FREQUENCY COMPARISON (H_MASER 40 0889) - (LNE-SYRTE-FO2)
From MJD 54279 to MJD 54309

The primary frequency standard LNE-SYRTE-FO2 was compared to the hydrogen Maser (40 0889) of the laboratory during the 28th of June to 28th of July 2007 period corresponding to MJD 54279 and MJD 54309.

	Period (MJD)	y(HMaser$_{40\ 0889}$ - FO2)	u_B	u_A	$u_{link\ /\ maser}$
BIPM	**54279 – 54309**	**-12770.7**	**4.5**	**4.1**	**1.0**

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

Figure 1 collects the measurements of fractional frequency differences during the 28th of June to 28th of July 2007 period. Error bars represent the statistical uncertainties. The measurements are corrected for the systematic frequency shifts listed below.

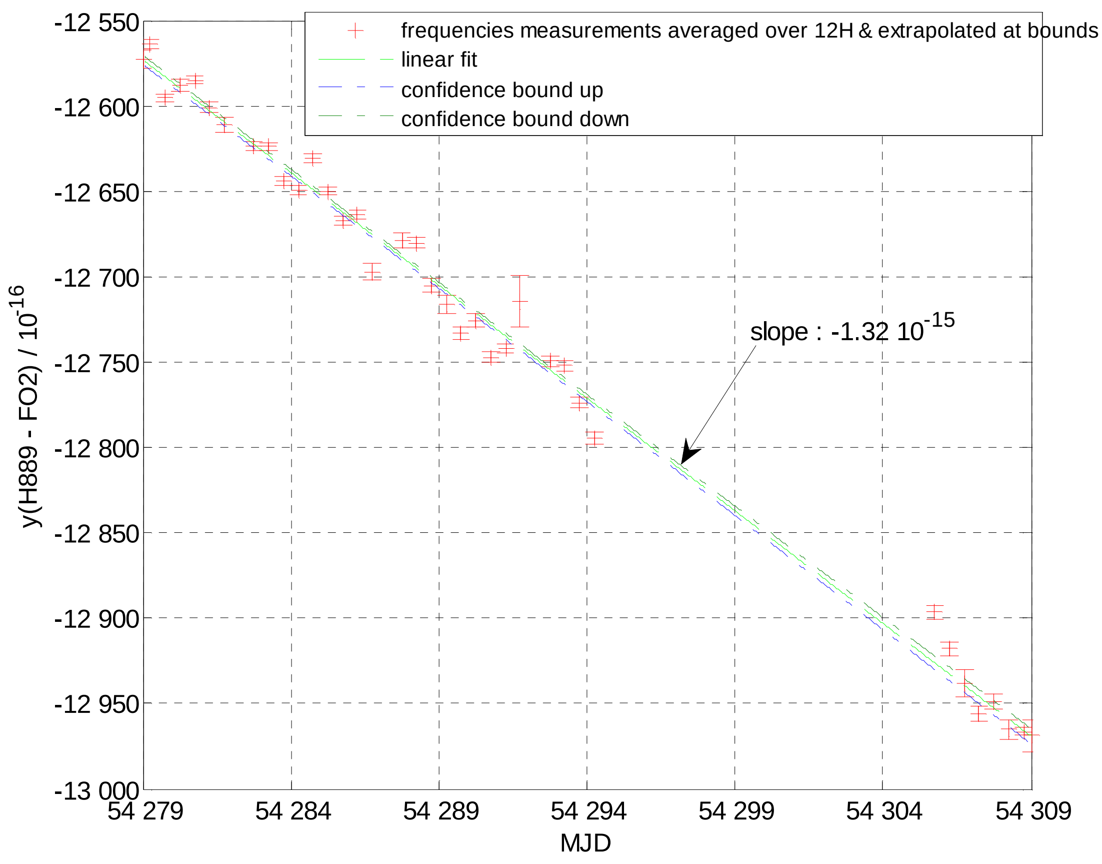

Figure 1: fractional frequency differences between H_Maser40 0889 & FO2 from MJD 54279 to MJD 54309

Table 2 gives the results of the frequency estimate for the middle date of the period, and the associated statistical uncertainty, using either a linear or a polynomial fit to the data. Here we have chosen the linear fit to estimate the frequency average.

.Dates of measurements .Duration & .Measurement Rate	Mean normalized frequency difference $y_{Maser} - y_{FO2}$	type A uncertainty σ_{Stat}	Uncertainty due to the dead times $\sigma_{deadTime}$
Start date MJD UTC **54278.976464** End date MJD UTC **54308.962286** Length of interval T = 29.9858 d Measurement Rate: 43.19%	Mean by linear fit at middle date 54264 $\bar{y}$ = **-12770.71 x 10^{-16}** Mean by polynomial fit order 9: $\bar{y}$ = **-12771.65 x 10^{-16}**	Uncertainty of linear fit **4.12** x **10^{-16}** Allan Deviation at T with assumption of White Frequency Noise σ_y = **1.8 x 10^{-16}**	$\sigma_{deadTime}$ = **0.2 10^{-16}**

Table 2: Statistics of measurements

Summary of the systematic corrections and uncertainties:

	Correction (10^{-16})	**Uncertainty (10^{-16})**
Cold collisions and cavity pulling	**177**	2.4
Quadratic Zeeman effect	**-1919.4**	0.2
Black body radiation	**167.6**	0.6
Microwave spectral purity & leakage		0.5
First order Doppler effect		3.0
Ramsey & Rabi pulling		< 1.0
Microwave recoil		< 1.4
Second order Doppler effect		< 0.1
Background gas collisions		<1.0
Total		**4.4**
Red shift	- 65.4	1.0
Total with red shift		**4.5**

Table 3: Budget of systematic effects and associated uncertainties in the FO2 fountain.

Systematic effects taken into account are listed in Table 3. The correction and estimated uncertainty for each of them is given. Here the collisional shift correction is the average correction over all measurements, which are taken alternatively at high and low densities. The uncertainty on this correction is taken as 1% of the collisional shift correction at high density to account for 1% spurious population in non-zero m_F states which affect the measurements equally at both densities. Finally, including also an uncertainty for the red shift effect, this gives the type B total uncertainty:

$$\sigma_B = \left(\sigma_{Zeeman2}^{\ 2} + \sigma_{BlackBody}^{\ 2} + \sigma_{Collision_{Syst}}^{\ 2} + \sigma_{Microwave\_Spectrum\_Leakage}^{\ 2} + \sigma_{first\_Doppler}^{\ 2} + \sigma_{Ramsey\_Rabi}^{\ 2} + \sigma_{Recoil}^{\ 2} + \sigma_{second\_Doppler}^{\ 2} + \sigma_{Background\_collisions}^{\ 2} + \sigma_{Redshift}^{\ 2} \right)^{(1/2)}$$

For the whole Jully 2007 period it gives

$$\sigma_B = 4.5 \times 10^{-16}$$

Uncertainty due to the dead times

During July, MJD 54279 to 54309, the hydrogen maser 400890 was compared with the hydrogen maser 400889. Figure 2 shows the measurements averaged over 100 seconds. After removing the frequency drift the time deviation was evaluated taking into account the dead times in the measurements of phase differences Maser 889 – Maser 890. Figure 3 shows this time deviation over the frequency, linear drift removed.

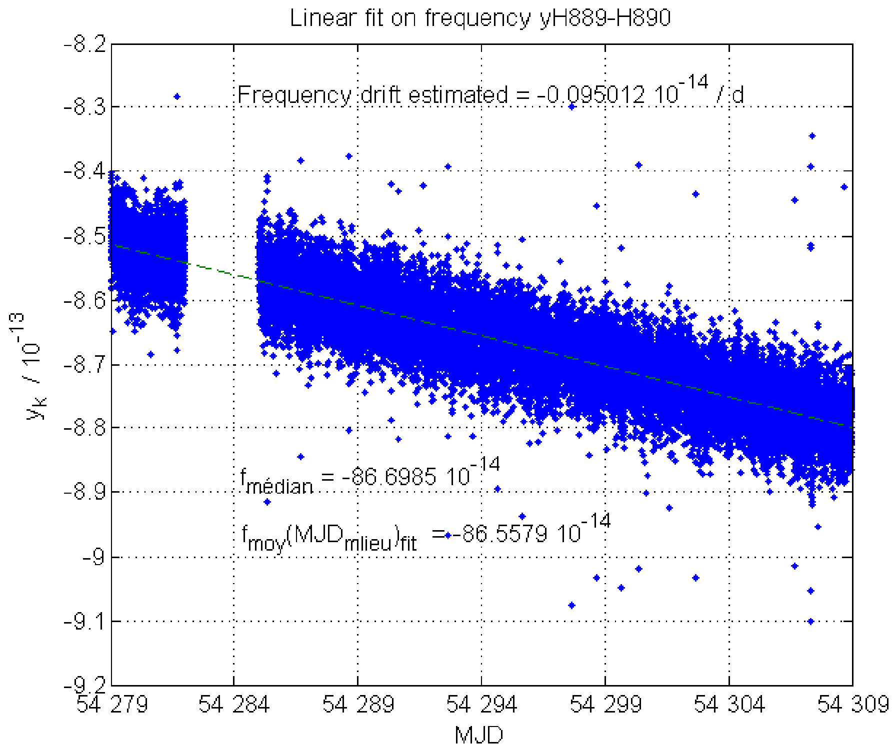

Figure 2: Frequency fluctuations between Maser 889 – Maser 890 obtained by first phase differences of phases averaged over 100s and estimation of the linear drift, July 2007, MJD 54279 au MJD 54309, outliers above 5σ removed

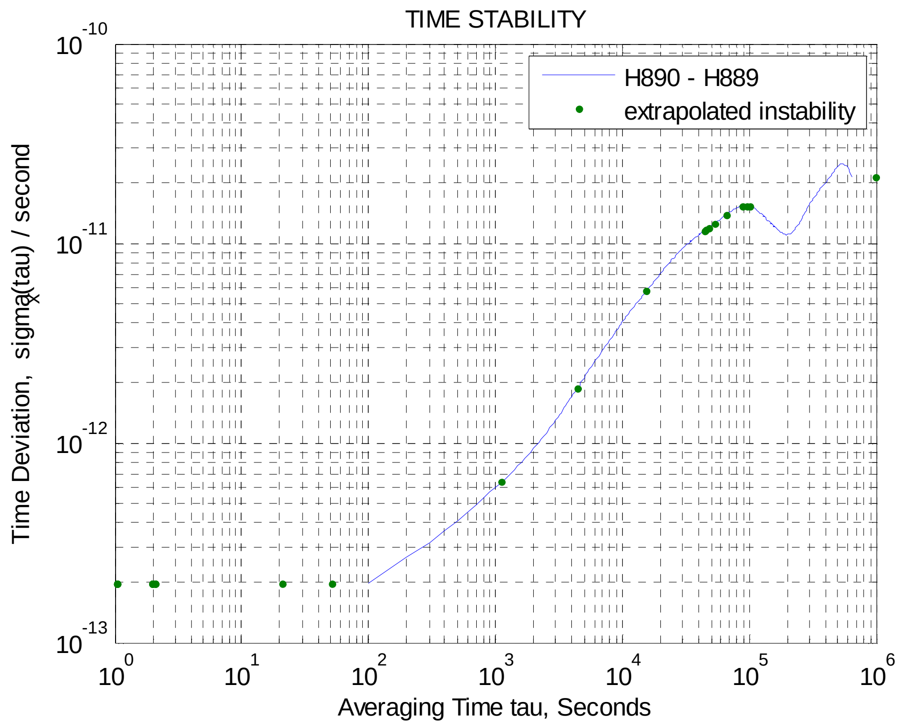

Figure 3: Time stability on frequency fluctuations between Masers H889 and H890 linear drift removed for the period of July 2007

Table 4 gives the measurements by joint intervals of duration 12 hours, the frequency mean and statistical uncertainty estimated by Allan deviation over time of measurements during interval, the duration of dead times and the associated uncertainty. The square of quadratic sum of the uncertainties of each dead times divided by the total duration (T = 29.9858 d) of this integration gives the uncertainty due to the dead times. The effect is very short due to the good stability of Maser 889 and so doesn't modify the uncertainty due to the link lab.

MJD start	MJD middle	MJD end	Duration of half interval / d	Frequency average over interval of 12H	Statistical uncertainty	Dead times duration / d	Uncertainty of dead times / s
54279	54279	54279	6,9444E-11	-1,2573E-12	5,6185E-16	1,2E-05	1,9699E-13
54279	54279,25	54279,5	0,24999919	-1,2564E-12	2,95E-16	2,3E-05	1,9699E-13
54279,5	54279,75	54280	0,25000036	-1,2595E-12	2,4152E-16	2,3E-05	1,9699E-13
54280	54280,25	54280,4936	0,24683084	-1,2588E-12	3,6583E-16	0,013009	6,398E-13
54280,5066	54280,75	54281	0,24670083	-1,2585E-12	2,2768E-16	2,4E-05	1,9699E-13
54281	54281,25	54281,5	0,24999904	-1,2601E-12	2,8945E-16	2,3E-05	1,9699E-13
54281,5	54281,75	54281,6221	0,06107029	-1,2611E-12	4,5061E-16	1,027975	1,5381E-11
54282,6501	54282,75	54282,9998	0,17484335	-1,2623E-12	2,7258E-16	0,000243	1,9699E-13
54283	54283,25	54283,5	0,24999993	-1,2624E-12	2,3091E-16	2,3E-05	1,9699E-13
54283,5	54283,75	54284	0,25000239	-1,2644E-12	2,6826E-16	2,3E-05	1,9699E-13
54284	54284,25	54284,5	0,25000559	-1,2649E-12	2,5719E-16	2,4E-05	1,9699E-13
54284,5	54284,75	54285	0,2499999	-1,263E-12	2,6226E-16	2,4E-05	1,9699E-13
54285	54285,25	54285,5	0,24999943	-1,265E-12	2,5578E-16	1,2E-05	1,9699E-13
54285,5	54285,75	54286	0,25000538	-1,2667E-12	2,6412E-16	2,4E-05	1,9699E-13
54286	54286,25	54286,5	0,24999943	-1,2663E-12	2,5678E-16	2,4E-05	1,9699E-13
54286,5	54286,75	54286,6535	0,0767589	-1,2697E-12	4,5722E-16	1,157465	1,5329E-11
54287,811	54287,75	54288	0,09451929	-1,2678E-12	4,3827E-16	1,2E-05	1,9699E-13
54288	54288,25	54288,3695	0,18473932	-1,268E-12	3,0042E-16	0,178368	5,7614E-12
54288,5478	54288,75	54288,7768	0,11449634	-1,2705E-12	3,9953E-16	0,559282	1,2016E-11
54289,3361	54289,25	54289,5	0,08196734	-1,2716E-12	5,208E-16	1,2E-05	1,9699E-13
54289,5	54289,75	54289,7785	0,13925885	-1,2733E-12	3,809E-16	0,533565	1,1768E-11
54290,3121	54290,25	54290,5	0,09396998	-1,2726E-12	4,3066E-16	2,3E-05	1,9699E-13
54290,5	54290,75	54291	0,24999988	-1,2747E-12	2,834E-16	2,3E-05	1,9699E-13
54291	54291,25	54291,5	0,24999991	-1,2742E-12	2,6476E-16	2,3E-05	1,9699E-13
54291,5	54291,75	54291,5162	0,00811298	-1,2715E-12	1,5078E-15	1,0964	1,5419E-11
54292,6126	54292,75	54292,9999	0,19366283	-1,275E-12	3,165E-16	0,000591	1,9699E-13
54293,0005	54293,25	54293,5	0,24975984	-1,2752E-12	3,0964E-16	2,4E-05	1,9699E-13
54293,5	54293,75	54294	0,24999385	-1,2774E-12	2,7458E-16	2,3E-05	1,9699E-13
54294	54294,25	54294,3324	0,16623236	-1,2795E-12	3,2775E-16	11,365012	2,1503E-11
54305,6975	54305,75	54305,8182	0,06037057	-1,2896E-12	3,9274E-16	0,511922	1,1553E-11
54306,3301	54306,25	54306,4633	0,06662685	-1,2918E-12	3,819E-16	0,050822	1,8649E-12
54306,5141	54306,75	54306,5547	0,02027788	-1,2938E-12	8,0104E-16	0,762234	1,3901E-11
54307,3169	54307,25	54307,5	0,09155622	-1,2956E-12	4,4071E-16	2,4E-05	1,9699E-13
54307,5	54307,75	54307,757	0,12853365	-1,2948E-12	4,4852E-16	0,612604	1,2521E-11
54308,3697	54308,25	54308,5	0,06517339	-1,2965E-12	6,0436E-16	2,3E-05	1,9699E-13
54308,5	54308,75	54309	0,25000534	-1,2966E-12	2,2172E-16	1,2E-05	1,9699E-13
54309	54309	54309	6,9444E-11	-1,2969E-12	9,3889E-16	0	1,9699E-13

Table 4: measurements by joint intervals of duration 12 hours with dead times between intervals & associated time deviation

The standard deviation of the fluctuations of frequency due to the dead times in measurements is estimated by the ratio

$$\frac{\sqrt{\sum_{i=1}^{37} \sigma_{x_i}^2(\tau)}}{T} = \sigma_{Dead\_Time} = 0.2 \text{ x } 10^{-16}$$

$\sigma_{Link\_Lab} = 1 \text{ x } 10^{-16}$ and $\sigma_{Link\_Maser} = \sqrt{(\sigma_{Dead\_Time})^2 + (\sigma_{Link\_Lab})^2} = 1.02 \text{ x } 10^{-16}$