State Scientific Center of the Russian Federation
VNIIFTRI
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FREQUENCY COMPARISON
(H–MASER 40 38xx) — (SU–CsFO2)
For the period MJD 58844 to MJD 58879.

The primary frequency standard SU–CsFO2 has been compared to the hydrogen Maser 40 3845 and H–Maser 40 3853 of the laboratory, during a measurement campaign between MJD 58844 and 58879 (27th December 2019 — 31st January 2020). The fountain operation covers $\sim 75\%$ of the total measurement duration for the period MJD 58844 – 58879. The mean frequency difference at the middle date of the period is given in the following table:

Period (MJD)	**Date of the estimation**	y (H–Maser 40 3845 — CsFO2)	u_B	u_A	$u_{\text{Link\_Maser}}$
58844 – 58859	58851.5	2150.3	2.2	2.5	1.1
Period (MJD)	**Date of the estimation**	y (H–Maser 40 3853 — CsFO2)	u_B	u_A	$u_{\text{Link\_Maser}}$
58859 – 58879	58869	−534.37	2.2	4.4	1.1

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

For the uncertainty due to the clock link $u_{\text{Link\_Lab}} = 0.1 * 10^{-15}$ is obtained by taking into account the actual measurement time.

Accuracy

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	**Shifts** (10^{-16})	**Uncertainty** (10^{-16})
Second-order Zeeman effect	1070.7	0.10
Black-body radiation	-163.8	0.5
Gravitational shift	244.3	0.5
Resonator pulling	0	0.1
Purity of probe signal spectrum	0	0.1
Light shift	0	0.1
Tilting (DCP)	0	0.1

Physical Effect	**Shifts** (10^{-16})	**Uncertainty** (10^{-16})
Collisions with residual gas	0	1
Microwave power dependence	0	1.8
Spin exchange shift (mean density)*	0.19*	0.19*
Total (not including spin exchange)	1151.2	2.2

Table 2: Budget of systematic effects and uncertainties for VNIIFTRI–CsFO2 fountain for the MJD 58844 – 58879 period.

$$\boxed{u_B = 2.2 * 10^{-16}}$$

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).

The standard deviation of the fluctuations of frequency due to the dead times in measurements is estimated by the ratio $\frac{\sqrt{\sum_i \sigma_{x_i}^2}}{T} = \sigma_{\text{Dead\_Time}}$.

Period (MJD)	$\sigma_{\text{Dead\_Time}}$
58844 – 58879	$4.5 * 10^{-17}$

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:

$$u_{\text{Link\_Lab}} = 1 * 10^{-16},$$
$$u_{\text{Link\_Maser}} = \sqrt{(\sigma_{\text{Dead\_Time}})^2 + (\sigma_{\text{Link\_Lab}})^2}.$$

Period (MJD)	$u_{\text{Link\_Maser}}$
58844 – 58879	$1.1 * 10^{-16}$

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. 2013. Vol. 55. № 10. PP. 1155–1162.

[2] Blinov I., Boiko A., Domnin Yu., Kostromin V., Kupalova O., Kupalov D. Budget of uncertainties in the cesium frequency frame of fountain type // Measurement Techniques. 2017. Vol. 60. № 1. PP. 30–36.