Report to the 20th Session of the CCTF

Working Group on GNSS time transfer
Report triennium 2012-2015

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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 possible evolution of CGGTTS format and stimulating the development of calibrations procedures. Some progresses of the WG members in terms of time/frequency transfer performances are also reported at the end of this report.

1. Evolution of CGGTTS format

The CGGTTS Version 02 standard only applies for GPS and GLONASS measurements. Considering the emergence of Galileo, BeiDou and QZSS, the Working Group on GNSS Time Transfer prepared the new version of the standard, with the name CGGTTS, for Common Generic GNSS Time Transfer Standard, version 2E.
The main features of the extended standard are:

- to provide extension for all GNSS systems in development;
- to be fully compatible with the previous versions GGTTS-V01 (GPS) and CGGTTS-V02 (GPS+GLONASS) for the computation algorithm and data format; in particular it is explicitly decided not to change the 16-minute data interval with 13-minute averaging so that common-view time transfer is possible between receivers providing any version of the format;
- to provide more flexibility in specifying the calibration information in the header, allowing a more synthetic presentation of the calibration delays. The hardware delays can be presented as SYSDLY (INTDLY+CABDLY) or TOTDLY (INTDLY+CABDLY+REFDLY)

The file name has been maintained for GPS and GLONASS, and defined for the other constellations. It has been decided that no mixed CGGTTS files will be provided, each file will contain only the results for a given constellation and all the results reported will be associated with the same code measurement or the same ionosphere-free combination.

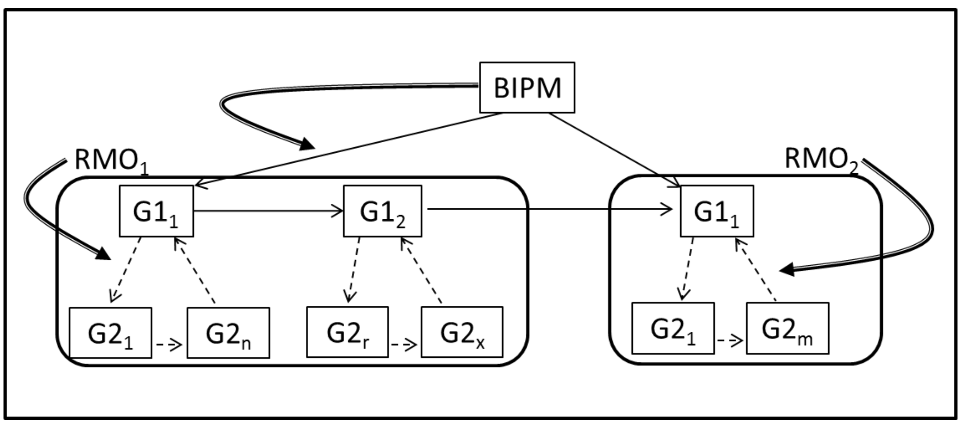
A detailed presentation of the CGGTTS V2E has been prepared and published in Metrologia [1].

2. Calibration Guidelines

Due to the increasing number of labs and GNSS equipment in the UTC network, not all the labs have their GNSS equipment calibrated or regularly calibrated. To remedy this situation, the CCTF recommended in 2012 collaboration between the BIPM and the RMOs for GNSS equipment calibration. To that aim, the BIPM in collaboration with the WG on GNSS time transfer produced guidelines in order to allow a better homogenization of the GNSS calibrations within the UTC community.
The goals of the cooperation between the BIPM and the RMOs are
1. To have all GNSS equipment used in laboratories for time transfer in UTC calibrated;
2. To regularly repeat calibrations so as to maintain the accuracy of time transfer for UTC;
3. To seek reduction of the uB by assessing the stability of the calibrations.

It was decided to organize the calibration as follows: the BIPM will organize the calibration of some stations (called “group 1” here after) in each RMO, and the RMOs, together with these “group 1” laboratories, will organize calibration campaigns for the other laboratories (called “group 2”) of their region. In addition, the BIPM will conduct “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 will maintain the calibrations of a set of equipment distributed in the regions (the Group 1 stations). These systems will provide the reference for the calibration trips organized by the RMOs.

A calibration uncertainty value u_{CAL0} will be associated to each calibration trip. This value u_{CAL0} (Cal_Id) will be assigned by the BIPM after the submission of the report as part of the validation process. However, in order to avoid that any laboratory (in particular pivot laboratory) receives a higher weight in the computation of TAI, it has been decided that the calibration uncertainty of a link will be assigned a conventional value depending only on the technique (single-frequency or dual-frequency) and the age of the oldest calibration trip.

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.

The guidelines for calibration procedure have been defined for the different receiver types used as traveling or station equipment. The standard process of calculation is also defined as well as a Template of calibration report to the BIPM. All these guidelines have been made available in ftp://tai.bipm.org/TFG/GNSS-Calibration-Results/Guidelines/ and are also available through the web page of the WG.

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 will contain the whole history so that it can be used when processing any Rinex file. The Calex file will be maintained by the BIPM Time department and made available to the community on an ftp server. An example is provided in the web page of the WG.

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. This will be studied by WG members during the next triennium.

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. In addition to the use of longer batches and moving overlapping batches already proposed and used by the BIPM for the realization of UTC, it was proposed to improve the PPP algorithms in order to be able 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.
Another study examined frequency biases between the code and phase measurements used in the PPP analysis, that also create discontinuities at the batch boundaries. One possible cause was identified to be due to a non-synchronism between the code and carrier phase measurements inside the receiver.

Recommendations to the CCTF

two draft recommendations for the coming CCTF, to recommend that:
•the calibration guidelines be applied and Group 2 calibration be organized;
•receiver manufacturer implement the CGGTTS format V2E in their new issues

Meetings:

Five meetings took place during the triennium:

28 Nov 2012 in Reston (VA)

24 July 2013 in Prague (Czech Republic)

4 December 2013 in Bellevue (WA)

24 June 2014 in Neuchâtel (Switzerland)

13 April 2015 in Denver (CO)

The slides and reports of all the meetings can be found on the WG web page at http://www.bipm.org/wg/AllowedDocuments.jsp?wg=WGGNSS.

Reference

[1] Defraigne P., Petit G., CGGTTS-Version 2E : an extended standard for GNSS time transfer, *Metrologia* 2015 **52** G1
available at http://metrologia.bipm.org/guides-stds-conventions/2015/10001.pdf.