

**FREQUENCY COMPARISON (H\_MASER 140 0890) - (LNE-SYRTE-FO1)  
For the period MJD 54644 to MJD 54669**

The primary frequency standard LNE-SYRTE-FO1 has been compared to the hydrogen Maser 140 0890 of the laboratory, during a measurement campaign between MJD 54644 and 54669 (27<sup>th</sup> June 2008-22<sup>th</sup> July 2008). The fountain operation covers  $\sim 80\%$  of the total measurement duration.

The mean frequency difference at the middle date of the period is given in the following table:

Period (MJD)	Date of the estimation	$y(\text{HMaser}_{140\ 0890} - \text{FO1})$	$u_B$	$u_A$	$u_{\text{link} / \text{maser}}$
54644 – 54669	54656.5	-231.0	4.2	3.5	1.5

*Table 1: Results of the comparison in  $1 \times 10^{-16}$ .*

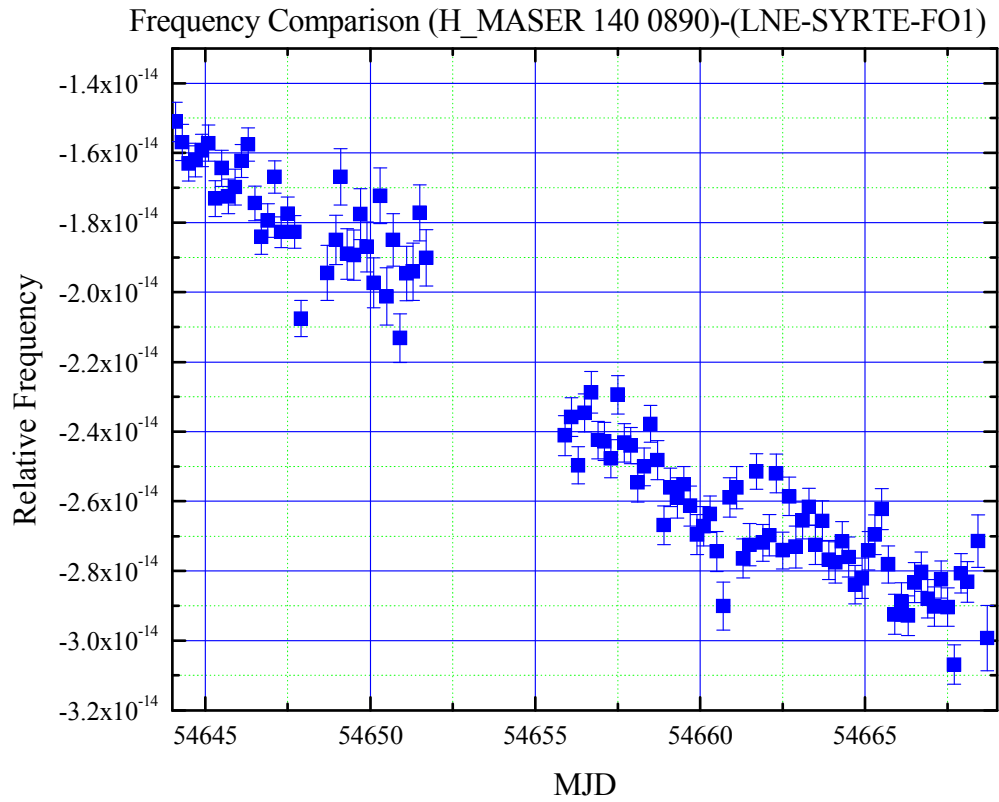
The FO1 fountain was operated in the same mode during all the period: the interrogating signal synthesis is based on the multiplication of a 100 MHz signal provided by a cryogenic oscillator phase locked on the maser 140 0890. It uses a synthesizer to lock the microwave signal on the atomic resonance. The frequency difference between the maser and the fountain is deduced from the average

**Average value and statistical uncertainty**

The data points of the frequency comparison between Maser 140 0890 and FO1 Fountain are plotted in Figure 1. Each point has been obtained by averaging the data over 0.2 day. The error bars are the corresponding statistical uncertainties.

To estimate the average frequency at middle date, we calculated the accumulated phase by integrating the data points, assuming a linear frequency drift during each segment, and during the dead times of the fountain operation. The average frequency is then obtained by dividing the total accumulated phase by the calibration period duration. This method has been preferred for the evaluation, this month, to better take into account the variations of the maser's drift.

The value given in Table 1 has been obtained with segments of 0.2 day duration. To estimate the uncertainty of the processing method, we performed calculations with segments of 0.01, 0.1 and 1 day durations. The differences between the results are within  $3.5 \times 10^{-16}$ . This value reflects the statistical uncertainty  $u_A$ .



*Figure 1: Frequency calibration of Maser 140 0890 by FO1 Fountain between MJD 54644-54669*

## Accuracy

The frequency is corrected from 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.

	<b>Correction (<math>10^{-16}</math>)</b>	<b>Uncertainty (<math>10^{-16}</math>)</b>
Quadratic Zeeman effect	-1276.5	0.2
Black body radiation	164.7	0.6
Cold collisions and cavity pulling	61.0	1.5
First order Doppler	0	3.2
Microwave spectral purity&leakage	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
<b>Total</b>	<b>-1050.8</b>	<b>4.1</b>
Red shift	- 69.3	1.0
<b>Total with red shift</b>	<b>-1120.1</b>	<b>4.2</b>

Table 2: budget of systematic effects and uncertainties for SYRTE-FOI fountain

$$u_B = 4.2 \times 10^{-16}$$

## 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 0889.

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  $\sigma_{x_i}$  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  $1.1 \cdot 10^{-16}$ .