Frequency comparison between H-maser 1404850 and NIM5 for the period MJD 60459 to 60489

I. SUMMARY

The primary frequency standard NIM5 was used to measure the average fractional frequency difference of the H-maser 21, identified by the clock code 1404821, during an evaluation campaign over 30 days in JUN. 2024. However, the H-maser 21 has not reported to BIPM yet. The H-maser 50 (clock code 1404850, reported data to BIPM every month) and H-maser 21 have been continuously compared through the fiber link. So we calculated the frequency difference between H-maser50 and NIM5 during these days. The results are given in table 1, together with the total uncertainties in relating NIM5 to maser 50.

Table 1 Summary of the frequency measurements of H-maser 50 (1404850)

Period	MJD 60459.0 to 60489.0
$y_{(\mathrm{H50\text{-}NIM5})}$ [×10^{-15}]	18.89*
Duty cycle [%]	93.0%
u_A [×10^{-15}]	0.29
u_B [×10^{-15}]	0.66
$u_{link/lab}$ [×10^{-15}]	0.10
u_{total} [×10^{-15}]	0.73

*NIM5 was compared with H-maser(code 1404821), which has been not report data to BIPM yet. The direct frequency difference between H-maser 1404821 and NIM5 is -10.84E-15, and the frequency difference between H-maser 1404850 and H-maser 1404821 is measured to be 29.73E-15.

The combined total uncertainty u_{total} is the square sum of the three uncertainties as following:

$$u_{total} = \sqrt{(u_A)^2 + (u_B)^2 + (u_{link/lab})^2} \quad (1)$$

Type A uncertainty u_A is the statistical uncertainty on the frequency measurement, u_B is the Type B uncertainty from bias evaluations, and $u_{link/lab}$ is the uncertainty induced by the link between NIM5 fountain clock and the H-maser 50, which includes the dead time and the phase noise of the link between NIM5 and H-50. All the above uncertainties are calculated at 1σ.

II. Measurement methods

Since the last report, the primary frequency standards NIM5 has undergone relocation work. Following the optimization of a portion of the electronic control system, the reconnection of fiber optic and electrical cables, and the subsequent debugging of functions, NIM5 has now resumed its operational capabilities. We re-evaluated frequency accuracy of NIM5 and a summary of the systematic frequency shift evaluations for NIM5 is listed in Table 2, some frequency shift terms changed. We have redesigned and developed an microwave interferometric switch, and measured the phase fluctuations introduced by it, and the uncertainty introduced by the switch was 0.1×10^{-16}. The orthometric height of the Ramsey cavity is 78.4(0.2) m which is measured by the dimensional metrology laboratory of NIM and traced to a leveling benchmark inside our campus, so the gravitational red shift is changed to 85.6×10^{-16} with the uncertainty 0.2×10^{-16} . The combined relative Type B uncertainty is approximately 6.6×10^{-16}.

leveling method height

Table 2 Uncertainty budget of NIM5 in these evaluations.

Physical Effect	Bias [$\times10^{-16}$]	Uncertainty [$\times10^{-16}$]
2nd order Zeeman	733.6	2.0
Collisional shift	-32.2*	1.6
Microwave interferometric Switch	0.0	0.1
Microwave leakage	0	0.1
DCP	0.0	6.0
Microwave spectral impurities	0.0	1.0
Blackbody radiation	-164.4	0.4
Gravitational red shift	85.6	0.2
Collision with background gases	0.0	0.1
Total	622.6*	6.6*

* The collision shift is calculated at low density.