Improvements in ALGOS

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Outline

- Clock prediction algorithm
  - Quadratic model
  - TT as frequency reference for drift evaluation

- Application and effect of the new prediction algorithm :
  - EAL frequency drift is almost completely removed
  - Effect on TAI and on the weights

- A new model for the weighting procedure
  - The prediction is taken into account
  - Effect on the UTC stability and on the weight

- Conclusion and discussion

EAL prediction algorithm

Until July 2011 the linear prediction had been used to describe the clock behaviour; the frequecy of the clocks is considered constant during the calculation period; the frequency drift (or the aging) is not included in the model.

UTC is calculated with more than 400 clocks of which:

- Caesium clocks 5071 (high performance tube): ~ 270
- H-masers Symmetricom/Sigma tau : more then 50

The ensemble of clocks shows very similar deterministic signatures (frequency drift or aging).

As a consequence of that EAL shows a frequency drift respect to TT of about:

-1.3×10^{-17}/day

EAL new prediction algorithm

After test and simulations for a long period (5 years), after publications and presentations[1,2,3] the new prediction algorithm for EAL has been validated and implemented.

From August 2011 a quadratic prediction is officially used to calculate UTC; the frequency drift is considered in the model for all kind of clocks.

The frequency drift affecting EAL is almost completely removed.

[1] G. Panfilo and E.F. Arias. "Studies and possible improvements on EAL algorithm". UFFC, Vol. 57, No.1, January 2010, pp. 154-160.

[2] G. Panfilo, A. Harmegnies, L. Tisserand. "A new prediction algorithm for the generation of International Atomic Time". Metrologia, 2012, 49, n°1, 49-56.

[3] G. Panfilo, A. Harmegnies, L. Tisserand. Report to CCTF. A new prediction algorithm for EAL.

The prediction algorithm for EAL

The main ideas of the new prediction algorithm are:

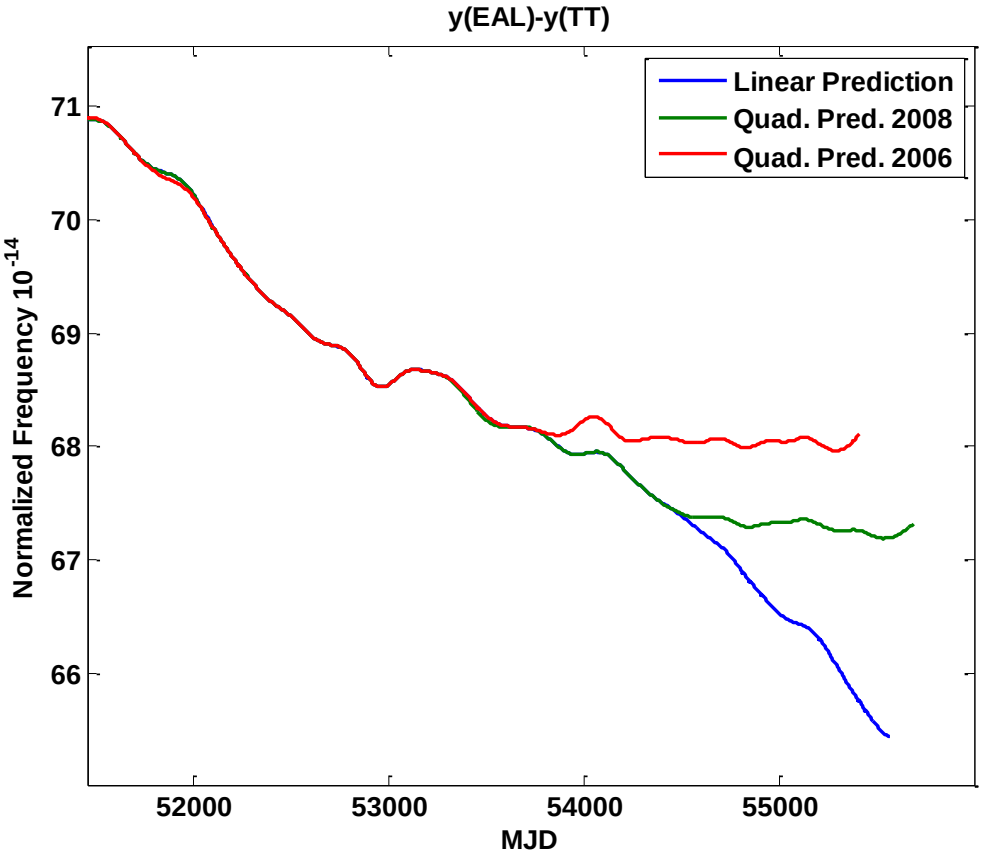
1. The use of the quadratic model to describe the frequency drift

$$h_i'(t) = \hat{a}_{i,I_k} + \hat{B}_{ip,I_k}(t - t_k) + \frac{1}{2}\hat{C}_{i,I_{k-1}}(t_k - t_{k-1})(t - t_k) + \frac{1}{2}\hat{C}_{ip,I_k}(t - t_k)^2$$

2. The use of TT (Terrestrial Time, a time scale optimized for frequency accuracy) as frequency reference to estimate the frequency drift

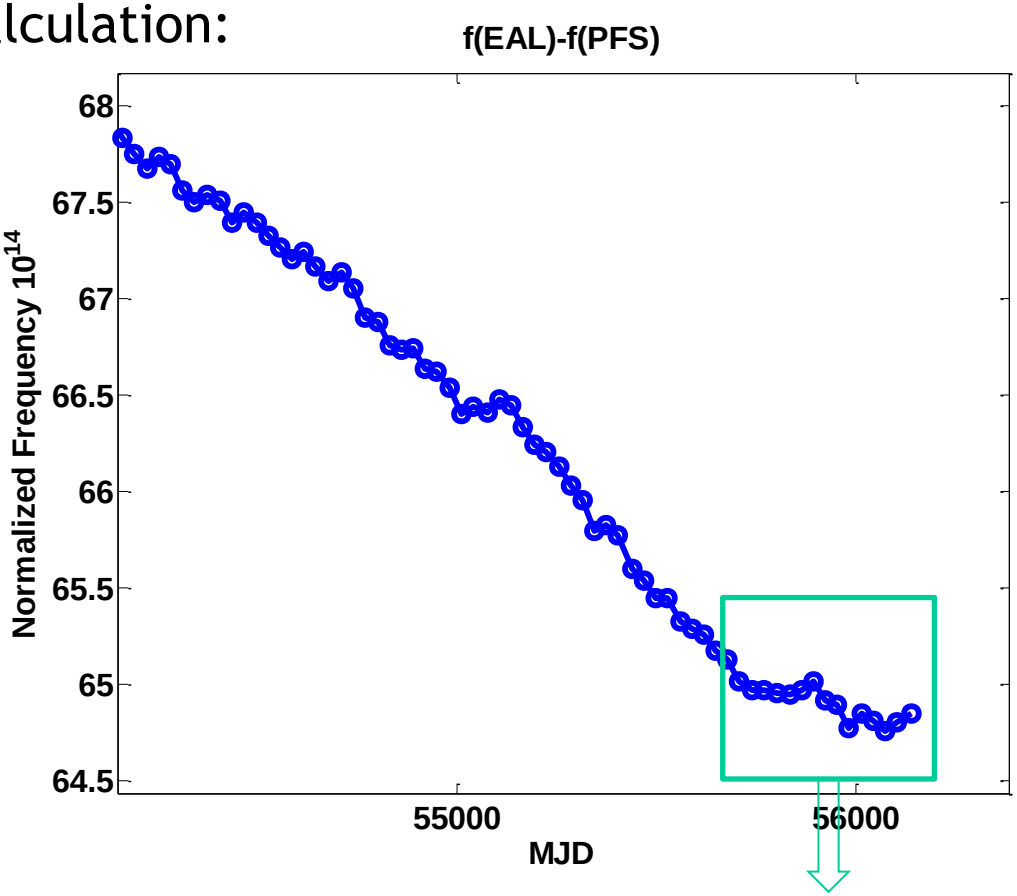
Simulation results

Two tests were performed on data starting in 2006 and in 2008 until 2010 to validate the new prediction algorithm.



Results: y(EAL)-y(PFS)

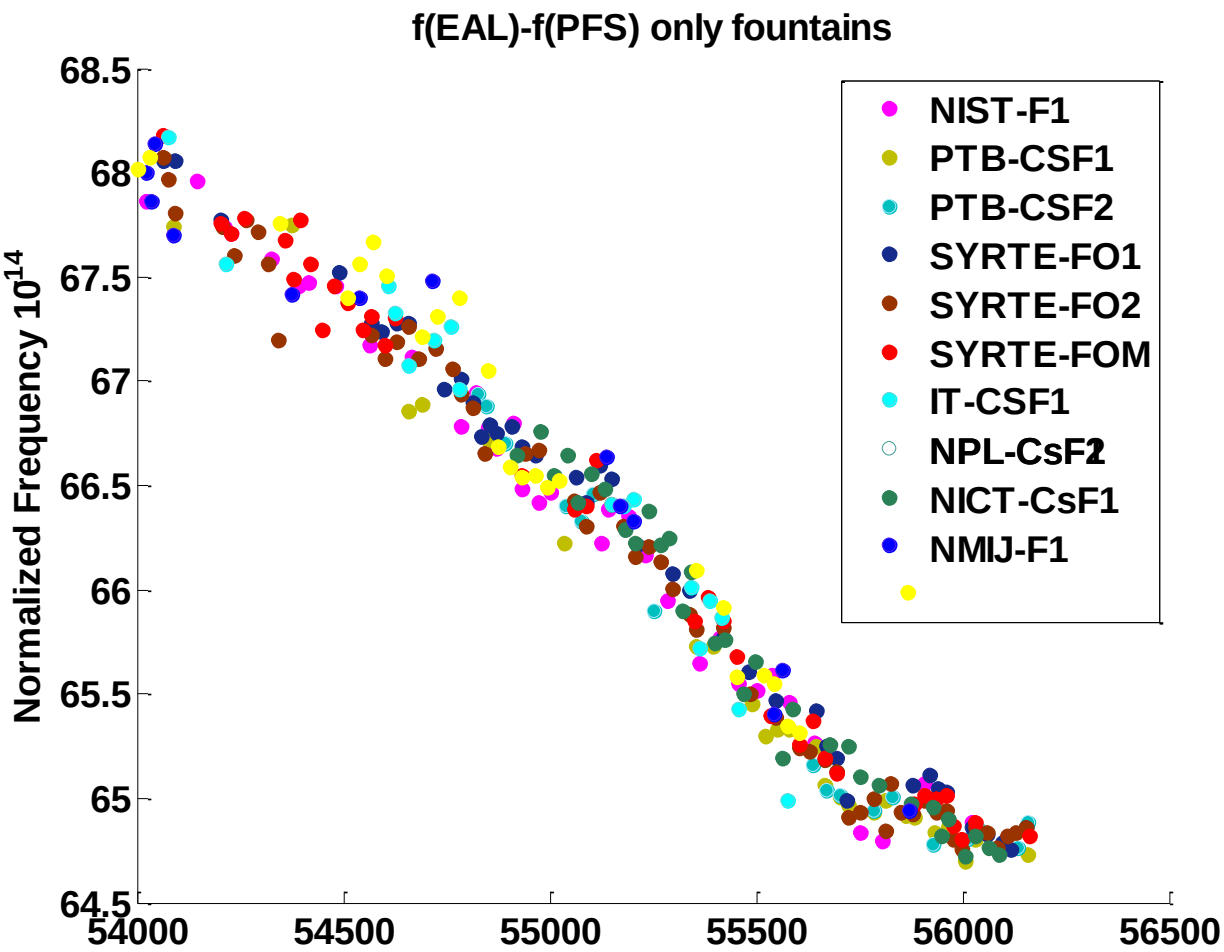
Starting from August 2011 the new algorithm is officially used in UTC calculation:



The frequency drift affecting EAL is almost completely removed

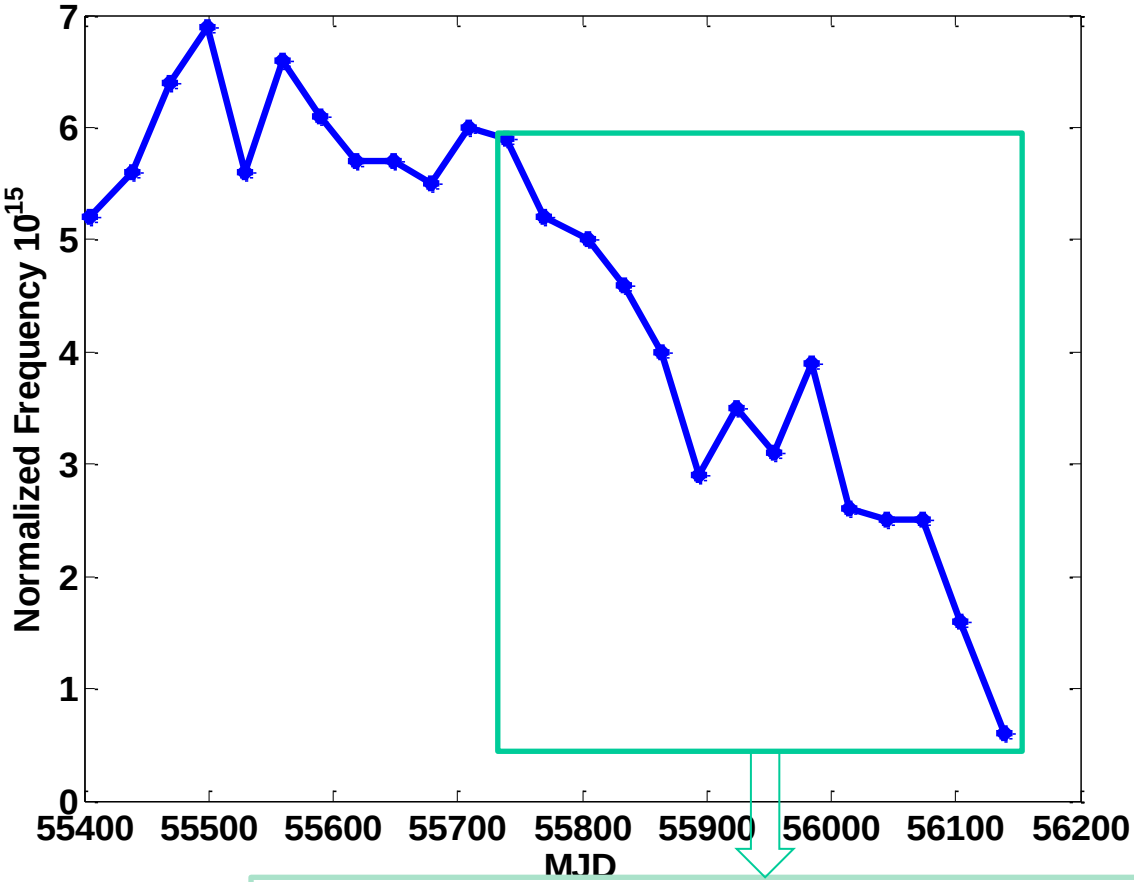
Period of application of the new algorithm

y(EAL)-y(PFS)


f(EAL)-f(PFS) only fountains
Normalized Frequency 10^{-14}
68.5
68
67.5
67
66.5
66
65.5
65
64.5
54000
54500
55000
55500
56000
56500
NIST-F1
PTB-CSF1
PTB-CSF2
SYRTE-FO1
SYRTE-FO2
SYRTE-FOM
IT-CSF1
NPL-CsF2
NICT-CsF1
NMIJ-F1

The effect on TAI

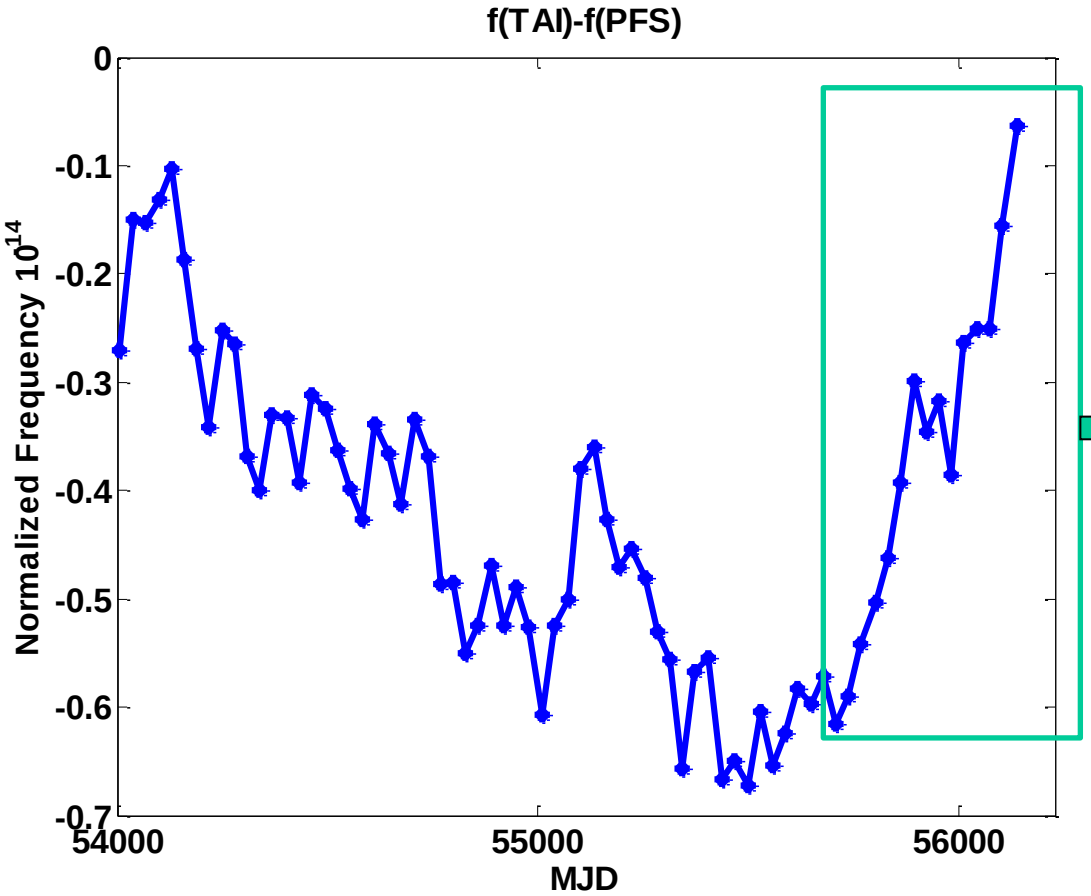
In the plot the fractional deviation *d* of the scale interval of TAI from that of TT based on all available PFS measurements is reported .



The value of *d* is decreasing to zero with some noise

Period of application of the new algorithm

.....f(TAI)-f(PFS)

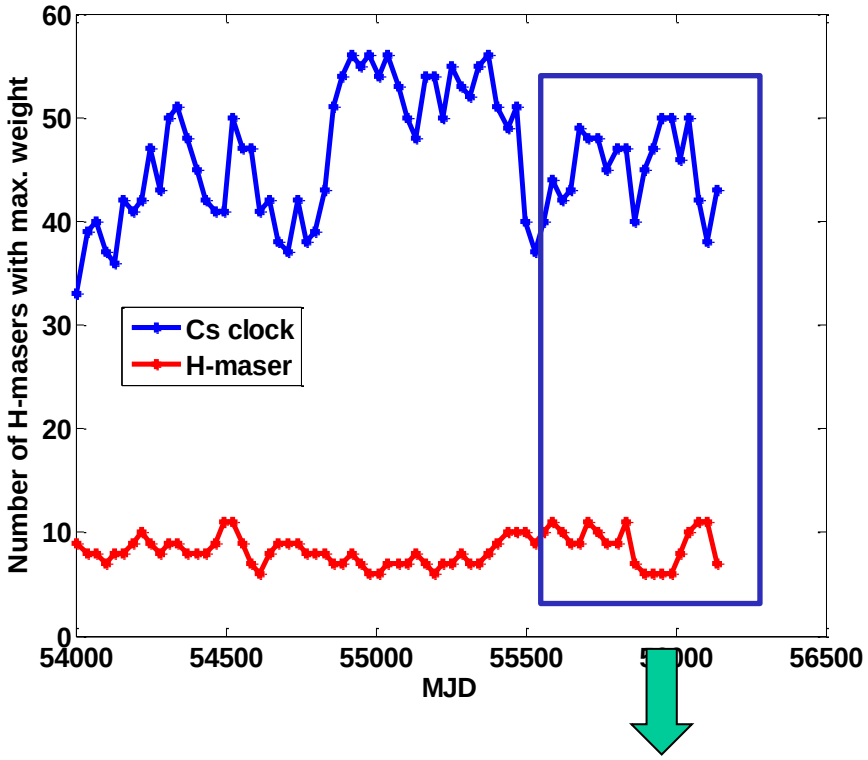


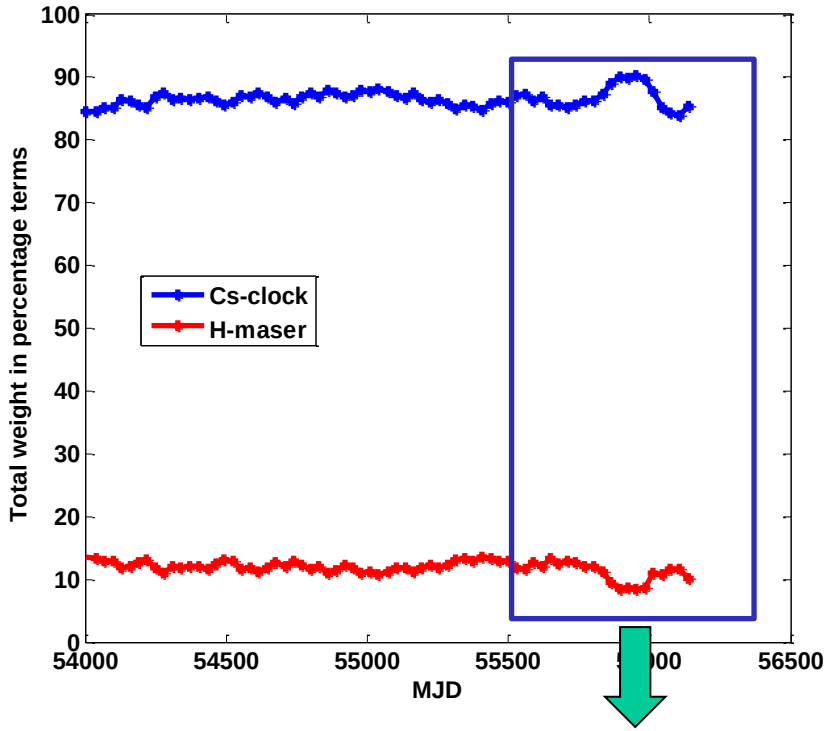
Period of application of the new algorithm

The value of the difference f(TAI)-f(PFS) should be close to zero. Starting from the application of the new prediction algorithm this value is approaching zero with some noise.

The effect on the weights

The weighting algorithm has not yet been changed. The new prediction algorithm has no effect on the weights.





Period of application of the new algorithm

EAL: Weighting Algorithm

In the current weighting algorithm the weight attributed to a clock reflects its long-term stability. The clocks with deterministic signatures like frequency drift or aging are de-weighted and considered “bad” clocks.

The H-masers have a small weight due to frequency drift affecting the behaviour.

In the time scale algorithms clock weights are generally chosen as the reciprocals of a statistical quantity which characterizes their frequency stability, such as a frequency variance (classical variance, Allan variance....)

A new proposed weight algorithm

After the implementation of the new prediction algorithm the deterministic signatures are eliminated or minimized in the time scale.

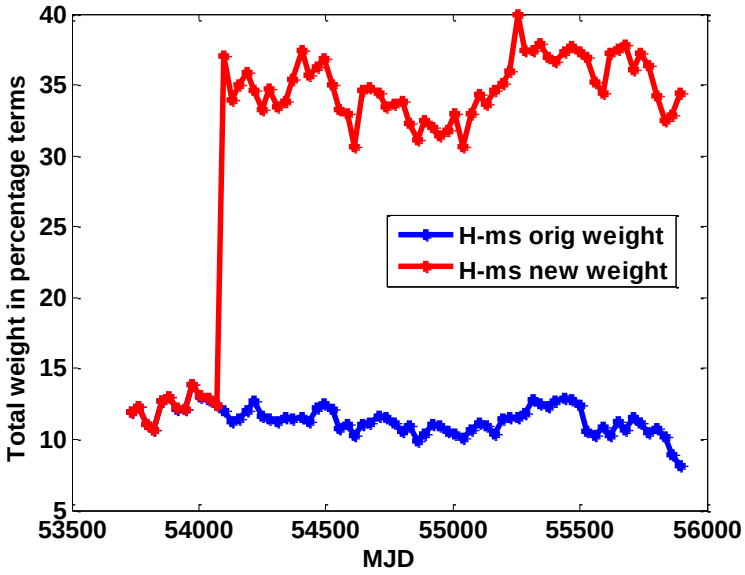
The main idea of the new weighting algorithm is that a good clock is not a stable clock but a predictable clock[1].

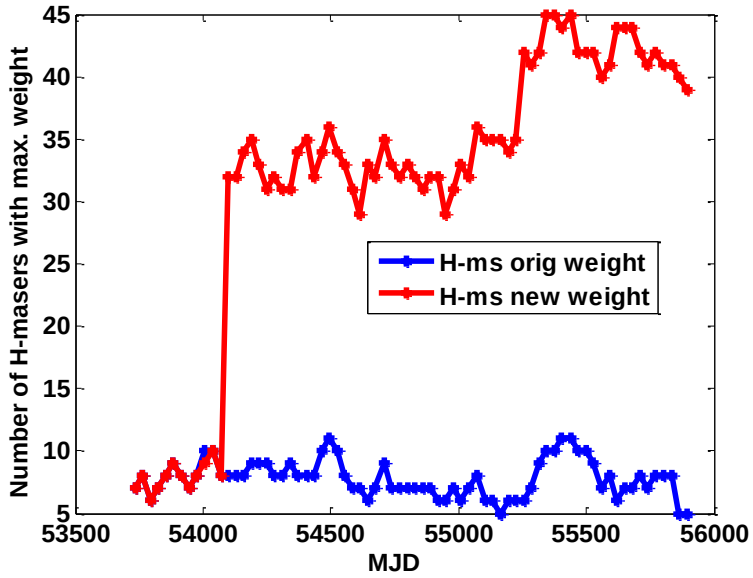
In this new version of the weighting algorithm 1 year of the difference between the predicted and real frequencies of the atomic clocks is evaluated. A filter is used to give a bigger role to the new measurement with respect to old ones.

[1] Levine J. "Introduction to time and frequency metrology". Review of Scientific Instruments, Vol. 70, No. 6, pp.2567-2596, 1999.

Effect of the weight distribution – H-maser

A test was performed using 6 years of data: 2006-2011



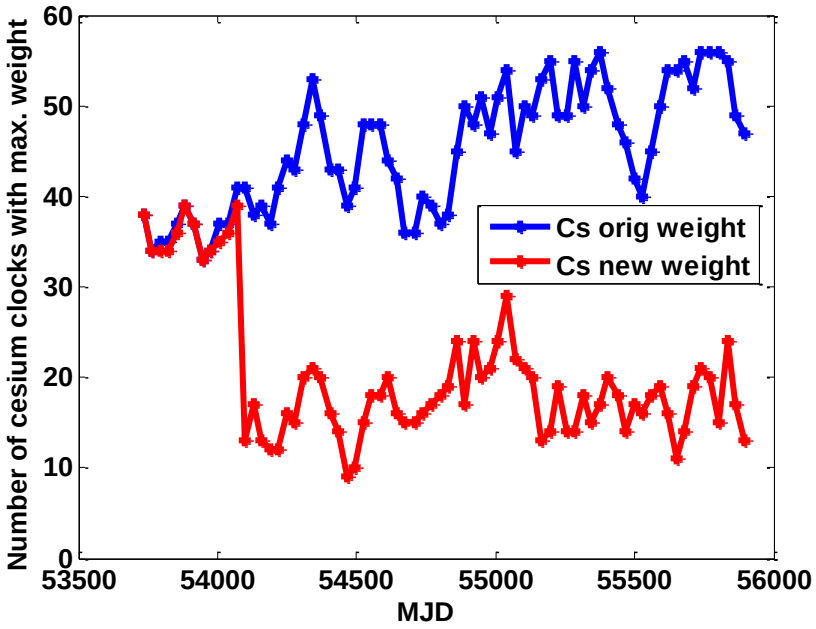


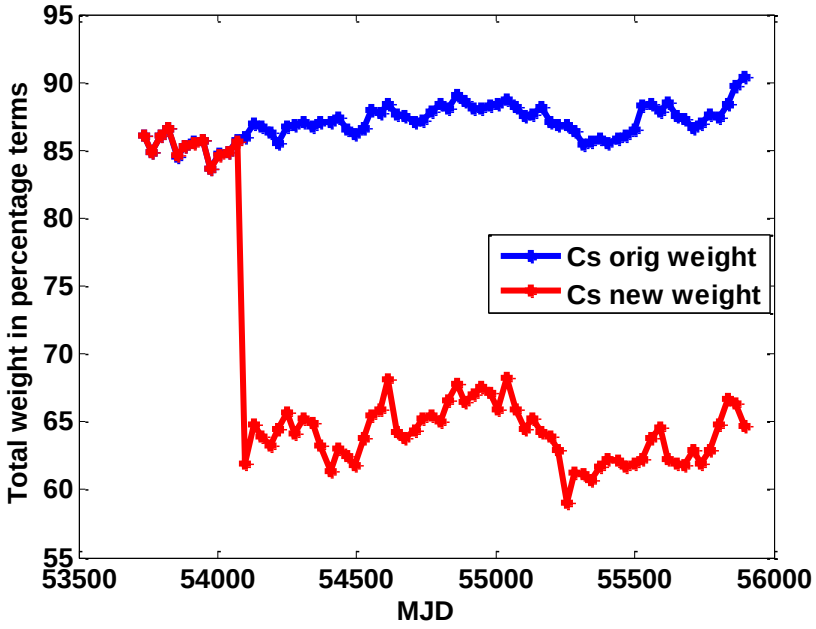
By applying the new weighting algorithm for the H-masers:

Total weight: ~ 15% ⟹ ~ 30%

Number of clocks at maximum weight: ~ 10 ⟹ ~30

Effect on the weight distribution – Cs clocks





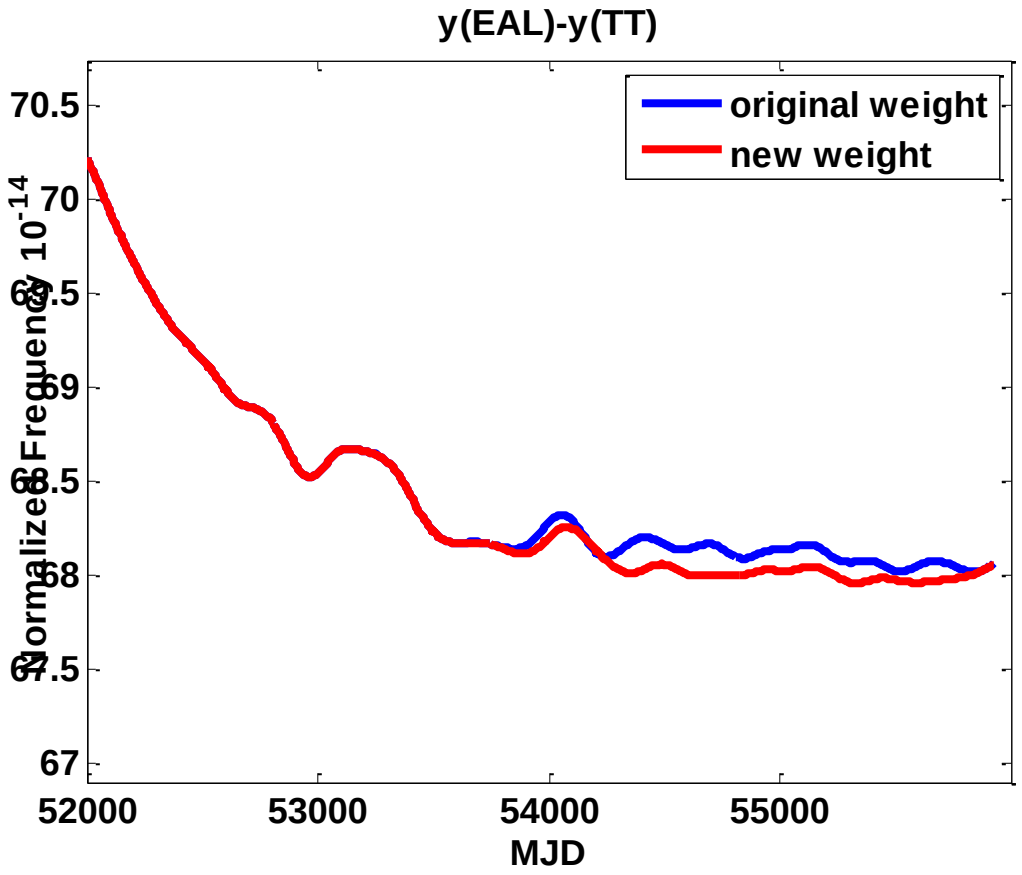
By applying the new weighting algorithm for the caesium clock:

Total weight: ~ 85% ⟶ ~ 70%

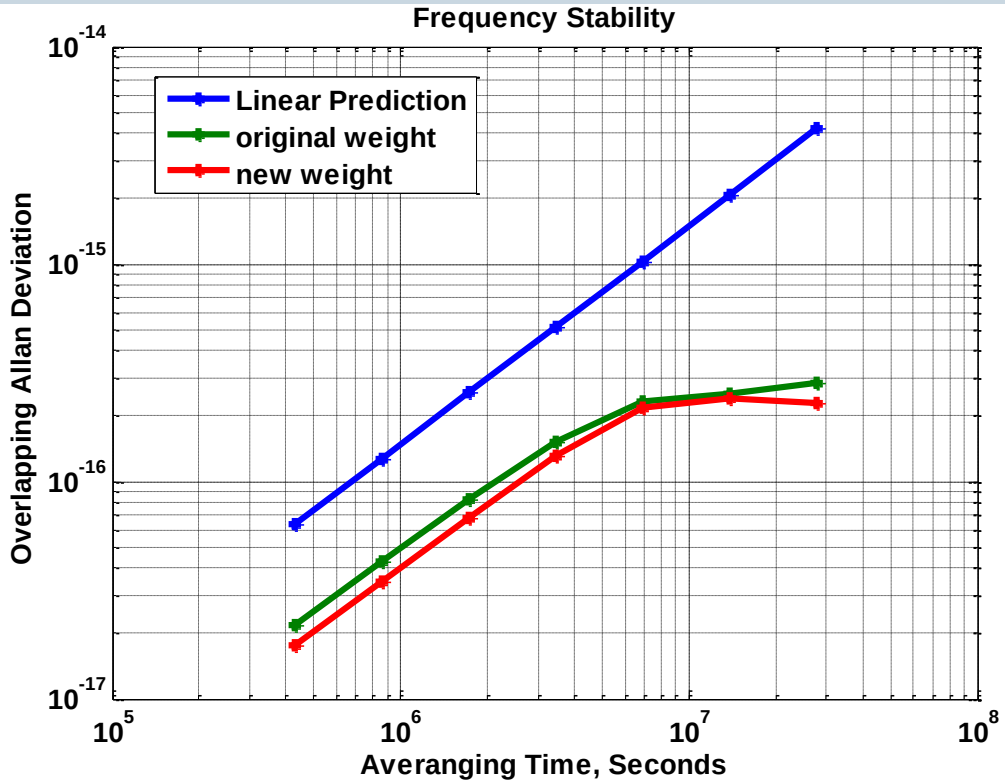
Number of clocks at maximum weight: ~ 55 ⟶ ~20

Results and effect on EAL

A test was performed using 6 years of data: 2006-2011 and by using the quadratic prediction algorithm.



Stabilty of f(EAL)-f(TT)

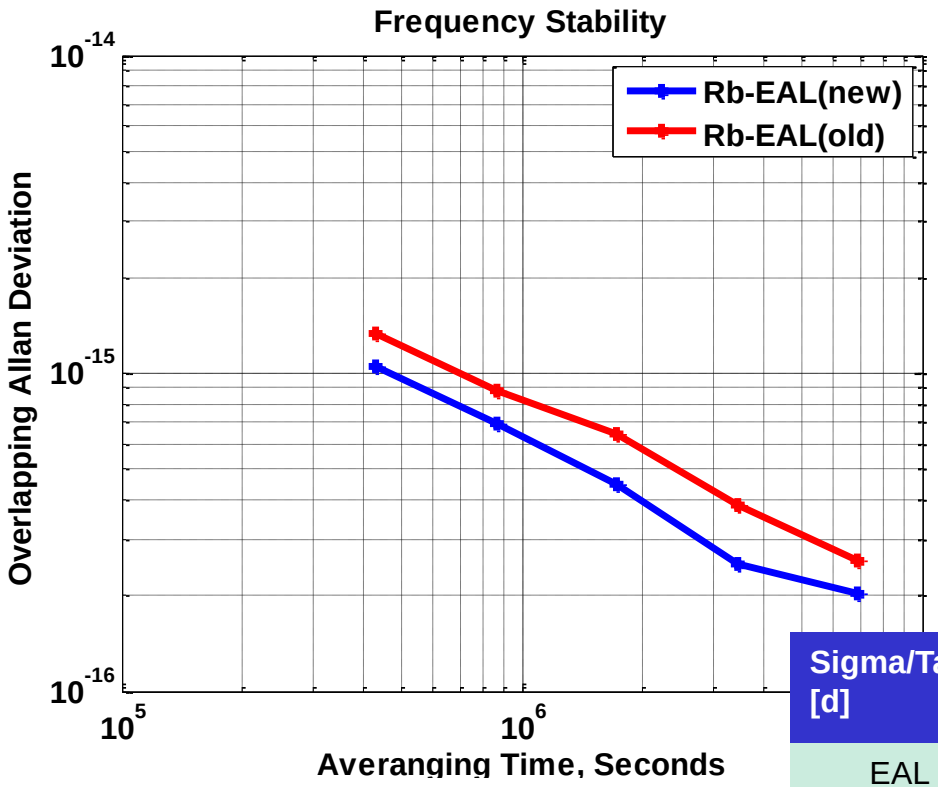


By using the new weighting algorithm the long term stability of EAL is not affected by the frequency drift of the H-Masers.

Due to short term correlation between EAL and TT we have only long term information from this analysis.

Stability of EAL and TT vs USNO Rb fountain

The data coming from USNO Rb fountain MJD 55634-55924 are used to evaluate EAL long term stability.



By using the new weighting algorithm the short and the long term stability of EAL is improved.

simulated EAL (new weight)
simulated EAL (old weight)

Sigma/Tau [d]	5	10	20	40	80
EAL	1.3E-15	8.7E-16	6.6E-16	3.9E-16	2.6E-16
EAL new	1.0E-15	6.9E-16	4.5E-16	2.5E-16	2.0E-16

Discussion and Conclusions - 1

Starting from August 2011 the new prediction algorithm has been officially used for UTC.

The used mathematical model takes in to account the treatment of the frequency drift.

No change in the weighting strategy has been implemented.

After 1 year of the application of the new algorithm the positive effects are evident.

The frequency drift of EAL is almost completely removed.

Discussion and Conclusions - 2

The new prediction algorithm has no impact on the weights.

A revision of the weight algorithm has been presented to increase the role of the H-masers in the time scale ensemble.

The new weighting algorithm gives a good weight to the H-masers.

Complementary studies are necessary to validate new weighting algorithm.

Future developments - Rapid UTC

In the framework of the Rapid UTC pilot project data clock and time transfer data are available at 1 day interval.

At 1 day interval the dominant noise is given by the time transfer system if the the H-masers are correctly used.

In this situation it can be interesting to test the effect of the new weighting algorithm with 1 day interval data to observe the short term contribution of the H-masers to the ensemble.


Thank You!