NEW TIME SCALE AT ROYAL OBSERVATORY OF BELGIUM

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ABSTRACT

The presently monitoring of the master clock frequency at ROB, is performed using a daily monitoring based on GNSS geodetic time transfer with different UTC(k)'s located in remote time laboratories. To enhance the independence of the ROB, a time scale algorithm is under process, using the ensemble of caesium clocks and H maser data. Equal clock weighting has been replaced by time-varying noise characteristics of the two different types of clocks. Correction of frequency drift is required by the masers. This paper presents the algorithm and the different tests performed in order to increase its robustness and reliability.

INTRODUCTION

The Royal observatory of Belgium provides time for the Belgium since more than 30 year by realization UTC(ORB). The ORB is presently equipped with three HP5071A Caesium clocks with standard tubes (CES4, CES5 and CES6) and three H-Masers (2 active CH1-75, CH1-75A and one passive CH1-76 respectively MAS1, MAS3, MAS2. Due to low stability, we are not using MAS2 data in time scale generation. H-maser clock (CH1-75) serves as master clock, maintaining UTC-UTC(ORB) within ±40 ns. Furthermore, the ROB time laboratory contains GPS receivers which are used for both the time transfer (remote clock comparisons) and geodesy. Right now, the tuning of the master clock frequency is performed using a daily monitoring based on GNSS geodetic time transfer with different UTC(k)'s located in remote time laboratories. Frequency changes are operated very rarely (minimum 15 days interval) thanks to the very good stability of the H-maser. In order to enhance the independence of the ROB, a time scale algorithm is under process, using the ensemble of cesium clocks and H maser data. The idea is that the long-term stabilites would be determined by the caesium and the short term stability would be determined by the H-maser. In order to optimize stability and reliability, the clock weighting has been given by a procedure reflecting the relative, time-varying noise characteristics of the two different types of clocks [1]. Correction of frequency drift is required by the masers [2]. This paper will present the algorithm and the different tests performed in order to increase the robustness and reliability of the algorithm.

TIMESCALE ALGORITHM TO ENSEMBLE ATOMIC CLOCKS

The combination of several clocks to generate a smoother virtual clock would have a better performance than that of a single clock. Different algorithms can be considered depending on the requirements of the time scale. We present hereafter the basic algorithm for scheming a time scale, and the particular case of ROB. In our previous study [3] in NPL(India) the basic concept of constructing a time scale was as follows:

$$TA(t_k) = \sum_{i=1}^{N} w_i \{h_i(t) - \hat{x}_i(t)\} \tag{1}$$

where N is the number of participating clocks and w_i is the relative weight of clock i, $h_i(t)$ is the reading of clock i at time t, and $\hat{x}_i(t)$ is the prediction of the reading of clock i that serves to guarantee the continuity of the time scale. w_i is an effective tool, it reflects the frequency stability of the clock [4]. The weights of clocks obey the relation:

$$\sum_{i=1}^{N} w_i(t_k) = 1 \tag{2}$$

DIFFERENT STUDY CASES

Initially, we attempted the same algorithms to ROB clocks data as we have already validated in NPLI, but the result was not at the level of our expectation . The reason being that in NPLI it was an ensemble of only caesium clocks data.

Now the situation is different, this is a combination of H-masers and caesium clocks. Correction of frequency drift is required by the masers [1-2]. The new time scale prediction is based on (3).

$$\hat{x}_i(t) = x_i(t_{k-1}) + y_i(t_k)(t_k - t_{k-1}) + \frac{1}{2}\dot{y}_i(t_k)(t_k - t_{k-1})^2 \quad (3)$$

The new time scale TA result is obtained using (3) in to (1). The linear prediction for caesium clocks and the quadratic prediction for the H-masers have been used. We conclude that a quadratic model predicts the phase of the H-masers better than the linear prediction model. We used UTC as a reference for evaluation of the stabilities of clocks, because it is a stable and independent time scale. The rate of a Cs atomic clock and H-Maser clocks are estimated from the data of the 10, 30 and 45days, but we observed better results for 30 days , because most clocks maintain their stabilities very well around 30 days [4]. According to the principle of weighted averaging the appropriate weight is in inverse proportion to the square of the uncertainty of each clock. We use the Allan deviation σ_y as uncertainty. We call it tight weighting and express it in w .

$$w_i(t) = \sigma^2_{yi}(t,\tau) / \sum_i \sigma^2_{yi}(t,\tau) \quad (4)$$

We adopt τ =30 days for the same reason as for clock rate. Fig. 1 is showing the UTC-UTC(ORB) output of timescale prediction for the next 45 days, in comparison with UTC-UTC(ORB) from Circular T .

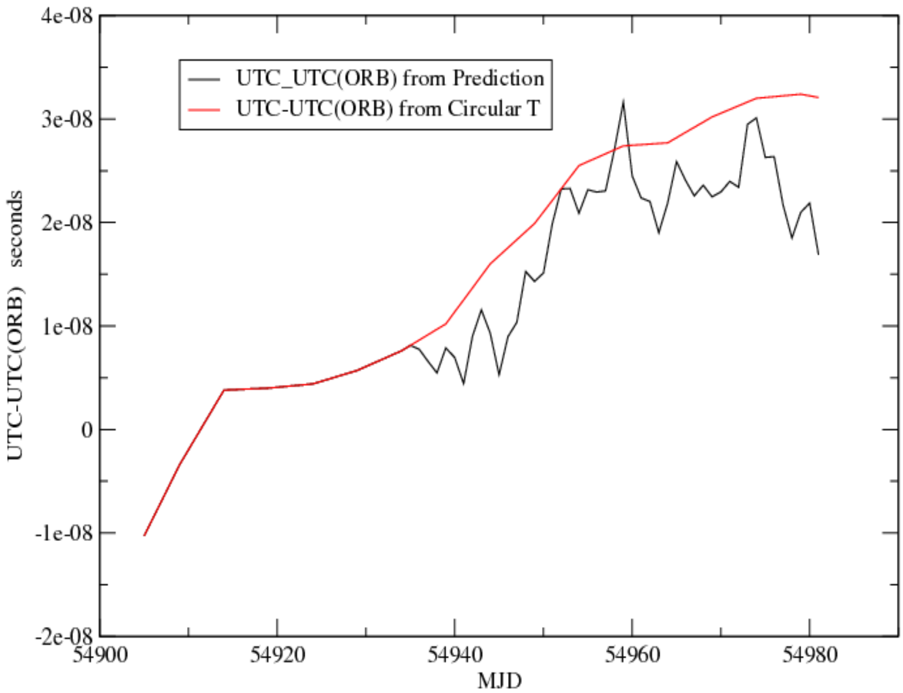

Fig. 1- Predicted UTC-UTC(ORB) for next 45 days with corresponding UTC-UTC(ORB) from Circular T by BIPM.

The clock weights are fixed by appropriate algorithms based on the clock behavior in the past, and in (4) they can be considered as time varying parameters. But it requires more analysis on weight assignment for clocks. From (1) and then following the steps described later in this section the differences between [UTC-clock i] predicted and

[UTC(ORB)-clocks i] measurement value will give [UTC-UTC(ORB)] predicted. Our purpose is to cancel the time difference between the H-maser (master clock) and TA so the rate adjustment is:

$$y_{adj} = x_j(t)/T - y'^{a}(t) \tag{5}$$

In above equation, $x_j(t)$ is the output of timescale, $y'^{a}(t)$ is the rate of H-maser clock. This is a direct and simple adjustment. The estimates are reliable up to 6 weeks beyond the latest issue of Circular T to allow up to keep UTC(ORB) close to UTC. In this algorithm we are taking the rate of 30 days data to and predicted for next 45 days.

CONCLUSIONS

We designed an algorithm that predicts the clock with a linear model that is well adapted to caesium clock, and a quadratic model well adopted to Hydrogen masers. In this algorithm 10 days, 30 days or 45 days of past data has been used to evaluate the rate and frequency drift but the 30 days past data is showing the best results.

REFERENCES

1. A. Lee Breakiron, "Timescale algorithms combining cesium clocks and hydrogen masers", *23rd Annual Precise Time and Time Interval(PTTI) Meeting*.
2. G. Panfilo and F.Arias, " Studies and possible improvements on EAL algorithm", In proc. of the 23rd joint meeting of the *IEEE International Frequency control symposium and EFTF*, Besancon, France 2009.
3. P. Banerjee, Suman Sharma and A. Chaterjee, "Time scale of NPLI:current status and future plan of improvement", *Metrologia,* vol. 45, pp.S66-S73, 2008
4. Y. Hanado and M. Hosokawa, "Improvement of rate shift in average atomic time scale algorithm", *Japanese J. of Appl. Phys.,* vol. 47*, no. 4*, pp.2294–2299, 2008.