Systèmes de Référence Temps-Espace

FREQUENCY COMPARISON (H_MASER 140 0889) - (LNE-SYRTE-FO1)
For the period MJD 54484 to MJD 54494

The primary frequency standard LNE-SYRTE-FO1 has been compared to the hydrogen Maser (140 0889) of the laboratory, during 1 measurement session between MJD 54484 and 54494.

The mean frequency difference is given in the following table:

Period (MJD)	Date of the estimation	y(HMaser$_{140\ 0889}$ – FO1)	u_B	u_A	$u_{link\ /\ maser}$
54484 – 54494	54489	-15380.8	4.1	4	1.2

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

The FO1 fountain was operated in the same mode during all the period: the interrogating signal synthesis is based on the multiplication of a 100 MHz signal provided by a cryogenic oscillator phase locked on the maser 140 0889. 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
54484 – 54494	(66.0 +/- 3.0) 10^{-12}	(-12.4 +/- 0.6) 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. We observe that the variance doesn't decrease as white frequency noise during the total measurement duration. This is attributed to the non linearity of the Maser's drift. Since the maser vanishes in the TAI calculation, we can extrapolate the comparison stability as white frequency noise at the total measurement duration. We nevertheless estimate a conservative value of 4 10^{-16} for the statistical uncertainty u_A. This value was confirmed by calculating the variance of the frequency difference between FOM and FO1 using synchronous data.

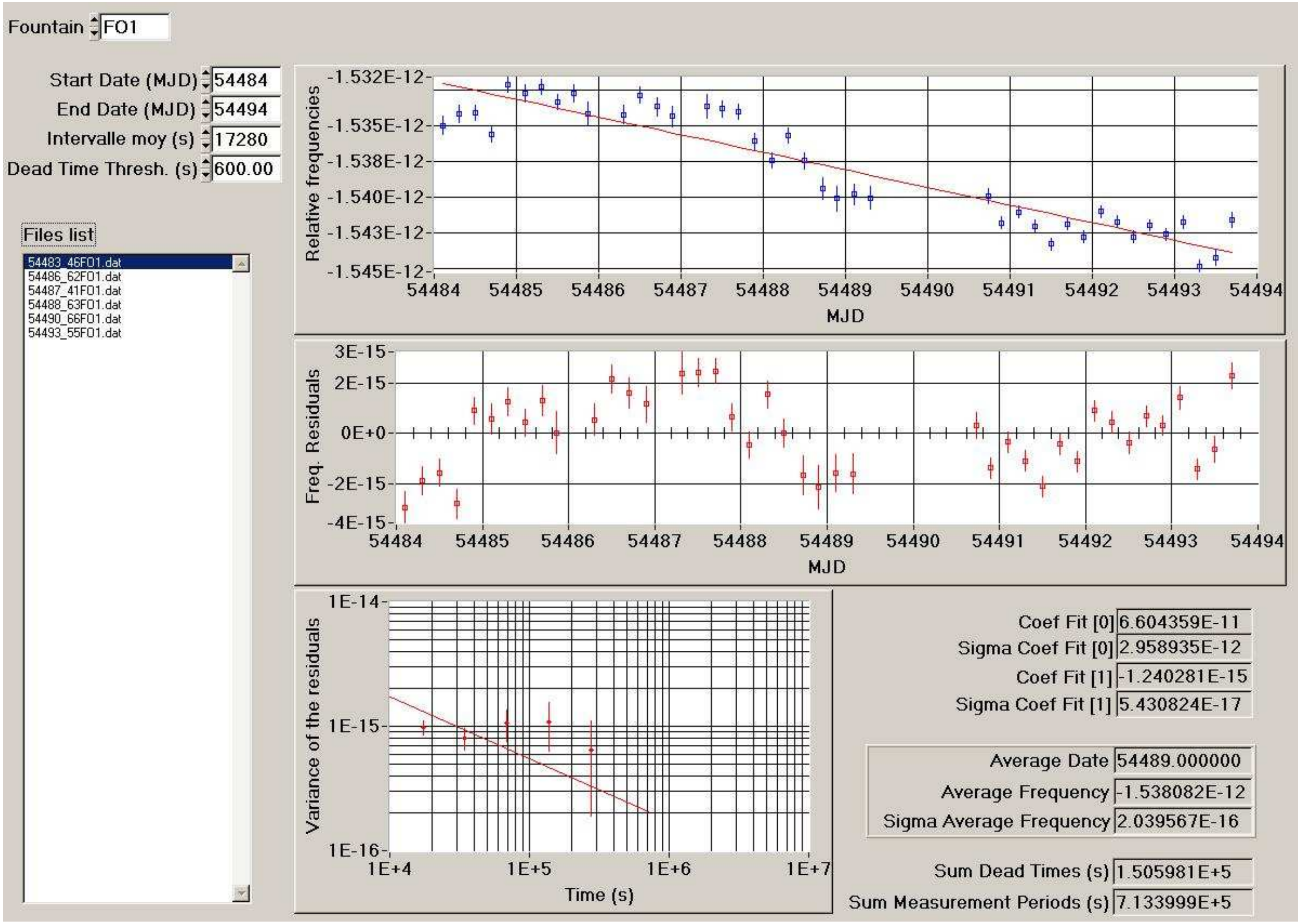

Figure 1: Data processing for the period MJD 54484-54494

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.

	Correction (10^{-16})	**Uncertainty (10^{-16})**
Quadratic Zeeman effect	-1271.7	0.3
Black body radiation	+165.1	0.6
Cold collisions and cavity pulling	+79.0	0.8
First order Doppler Effect	0	3.2
Synchronous Phase Fluctuations	0	< 1
Microwave Spectral Purity	0	< 0.1
Microwave Leaks	0	< 0.1
Ramsey & Rabi pulling	0	< 1
Microwave recoil	0	< 1.4
Second order Doppler effect	0	< 0.1
Background gas collisions	0	<0.3
Total		**4.0**
Red shift	- 69.3	1.0
Total with red shift	**-1096.9**	**4.1**

Table 3: budget of systematic effects and uncertainties for SYRTE-FO1 fountain

$$u_B = 4.1 \times 10^{-16}$$

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 0.7 10^{-16}.