Consultative Committee for Time and Frequency

Note on Coordinated Universal Time UTC

The Consultative Committee for Time and Frequency (CCTF), requests that the Bureau International des Poids et Mesures (BIPM), in its role of member of the Radiocommunication Sector of the International Telecommunication Union (ITU-R), pass on this note on Coordinated Universal Time UTC for consideration as a working document at the next meeting of the Study Group 7A of the ITU-R in Geneva in September 2007.

This note intends to express the position of the CCTF with respect to the discussion on the future of UTC and its possible redefinition suppressing the application of leap seconds, and to clarify issues concerning the definition and use of time scales.

Definition and use of time scales and system times

Universal Time UT1: UT1 is computed from the raw observed universal time UT0 by correcting it for the effect of polar motion on the longitude of the observing site.
UT1 is commonly used as a time based on Earth rotation. It is loosely related to the apparent diurnal motion of the Sun and served as the basis for the definition of the SI second until 1960, when the 11th General Conference for Weights and Measures (CGPM) ratified a new definition based on ephemeris time, a time based on the rotation of the Earth around the Sun.

International Atomic Time TAI: TAI is an 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 CGPM (1967/1968) adopted a definition of the SI second, based on a caesium transition, and opened the way towards the formal definition of International Atomic Time (TAI).

TAI is an international time standard. It is calculated by the BIPM from the readings of some 400 atomic clocks located in metrology institutes and observatories in more than 40 countries around the world. The unit interval of TAI is exactly one SI second at mean sea level. The origin of TAI is such that UT1-TAI was approximately 0 on 1 January 1958.

TAI is a coordinate time scale defined in a geocentric reference frame with the SI second as realized on the rotating geoid as the scale unit. It is established at the BIPM on the basis of the readings of atomic clocks operating in various establishments in accordance with the definition of the second.

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TAI has scientific applications, but it is not physically represented by clocks currently. Consequently it is not used for time dissemination.

Coordinated Universal Time UTC: UTC is currently defined as an atomic time scale adjusted to be close to UT1. Before 1972 changes in the length of the UTC second as well as step adjustments were made to accomplish this. This procedure was adopted principally to accommodate navigation by celestial observations.
The UTC system as defined today is a stepped atomic time scale and was adopted in 1972 on recommendation of the ITU-R. It has been defined so that the difference between UTC and UT1 remains smaller than 0.9 s in absolute value and is adjusted in integer (leap) seconds. The leap second, either positive or negative, is introduced in UTC whenever the International Earth Rotation and Reference Systems Service (IERS) determines that an adjustment is necessary based on astronomical observations of the Earth's rotation. The frequency of application of the leap seconds is irregular, depending on the unpredictable long-term irregularities of the Earth's rotation. As of June 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 determination of UTC is provided by publication monthly in BIPM Circular T, that gives traceability to UTC by determination of the final time scale to the approximations UTC(k). The broad 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-R. In many countries UTC is used as the basis for the definition of legal times.

The BIPM has accepted the responsibility for maintaining and disseminating reference time scales whose metrological qualities should respond to the requirements of the various users, in a range of stability and accuracy that ranges from the most demanding applications to civil time reckoning.

Global Navigation Satellite System (GNSS) system times: GNSSs rely on precise time to enable precise ranging measurements for positioning, where the requisite is intra-system consistent synchronization. They maintain internal system times to provide this navigational service, and these system times do not need to be related to external standards. System times are formed using system clock ensembles. They may be steered to an external time scale considered to be the reference maintaining constraints on their maximum tolerated departure. This is the case of GPS time, which follows UTC (USNO) modulo one second via its local representation at the U. S. Naval Observatory (USNO). GPS time is steered to UTC(USNO) as necessary to keep the system time within one microsecond of UTC(USNO) and is actively corrected to a more precise value by means of data transmitted in the GPS satellites Navigation Message (described in GPS-ICD-200). GPS time is continuous and is not adjusted for leap seconds. It is currently 14 seconds ahead of UTC within a precision limit less than tens of nanoseconds. During the last several years fractional difference of GPS time has been within a hundred nanoseconds of UTC.

GLONASS time is constructed following similar principles, but it is steered to the Russian representation of UTC, so affected by the discontinuities of the application of leap seconds. Consequently, it does make adjustments for leap seconds and thus subject to discontinuities when leap seconds are inserted.

It has been decided that the future Galileo internal system time (Galileo time) will rely on a reference to a continuous time, without leap seconds. For the sake of interoperability between different GNSSs it appears that Galileo time will have the same initial epoch as GPS time.

The GNSSs represent by far the most common means to obtain precise UTC; GPS and GLONASS respectively disseminate corrections to their system time to obtain UTC(USNO) and UTC(SU).

Position of the CCTF concerning the redefinition of UTC

The UTC system with leap seconds was essentially introduced to provide a common standard for broadcast time and frequency signals generated from the UTC(k) physical representations and give ready access to low-precision UT1 from these broadcast time and frequency signals maintained within the necessary approximation for celestial navigation. The CCTF is aware that celestial navigation has almost completely disappeared, and that on the other hand, an increasing number of applications are requiring continuous time scales.

In response to this need, several international organizations whose activities are related to time keeping and timing applications, started a discussion on the need to discontinue the application of leap seconds in UTC. The question of the redefinition of UTC has been taken up at the ITU-R, and after several years of discussions and analysis of documents no firm position has been taken.

The CCTF notes that continuous time scales are proliferating to avoid the use of a discontinuous UTC. These scales may differ by an integer number of seconds.

The CCTF realizes that some misunderstanding exists regarding the scope of application of the various time scales. It stresses that TAI is the uniform time scale underlying UTC, and that it should not be considered as an alternative time reference. Already in the 1960s the idea of having two coexisting time references, respectively adapted to different purposes, was considered as a source of confusion.

For those applications needing UT1, the CCTF notes that the IERS publishes predictions of the difference between UT1 and UTC at different delays, allowing near real time access to UT1with precision far better than that available by assuming that UTC is a close approximation to UT1. It would be possible to disseminate an accurate value of *UT1 – UTC* in real time and this is being considered for implementation in the GALILEO and GPS systems in the near future. An accurate value could also be made available on the internet implemented in a manner similar to an NTP server, thereby providing an accurate UT1 directly for automated services.

The CCTF requests the ITU-R to consider the following issues:

- there is a clear need for a continuous reference time scale in broadcast time and frequency signals;
- different time scales are proliferating and being used as a reference, not offering the reliability, accessibility or metrological quality of the international reference UTC;
- new GNSS and GNSS augmentations are under development, requiring decisions on the definition of the respective system times;
- the access to rotational time UT1 with an accuracy better than that via UTC with leap seconds is possible through the prediction of the difference *UT1-UTC* by the IERS;
- the different interested sectors have been given the opportunity to express their opinion on the advantages and drawbacks of the present system, providing technical arguments to the discussion;

and urges the ITU-R to make a decision on the future of UTC as soon as possible.

In the case of a redefinition of UTC without leap seconds, the CCTF would consider discussing the possibility of suppressing TAI, as it would remain parallel to the continuous UTC.

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On behalf of the Consultative Committee for Time and Frequency

3 September 2007