Systèmes de Référence Temps-Espace

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CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

FREQUENCY COMPARISON (H_MASER 140 0890) - (LNE-SYRTE-FOM)
For the period MJD 55344 to MJD 55359

The primary frequency standard LNE-SYRTE-FOM has been compared to the hydrogen Maser 140 0890 of the laboratory, during 1 measurement campaign between MJD 55344 and 55359 (28^{th} May 2010 – 12^{th} June 2010).

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

Period (MJD)	Date of the estimation	$y(HMaser_{140\ 0890} – FOM)$	u_B	u_A	$u_{link\ /\ maser}$
55344 – 55359	**55351.5**	**-1974.0**	**8.6**	**2**	**20.0**

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

During that period, the FOM fountain was operated at the Max Planck Institut für Quantenoptik (MPQ) in Garching, Germany, for an absolute frequency measurement of the 1S-2S transition of hydrogen. The FOM operation was similar to the one at SYRTE, in Paris Observatory. The interrogating signal synthesis is based on the multiplication of a 100 MHz signal provided by a quartz oscillator phase locked to a hydrogen maser. It uses a synthesizer to lock the microwave signal on the atomic resonance. The frequency difference between the MPQ Maser and the fountain is deduced from the corrections applied to the synthesizer. The MPQ Maser in Garching is connected to the H-Maser 140 0890 in Paris, via a GPS carrier phase time transfer link.

Average value and uncertainties

The average value of H-Maser 140 0890 is calculated as follows:
First, we calculate frequency data of the local comparison MPQ Maser - FOM, averaged over 0.1 day. We use a linear fit to estimate the frequency at the middle of each 0.1 day interval.
Second, the GPS phase data are filtered using a quadratic fit calculated over 0.1 day intervals. The average frequencies are then determined by differentiation of the phase data every 0.1 day.
We then select the points corresponding to the synchronous operation of the fountain and the GPS link. The synchronous operation covers ~ 73 % of the total measurement duration.
The average data of H-Maser 140 0890 - FOM are plotted on figure 1, together with a linear fit $y=a + b(x-x_{middle\ date})$. The parameters of the fit are given in the insert of Figure 1.

These coefficients are used to remove the frequency drift and to calculate the average value at the middle date, given in table 1. Figure 2 gives the variance of the frequency residuals. The major contribution on uncertainty of the comparison H-Maser 140 0890-FOM is the noise of the GPS link, which is limited to u_{link}~2 10^{-15}. We verified the short term stability of FOM against the MPQ Maser is lower than 2 10^{-13} at 1s. We estimate a conservative value u_A~2 10^{-16} for the statistical uncertainty over the measurement duration. At the noise level of the link, the effect of the dead times is negligible.

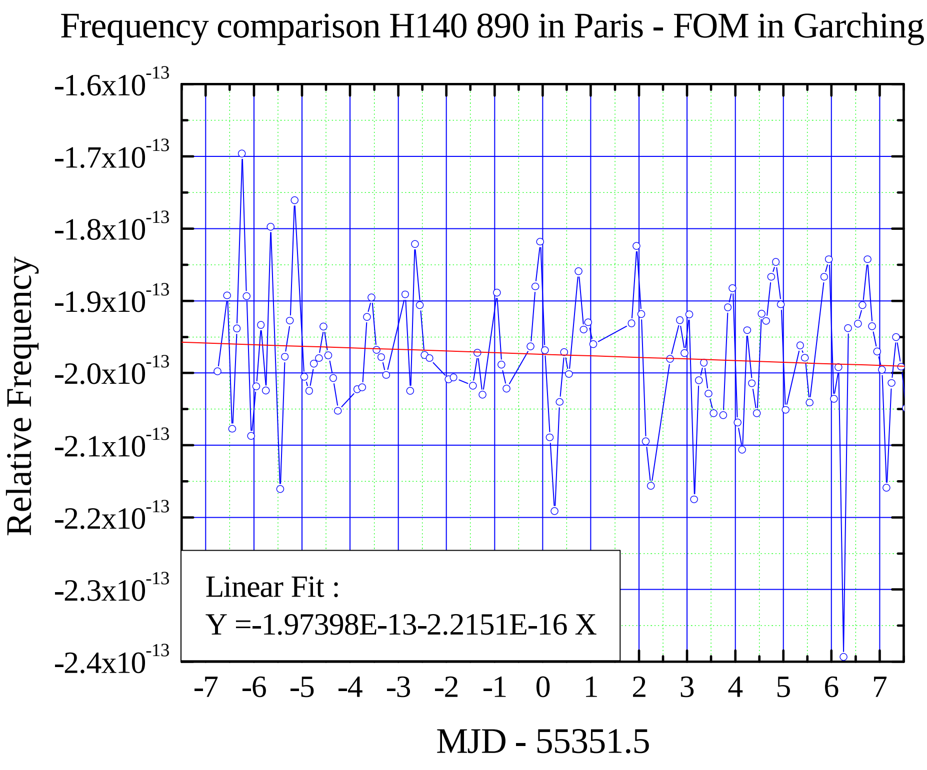

Figure 1: Data processing for the period MJD 55344-55359

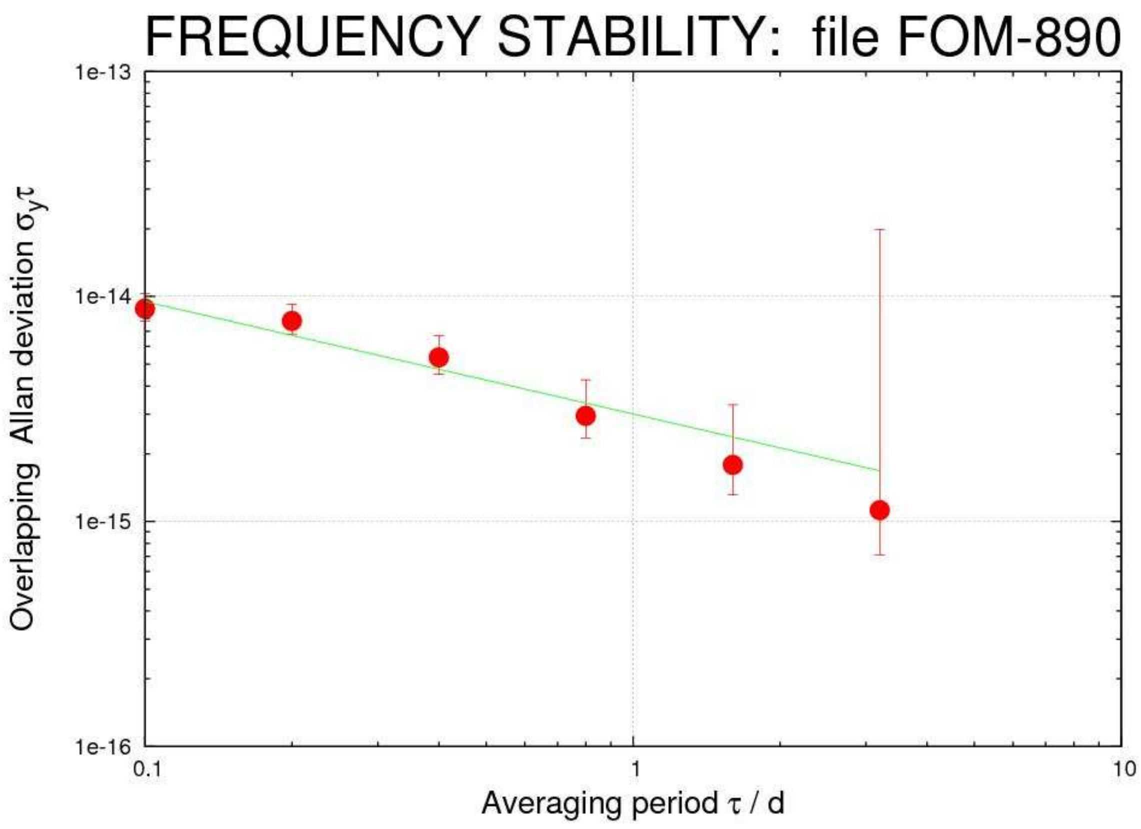

Figure 2 : Overlapping Allan deviation of the comparisons H140 0890-FOM

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.

	Correction (10^{-16})	**Uncertainty (10^{-16})**
Quadratic Zeeman effect	-295.9	1.2
Black body radiation	165.8	0.6
Cold collisions and cavity pulling	25.1	5.0
Microwave power dependence : First order Doppler & Microwave spectral purity & leakage	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	**-105.0**	**8.1**
Red shift	- 520.5	3.0
Total with red shift	**-625.5**	**8.6**

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

$$u_B = 8.6 \times 10^{-16}$$