# INRIM Multi GNSS All-in-View: Software and Results

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Time transfer techniques have been playing a crucial role in time metrology since they allow comparison of oscillators all around the world, contributing to the generation of the Coordinated Universal Time (UTC) at the International Bureau of Weights and Measures (BIPM). The Common View (CV) technique using GPS satellites [1] has been used since the eighties for this purpose to compare local realizations of UTC at timing laboratories (namely UTC(k)); later on GLONASS satellites were also included. Currently the most used technique is the All-in-View (AV) technique [2]. Such technique relies on measurements of all satellites in view of a GNSS receiver connected to the local UTC(k), which are included in a standard file called CGGTTS [3] [4]. Currently with many GNSS being operational, an extension to the standard called CGGTTS V2E [5] has been published to include not only GPS and GLONASS, but also Galileo, Beidou and QZSS; the latter three are still not yet officially used in the frame of UTC and TAI computation [6]. This work presents a MATLAB software developed at INRIM, capable of processing different version of CGGTTS files and to compute the time offset between remote laboratory clocks (baselines) using AV technique. Preliminary results obtained using GPS, GLONASS (GLO), Galileo (GAL) and Beidou (BDS) are reported.

The algorithm flow of the software Multi-GNSS AV software is reported in Fig. 1. Multi-GNSS AV works by first reading its configuration from separate files where information such as input/output directories, naming conventions or filter parameters are written. Based on such information, input files of CGGTTS format are parsed and checked. Then the software takes valid measurements of both laboratories to combine them using the AV principle with added filtering for possible outliers rejection . The main features of Multi -GNSS AV are that:

- It is capable of process all existing CGGTTS versions (V1, V2 and V2E).
- It can be used for batch processing of different baselines with respect to different UTC(k) and receivers
- It is written in modules allowing for easy debugging, patching and adding features.
- It is written in MATLAB language which is fairly easy to understand and adapt and can be deployed to both Windows and Linux environment.
- It includes CGGTTS file checks and data filters with parameters that can be configured and easily suppressed both epoch-wise and baseline-wise.
- It also computes so-called half-baselines i.e. *LAB–GNSSTime*.

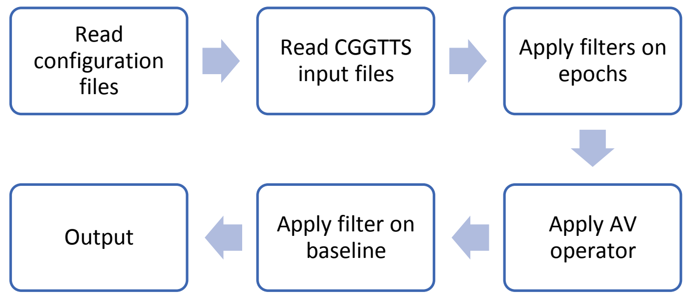


Fig. 1. Multi – GNSS AV software algorithm

CGGTTS files are checked based on header and data line checksums, correctness of each data field, tracking length of each measurement, frequency combination of measurement and an elevation mask. Each valid CGGTTS measurement is registered and collected epoch-wise, where a Median Absolute Deviation (MAD) [7] is used to reject outliers on each epoch. Then the AV combination is done using a simple average or an elevation-based weighted average on measurements of each side to obtain *LAB1–GNSSTime* and *LAB2–GNSSTime* (half-baselines). Combining the two it is possible to obtain the difference of the two laboratories time offset (*LAB1–LAB2)*, of which outliers can be removed further using MAD filter or Sliding MAD (SMAD) filter [7] before output. Multi-GNSS AV output has been validated against the scientific software used at INRIM Time and Frequency Laboratory to compute time transfer data with other UTC(k).

Using this software we computed GPS, GLONASS, Galileo and Beidou-based time offset for a short baseline and a long baseline to assess performance of time transfer in multi GNSS environment. We perform a test involving the pseudorange measurements and navigation messages of INRIM INR6 receiver, Royal Observatory of Belgium (ORB) BRUX receiver and Hong Kong Lands Department HKWS receiver; for the latter two public data taken from the International GNSS Service (IGS) [8] are used. RINEX [9] observation and navigation files are collected and passed by R2CGGTTS (software developed at ORB [10]) to generate CGGTTS measurements for each station using the following iono-free combination: GPS/GLO L3P (P1 & P2), GAL L3E (E1 & E5a) and BDS (B1i & B2i). It is observed (Fig. 2 and Fig. 3) that baselines based on GPS and Galileo constellation are comparable for the short baseline (INR6 - BRUX) in both short-term and long-term noise, probably due to the fact that visibility and orbital configuration of these satellites are quite similar. Baselines using GLONASS satellites can be noisier due to inter-frequency biases of the constellation's Frequency Division Multiple Access scheme. Baselines with Beidou satellites are instead less reliable due to very low visibility in European region; also its particular orbital configuration (MEO + IGSO + GEO) might play a role. On the long baseline (INR6 – HKWS, Fig. 4 and Fig. 5) estimations with Beidou satellites show similar performance to those using GPS and Galileo constellation, probably due to a better visibility.

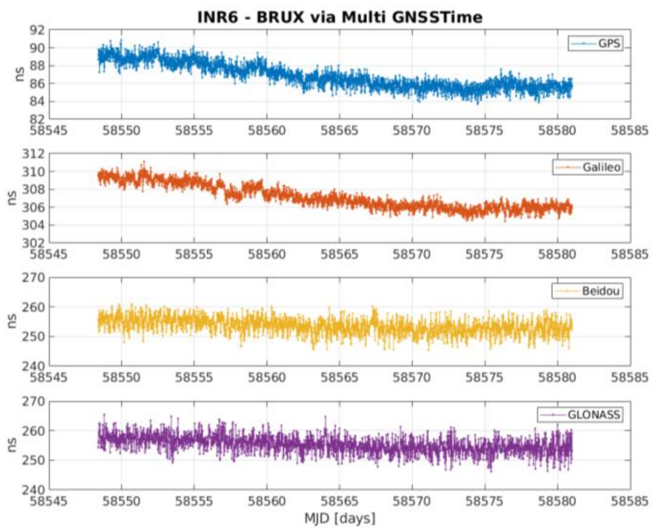


Fig. 2. INR6 – BRUX time offset through multi GNSS AV

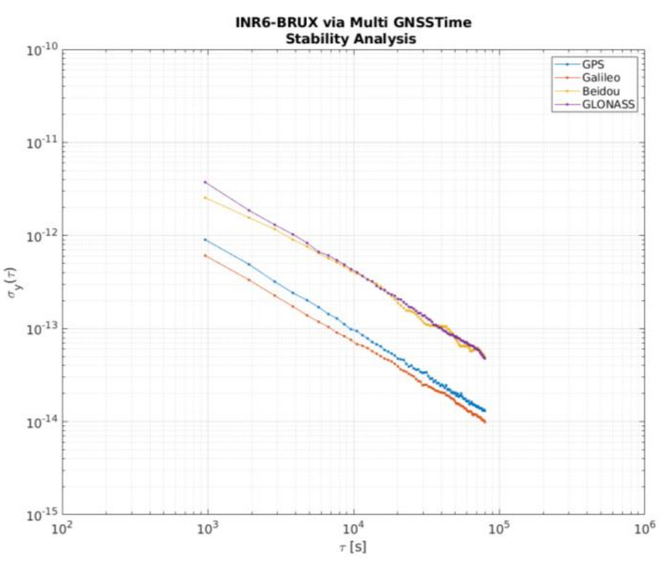


Fig. 3. INR6 – BRUX through multi GNSS AV stability analysis

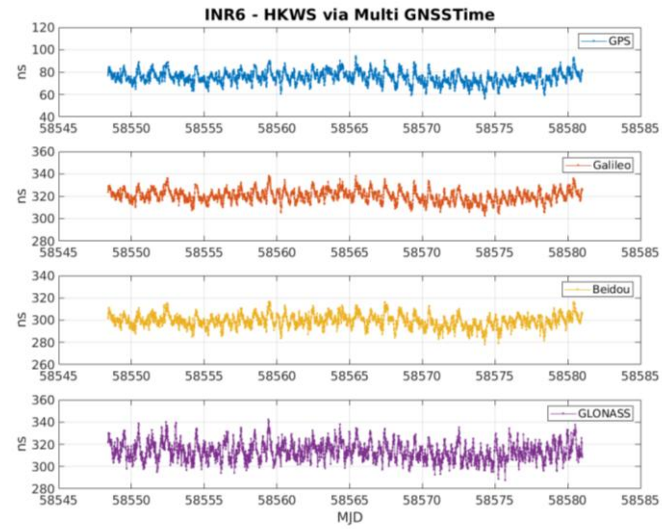


Fig. 4. INR6 – HKWS time offset through multi GNSS AV

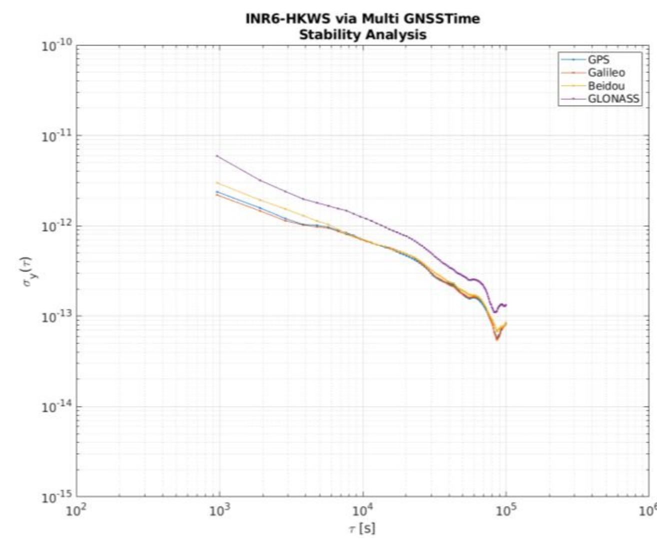


Fig. 5. INR6 – HKWS through multi GNSS AV stability analysis

Possible next steps are to consider together all satellites in view of the different constellations to apply the AV operator to a single observable instead of separate ones. Doing so requires the knowledge of the time offset between systems (which is unfortunately not broadcast by all GNSS providers, but can anyway be estimated at user receiver level). Once known, the AV combination can be made with respect to one system of choice or of convenience, and so improve the statistics of the measurements, especially during low visibility of a single GNSS constellation.

## REFERENCES

[1] D W. Allan, Marc A. Weiss, "Accurate Time and Frequency Transfer During Common-View of a GPS Satellite," Proc. 34th Ann. Freq. Control Symposium, May 1980.

[2] Z. Jiang, G. Petit, "Time transfer with GPS satellites All-in-View," Proc. ATF2004, 236, 2004.

[3] D.W. Allan, C. Thomas, "Technical Directives for Standardization of GPS Time Receiver Software," Metrologia, 1994, 31, pp.67-79.

[4] W. Lewandowski, J. Azoubib, A.G. Gevorkyan, P.P. Bogdanov, W.J. Klepczynski, M. Miranian, J. Danaher, N.B. Koshelyaevsky, D.W.

Allan, "A Contribution to the Standardization of GPS and GLONASS Time Transfers," Proc. 28th PTTI, 1996, pp. 367-386.

[5] P. Defraigne, G. Petit, “CGGTTS-Version 2E : an extended standard for GNSS Time Transfer,” Metrologia 2015 52 G1.

[6] “Time Transfer: Overview,” BIPM, https://www.bipm.org/en/bipm/tai/time-transfer/

[7] I. Sesia, E. Cantoni, A. Cernigliaro, G. Signorile, G. Fantino, P. Tavella, "An efficient and configurable Preprocessing algorithm to improve stability analysis", IEEE Trans. Ultrason. Ferroelect. Freq. Control, vol. 63, no. 4, pp. 575-581, Apr. 2016.

[8] International GNSS Service http://www.igs.org – Data center CDDIS https://cddis.nasa.gov

[9] “RINEX The Receiver Independent Exchange Format Version 3.03,” International GNSS Service (IGS), RINEX Working Group and Radio Technical Commission for Maritime Services Special Committee 104 (RTCM-SC104), July 14th, 2015

[10] R2CGGTTS V8, BIPM FTP server ftp://tai.bipm.org/soft/r2cggtts/8.0/R2CGGTTS-V8_ReadMe.pdf