Structure of Services

Bureau International des Poids et Mesures (BIPM)
– Time, Frequency and Gravimetry Section –

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

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Since 1 January 2006, the traditional BIPM time section has been transformed into the BIPM time, frequency and gravimetry (TFG) section. This new section gathers the staff working on the formation of the international reference time scales and the members of the former length section, with activities in laser work, frequency combs and gravimetry. The TFG section is headed by Dr Elisa Felicitas Arias, head of the former time section.

The impact of the section on fields related to Earth sciences relevant to the IAG is concentrated on two activities of the section, (a) the formation of time scales and (b) the gravimetry.

The frequency combs, which served until the end of 2006 to the key comparison of primary wavelength standards in national laboratories, and the reference lasers are maintained and used for in-house applications only. The section also disposes of a service for filling and testing of iodine cells at the request of national laboratories and other customers.

International Time Scales at the BIPM

International Atomic Time TAI is a continuous, uniform atomic time scale with its second equivalent to the second of ephemeris time. The first time measurements with atomic standards became possible in 1955 after the construction of the caesium standard of the National Physical Laboratory (NPL) in the United Kingdom. The 13th Conférence Générale des Poids et Mesures (1967/1968) adopted a definition of the SI second, based on a caesium transition, and opened the way towards the formal definition of TAI.

Coordinated Universal Time UTC is currently defined as an atomic time scale adjusted to be close to the time of the Earth’s rotation (namely UT1). The UTC system as defined today is a stepped atomic time scale and was adopted in 1972 on recommendation of the International Telecommunication Union, Radiocommunication Sector (ITU-R). A one-second step (leap second) is introduced in UTC whenever the International Earth Rotation and Reference Systems Service (IERS) determines that an adjustment is necessary based on space technique observations of the Earth’s rotation. As of December 2007, the difference between the continuous TAI and UTC amounts to 33 s. UTC has been adopted by the ITU-R as the international time scale for time dissemination. It is derived from TAI by applying a correction of an integer number of seconds. Like TAI, UTC is a “paper” time scale, but it is approximated by local physical representations UTC(k) through clocks in national metrology laboratories and observatories that contribute to the formation of the international time scales at the BIPM.

The BIPM is responsible for realizing, maintaining and disseminating TAI and UTC. These activities result from the cooperation of 62 laboratories in 47 member states of the Metre Convention and associates. These laboratories are equipped of industrial atomic clocks and of devices to allow the comparison of the local UTC(k) which are necessary to the calculation of the time scales at the BIPM. Some ten of these laboratories have developed and maintain primary frequency standards – the best are the caesium fountains – that provide the primary definition of the time unit of the SI.

TAI and UTC are obtained from a combination of data from about 350 atomic clocks kept by the contributing laboratories. The data are in the form of time differences \([\text{UTC}(k) - \text{Clock}]\) taken at 5 day intervals.
Local UTC(k) comparisons can presently be made by three techniques: (a) observations based on C/A code measurements from GPS single frequency receivers; (b) data obtained with dual-frequency, multi-channel GPS geodetic type receivers (P3); and (c) two-way frequency and frequency transfer through geostationary telecommunications satellites (TWSTFT). Significant improvement is being made with the growing number of time links with P3 receivers (20% of the official links in October 2007) and with the increase of the frequency of TWSTFT observations (up to twelve per day). The classical GPS single-channel single-frequency receivers that today represent only 25% of the time transfer equipment are being replaced to allow multi-channel, single or dual frequency observations. As a result, there has been an improvement in the accuracy for time transfer, and the whole system of time links becomes more reliable.

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.

Since 2003, it is estimated that the stability of EAL, expressed in terms of an Allan deviation, has been at or below $0.4 \times 10^{-15}$ for averaging times of one month. Slowly varying long-term drifts limit the stability to around $2 \times 10^{-15}$ for averaging times of six months.

To characterize the accuracy of TAI, estimates are made of the relative departure, and its uncertainty, of the duration of the TAI scale interval from the SI second, as produced on the rotating geoid, by primary frequency standards. Since July 2006, individual measurements of the TAI frequency have been provided by eleven primary frequency standards, including seven caesium fountains. Since then, the global treatment of individual measurements has led to a relative departure of the duration of the TAI scale unit from the SI second on the geoid ranging from $+0.7 \times 10^{-15}$ to $+3.7 \times 10^{-15}$, with a standard uncertainty of about $1 \times 10^{-15}$.

Because TAI is computed for fast publication 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 TT(BIPM) in post-processing, which is based on a weighted average of the evaluation of the TAI frequency by all available data of the primary frequency standards.

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 ITU.

**Gravimetry at the BIPM**

The BIPM makes a regular monitoring of the gravity field at the site. Improvement on gravimeter design and performances allows having in our laboratories equipment with high metrological quality.

Together with the IAG the Commission 2 "Gravity Field" and the working group on gravimetry of the Consultative Committee for the Mass and Related Quantities (CCM), the BIPM organizes every four years the International Campaign of Absolute Gravimeters (ICAG). About 20 absolute gravimeters from 16 countries, the BIPM and the ECGS participated to the last ICAG in September 2005. In July 2005, relative gravimeters carried out supportive measurements of the gravity gradients and the links between the sites of the BIPM gravity micro-network. The next campaign is scheduled for 2009.

At each campaign, the BIPM provides the calibration of the lasers in gravimeters (at 633 nm and 532 nm), measurements of the laser beam shape, verification of the frequency of the rubidium clocks and continues atmospheric pressure measurements.

Part of the work of the group is devoted to the investigation of the sources of uncertainty in absolute measurements.

Support to the BIPM special projects is given with the characterization of the gravity field for the watt balance.

**Relationship with other Organizations**

The BIPM time, frequency and gravimetry section is a service of the IAG. The section interacts with many other international organizations related to time metrology. This interaction is fundamental to our activities, since many fields of the physical sciences contribute to the formation and maintenance of time scales. This is the case of Earth sciences, astronomy, satellite navigation, telecommunications, informatics, electronics, etc. Some examples of links with international organizations are the International Astronomical Union (IAU), the ITU, the IERS, the International GNSS Service (IGS), the International Committee for GNSS (ICG).