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FREQUENCY COMPARISON (H_MASER 40 3818) - (SU-CsFO2)
For the period MJD 56484 to MJD 56504.

The primary frequency standard SU-CsFO2 has been compared to the hydrogen Maser 40 3818 of the laboratory, during a measurement campaign between MJD 56584 and 56504 (11th July 2013 - 31th July 2013). The fountain operation covers ~ 83 % of the total measurement duration for the period MJD 56584-56504**.** The mean frequency difference at the middle date of the each period is given in the following table:

Period (MJD)	Date of the estimation	y(HMaser40 3818 – CsFO2)	u_A	u_B	u_{Link_Maser}	y(HMaser40 3810 – CsFO2)*
56484-56504	**56494**	**318.4**	**3.3**	**5.0**	**1.1**	**-158.3**

Table 1: Results of the comparison in 1 × 10-16.

*The mean frequency difference y(HMaser40 3810 – CsFO2) was calculated through the measurement of fractional frequency difference between CsFO2 and the hydrogen maser HMaser40 3818, which is not included in the composition of reference group.

The relative frequency instability of CsFO2 was :

1.7×10^{-13} $(\tau/s)^{-1/2}$ during the 20 days (MJD 56484-56504)

For the uncertainty due to the clock link $\mathbf{u}_{Link\_Lab} = 0.1\times10^{-15}$ is obtained by taking into account the actual measurement time.

The CsFO2 standard uncertainty u_B is estimated as 0.5×10^{-16} (1σ) for the relevant periods.

Figure 1 shows the shot by shot data measurements during the period MJD 56484 to MJD 56504.

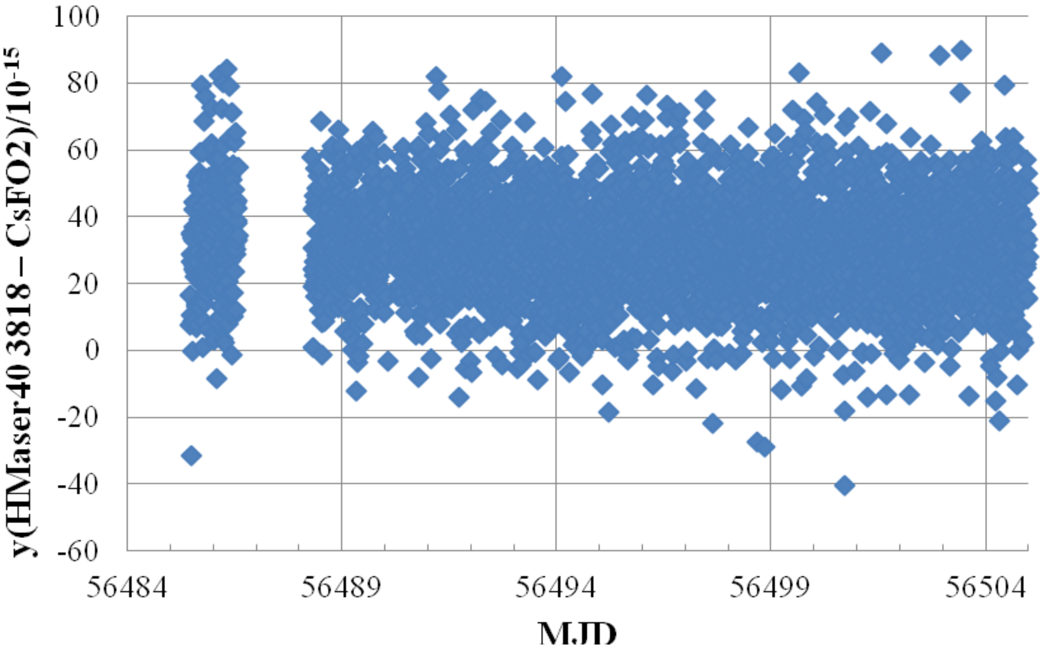

Figure 1: shot by shot data measurements during the period MJD 56484 to MJD 56504

Feature of fountain's measurement procedure

Frequency measurement of H-maser is shared by blocks, each block consists of one hundred shots. Fountain operating mode may differ from block to block or may be the same for all blocks. Fountain work can be programmed with a set of various modes in block.

For example, collision shift measurement cycle consists of three blocks. The number of atoms is determined by frequency of selection cavity signal. This frequency is adjusted to the peak or semi-slope resonance of cesium atoms.

- The first block: a low number of atoms. ($f = f_p - \Delta f$);
- the second block: a high number of atoms ($f = f_p$);
- the third block: a low number of atoms. The frequency of selection cavity is $f = f_p + \Delta f$.

Where f is the selection cavity frequency, f_p is the cesium resonance frequency, Δf is the semi-slope resonance of cesium atoms.

Then the cycle (three blocks) is repeated.

Measurement cycle of the microwave power shift may consist of six blocks. Such work allows to remove frequency drift of H-maser.

A detailed description of the measurement procedure together with a complete evaluation of the systematic frequency biases and their uncertainties is given in references [1].

Accuracy

The frequency is corrected from the quadratic Zeeman, the Black Body radiation, the cold collisions and cavity pulling, , microwave power dependence, and gravity.

The following table summarizes the budget of systematic effects and their associated uncertainties. The accuracy is the quadratic sum of all the systematic uncertainties.

Physical Effect	Correction (10^{-16})	Uncertainty (10^{-16})
Quadratic Zeeman effect	-1073.	0.10
Black body radiation	179.9	1.0
Cold collisions	5.2	2.3
Microwave power dependence	0.39	3.8
Gravity	-244.3	0.1
Total	**-1132**	**4.6**

Table 2: Budget of systematic effects and uncertainties for VNIIFTRI- CsFO2 *fountain for the MJD 56484 – 56504 period*

$$u_B = 5 \times 10^{-16}.$$

Uncertainty due to the dead times

During the evaluation period there were gaps in the data collection (dead time) due to both intentional and unintentional breaks. Most of the unintentional breaks were caused by failures of the laser locking systems(due to rapid change barometric pressure).

Start of date of measurements (MJD)	End of date of measurements (MJD)	Duration of dead Times H:m:s	second	σ_{x_i}

	56484			
56485.4674	56486.5774	35:13:03	126783	2.9989E-11
56488.5587	56490.0684	47:33:04	171184	3.0889E-11
56490.2527	56496.3182	4:25:24	15924	1.0931E-11
56496.3416	56504.99	0:33:42	2022	3.8015E-12

Table 3: Distribution of Dead Times for the MJD 56584 – 56504 period

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

$$\frac{\sqrt{\sum_i \sigma_{x_i}^2}}{T} = \sigma_{Dead\_Time}$$

Period	σ_{Dead_Time}
56584 - 56504	2.49E-17

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:

$\mathbf{u}_{Link\_Lab} = 1\times10^{-16}$,

$\mathbf{u}_{Link\_Maser} = \sqrt{(\sigma_{Dead\_Time})^2 + (\sigma_{Link\_Lab})^2}$

Period	$\mathbf{u}_{Link\_Lab}$
56484-56504	1.1×10^{-16}

References

[1] Domnin, Yu.; Baryshev, V.; Boyko, A.; Elkin, G.; Novoselov, A.; Kopylov, L.; Kupalov, D., "The MTsR-F2 fountain-type cesium frequency standard", Measurement Techniques, Volume 55, Number 10, January 2013 , pp. 1155-1162(8)