# Timescale Algorithm at CSIR-NPL

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**Abstract**

A timescale algorithm is developed at CSIR-NPL (Council of Scientific and Industrial Research-National Physical Laboratory, New Delhi) to steer UTC (NPLI) towards the UTC. The algorithm is based on weighted average of an Active Hydrogen Maser (AHM) and five high performance cesium clocks.

## 1. Introduction

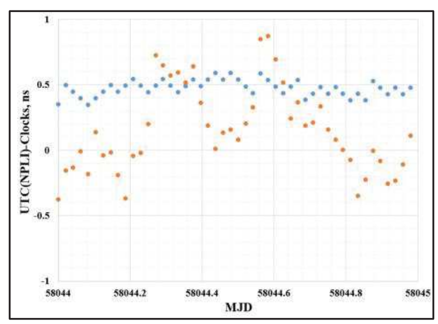
CSIR-National Physical Laboratory is the custodian of Indian Standard Time (IST), which is 5:30 hours ahead of Coordinated Universal Time (UTC). The UTC(NPLI) is the steered output of an Active Hydrogen Maser (AHM). The presented algorithm is made for steering the UTC(NPLI) towards the UTC [1-4] and this algorithm taking weighted average of an AHM and five Cesium clocks. The cesium clocks provide an absolute atomic reference of the time which has exceptional long-term stability, whereas the hydrogen maser has ultimate short-term stability.

## 2. Time Scale Algorithm

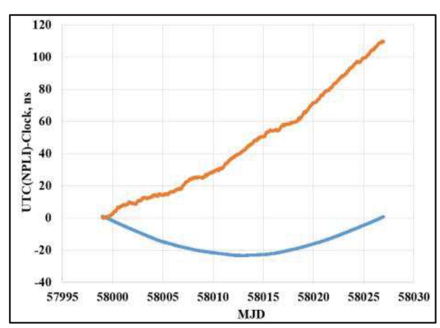
Any single clock is not perfect due to its limitation i.e. aging drifting etc. Therefore, the timescale algorithm [5-6] makes the contribution of all clocks based on their performance. The different clocks are ensemble to make a virtual clock that would have a better performance than a single clock. The CSIR-NPL uses an AHM and five cesium clocks to make a virtual clock. The UTC(NPLI) is the steered output of an AHM. The output of the AHM as in frequency and pulse are given input to a micro-phase steeper. The clock comparison of an AHM and cesium clocks are taken placed with UTC(NPLI). The combination of Time Interval Counter (TIC) and Switching System (SS) are used for clock comparison. So to make UTC(NPLI) reliable and comparable to UTC, we use an algorithm which evaluates the stability of clocks and their weights on the basis of their performance and calculate the amount of frequency correction. The calculated amount of frequency correction is applied to micro phase stepper to compensate its output. There are mainly three factors which are taken into account to make an algorithm which are:

### (i) Aging rate of the Active Hydrogen Maser

An AHM has good short-term stability but not long term, but cesium clocks have good long term stability but bad in short term. The short term and long term behavior of an AHM and cesium clocks are shown in figure1.




(a)




(b)

**Figure1 (a)** Short term **(b)** Long term, behavior of a cesium clock (in orange color) and an AHM (in blue color)

The stability of the AHM and cesium clocks are given in figure2. We used stable32 software for stability measurement.

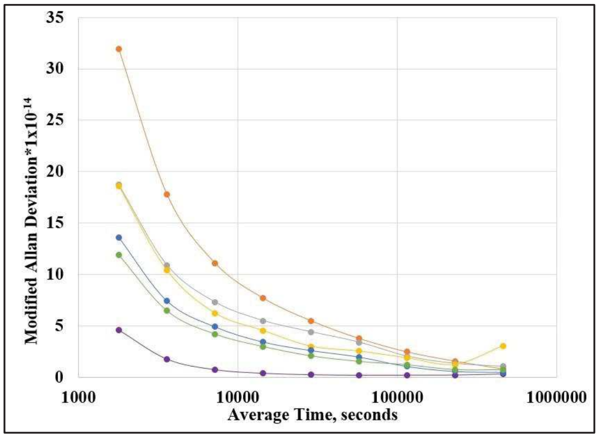



**Figure2** Clocks Frequency Stability, Cs02(Orange), Cs06(Gray), Cs08(Yellow), Cs09(Blue), Cs10(Green), AHM(Purple)

The Table1 shows the value of Modified Allan Deviation.

**Table1**

| Average Time, seconds | Modified Allan Deviation*1x10$^{-14}$ | | | | | |
|---|---|---|---|---|---|---|
| | AHM | Cs02 | Cs06 | Cs08 | Cs09 | Cs10) |
| 1800 | 4.6 | 31.9 | 18.7 | 18.6 | 13.6 | 11.9 |
| 3600 | 1.76 | 17.8 | 10.9 | 10.4 | 7.43 | 6.46 |
| 7200 | 0.72 | 11.1 | 7.3 | 6.23 | 4.91 | 4.19 |
| 14400 | 0.368 | 7.69 | 5.49 | 4.53 | 3.43 | 2.97 |
| 28800 | 0.23 | 5.48 | 4.4 | 2.99 | 2.6 | 2.06 |
| 57600 | 0.18 | 3.76 | 3.39 | 2.52 | 1.97 | 1.52 |
| 115000 | 0.19 | 2.45 | 2.03 | 1.86 | 1.05 | 1.19 |
| 230000 | 0.2 | 1.55 | 1.32 | 1.23 | 0.564 | 0.716 |
| 461000 | 0.307 | 0.782 | 1.03 | 3.04 | 0.48 | 0.716 |

With time, the frequency of AHM is shifted, so we take into account the aging effect of AHM.

A=Aging of AHM (1)

**(ii) Compensation of current UTC(NPLI) wrt Rapid UTC**

Earlier BIPM publishes circular T only, but since 2013 BIPM is publishing rapid UTC(UTCr) in a week. Due to this, we know early that how much UTC(NPLI) deviate from the UTCr. Although UTCr and UTC are off by few nanoseconds but we are reducing this effect by offset by using larger N number of days to compensate the UTCr-UTC(NPLI). By using UTCr we add the compensation factor in N number of days which is given by,

$$B = \frac{\mathrm{UTCr - UTC(NPLI)} \times 10^{-9}}{86400 \times \mathrm{N}} \qquad (2)$$

This factor is updated weekly.

**(iii) Clock error correction**

The another factor of the algorithm is contributing the correction due to the stability of clocks. The clocks rate and weight are important in this step. The rates of clock used from the monthly publishing Circular-T. The weight of the clocks is assigned on the basis of their stability and performance. The stability of a clocks is expressed in terms of statistical quantity such as Allan deviation(σ) which is calculated from the frequency stability curve as shown in figure2. The weights of different clocks are expressed by the following relationship:

$$W_n = \left[\frac{\left(1/\sigma_n\right)^2}{\Sigma}\right] \qquad (3)$$

$$\Sigma W_n = 1 \qquad (4)$$

here

$$\Sigma = \left[\left(1/\sigma_1\right)^2 + \left(1/\sigma_2\right)^2 + \cdots + \left(1/\sigma_n\right)^2\right]$$

and the total weight of all clocks is unity.

The frequency offset due to the clocks offset leads to following way:

$$\text{offset of clock n} = \frac{(\text{clock slope} - \text{clock rate}) \times \text{weight} \times 10^{-9}}{86400} \quad --- (4)$$

in this formula the clock rates are taken from BIPM Circular-T and clock slope are calculated offset of individual clocks wrt UTC(NPLI)

$$\text{Clock error correction(C)} = \frac{\sum_{i=1}^{n} \text{offset of clock n}}{n \times 1.157 \times 10^{-15}} \quad --- \quad (5)$$

## 3. Steering to UTC(NPLI)

The frequency correction to micro phase stepper is applied to compensate the output frequency. Therefore, all these three component (aging rate of hydrogen maser, compensation of current UTC(NPLI) with respect to Rapid UTC and clock error correction) added algebraically and applied on scheduled.

## 4. Conclusion:

CSIR-NPL has developed a timescale algorithm for steering UTC(NPLI). The algorithm is based on weighted average of cesium clocks and AHM.

## 5. Acknowledgments

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