Bureau International des Poids et Mesures

2018 December 18th

EXPLANATORY SUPPLEMENT OF BIPM *CIRCULAR T*

This document describes the contents of the sections in BIPM *Circular T* from January 2016.
For automatic data extraction, a *Circular T* format description file is available at ftp://ftp2.bipm.org/pub/tai/publication/notes/cirt_format_v0.1.txt.
The issues of BIPM *Circular T* are available at the BIPM website at https://www.bipm.org/en/bipm-services/timescales/time-ftp/introduction.html ; data used in the calculation of each *Circular T* are available at http://www.bipm.org/fr/bipm-services/timescales/time-ftp/data.html .

In *Circular T*, all uncertainties are expressed with a coverage factor k = 1.

Section 1
Difference between UTC and its local realizations UTC(k) and corresponding uncertainties

This section gives the values of [*UTC-UTC*(*k*)] (in ns) at five-day intervals on MJD ending by 4 and 9, at 0 h UTC for local realizations of UTC maintained at contributing laboratories "*k*" and their respective uncertainties, valid for the month [1]. Notes on this section provide relevant information relating to a result.

[1] Lewandowski W., Matsakis D., Panfilo G., Tavella P., The evaluation of uncertainties in [*UTC-UTC*(*k*)], *Metrologia,* 2006, 43(3), 278-286

Section 2
Difference between the normalized frequencies of EAL and TAI

This section gives the values of the difference between the normalized frequencies of EAL (free atomic time scale) and TAI for the interval covered by the current *Circular T* as well as those for the following two months. They indicate if a steering correction of the frequency of EAL has been applied and/or is foreseen necessary for preserving the accuracy of TAI.

Section 3
Duration of the TAI scale interval *d*

TAI is a realization of coordinate time TT. The tables give the fractional deviation d of the scale interval of TAI from that of TT (in practice, the SI second on the geoid), i.e. the fractional frequency deviation of TAI with the opposite sign: $d = -y_{TAI}$. In this section, a frequency over a time interval is defined as the ratio of the end-point phase difference to the duration of the interval. Whenever needed, the instability of EAL should be expressed as the quadratic sum of three components with τ in days:

1. a white frequency noise of $1.7\times10^{-15}/\sqrt{\tau}$,
2. a flicker frequency noise of 0.35×10^{-15},
3. a random walk frequency noise of $0.2\times10^{-16} \times \sqrt{\tau}$.

The relation between EAL and TAI is given in Section 2 of *Circular T* and in the *BIPM Annual Report on Time Activities.*

In the first table, *d* is obtained, on the given periods of estimation by comparison of the TAI frequency with that of the given individual Primary and Secondary Frequency Standards (PFS/SFS).
In this table:

- u_A is the uncertainty originating in the instability of the standard,
- u_B is the combined uncertainty from systematic effects,
- $u_{l/lab}$ is the uncertainty in the link between the standard and the clock participating to TAI, including the uncertainty due to the dead-time,
- $u_{l/TAI}$ is the uncertainty in the link to TAI,
- ***u*** is the quadratic sum of all four uncertainty values,
- ***Ref***(u_B) is a reference giving information on the values of u_B or is the *Circular T* where the reference was first given,
- u_B***(Ref)*** is the u_B value stated in this reference.

Note that all uncertainties may vary over time and that the current u_B values are generally not the same as the peer reviewed values given in Ref(u_B).

See http://www.bipm.org/jsp/en/TimeFtp.jsp for previous issues of *Circular T* and individual Reports of Evaluation of Primary and Secondary Frequency Standards that explain changes in uncertainties.

For the SFS, u_S***rep*** represents the recommended uncertainty of the secondary representation of the second and ***Ref***(u_S) provides the reference for the frequency of the transition and its uncertainty $u_S$rep, these two fields are not applicable to PFS.

All values are expressed in 10^{-15} and are valid only for the stated period of estimation.

The second table gives the BIPM estimate of *d*, based on all available PFS and SFS measurements over the indicated period, taking into account their individual uncertainties and characterizing the instability of EAL as noted above. *u* is the computed standard uncertainty of *d* .

Section 4
Relations of UTC and TAI with predictions of UTC(k) disseminated by GNSS,

Global Navigation Satellite Systems (GNSS) broadcast predictions of UTC. [*UTC*(*USNO*)_*GPS*] and [*UTC*(*SU*)_*GLONASS*] are, respectively, UTC(USNO) and UTC(SU) as predicted by USNO and SU and disseminated by GPS and GLONASS respectively.

[*UTC-UTC*(*USNO*)_*GPS*] = C_0',
[*TAI-UTC*(*USNO*)_*GPS*] = ***XX*** s + C_0', global uncertainty is of the order of 10 ns.
[*UTC-UTC*(*SU*)_*GLONASS*]= C_1',
[*TAI-UTC*(*SU*)_*GLONASS*]= ***XX*** s + C_1', global uncertainty is of the order of hundreds ns.

The ***XX*** value is the difference [*TAI-UTC*] as an integer number of seconds. It may change by insertion of positive or negative leap seconds under the responsibility of the IERS, see the IERS website :
https://hpiers.obspm.fr/eoppc/bul/bulc/UTC-TAI.history.

The C_0' values provide realizations of the prediction of UTC(USNO) broadcast by GPS, as obtained using the values [*UTC-UTC*(*OP*)] and the GPS data taken at the Paris Observatory, corrected for IGS precise orbits, clocks and ionosphere maps.

The C_1' values provide realizations of the prediction of UTC(SU) broadcast by GLONASS, as obtained using the values [*UTC-UTC*(*AOS*)] and the GLONASS data taken at the Astrogeodynamical Observatory Borowiec (AOS).

N_0' and N_1' are the number of 13-minute CGGTTS intervals; when N_0' or N_1' is 0, the corresponding values in the table are interpolated.

The standard deviations σ_0' and σ_1' characterize the dispersion of individual measurements.
The actual uncertainty of users' access to GPS and GLONASS times may differ from the published values.

Section 5
Time links used for the computation of TAI, calibrations information and corresponding uncertainties

This section provides information on the time links used in the elaboration of each *Circular T*, including equipment and calibration identifiers, uncertainties and alignment corrections applied by the BIPM, if any.
Description of the plots content is available in section 2.3 of the document ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/ReadMe_LinkComparison_ftp_v11.pdf.

The first table includes links formed with station-based GNSS techniques indicated as follows:

- ***GPS MC*** for GPS all-in-view multi-channel C/A data,
- ***GPS P3*** for GPS all-in-view multi-channel dual-frequency P code data,
- ***GPS PPP*** for GPS Precise Point Positioning technique,
- ***GLN MC*** for GLONASS common-view multi-channel C/A data,
- ***GPSGLN*** for the combination of GPS MC and GLN MC.

The second table includes link-based techniques, indicated as

- ***TWSTFT*** for two-way satellite time and frequency transfer,
- ***TWGPPP***/***TWGPP3*** for the combined smoothing of TWSTFT and GPS PPP/GPS P3,
- ***INT LK*** for ***internal*** cable link.

The second table also includes GNSS links calibrated with such link-based techniques.

For a link, the equipment at each laboratory is designated by its unique identifier (4-character for GNSS receiver and 6-character for TWSTFT ground station).

- ***Cal_ID*** is the calibration identifier of the campaign where the equipment/link has been calibrated [1],
- ***NC*** stands for no calibration,
- ***NA*** stands for no availability of the calibration report,
- ***NC_Al*** indicates that a correction has been applied for aligning the current link to another link previously used, non-calibrated,
- ***NA_Al*** indicates that a correction has been applied for aligning the current link to another link previously used and calibrated, for which the calibration report is not available,
- ***NL*** indicates that no time transfer data was available for this *Circular T* period,
- ***uStb*** is the standard uncertainty representing the link instability and accounting for measurement noise and random effects with typical duration between 1 and 30 days,
- ***uCal*** represents the total uncertainty from calibration, derived from the original equipment/link calibration uncertainty and also including components for aging and for alignment when appropriate. In the case of links involving TWSTFT the standard measurement uncertainty of ESDVAR (ESIG) is also included, if applicable.

A value of 20 ns is conventionally assigned to u_{CAL} for non-calibrated equipment/links; this value does not represent the uncertainty of the link, which cannot be evaluated,

- ***uAg*** is the uncertainty accounting for calibration aging [2],
- ***Al*** is the link alignment correction applied if necessary by the BIPM on ***YYMM*** (year and month), the conventional uncertainty increment for an alignment is 1 ns.

For the calibration uncertainty of GNSS equipment prior to 2014, refer to the BIPM guidelines for GNSS calibrations [3], sub-section A1.

[1] BIPM calibration information can be found in: http://www.bipm.org/jsp/en/TimeCalibrations.jsp

[2] Jiang Z., Arias F., Lewandowski W., Petit G. , BIPM Calibration Scheme for UTC Time Links, Pro*c. 2011 Joint Conference of IFCS and EFTF*, pp 1064-1069

[3] BIPM guidelines for GNSS calibration