Precise Timekeeping for Research Advancements

Jahnvi Verma[1], Nischal Bhattarai[1], Charles Rasor[1], Thejesh N. Bandi[1],

[1]Department of Physics and Astronomy, The University of Alabama, Tuscaloosa, USA

Email: tbandi@ua.edu

Precise timekeeping is the basis for maintaining the International Atomic Time (TAI) – as a weighted average of the contributions by metrology labs around the world[1]. The conventional method of timekeeping needs a relook in terms of the algorithms and diligent utilization of big data for improving the accuracies and reliability. Redefinition of the time[2] may need evaluating new algorithms, prior to the actual implementation in TAI. We are developing a timescale focused on the advancements for precision timekeeping that is flexible for research and testing purposes.

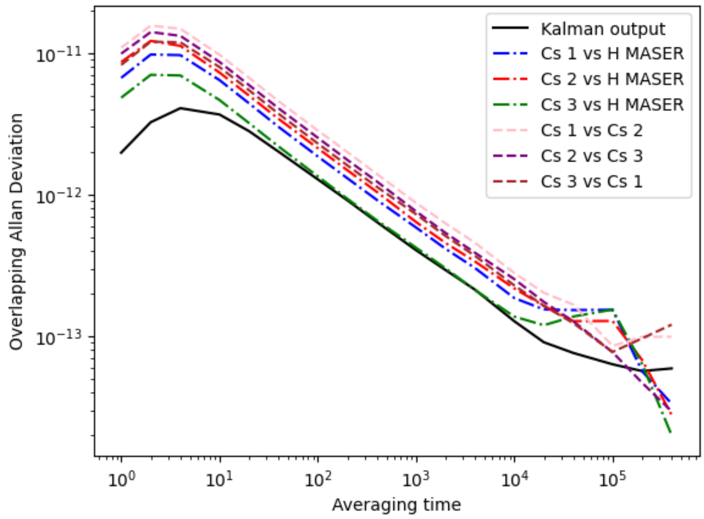

Fig. 1: Performances of the individual clocks in the timescale and the Kalman Filter (KF) algorithm output.

Our timescale utilizes three Cesium (Cs) clocks and one Active Hydrogen MASER (AHM). Two more AHMs will be added to the ensemble in future. The 5 MHz outputs are fed to a Multichannel Measurement System (MMS), which provides the phase differences every second between all the clocks in the system. Our clock ensemble is synchronized to the UTC time, via a Novatel GNSS receiver. To evaluate our developed algorithm's robustness, the AHM was perturbed by placing it in a temperature control chamber. Fig. 1 shows the stability of the Cs clocks by 3-corner hat method (dashed lines) for over 20 days of continuous data. Cs 1 has a degraded performance after 10^5 s. The Cs vs AHM curves (dash-dot lines) show degradation starting around 20,000 s due to the thermal effects on AHM. However, the algorithm ensures the weighted linear Kalman Filter (KF) output (solid line) without any impact – either due to AHM thermal effects or the Cs 1 clock – indicating the robustness of our developed algorithm. The estimations of the 3 cornered hat method were used to model the noise covariance matrices of the 3 Cs clocks. The KF output is a weighted average of all the 6 measurement predictions by the algorithm. The weights were dynamically adapted based on the performance of the clocks. We will present our timescale work, including the ongoing development and implementation of an unscented Kalman filter based algorithm[3] and a neural network-based AI algorithm output, compare the results with our present KF algorithm and highlight the future efforts.

We gratefully acknowledge the support from USNO via educational partnership with UA, and courteously thank the continued support from Microchip Technology Inc., Tuscaloosa.

---

[1] T. J. Quinn, "The BIPM and the accurate measurement of time," Proc. IEEE, vol. 79, no. 7, p. 894–905, 1991.
[2] N. Dimarcq *et al.*, "Roadmap towards the redefinition of the second," Metrologia, vol. 61, p. 012001, 2024.
[3] M. Impraimakis and A. W. Smyth, "An unscented Kalman filter method for real time input-parameter-state estima tion," Mech. Syst. Signal Process., vol. 162, p.108026, 2022.