l'Observatoire de Paris — SYRTE — Systèmes de Référence Temps-Espace

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FREQUENCY COMPARISON (H_MASER 140 0816) - (LNE-SYRTE-FOM)
For the period MJD 54544 to MJD 54554

The primary frequency standard LNE-SYRTE-FOM has been compared to the hydrogen Maser (140 0816) of the laboratory, during 1 measurement session between MJD 54544 and 54554.
The maser 140 0889 usually used for the SYRTE TAI contributions is under maintenance and is replaced by the maser 140 0816.

The mean frequency difference is given in the following table:

Period (MJD)	Date of the estimation	y(HMaser$_{140\ 0816}$ - FOM)	u_B	u_A	$u_{link\ /\ maser}$
54544 – 54554	**54549**	**+5171.0**	**6.7**	**5**	**1.5**

Table 1: Results of the comparison in 1 x 10^{-16}.

The FOM fountain was operated in the same mode during all the period: the interrogating signal synthesis is based on the multiplication of a 1 GHz signal provided by a cryogenic oscillator phase locked on the maser 140 0816. It uses a synthesizer to lock the microwave signal on the atomic resonance. The frequency difference between the maser and the fountain is deduced from the average correction applied to the synthesizer.

Average value and statistical uncertainty

The details of the calculation are given in figure 1:

The frequency data averaged over 0.2 day are plotted on the upper graph (blue points) together with a linear unweighted fit (red line).
The parameters of the fit y=a + bx are respectively:

Period (MJD)	a	b
54544 – 54554	**(-27.3 +/- 3.6) 10^{-12}**	**(+5.1 +/- 0.7) 10^{-16}/day**

Table 2: coefficients of the linear fit

These coefficients are used to remove the drift (data plotted in the graph in the middle, red points) and to calculate the average value at middle date, given in table 1. The lower graph gives the variance of the frequency residuals. It is degraded by the ~10^{-14} frequency jumps of the maser. The duration the jumps is of the order of half a day, 5% of the 10 days of measurements. We thus estimate that the statistical uncertainty u_A is 5 10^{-16}.

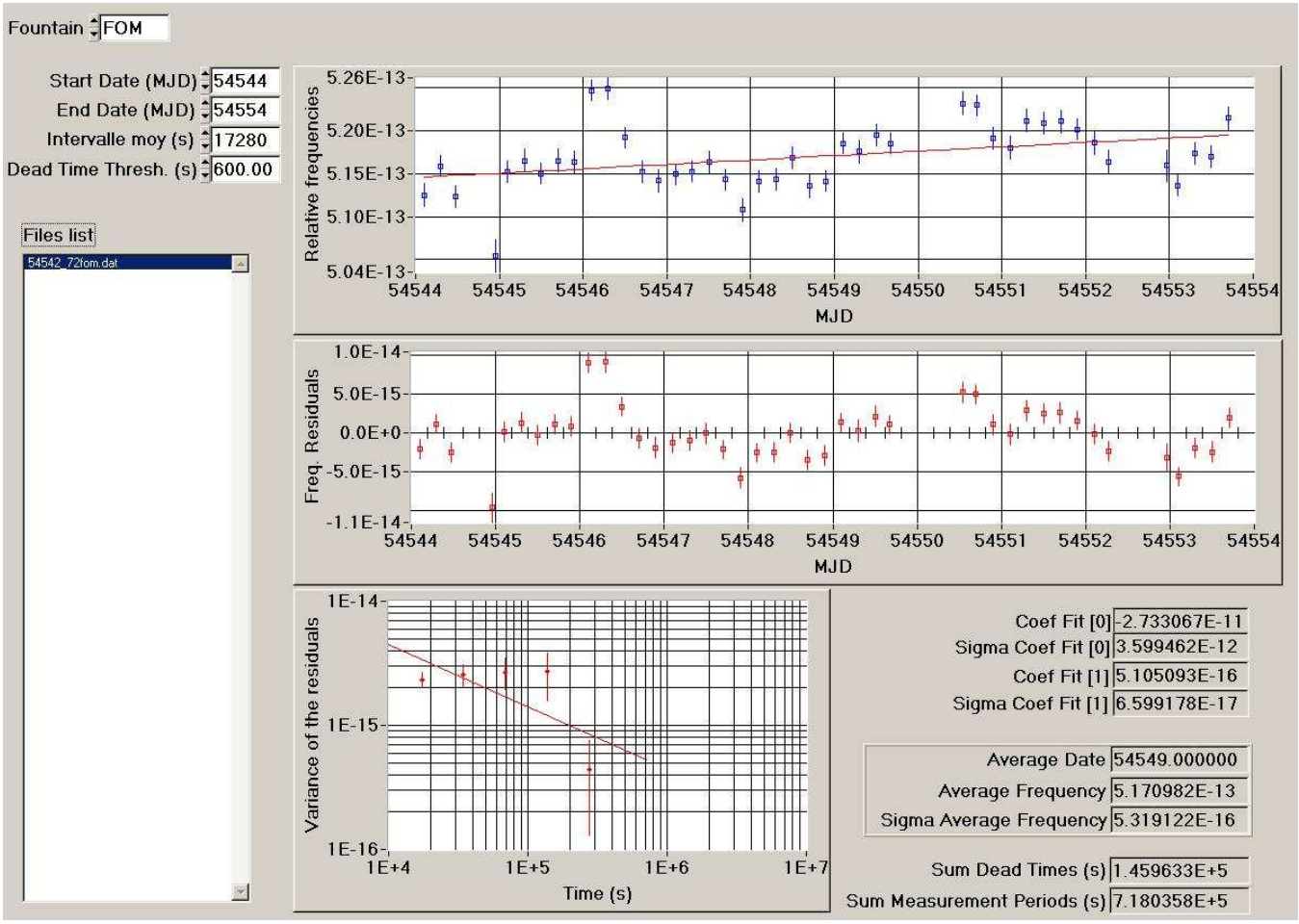

Figure 1: Data processing for the period MJD 54544-54554

Accuracy

The frequency is corrected form the quadratic Zeeman, the Black Body radiation, the cold collisions and cavity pulling, and the red shift effects. The following table summarizes the budget of systematic effects and their associated uncertainties. The accuracy is the quadratic sum of all the systematic uncertainties. The accuracy of the clock is better during this period because the number of atoms has been reduced (and consequently the cold collisions frequency shift).

	Correction (10^{-16})	**Uncertainty (10^{-16})**
Quadratic Zeeman effect	-305.4	1.1
Black body radiation	162.6	0.6
Cold collisions and cavity pulling	16.7	1.7
Microwave power dependence	0	6
Ramsey & Rabi pulling	0	< 0.1
Microwave recoil	0	< 1.4
Second order Doppler effect	0	< 0.1
Background gas collisions	0	<1.0
Total		**6.6**
Red shift	- 68.7	1.0
Total with red shift	**-194.8**	**6.7**

Table 3: budget of systematic effects and uncertainties for SYRTE-FOM fountain

$$u_B = 6.7 \times 10^{-16}$$

Uncertainty of the link

The uncertainty of the link is the quadratic sum of 2 terms:
-A possible effect of phase fluctuations introduced by the cables that connect the primary standard to the Maser. It is estimated to be 10^{-16}.
-The uncertainty due to the dead times of the frequency comparison.
To estimate this contribution, we use the comparison between the reference Maser and Maser 140 0890. We calculate the time deviation of the normalized phase differences with the linear frequency drift removed. The uncertainty is given by:

$$\sigma_{y_{Dead\ Time}} = \frac{\sqrt{\sum_i \sigma_{x_i}^2}}{T}$$

where σ_{xi} are the extrapolated TVar for each dead times. We applied the method to the dead times longer than 600 s and obtained stability degradation of 1.0 10^{-16}.