NTSC
National Time Service Center,CAS
中国科学院国家授时中心

Frequency comparison between H-maser 1415085 and NTSC-CsF2 for the period MJD 60764 to 60794

The primary frequency standard NTSC-CsF2 has been compared to the local hydrogen Maser 1415085, during the period MJD 60764-60794. The fractional frequency difference at the middle date of the interval is given in the following table:

Table 1 Results of the frequency comparison in 1×10^{-16}

Period (MJD)	y(H-maser 1415085–NTSC-CsF2)	u_A	u_B	$u_{A/lab}$	$u_{B/lab}$	Uptime (%)
60764-60794	1483.0	4.6	3.7	1.0	0.0	94.7

The hydrogen maser is used as a local oscillator for Ramsey interrogation of the fountain. During the reported period, accuracy evaluation is completed to correct the frequency shifts. The frequency data were averaged over 1-hour interval firstly. Then, an unweighted linear fitting was applied to the mean data points to ascertain the frequency at the midpoint of this evaluation period.

Uncertainties

- Type A uncertainty u_A

During the period MJD 60764-60794, NTSC-CsF2 was operated continually in a differential configuration with 200 cycles of high density and 200 cycles of low density. NTSC-CsF2 uses extrapolated frequency stability as the type-A uncertainty from high and low density configuration[1].

- Type B uncertainties u_B

NTSC-CsF2 was corrected for frequency shifts due to the following effects: second-order Zeeman, black body radiation, cold atom collisions, gravitational redshift and microwave leakage, as stated in reference [1]. The frequency biases due to all other physical effects are negligible. Its performance was also tested and reported in reference [1]. A summary of systematic frequency shifts for this evaluation are listed in Table 2.

Table 2 Uncertainty budget of NTSC-CsF2 for the MJD 60764-60794

Effect	Correction/10^{-16}	Uncertainty/10^{-16}
Second-order Zeeman	-1300.8	0.8
Blackbody radiation	166.7	0.8
Cold atom collisions	17.8	2.7
Gravitational redshift	-524	0.5
Microwave leakage	-4.7	1.5
DCP	0	1.4
Lensing	0	0.6
Background gas collisions	0	0.1
Total	-1645.0	3.7

- Uncertainty due to the link in the laboratory $u_{A/lab}$

The statistical uncertainty induced from the link in the laboratory is obtained by quadratic sum of the following 2 terms:

(1) u_{dead_time} is the uncertainty due to operational dead time of NTSC-CsF2. During the evaluation period, there were gaps in the data collection (dead time) due to both system maintenance and occasionally unintentional breaks such as laser unlocks, etc.

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

$$u_{dead\_time} = \frac{\sqrt{\sum_{i=1}^{i=N} \sigma_{x_i}^2}}{T} \tag{1}$$

where σ_{xi} is the time deviations (TDEVs) of the H-maser for each dead times.

(2) $u_{internal\_link}$ encapsulates the phase fluctuation resulting from the cables connecting H-maser 1415085 to the NTSC-CsF2. It is estimated to be 1.0×10^{-16}.

- Uncertainty due to the link in the laboratory $u_{B/lab}$

The signal from hydrogen maser feeds directly into the microwave synthesizer of the fountain. The frequency comparison between the maser and UTC(NTSC) is performed by a time interval counter. Therefore, the systematic uncertainty of the link $u_{B/lab}$ is estimated to be negligible.

References

1. Xin-Liang Wang et al, 2023 Metrologia, 60 065012