Report to the 18th session of the Consultative Committee for Time and Frequency (CCTF), 4th and 5th June 2009

Federal Office of Metrology (METAS)

1. Clocks for TAI

1.1 Commercial clocks

At present, 4 cesium standards and 1 hydrogen maser form together the ensemble of clocks that METAS operates for the local time scales UTC(CH) and TA(CH). This number has been maintained since the last report to CCTF in 2006. The data of all clocks are reported to BIPM and contribute to the computation of TAI.

1.2 Cold cesium continuous beam standard

FOCS-1 [1] is a primary frequency standard based on a continuous beam of cold cesium atoms, developed in collaboration with the University of Neuchâtel. The design and partial results have been presented on various occasions. Short-term instabilities of $3{\cdot}10^{-13}\ \tau^{-1/2}$ are only limited by the signal to noise ratio of the currently available atomic flux.
METAS and the University of Neuchâtel collaborate also on the construction of a second continuous fountain standard FOCS-2. FOCS–2 is an improved version of FOCS–1, including a 2D–MOT pre-source and a more efficient transverse cooling scheme both designed to increase the atomic flux by a factor of 40 [2]. The goal of this second instrument is to achieve lower short-term instabilities through a higher atomic flux obtained by implementing those two techniques.
In a continuous fountain, contrary to a pulsed fountain, the lasers must remain on at all times and some light can be scattered in the free flight region of the atoms, shifting the clock frequency ($+1.2{\cdot}10^{-12}$ measured in FOCS–1). To solve this problem, a continuously rotating light-trap driven by an electrostatic motor, blocking the light but not the atoms, was developed and implemented [3].

The effect of aliasing or intermodulation on the frequency stability of continuous fountains was evaluated. By deliberately degrading the phase noise performance of the local oscillator, it was possible to demonstrate experimentally a substantial removal of the intermodulation effect [4].
Recently an unexpectedly high end-to-end phase shift has been observed on FOCS-1 and the microwave cavity is under investigation.

2. Timescales

At the beginning of November 2007 a new real-time master clock definition of UTC(CH) was officially introduced [5]. Until then UTC(CH) was defined as a paper time scale computed for epoch UTC 00:00 of each day. UTC(CH) is now realized by one of two redundant master clocks which are respectively driven by a hydrogen maser and a cesium clock. Two paper time scales are computed daily on the basis of the ensemble of free running clocks using the AT1 NIST algorithm. TA(CH.P) is a free running time scale, while UTC(CH.P) is steered occasionally to track UTC. An auxiliary time scale UTC(CH.H) is computed every hour. The auxiliary time scale uses the last computed daily state of

UTC(CH.P) as an initial condition and is used to extrapolate the daily paper time scale up to the current epoch. The master clocks are steered every hour to track the auxiliary time scale.
The change from the traditional paper clock definition of UTC(CH) to the new master clock definition improves not only the sampling interval of the clock data but also the short-term stability of UTC(CH). This opens up new possibilities, in particular for the short-term performance analysis of the remote comparison links. Thanks to the new definition, the local atomic clocks, and in particular clocks that drive the remote comparison links, can be related to each other and to UTC(CH) within an uncertainty margin of 0.1 ns, UTC(CH) and the state of any clock become traceable to UTC with an accuracy limited only by the calibration uncertainty of the remote link.

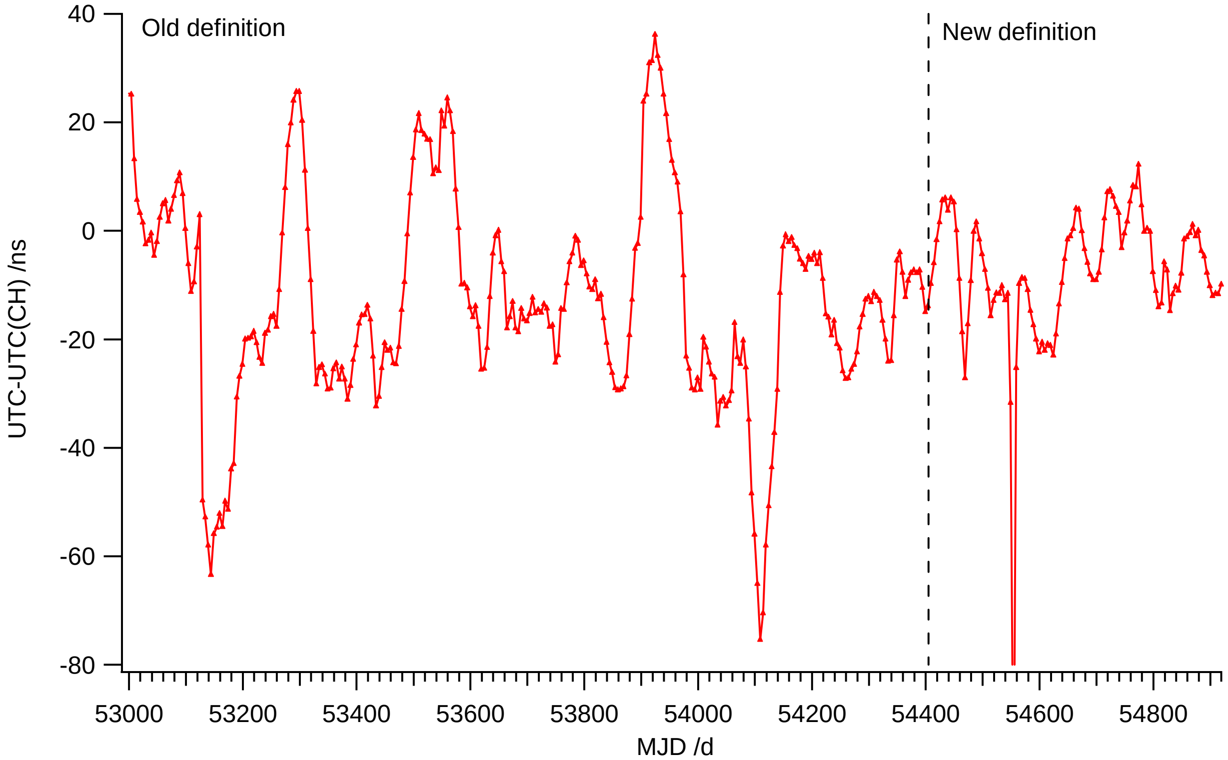

Figure 1 Evolution of UTC-UTC(CH) over the past 5 years

2. Remote Comparisons

2.1 GPS links

METAS operates two Ashtech Z-XII-T geodetic receivers. The links labeled CH00 (site WAB1) and ID CH01 (site WAB2) are operated as a back-up of the TWSTFT link. CH01 was calibrated in July 2007 in a calibration campaign run by BIPM. Additionally METAS operates a Septentrio PolaRx-2 geodetic receiver (CH03) for receiver comparison purpose. Using the real time UTC(CH), accurate comparisons of different type of receivers and GPS-methods can be done and related to the TWSTFT measurements [7].

2.3 TWSTFT-Station

Since July 2007 the TAI link used by BIPM to relate the CH clocks to TAI is the TWSTFT link METAS-PTB. The link was calibrated in June 2006 and in September 2008. The free-running hydrogen maser drives the TWSTFT link. Thanks to the new definition of UTC(CH), UTC(CH) can be compared to UTC(X) by taking advantage of the high resolution of the TWSTFT method.

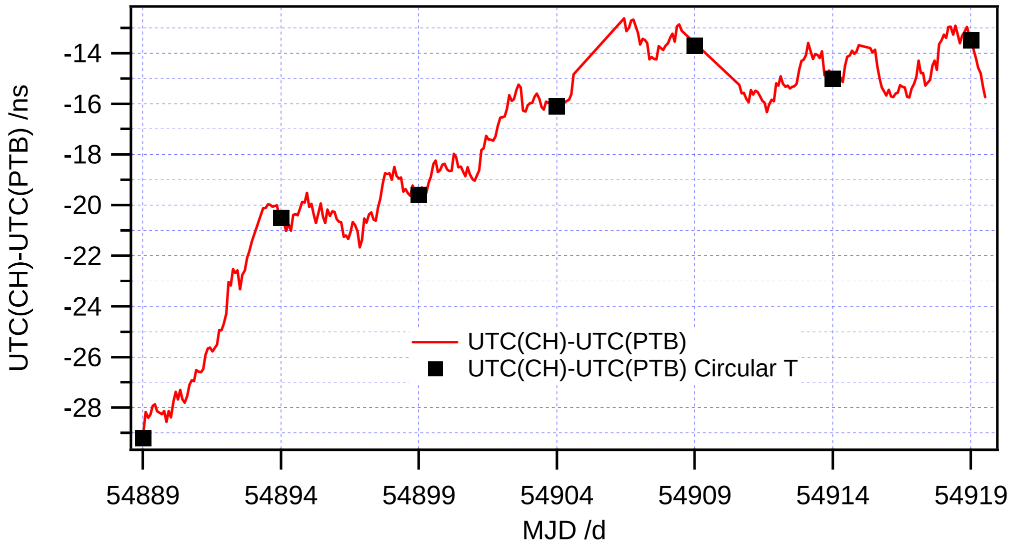

Figure 2 UTC(CH)-UTC(PTB) over one month

[1] A. Joyet, G. Di Domenico, A. Stefanov, and P. Thomann, “Status of the Continuous Cold Fountain Clocks at METAS‐LTF”, 7th Symposium on Frequency Standards and Metrology, 2008

[2] F. Füzesi, M. D. Plimmer, G. Dudle, J Guéna and P. Thomann, “Design Details of FOCS-2, an Improved Continuous Cesium Fountain Frequency Standard”, EFTF 2007

[3] F. Füzesi, A. Jornod, P. Thomann, M.D. Plimmer, G. Dudle, R. Moser, L. Sache, H. Bleuler, “An electrostatic galss actuator for ultra-high vacuum: a rotating light trap for continuous beams of laser-cooled atoms”, Review of Scientific Instruments **78**, 103109 (2007)

[4] J. Guéna, G. Dudle and P. Thomann, “An experimental study of intermodulation effects in an atomic fountain frequency standard”, Eur. Phys. J. Appl. Phys. **38**, 183-189 (2007)

[5] L.-G. Bernier,“Impact of the Change of definition of UTC(CH)”, EFTF 2008 proceedings

[6] C. Schlunegger, G. Dudle, L.-G. Bernier, D. Piester, B. Blanzano “Description of the TWSTFT Station at METAS and Presentation of the Calibration Campaign 2006”, EFTF-FCS/ENC, 2007

[7]. G. Petit, L.-G. Bernier, P.Uhrich, “Time and frequency transfert by geodetic GPs : comparison of receivers and computation techniques”, EFTF-IEEE IFCS 2009.