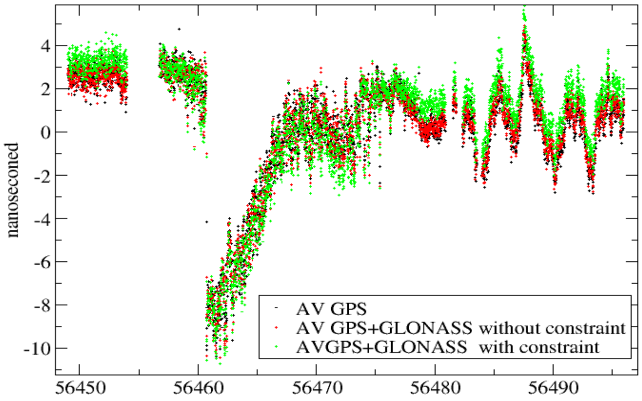


Figure 5. Comparison between the time transfer solution for OPM8-BRUX computed with AV in both stations using GPS-only (black), GPS+GLONASS with (green) and without (red) the GLONASS calibration data.

- The ORB identified a possible origin for the apparent code-phase frequency bias that was observed in the PPP solutions of some receivers. This would result from a difference between the phase and code latching time in the receiver [20]. Using simulations (Figure 6) it was demonstrated that an offset of 1 µs in the latching of code and phase measurements causes a drift of 30 ps/day in the PPP clock solution, and the magnitude of the drift is directly proportional to the offset.

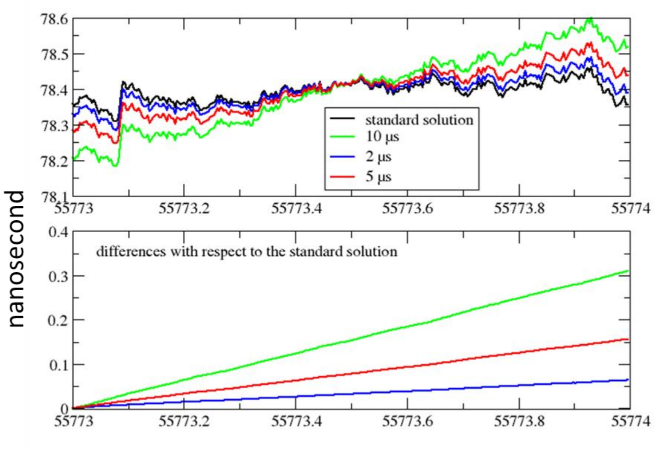


Figure 6. Impact of a given delay between the code and carrier phase latching simulated with the Doppler frequency detrmined from the carrier phase data

For a receiver of known delay between the code and phase measurement latching, it was shown how this the carrier phase data can be corrected before the PPP inversion so as to avoid the artificial slope in the clock solution.

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