Statistical Analysis Of H-Masers To Improve The Long-Term Stability Of UTC

J. Milton
School of Physics
University of Edinburgh
Scotland

G. Panfilo
BIPM
Time Department
Sevres, France

***Abstract*—In this work a statistical analysis of individual H-Masers is presented to optimize the prediction and weighting algorithms used for the generation of UTC. The H-Masers have been grouped by manufacturers' model to identify common signatures and statistical similarities. This allowed the agreement of the weights associated with the clocks in UTC to be checked with the output of this statistical analysis.**

To confirm these results a statistical analysis of the weighted residuals of the real and the predicted values of [(EAL-clocks)-(EAL-clocks)'] of each clock has been performed for several calculation months. This allowed an estimate of the stability of EAL (the component impacted by the clocks) to be made and a determination of the clocks which were impacting UTC more negatively. This study identified where improvements to the contribution of clocks in UTC could be made, and where problems and possible solutions lie.

Keywords—UTC, algorithms, time and frequency, stability analysis.

I. INTRODUCTION

UTC (Coordinated Universal Time) [1] is calculated by using more than 400 atomic clocks located in 80 institutions across the world. At the first stage EAL (free atomic time scale) is calculated as weighted average of atomic clocks by using appropriate weighting and prediction algorithms. Its frequency is corrected with respect to the frequency of Primary and Secondary Frequency Standard (PFS/SFS) to obtain TAI (International Atomic Time) and the leap second is added to finally obtain UTC. During the last years, important improvements have been made in the prediction and weighting algorithms to improve the long-term stability of EAL. The main scope of the previous work was to minimise the effect of the frequency drift of the H-masers and of the ageing of caesium clocks affecting EAL and to use the best of the atomic clocks in the ensemble. Having reached this important point, studies have aimed to continuously check the behaviour of EAL (and UTC) and improvements of its stability are performed continuously.

In this work it will be presented how the approach followed until now, treating all the clocks in the same way, is no more adapted and that there is a need to study each clock singularly and to identify each single problem is a possible way to proceed.

Consequently, a detailed statistical analysis of the atomic clocks which have an important role in UTC, e.g. the H-Masers, started. This study allowed identification of the atomic clocks which need to be treated differently and has given some ideas on the next step to follow to improve the EAL long-term stability.

II. RESULTS

The H-masers are considered with respect to the Terrestrial Time (TT(BIPM)), the better frequency reference exiting. The longest period of (TT(BIPM)-HM) without steps or anomalies has been found, in order to perform a significant statistical analysis.

The minimum value of the Allan and Hadamard variances (see Figs. 1 and 2) of the H-Masers grouped by the constructor (in this abstract indicated by A, B etc.) has been found to find the period over which each clock could be considered stable and the maximum integration interval useful for the prediction.

By the analysis of the residuals between real data and prediction of EAL-clocks (see Fig 3) the list of clocks with larger values (H-Masers in red in the plot) is established. The larger number of these clocks corresponds to the clocks showing a poor statistic in the first analysis confirming the results obtained.

Preliminary results showed common signatures in clocks of the same type and suggests a different treatment to improve the stability of EAL.

Allan Variance - Percentage with minimum Allan Variance at Tau (days) or above								
Clock Type	5=<x	10=<x	20=<x	40=<x	80=<x	160=<x	320=<x	total
A	100.0	90.0	50.0	30.0	25.0	20.0	10.0	20
B	100.0	0.0	0.0	0.0	0.0	0.0	0.0	2
C	100.0	75.0	50.0	0.0	0.0	0.0	0.0	4
D	100.0	100.0	0.0	0.0	0.0	0.0	0.0	1
E	100.0	42.9	25.0	14.3	14.3	12.5	8.9	56
F	100.0	0.0	0.0	0.0	0.0	0.0	0.0	1
G	100.0	0.0	0.0	0.0	0.0	0.0	0.0	1
H	100.0	72.7	27.3	0.0	0.0	0.0	0.0	11
I	100.0	100.0	0.0	0.0	0.0	0.0	0.0	1
J	100.0	64.3	42.9	21.4	21.4	14.3	0.0	14
K	100.0	40.0	40.0	20.0	20.0	0.0	0.0	5
L	100.0	100.0	100.0	50.0	25.0	25.0	0.0	4
M	100.0	33.3	33.3	33.3	0.0	0.0	0.0	3
N	100.0	100.0	100.0	50.0	0.0	0.0	0.0	2

Fig. 1. Percentage of clocks with an Allan Variance at Tau (days) or above, grouped by constructor.

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Hadamard Variance - Percentage with minimum Hadamard Varaince at Tau (days) or above								
Clock Type	5=<x	10=<x	20=<x	40=<x	80=<x	160=<x	320=<x	total
A	100.0	100.0	100.0	85.0	55.0	40.0	20.0	20
B	100.0	50.0	0.0	0.0	0.0	0.0	0.0	2
C	100.0	75.0	50.0	50.0	50.0	0.0	0.0	4
D	100.0	100.0	100.0	100.0	100.0	100.0	0.0	1
E	100.0	87.5	76.8	42.9	25.0	8.9	3.6	56
F	100.0	0.0	0.0	0.0	0.0	0.0	0.0	1
G	100.0	0.0	0.0	0.0	0.0	0.0	0.0	1
H	100.0	90.9	63.6	9.1	0.0	0.0	0.0	11
I	100.0	100.0	0.0	0.0	0.0	0.0	0.0	1
J	100.0	100.0	85.7	42.9	7.1	0.0	0.0	14
K	100.0	80.0	40.0	40.0	0.0	0.0	0.0	5
L	100.0	100.0	100.0	75.0	0.0	0.0	0.0	4
M	100.0	100.0	66.7	33.3	33.3	0.0	0.0	3
N	100.0	100.0	100.0	50.0	0.0	0.0	0.0	2

Fig. 2. Percentage of clocks with an Hadamard Variance at Tau (days) or above, grouped by constructor.

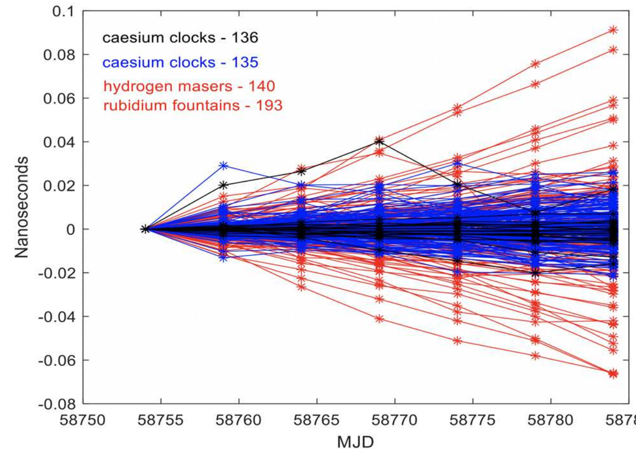

Fig. 3. Difference between (EAL-h) and (EAL-h)' in one UTC calculation month.

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References

[1] Panfilo G and Arias F 2019 The Coordinated Universal Time (UTC) Metrologia 56 042001.