REALIZATION OF THE NEW UTC(OP) BASED ON LNE-SYRTE ATOMIC FOUNTAINS

B. CHUPIN, S. BIZE, J. GUÉNA, Ph. LAURENT, P. ROSENBUSH, P. UHRICH, M. ABGRALL and G.D. ROVERA
LNE-SYRTE, Observatoire de Paris, CNRS, UPMC, France
e-mail: baptiste.chupin@obspm.fr

1. INTRODUCTION

For many years, UTC(OP), the real-time approximation of UTC built in LNE-SYRTE, Observatoire de Paris (OP), Paris, France, had been based on industrial Cesium (Cs) standards [1]. Since October 2012, new algorithm for the generation of UTC(OP) has been put in operation. It is based on the steering of a H-maser signal on the LNE-SYRTE Primary Frequency Standards. The current OP atomic fountain ensemble [2] comprises a Cs fountain called FO1, a dual fountain working with Cs and Rubidium (Rb) atoms called FO2, and a mobile Cs fountain called FOM. All fountains share the same cryogenic oscillator which is phase locked to a H-maser, so that all fountains measure the frequency of the same H-maser. Automatic fountain data processing provides hourly preliminary data corrected of all systematic frequency shifts. The steering of the H-maser frequency is calculated daily by a fit to the fountain data. First we describe the implementation of all the instruments used for the generation of UTC(OP) together with the current version of the algorithm. The choice of this algorithm has been oriented to obtain robustness of the system instead of the ultimate optimization of performances. We then present the results obtained during the first year of operation.

2. UTC(OP) IMPLEMENTATION

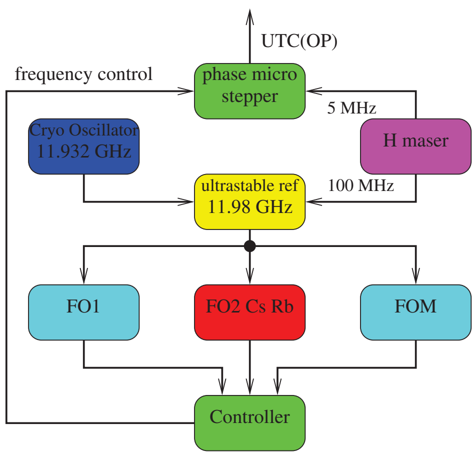

Table 1: Simplified block diagram of UTC(OP) generation.

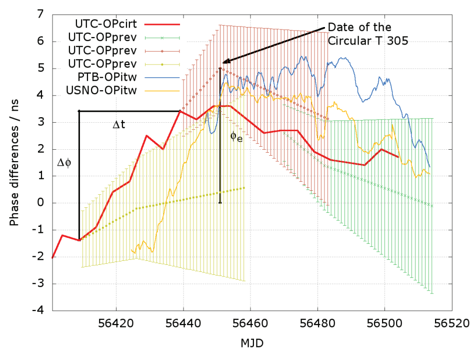

Table 2: The red lines show UTC − UTC(OP) as reported in Circular T. The colored dots with error bars are the predictions and prediction error propagation.

Figure 1 shows a simplified block diagram of the current hardware set-up used for the generation of UTC(OP). In normal operation the cryogenic oscillator that drives the three LNE-SYRTE atomic fountains is locked to the 100 MHz output of the free-running H-maser generating UTC(OP). Currently, the 5 MHz commercial phase micro stepper, historically used to steer commercial Cs standards, is still generating UTC(OP). A detailed description of the H-maser frequency distribution, filtered by the cryogenic oscillator can be found in [2].

A sophisticated automated post-processing allows for a quasi real time monitoring of the fountain operations. A more careful manual processing is performed to provide data to BIPM for the monthly steering of TAI. But for the daily steering of the H-maser the quasi real time data are largely sufficient as they are to guarantee a stability at the 10^{-16} level for the time scale generation.

The frequency of the H-maser is measured simultaneously by all the fountains available in LNE-SYRTE. But in practice only data from one fountain are used for the automated steering. The choice of the selected fountain depends on the planning of operations.

In the normal data post-processing of LNE-SYRTE fountains all the systematic shifts are corrected every one cycle. For routine fountain comparison, and UTC(OP) generation, the original data files are converted in quasi real time to files with a reduced set of data averaged over 0.1 d. These pack files contain ten frequency values per day dated at pre-established epochs, namely 0.05 d, 0.15 d, etc.. Each point is obtained after filtering out some periods of the original file due to possible problems either in the fiber links or in the lock of the cryogenic oscillator. An additional cleaning is performed by fitting linearly the resulting data over each 0.1 d period and removing possible outliers exceeding the 5 sigma limit. The value of the linear fit at the middle of the interval is used to generate the pack file. The steering software predicts once a day the H-maser frequency for the next day by extrapolating the linear fit of pack files spanning the last 20 d.

The correction to be applied to the phase micro stepper for the next day is the sum of the predicted H-maser frequency and of an additional term updated monthly, that finely adjust the phase and the frequency of UTC(OP) to UTC, using data published by the BIPM in the Circular T. This fine adjustment is the sum of 2 terms. The first one is the average frequency difference, $\nu_p = \frac{\Delta\phi}{\Delta t}$, between UTC(OP) and UTC calculated over the Circular T period. The second term, $\nu_e = \frac{\phi_e}{60\times86400}$, is calculated to compensate the last known time offset, ϕ_e, between UTC(OP) and UTC within 60 days. One can see on figure 2 these terms, the prediction and prediction error propagation.

3. RESULTS

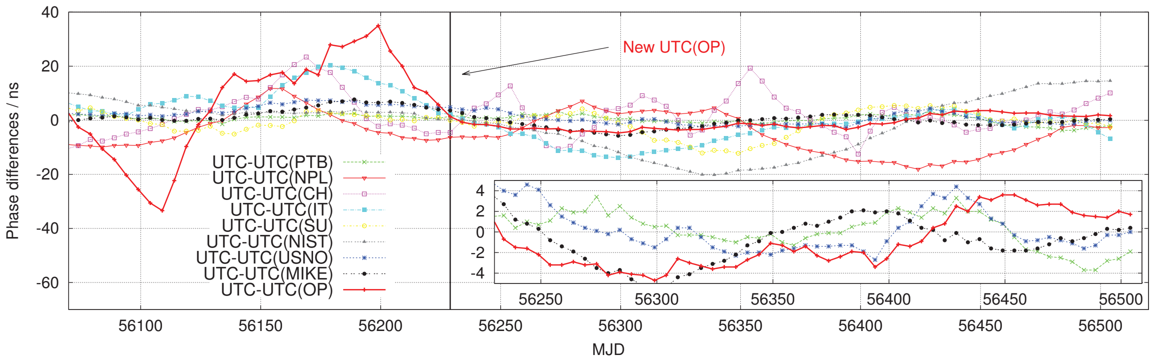

Figure 1: Comparison in ns of UTC − UTC(k) [from BIPM Circular T].

Figure 1 shows the differences between UTC − UTC(k) with the values extracted from the BIPM Circular T. Since the effective start of operations in October 2012, the departure of UTC(OP) from UTC has remained well below 10 ns. We expect that these performances might be kept on the long term with the current system.

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4. REFERENCES

[1] P. Uhrich *et al.*, 2005, Proc. of the 19$^{\text{th}}$ European Frequency and Time Forum.
[2] J. Guéna *et al.*, 2012, IEEE Transactions on UFFC, vol. 59, pp. 391–409.