FREQUENCY COMPARISON (H_MASER 140 0890) - (LNE-SYRTE-FO2)
For the period MJD 54644 to MJD 54674

The primary frequency standard LNE-SYRTE-FO2 has been compared to the hydrogen Maser 140 0890 of the laboratory, during a measurement campaign between MJD 54644 and 54674 (27th June 2008-27th July 2008). The fountain operation covers ~ 81 % 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(HMaser$_{140\ 0890}$ – FO2)	u_B	u_A	$u_{link\ /\ maser}$
54644 – 54674	**54659**	**-245.8**	**4.1**	**2**	**1.4**

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

The FO2 fountain was operated in the same mode during all the period: the interrogating signal synthesis is based on the down conversion to 9.192 GHz of a 11.98 GHz signal provided by a cryogenic oscillator phase locked to 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 correction applied to the synthesizer.

Average value and statistical uncertainty

The data points of the frequency comparison between Maser 140 0890 and FO2 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 2 10^{-16}. This value reflects the statistical uncertainty u_A.

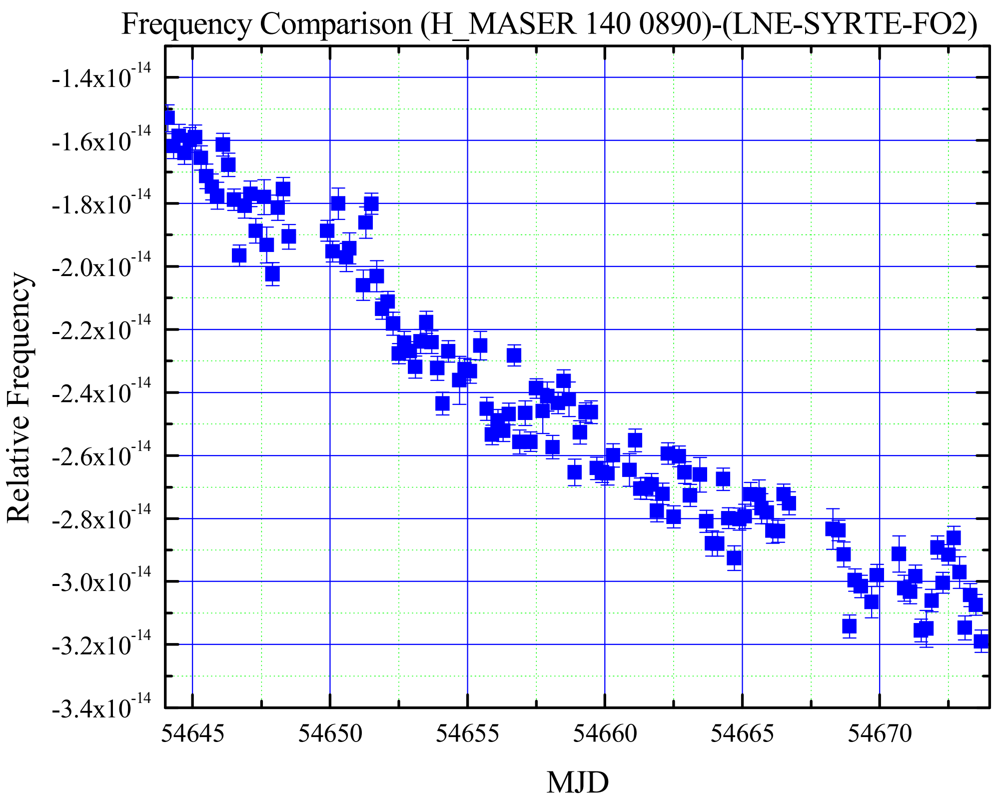

Figure 1: Frequency calibration of Maser 140 0890 by FO2 Fountain between MJD 54644-54674

Accuracy

The frequency is corrected from the quadratic Zeeman, the Black Body radiation, the cold collisions and cavity pulling, and the red shift effects. Here the uncertainty in the cold collisions correction is taken as 0.5% of the correction for high density measurements. It accounts for at most 1% residual population in F=3, non zero mF Zeeman states which cause a collisional shift that is a fraction of the cold collision shift associated with the clock F=3, mF=0 state.
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	-1914.9	0.2
Black body radiation	166.8	0.6
Cold collisions and cavity pulling	255	1.7
First order Doppler	0	< 3.0
Microwave spectral purity&leakage	0	<0.5
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	**-1493.1**	**3.9**
Red shift	- 65.4	1.0
Total with red shift	**-1558.5**	**4.1**

Table 2: budget of systematic effects and uncertainties for SYRTE-FO2 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 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 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 10^{-16}.