Workshop of the CCTF GNSS Working group
Brussels, November 28, 2018 9h00

Pascale Defraigne, chair of the WG, opened the meeting and presented the meeting's agenda.

1. Time links

W. Wu presented "Recent progress of BeiDou time transfer at NTSC" (see slides) reporting on studies conducted at NTSC on BDS time transfer links in Common-view (CV) and All-in-view (AV), on combining different GNSS for PPP, on monitoring GNSS time offset and on the development of a BDS-3 receiver and of a GNSS calibrator.

K. Liang presented "BDS time transfer on multiple inter-continental and continental links" (see slides) in which he studies BDS time transfer using NIM-TF-GNSS-3 receivers placed in different time laboratories in the UTC network along with some data from selected IGS tracking sites. Results from CCD experiments as well as over long baselines show that the measurement noise of the NIM time and frequency transfer receivers is about 1 ns. Satellite coverage data are shown for various locations and the correction model for the elevation-dependent code bias was implemented with a positive effect. Results of BDS and GPS time transfer links are shown.

A. Bauch presented "Galileo and BeiDou time transfer at PTB" (see slides). He stated that one goal is to monitor REFSYS values of all PTB receivers and to monitor CV between local receivers for validation purposes, and to monitor CV along selected links for tests of BeiDou time transfer. He mentioned a possible elevation dependence of the REFSYS values for Galileo.

G. Petit presented "Time transfer using Galileo and BeiDou: First tests in the UTC software" (see slides), summarizing the work carried out at the BIPM with dual frequency code data from 8 laboratories in Europe and Asia, in order to prepare the possible introduction of the new GNSS in the ensemble of time links for UTC. First results on several 1-month periods in 2018 indicate that the stability of Galileo links is equivalent or somewhat better than GPS links with reduced signatures at averaging time below 1 day, despite the number of Galileo observations being lower. BeiDou links are more difficult to assess because of the different subsets of satellites (GEO, IGSO, MEO) have different properties and because precise orbits and clocks need to be validated. The instability of BeiDou links is typically found to be about twice that of Galileo or GPS.

P. Defraigne presented "R2CGGTTS and multi-GNSS AV" (see slides). The Version 8.0 of the R2CGGTTS software has been distributed and V8.1, correcting some bugs, is expected soon. She showed single constellation links for all four systems on several short and long baselines where Galileo and GPS provide best stability, with some advantage to Galileo. She provided evidence of inter-satellite biases in GPS. Two approaches for multi-GNSS solutions are proposed and results are presented for one short baseline NTSC-TL and one long baseline ORB-NTSC. Using Galileo as reference and determining inter-satellite biases for GPS and BDS as for GLONASS improves the combined solution.

In the ensuing exchanges, the following topics were discussed:

- The next CCTF meeting is unlikely to occur before mid-2020 so that the question of a formal recommendation is premature.
- Such a GNSS WG workshop is the first of its kind in years and the WG feels this should be repeated e.g. annually, so that the next workshop will examine formal recommendations
- Whether the inclusion of new GNSS in UTC could occur before a procedure for calibration is defined (see next section).
- Whether only the constellation providing the best results, or a multi-GNSS approach, should be used for UTC.
- The BIPM intends to use new GNSS as additional links (not used in UTC) as soon as practical, i.e. a procedure to obtain reliable results has been determined. This could be rapid for Galileo, but further study is necessary to determine how to use multi-GNSS data.

2. Calibration

P. Defraigne presented a table with the status of the G1/G2 calibration in time laboratories that she established from the content of the BIPM Time department database. She showed that the number of recently calibrated labs is increasing notably for EURAMET and APMP. Some additional calibrations were reported by G1 re^resentatives: IFAG (done), SG and CNM (in progress).

At the request of G. Petit, representatives of the G1 laboratories of SIM and COOMET indicated their plans.
- S. Römisch for NIST indicated that two trips have been completed but that manpower issues will hamper the work in the coming year.
- W. Walls for USNO indicated also some manpower problems after the leaving of E. Powers.
- N. Kosheliaevskii for SU indicated that G2 trips should be conducted, initially at BY and KZ.

G. Petit presented "The G1 2018 trip and steps towards including Galileo" (see slides), summarizing the status of the work on G1 calibration by the BIPM and reminding the method of ensemble average used to determine the G1 reference values. The third Group 1 trip is under way and includes, starting with the EURAMET leg, a test for Galileo differential calibration. It is proposed to start with a Galileo reference value based on an absolute calibration, then using the ensemble average method to maintain the reference in the future.

N. Kosheliaevskii presented "Absolute calibration at VNIIFTRI" (see slides) discussing the facilities for absolute calibration at VNIIFTRI, including a vast anechoïc chamber. These facilities were used for GPS and GLONASS calibration, notably of the BIPM traveling receiver during visits for G1 trips.

J Delporte presented "Absolute calibration activities at CNES" (see slides) describing the CNES facilities and the calibration techniques developed notably to calibrate the simulator and to calibrate the antenna with a simulator. He presented results of absolute calibration of GPS-BeiDou and GPS-Galileo chains and the comparison of results in common-clock experiments. He also gave a brief outlook of the work at CNES for monitoring and assessing the quality of Galileo Services in the GRC.

P. Waller presented "Absolute calibration activities at ESTEC" (see slides) describing the ESTEC facilities and the procedure for the absolute calibration of multi-GNSS receiver chains. He presented

several comparisons of absolute calibration results: comparisons with CNES absolute calibration results, comparisons with results using real signals in common clock, comparisons with G1-G2 reference values. All comparisons show agreement of order 1-3 ns, with values in the upper end of this range needing further studies.

P. Defraigne presented "Galileo Calibration from BGDs/TGDs: new values?" (see slides), showing how absolute calibration results and ionospheric maps allow determing the satellite group delays. In the case of Galileo she compared these determinations to the ESA values and showed some differences at the 1-3 ns level. She discussed options to choose reference values for Galileo caibrations.

In the ensuing exchanges, the following topics were discussed:
- It was agreed that the simplest solution for introducing Galileo (and other new GNSS) in G1/G2 is to use an absolute calibration of one receiver as the reference. Indeed the G1/G2 reference can be arbitrary but it is convenient that it is not far from an absolute calibration (as is the case for GPS). Possibly an "average of absolute calibration results" could be used.
- In the meantime, stations that need Galileo calibration for e.g. Galileo system or monitoring activities, should decide on their own, this decision being outside the task of the WG.
- G. Petit expressed a request from the BIPM, whether results from an absolute calibration by a laboratory could be used for UTC along with G1/G2 receivers (possibly with some specific uncertainty). It was the WG opinion that such absolute calibrations should not (in the present status) be directly used in G1/G2, at least not until procedures to validate AC results have been established.

3. **CIRCULAR T Section 4 (UTC-UTC(i)$_{\text{BROADCAST BY GNSS}}$)**

K. Liang presented "UTC disseminated by Beidou system" (see slides), discussing the computation of (GNSS time - UTC(i)$_{\text{BROADCAST BY GNSS}}$) from broadcast information. He presented various comparisons for the case of BeiDou comparing data from monitoring stations at NIM to values from direct measurements between NIM and BSNC.

P. Waller presented "UTC_ as disseminated by Galileo" (see slides), reminding the definition of what is broadcast by Galileo under the denomination $\{\text{GST} - \text{UTC}\}_{\text{pred}}$ and expressed his recommendations for the content of Circular T section 4.

N. Kosheliaevskii presented "UTC(SU) as the reference time scale for GLONASS" and "GNSS monitoring services at VNIIFTRI" (see slides). He showed the VNIIFTRI time department equipment for generation of UTC(SU) and time transfer, and for the GNSS monitoring services and publications. He presented results inferring significant offsets in the data published in Circular T section 4.

G. Signorile presented "Galileo broadcast timing information monitoring at INRIM" (see slides), describing the INRIM timing performance monitoring facility for Galileo, providing comparisons of the prediction of UTC through SIS to UTC(k) and comparing results obtained at INRIM with similar results at ORB.

A. Bauch presented "Results of Galileo and BeiDou time offset monitoring in PTB" (see slides), and concluded that, at the single ns level some discrepancy exists between calibration of signal delays in receivers used for monitoring and for signal generation in Galileo Ground Segment, and that the „UTC prediction" in the Galileo navigation message agrees with Circular T results within 2-3 ns

P. Uhrich presented "LNE-SYRTE contribution to the discussion on Circular T Section 4" (see slides) stating that (GNSS time - UTC(i)$_{\text{BROADCAST BY GNSS}}$) should be based on the measurements by a set of stations calibrated against absolutely calibrated traveling stations.

P. Defraigne presented "UTC-UTC(xx) broadcast computed from an absolute calibration" (see slides), where she inferred (UTC - UTC(i)$_{\text{BROADCAST BY GNSS}}$) from an absolutely calibrated receiver operated at ORB and compared the results to the same quantity in Circular T section 4 and to (UTC - UTC(i)). She reported significant differences with respect to the results in section 4 and hinted at possible improvements.

In the ensuing exchanges, the following topics were discussed:
- The role of Section 4 is unclear (which users, which accuracy goals _presently only a crude uncertainty is stated for data in section 4_, which data interval…).
- There is no need for a new general CCTF Recommendation as Rec 2 CCTF(2015) has this role.
- New GNSS should appear but all GNSS should be treated equivalently i.e. existing GPS and GLN procedures should be updated as needed (use of recent calibration, method of recovering DUTC, use of single- or dual-frequency solutions…).
- Using multiple receivers to access (UTC-UTC(i)$_{\text{BROADCAST BY GNSS}}$) should be studied.

The meeting was closed at 18h00.
A few photographs taken during the meeting (thanks to N. Kosheliaevskii) can be found here.

Published 12 December 2018 (P. Defraigne, G. Petit)

List of participants

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