International Bureau on Weights and Measures
Bureau International de Poids et Mesure (BIPM)
– Time Department –

(Time, Frequency and Gravimetry Department until end of 2010)

http://www.bipm.org/en/scientific/tfg/

Director of Department: **E. F. Arias** (France)

The Time Department is one of the five scientific departments of the BIPM. The activities at the Time Department are focused on the maintenance of the SI second and the formation of the international reference time scales.

The International Committee for Weights and Measures (CIPM) decided in October 2009 to discontinue the activities on gravimetry. Consequence of these decisions, the BIPM time, frequency and gravimetry (TFG) section became since 1 January 2011 the BIPM Time Department.

The BIPM provides, together with the US Naval Observatory, the IERS Conventions Centre, with the responsibility of the establishment and publication of the IERS Conventions, providing standards and models for applications in the fields of geodesy, geophysics and astronomy.

The establishment and maintenance of the International System of Units (SI) at the BIPM constitutes a fundamental contribution to the activities relating to the IAG.

International Time Scales at the BIPM

The international time scales International Atomic Time (TAI) and Coordinated Universal Time (UTC) are regularly computed and published in monthly *BIPM Circular T*. The frequency stability of UTC, expressed in terms of an Allan deviation, is estimated to 3×10^{-16} for averaging times of one month. About 400 industrial clocks located in almost 70 national laboratories contribute to the calculation of TAI. Some of these laboratories develop and maintain primary frequency standards – among them caesium fountains – that contribute to the improvement of the accuracy of TAI. The scale unit of TAI has been estimated to match the SI second to about 5×10^{-16}.

The laboratories contributing to the formation of UTC maintain representations of the international time scale named UTC(k). Routine UTC(k) comparison is undertaken using different techniques and methods of time transfer. All laboratories contributing to the calculation of UTC at the BIPM are equipped for GNSS reception. GPS C/A observations from time and geodetic-type receivers are used with different methods, depending on the characteristics of the receivers. Dual-frequency receivers allow performing iono-free solutions. Since October 2009 a combination of code and phase measurements of geodetic-type receivers is used in the computation of TAI. Also at the end of 2009 observations of GLONASS are used for the computation of TAI. Thanks to this evolution, the statistical uncertainty of time comparisons is at the sub-nanosecond level for the best GNSS time links. Some laboratories are equipped of two-way satellite time and frequency transfer (TWSTFT) devices allowing time comparisons independent from GNSS through geostationary communication satellites. The uncertainty of time comparison by GNSS is still limited by the hardware to 5 ns for the calibrated links whilst in the case of TWSTFT it is at the nanosecond order.

The algorithm used for the calculation of time scales is an iterative process that starts by producing a free atomic scale (*Échelle atomique libre* or EAL) from which TAI and UTC are derived. Research into time scale algorithms is conducted in the section with the aim of improving the long-term stability of EAL and the accuracy of TAI.

Because TAI is computed on a monthly basis and has operational constraints, it does not provide an optimal realization of Terrestrial Time (TT), the time coordinate of the geocentric reference system. The BIPM therefore computes an additional realization TT(BIPM) in post-processing, which is based on a weighted average of the evaluation of the TAI frequency by the primary frequency standards. The last updated computation of TT(BIPM), named TT(BIPM10), valid until December 2010, has an estimated accuracy of order 0.3×10^{-15}. Starting with TT(BIPM09), an extrapolation for the current year of the latest realization TT(BIPMYY) is provided and is updated each month after the TAI computation.

Radiations other than the caesium 133, most in the optical wavelengths, have been recommended by the International Committee for Weights and Measures (CIPM) as secondary representations of the second. These frequency standards are at least one order of magnitude more accurate than the caesium. Their use for time metrology is still limited by the state of the art of frequency transfer, still unable to compare these standards at the level of their performances. Studies on the use of optical fibres show excellent results. The time community is engaged in a collective effort for solving this issue, since one of the interests is the possibility of redefining the SI second.

The computation of TAI is carried out every month and the results are published monthly in *BIPM Circular T*. When preparing the *Annual Report*, the results shown in *Circular T* may be revised taking into account any subsequent improvements made to the data. Results are also available from the BIPM website (*www.bipm.org*), as well as all data used for the calculation. The broad real-time dissemination of UTC through broadcast and satellite time signals is a responsibility of the national metrology laboratories and some observatories, following the recommendations of the International Telecommunication Union (ITU-R).

Interruption of activities on gravimetry

The 8th International Comparison of Absolute Gravimetres in 2009 (ICAG 2009) was the last organized by the BIPM. The task of the BIPM on the ICAGs had concluded with the calculation of results of this last comparison and its subsequent publication. As agreed with the IAG, the future ICAGs will be organized at national institutes under a regional scheme. The Consultative Committee for the Mass and Related Quantities (CCM) continues organizing the Working Group on Gravimetry (WGG), and thus cooperating with the IAG in providing support to the future ICAGs.

Conventions and references

Research work is also dedicated to space-time reference systems. The BIPM provides, in partnership with the US Naval Observatory, the Conventions Product Centre of the IERS. A new version of the IERS Conventions (2010) has been published in the IERS Technical Note N°36, also available in electronic version at (http://www.iers.org/nn_11216/IERS/EN/Publications/ TechnicalNotes/tn36.html). Updates to the last published version are made whenever necessary and available on the internet at http://tai.bipm.org/iers/conv2010/conv2010.html, http://maia.usno.navy.mil/conv2010/convupdt.html.

Activities in cooperation with Paris Observatory within the IERS International Celestial Reference System Centre on the realization of reference frames for astrogeodynamics, contribute to the maintenance of the international celestial reference frame in the scope of the activities of the International Astronomical Union and International VLBI Service.

International validation of the International Terrestrial Reference System (ITRS)

Thanks to the actions of the BIPM and the Consultative Committee for Time and Frequency (CCTF), the 24rd General Conference on Weight and Measures adopted in October 2011 by unanimity a resolution that recommends the adoption of the International Terrestrial Reference System, as defined by the IUGG and realized by the IERS, for all metrological applications. The full text of the recommendation is annexed to this report. This resolution, adopted in the frame of an international diplomatic treaty (The Metre Convention), and of an intergovernmental organization (the BIPM) gives world-wide validity to the ITRS, putting it at the level of other international standards as, for example, UTC. This resolution reinforces the Resolution 2 of the IUGG, adopted at the XXIV IUGG General Assembly in 2007 on the Geocentric and International Terrestrial Reference Systems (GTRS and ITRS).

Activities planned for 2012-2015

- Calculation and dissemination of UTC through the monthly publication of *BIPM Circular T*;
- Improvement of techniques of time and frequency transfer for
  - Clock comparison for UTC;
  - Comparison of optical frequency standards requiring an accuracy at the level of $10^{-17} – 10^{-18}$;
- Improvement of the algorithms for calculation of timescales;
  - Calculation of TT(BIPM) annually, and of its monthly extrapolation;
  - Calculation and dissemination of a “rapid UTC” on a weekly basis for providing a reference to the UTC(k) available on a short delay;
- Supporting with expert advice the organization of the future international comparisons of absolute gravimeters;
- Continuing operating in cooperation with the USNO the IERS Conventions Centre;
- Continuing the cooperation with the IERS for the establishment of space references;
- Liaising with the relevant organizations, such as: IUGG, IAG and GGOS, IERS, IAU, ITU-R, IGS, and the International Committee for GNSS (ICG).