FREQUENCY COMPARISON (H_MASER 140 0889) - (LNE-SYRTE-FOM)
From MJD 54344 to MJD 54374

The primary frequency standard LNE-SYRTE-FOM was compared to the hydrogen Maser (140 0889) of the laboratory, from 1st September MJD 54344 to 1st October MJD 54374.

The mean frequency differences measured between the hydrogen Maser 140 0889 and fountain FOM during this period is given in table 1.

Period (MJD)	y(HMaser$_{140\ 0889}$ - FOM)	u_B	u_A	$u_{link\ /\ maser}$
54344 – 54374	-13663.85	9.3	1.0	1.1

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

Figure 1 collects the measurements of frequency differences during the 1st September to 1st October 2007 period averaged by interval of 12 hours from MJD 54344 to 54374. Frequency at MJD 54344 is extrapolated from weighted linear fit.

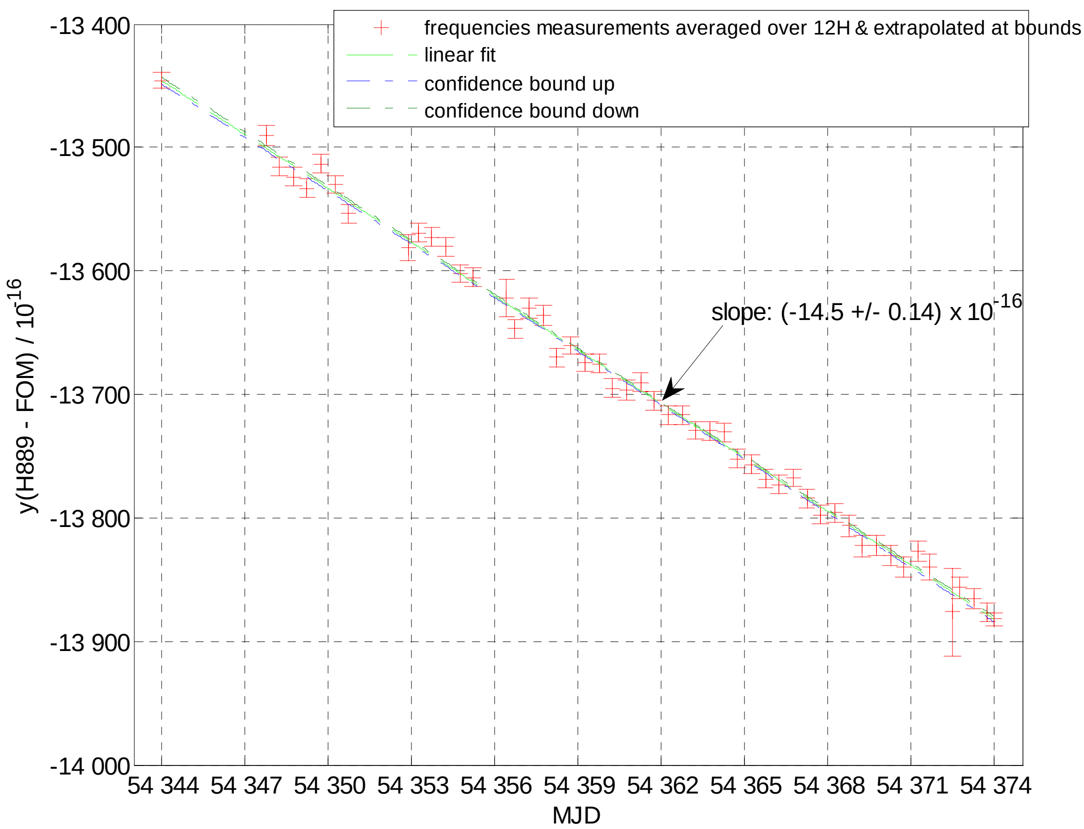

Figure 1: Frequency differences averaged over 12H and associated uncertainty of H889-FOM during the period 54344 to 54374. The weighted linear fit and, the confidence bounds up and low at ± 1σ are represented in dashed lines.

Figure 2 shows the shot by shot data measurements during the period MJD 54344 to MJD 54374.

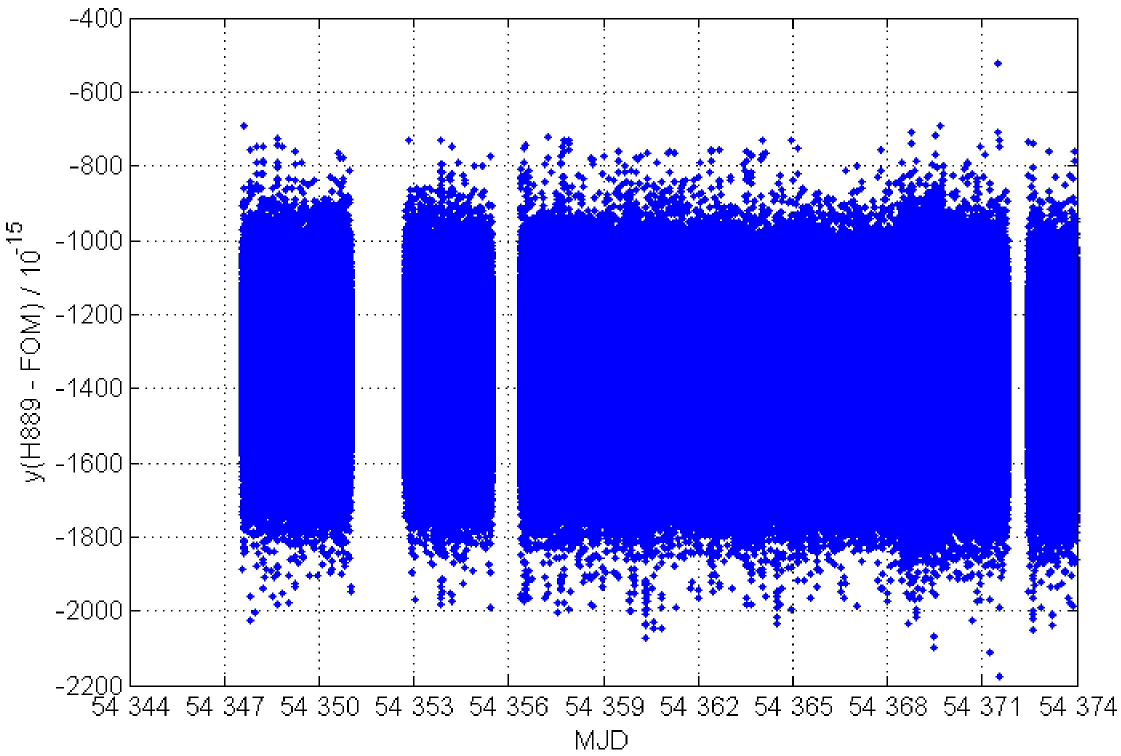

Figure 2: shot by shot data measurements during the period MJD 54344 to MJD 54374

Table 2 gives the results of the frequency estimated at the middle date of the period, and the associated statistical uncertainty, using a linear fit weighted by the statistical uncertainties of the data measurements and using a polynomial fit order 5.

.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 **54347.5897** End date MJD UTC **54373.9999** Duration of period **30** d Effective Duration of measurements **24 d** Measurement Rate: **80** % Mean date of BIPM interval **54359**	Mean by weighted linear fit at middle date 54359 $\bar{y}$ = **-13663.85 x 10^{-16}** Mean frequency by polynomial fit order 5: $\bar{y}$ = -13663.90 x **10^{-16}**	Uncertainty of weighted linear fit at 1σ **1.0** x **10^{-16}** Uncertainty of polynomial fit **2.05** x **10^{-16}**	$\sigma_{deadTime}$ = **0.23 10^{-16}**

Table 2: Statistics of measurements

Linear fit equation y(t) = **a** + **b***t obtained by weighted lms algorithm for frequencies averaged over intervals of 12H:

Slope of Maser frequency drift measured by FOM: **b** = -1.45896607645276e-015

Slope uncertainty: **δb** = 1.48605453814644e-017

Frequency Origin of linear fit: **a** = 9415517053599e-011

Origin uncertainty: **δa** = 838842713863e-013

Uncertainties budget of systematic effects in the FOM fountain

During this period FOM has operated in an autonomous way: the clock signal is delivered by a quartz oscillator frequency locked on the hyperfine resonance. The results presented here correspond to the phase comparison between the quartz oscillator and the H-maser.
Systematic effects taken into account are the quadratic Zeeman, the Black Body, the cold collision and cavity pulling, the microwave leakage and the 1st Doppler effects, the Ramsey Rabi pulling, the recoil, the 2nd Doppler and the background collisions. The red shift effect is also included in the systematic uncertainty budget. Systematic uncertainty is estimated by the sum of quadratic systematic uncertainties. The following table summarizes the budget of systematic effects and their associated uncertainties.

	Correction (10^{-16})	**Uncertainty (10^{-16})**
Quadratic Zeeman effect	-305.7	1.1
Black body radiation	165.35	0.6
Cold collisions and cavity pulling	37.9	6.7
Microwave power dependence	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		**9.25**
Red shift	- 68.7	1.0
Total with red shift	**-171.15**	**9.3**

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

For the September 2007 period it gives:

$$u_B = 9.3 \times 10^{-16}$$

Uncertainty due to the dead times

During September 2007, MJD 54344 to MJD 54374, the hydrogen Maser 140 0890 was compared with the hydrogen Maser 140 0889. Figure 3 shows the frequency differences averaged over 100 seconds. Figure 4 plots the modified Allan deviation over these frequency differences linear drift removed. Blue curve represents the Allan deviation over concatenated frequencies averaged on intervals of 100s linear drift removed and green curve represents the Allan deviation over frequencies averaged on intervals of 100s with dead times taking into account and linear drift removed. Figure 5 plots the time deviation of the normalized phase differences, linear frequency drift removed.

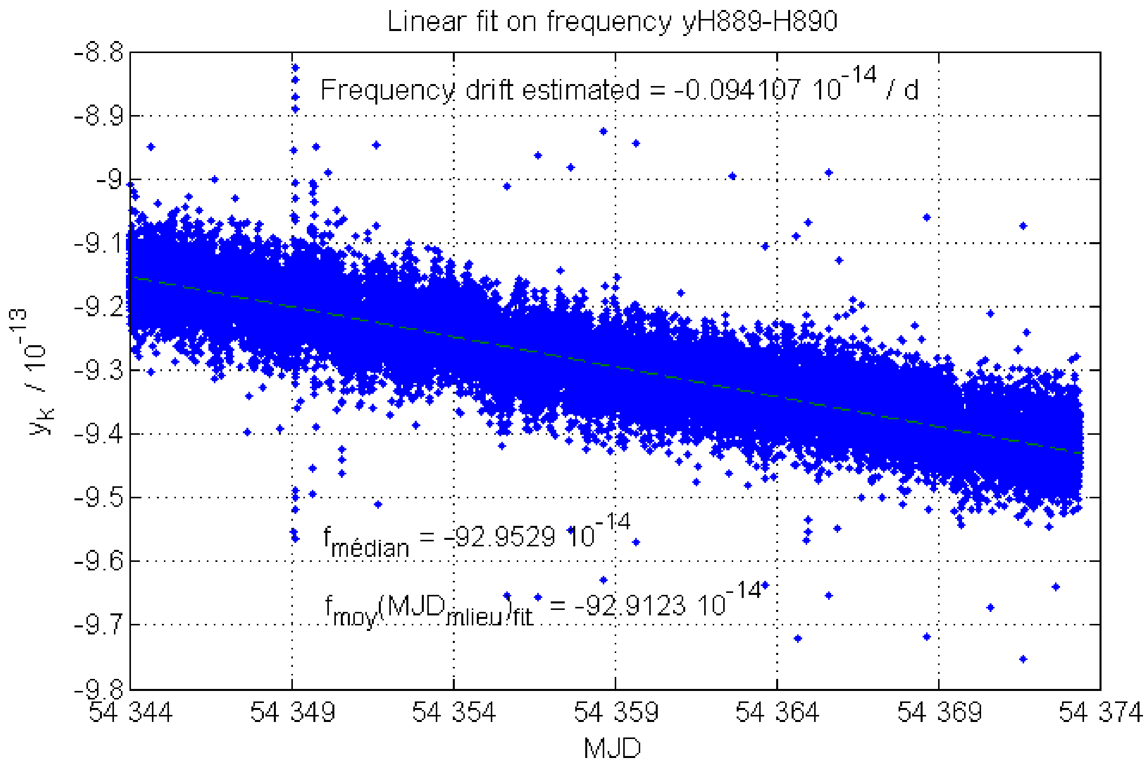

Figure 3: Frequency differences between Maser 889 – Maser 890 obtained by first phase differences of phases averaged over 100s and estimation of the linear drift, September 2007, MJD 54344 to MJD 54374, outliers above 5σ removed

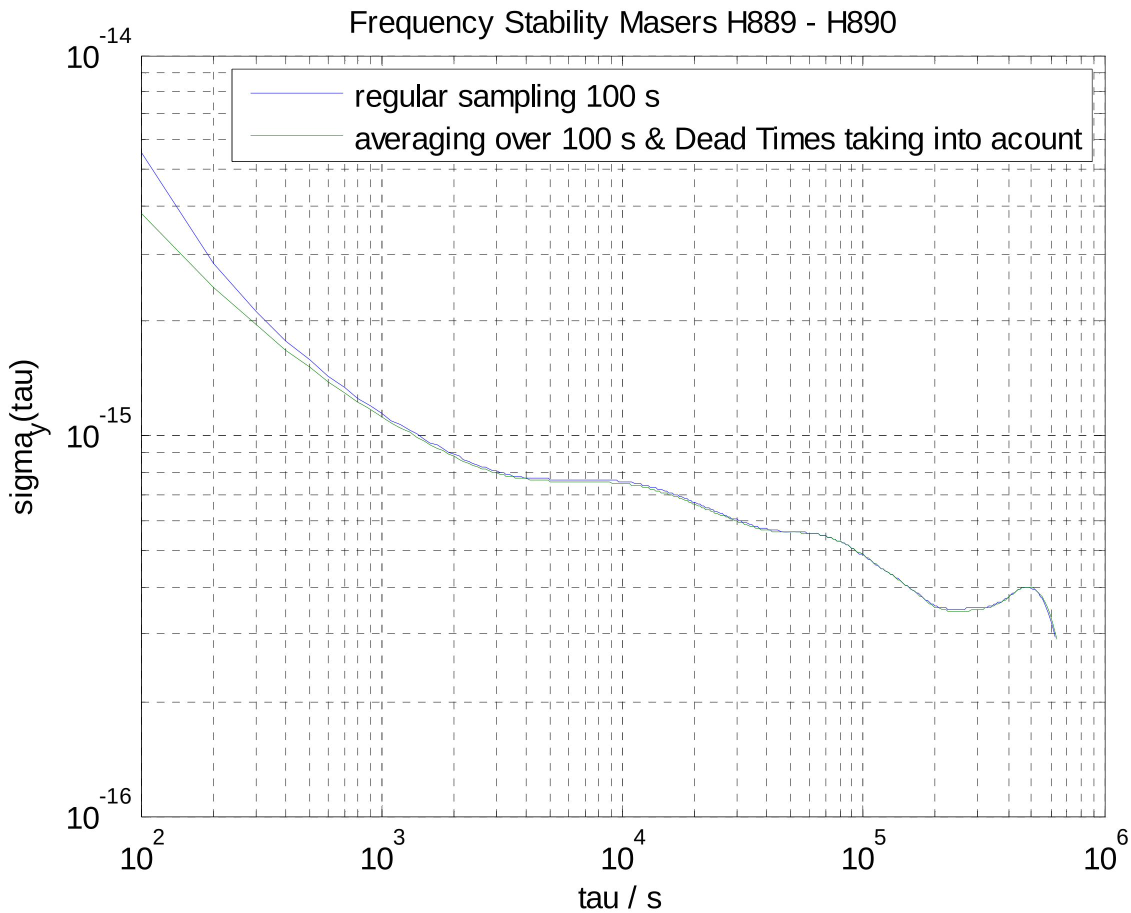

Figure 4: Modified Allan deviation over frequency differences between Maser 140 0889 – Maser 140 0890 linear drift removed, from MJD 54344 to MJD 54374

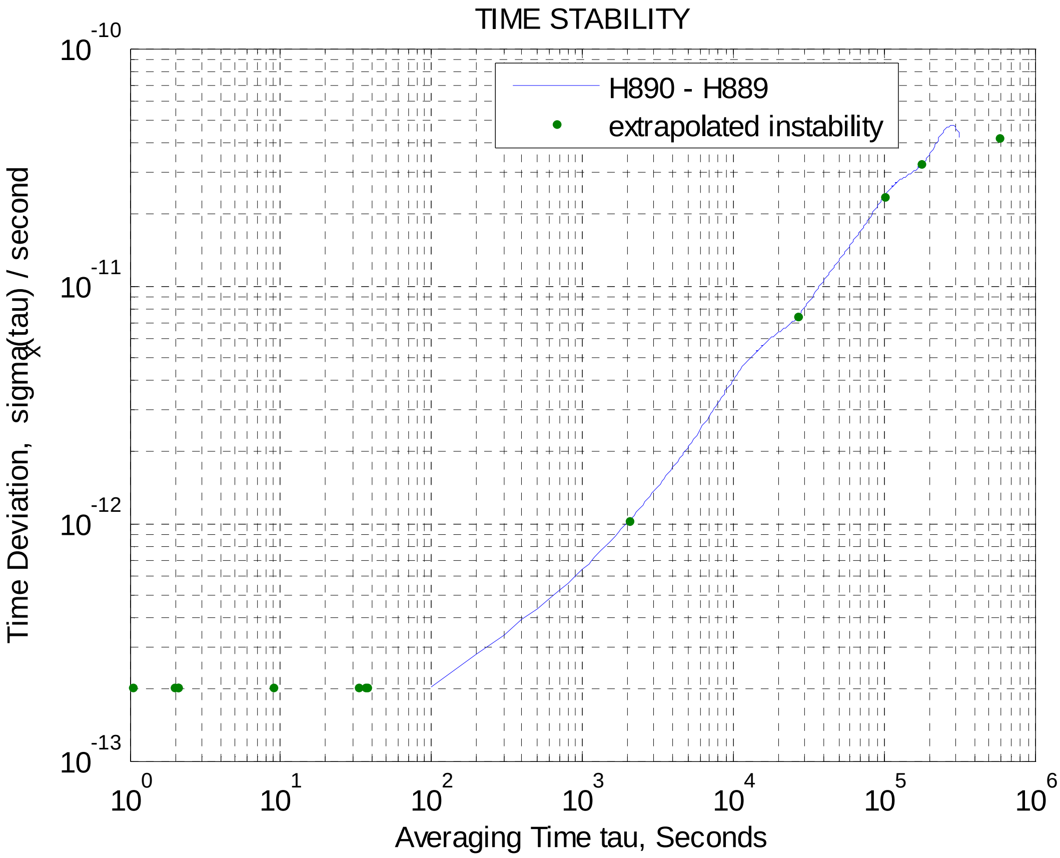

Figure 5: Time stability on normalized phase differences between Masers 140 0889 and 140 0890 linear drift removed, from MJD 54344 to MJD 54374

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 each interval of 12H, 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 = 30 d) of this period gives the uncertainty due to the dead times. The effect is weak due to the good stability of Maser 140 0889 and so doesn't modify the uncertainty due to the link lab.

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

$$\frac{\sqrt{\sum_{i=1}^{51} \sigma_{x_i}^2(\tau)}}{T} = \sigma_{Dead\_Time} = 0.3 \text{ x } 10^{-16}$$

The uncertainty on the link Maser is obtained by the quadratic sum of the link lab uncertainty and the uncertainty due to the dead times calculated above:

$$\sigma_{Link\_Lab} = 1 \text{ x } 10^{-16} \text{ and } \sigma_{Link\_Maser} = \sqrt{(\sigma_{Dead\_Time})^2 + (\sigma_{Link\_Lab})^2} = 1.04 \text{ x } 10^{-16}$$

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
54344	54344	54344	2,07742E-05	-1,3445E-12	6,28403E-16	3,58977503	6,2649E-11
54347,58978	54347,79488	54347,99998	0,205110872	-1,34901E-12	7,83474E-16	3,602E-05	2,2199E-13
54348,00002	54348,25001	54348,49999	0,249991864	-1,35156E-12	7,32494E-16	1,2011E-05	2,2199E-13
54348,50001	54348,75	54348,99999	0,249997364	-1,35237E-12	7,16178E-16	3,4981E-05	2,2199E-13
54349,00002	54349,25001	54349,5	0,249992366	-1,35331E-12	7,1929E-16	1,1981E-05	2,2199E-13
54349,50001	54349,75	54349,99999	0,24999689	-1,35133E-12	7,11733E-16	3,6014E-05	2,2199E-13
54350,00003	54350,24982	54350,49962	0,249804362	-1,35297E-12	7,12234E-16	0,00045699	2,2199E-13
54350,50008	54350,75004	54350,99999	0,249962436	-1,35534E-12	7,0859E-16	1,750018	3,5226E-11
54352,75001	54352,875	54352,99998	0,124992827	-1,35809E-12	1,03161E-15	3,602E-05	2,2199E-13
54353,00002	54353,25001	54353,49999	0,249991868	-1,35693E-12	7,22776E-16	1,2011E-05	2,2199E-13
54353,50001	54353,75	54353,99999	0,249997373	-1,35729E-12	7,40349E-16	3,4981E-05	2,2199E-13
54354,00002	54354,25001	54354,49999	0,249991867	-1,35805E-12	7,15722E-16	1,1027E-05	2,2199E-13
54354,50001	54354,75	54354,99999	0,249998878	-1,36021E-12	7,14169E-16	3,3987E-05	2,2199E-13
54355,00003	54355,23525	54355,47047	0,235230448	-1,36055E-12	7,3145E-16	0,901548	2,3876E-11
54356,37202	54356,43601	54356,5	0,0639939	-1,36224E-12	1,43241E-15	1,204E-05	2,2199E-13
54356,50001	54356,75	54356,99998	0,249992662	-1,36469E-12	7,23461E-16	3,4974E-05	2,2199E-13
54357,00002	54357,2498	54357,49958	0,249787369	-1,363E-12	7,60582E-16	0,00044397	2,2199E-13
54357,50002	54357,75	54357,99998	0,249985892	-1,3636E-12	7,5489E-16	3,602E-05	2,2199E-13
54358,00002	54358,25001	54358,49999	0,249991849	-1,36701E-12	7,26763E-16	1,0998E-05	2,2199E-13
54358,5	54358,75	54358,99999	0,249997888	-1,36604E-12	7,27662E-16	3,4981E-05	2,2199E-13
54359,00002	54359,25001	54359,49999	0,249991848	-1,36746E-12	7,19662E-16	1,1027E-05	2,2199E-13
54359,50001	54359,75	54359,99999	0,249997844	-1,36752E-12	7,29034E-16	3,5014E-05	2,2199E-13
54360,00003	54360,25001	54360,5	0,249991886	-1,36951E-12	7,12039E-16	1,201E-05	2,2199E-13
54360,50001	54360,75	54360,99999	0,249998293	-1,36966E-12	7,48452E-16	3,6974E-05	2,2199E-13
54361,00003	54361,25001	54361,5	0,249990388	-1,36902E-12	7,28649E-16	1,204E-05	2,2199E-13
54361,50001	54361,75	54361,99998	0,249992044	-1,37052E-12	7,4843E-16	3,5987E-05	2,2199E-13
54362,00002	54362,25	54362,49999	0,249991369	-1,37166E-12	7,27057E-16	1,2041E-05	2,2199E-13
54362,5	54362,74999	54362,99999	0,249998034	-1,37167E-12	7,36857E-16	3,4007E-05	2,2199E-13
54363,00002	54363,25001	54363,49999	0,249992379	-1,37291E-12	7,08808E-16	1,2011E-05	2,2199E-13
54363,50001	54363,75	54363,99999	0,249996946	-1,37292E-12	7,34374E-16	3,5994E-05	2,2199E-13
54364,00002	54364,25001	54364,49999	0,24999264	-1,37307E-12	7,68538E-16	1,1981E-05	2,2199E-13
54364,50001	54364,75	54364,99999	0,249997425	-1,37522E-12	7,3482E-16	3,5014E-05	2,2199E-13
54365,00003	54365,25001	54365,5	0,249991846	-1,37568E-12	7,18149E-16	1,201E-05	2,2199E-13
54365,50001	54365,75	54365,99999	0,249997362	-1,37684E-12	7,23521E-16	3,5987E-05	2,2199E-13
54366,00003	54366,25001	54366,5	0,249991344	-1,37729E-12	7,15875E-16	1,204E-05	2,2199E-13
54366,50001	54366,75	54366,99998	0,249991844	-1,37674E-12	7,19869E-16	3,5987E-05	2,2199E-13
54367,00002	54367,25	54367,49999	0,249990858	-1,3784E-12	7,01207E-16	1,3024E-05	2,2199E-13
54367,5	54367,74999	54367,99998	0,249997496	-1,37975E-12	7,17626E-16	3,602E-05	2,2199E-13
54368,00002	54368,25001	54368,49999	0,249991961	-1,37958E-12	7,46337E-16	1,3024E-05	2,2199E-13
54368,50001	54368,75	54368,99999	0,249996401	-1,38063E-12	8,02882E-16	3,4994E-05	2,2199E-13
54369,00002	54369,25001	54369,49999	0,249992408	-1,38229E-12	7,95456E-16	1,1981E-05	2,2199E-13
54369,50001	54369,75	54369,99999	0,249997393	-1,38225E-12	8,14192E-16	3,5014E-05	2,2199E-13
54370,00003	54370,25001	54370,5	0,24999245	-1,38302E-12	7,50801E-16	1,0997E-05	2,2199E-13
54370,50001	54370,75	54370,99999	0,24999741	-1,38397E-12	7,83167E-16	3,4987E-05	2,2199E-13
54371,00003	54371,25001	54371,5	0,249992707	-1,38271E-12	7,93637E-16	1,1027E-05	2,2199E-13
54371,50001	54371,64395	54371,78789	0,143945016	-1,38398E-12	1,06244E-15	0,68397698	1,8892E-11
54372,47186	54372,48593	54372,49999	0,014069849	-1,38764E-12	3,57691E-15	1,1027E-05	2,2199E-13
54372,5	54372,74999	54372,99998	0,249998765	-1,38564E-12	8,77014E-16	3,502E-05	2,2199E-13
54373,00002	54373,25001	54373,49999	0,249992374	-1,38655E-12	7,73768E-16	1,2011E-05	2,2199E-13
54373,50001	54373,75	54373,99999	0,249996866	-1,38767E-12	7,69124E-16	1,2994E-05	2,2199E-13
54374	54374	54374	7,51968E-11	-1,38827E-12	4,86141E-16	0	2,2199E-13

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