Report to the 21th Session of the CCTF

Working Group on GNSS time transfer
Report biennium 2015-2017

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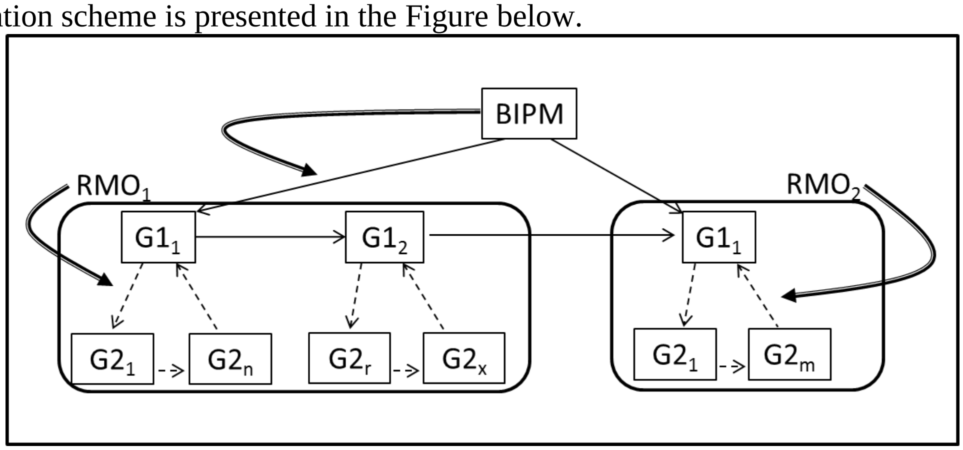
The long-term goal of the Working Group on GNSS time transfer is to progress in the performances of remote clock comparisons between laboratories separated by any distance, both in terms of accuracy and stability for averaging times up to about 30 days. In parallel, the WG defines the clock result formats in agreement with the user needs.

Two main subjects have been developed during the triennium: the development of calibration procedures, and the study of long-term variations between TW and GPS time transfer for stations of the TAI network. Some progresses of the WG members in terms of time/frequency transfer performances are also reported at the end of this report.

1. Calibration Status

New calibration guidelines were presented in the previous CCTF (2015). The goal was to remedy the past situation in which not all the labs had their GNSS equipment calibrated or regularly calibrated, starting a collaboration between the BIPM and the RMOs for GNSS equipment calibration.
It was decided to organize the calibration as follows: the BIPM organize the calibration of some stations (called "group 1" here after) in each RMO, and the RMOs, together with these "group 1" laboratories, organize calibration campaigns for the other laboratories (called "group 2") of their region. In addition, the BIPM conduct some "Group 2" trips as necessary to accommodate special cases, using either one BIPM system or a "Group 1" system as a reference.

The calibration scheme is presented in the Figure below.



Schema of the GNSS calibration organization for the UTC generation. G1 and G2 refer to Group 1 and Group 2 laboratory, the curved arrows shows the organization responsibility. Solid arrows represent Group 1 trips and dashed arrows represent Group 2 trips.

This procedure is based essentially on "differential calibration with closure" trips with the reference values provided by a set of systems operated in selected laboratories. In the new calibration scheme, the BIPM maintain the calibrations of a set of equipment distributed in the regions (the Group 1 stations). These systems provide the reference for the calibration trips organized by the RMOs.

The Group 1 laboratories per RMO are:

- EURAMET: OP, PTB, ROA
- SIM: NIST, USNO
- APMP: NICT, NIM, TL
- COOMET: SU

Note that there are no G1 laboratories in AFRIMETS and GULFMET.

A new version of the guidelines (version 3.2) was proposed by the WG and made available in ftp://tai.bipm.org/TFG/GNSS-Calibration-Results/Guidelines/ as well as on the web page of the WG.

Group 1&2 calibrations

A complete "Group1" calibration trip was organized from January 2014 to June 2015, in 4 different phases. The results received the calibration ID cal_Id=1001-2014, and were published on the BIPM web page.

A second Group 1calibration trip was started in March 2016, and only two phases have been achieved up to now, covering TL, NICT, NIM, PTB, ROA and OP (plus NTSC as Group 2 labo).

Over the period, about fifteen Group 2 laboratories were additionally calibrated, either by the Group1 laboratories or directly by the BIPM.

Calex format

While the CGGTTS results are by convention corrected for the GNSS station hardware delays indicated in the header of the file, the PPP software tools generally provide a clock solution still containing the hardware delays. In order to allow an easy access to the calibration results for the correction of hardware delays in the PPP clock solutions, the WG proposed the use of a unique file reporting all the calibration results of all the stations involved in the TAI network. This file named Calex contain the whole history so that it can be used when processing any Rinex file. An evaluation version of the Calex file has been created with the available Group1 and Group2 calibrations and made available to the community on the BIPM ftp server.

C1-P1 time bias

The WG evocated an issue related to the existence of hardware bias between the C1 and P1 measurements at the satellite level. The IGS solves for C1-P1 biases by constraining the average of all satellite biases to be zero. This may yield a deviation of some ns with respect to true values

that could be obtained by absolute calibration. As a consequence, the clock results obtained from receivers measuring only the C1 code are most probably affected by some offset. This offset should be determined from absolute calibration of ground receivers for P1 and C1 separately.
In the absence of such an absolute calibration, the BIPM has initially proposed a conventional reference for the C1 delays of Group 1 receivers that should be used as a base for future C1 differential calibration. An alternate proposal is to base the C1 reference on the ensemble of C1 Inter Signal Corrections available from the Civilian Navigation message for a set of modernized satellites. The issue is to be discussed by the Working group.

2. R2CGGTTS multi-constellations

ORB developed and distributed to the time laboratories a new R2CGGTTS software (version 7.1) allowing analysis of RINEX3, for GPS, GLONASS and Galileo. This software provides CGGTTS results in the format version V2E.

3. Precise Point Positioning

Some members of the WG continued the progress in using the PPP technique for remote clock comparisons. The major goal is to get a continuous solution and mitigated as much as possible the discontinuities appearing at the boundaries between batch solutions. Several options have been studied such as the use of longer batches or moving overlapping batches; all show similar performances as the monthly solutions used by the BIPM for the realization of UTC. Another proposed improvement to the PPP algorithm is to solve the carrier phase ambiguities as integer numbers. This requires the availability of dedicated satellite clock products and hence a strong collaboration started with the geodetic community providing such products. Studies at the BIPM show that a frequency transfer accuracy of 1×10^{-16} is obtained at a few day averaging and that the performance still improves at longer averaging time.

4. Long-term variations between TW and GPS time transfer

During this biennium was started a joint task group of the CCTF Working Groups on TWSTFT and on GNSS Time Transfer to investigate the long-term stability of the UTC time transfer links. Is was found that many links are stable, but several instances of long-term variations of several ns can also be observed. These occur in GNSS-only links, TW-only links, and in differences between GNSS and TW links. It was also observed that past performance is not a reliable indicator of future stability. Long-term drifts can begin, or halt, for no apparent reason. While they can often be quickly identified through comparisons with independent redundant systems, extremely important supplementary information can be obtained via frequent calibrations. In order to be able to better control the stability of GPS and TW hardware delays, a recommendation to the 21th CCTF has been proposed by the two WG on GNSS and TW (see below).

5. Recommendations to the CCTF

On the utilization and monitoring of redundant time transfer equipment in the timing laboratories contributing to UTC

6. Meetings:

The slides and reports of the meeting organized in York, on April 5 2016, can be found on the WG web page at http://www.bipm.org/wg/AllowedDocuments.jsp?wg=WGGNSS.