Frequency Evaluation of the Primary Frequency Standard NIM5

National Institute of Metrology (NIM) China

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I. SUMMARY

The primary frequency standard NIM5 was used to measure the average fractional frequency difference of the H-maser H271, identified by the clock code 1404871, during an evaluation campaign over 20 days in March 2016. The results are given in table 1, together with the total uncertainties in relating NIM5 to maser H271.

Table 1 Summary of the frequency measurements of H-maser H271 (1404871)

Period	MJD 57459.0 to 57479.0
$y_{(\mathrm{NIM5\text{-}H271})}$ [$\times 10^{-15}$]	3397.0
Duty cycle [%]	99.2%
u_A [$\times 10^{-15}$]	0.8
u_B [$\times 10^{-15}$]	1.4
$u_{link/lab}$ [$\times 10^{-15}$]	0.2
u_{total} [$\times 10^{-15}$]	1.6

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 H271, which includes the dead time and the phase noise of the link between NIM5 and H271. All the above uncertainties are calculated at 1σ.

II. Measurement methods

One of the NIM5 slave lasers was broken and replaced by a new one. After optimizing the optical system, the atom numbers is a little higher than the last evaluation, and the collisional shift is also higher as shown in the following table. The system is more stable and Type A instability is lower compared with the data published last year on Metrologia. The instability of $2.6\times10^{-13}(\tau/s)^{-1/2}$ is obtained when running at high density. No other changes have been made since last report, and the evaluation method is about the same as published. A summary of the systematic frequency shift evaluations for NIM5 is listed in Table 2. The combined relative Type B uncertainty is approximately 1.4×10^{-15}.

Table 2 Uncertainty budget of NIM5

Physical Effect	Bias [$\times10^{-15}$]	Uncertainty [$\times10^{-15}$]
2nd order Zeeman	73.5	0.2
Collisional shift	-4.1*	0.4
Microwave interferometric Switch	0.0	1.2
Microwave leakage	0	<0.1
DCP	0.0	0.6
Microwave spectral impurities	0.0	0.1
Blackbody radiation	-16.2	0.1
Gravitational red shift	11.8	0.1
Majorana transition	0.0	0.1
Light shift	0.0	<0.1
Rabi and Ramsey pulling	0.0	<0.1
Cavity pulling	0.0	<0.1
Collision with background gases	0.0	<0.1
Total	65.0*	1.4 *

* The collision shift is calculated at low density.

The dead time distribution during the 20 days of report period is shown in the figure 1:

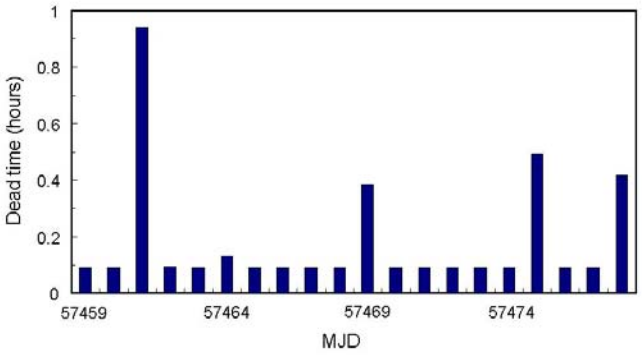

Figure 1 Dead time distributions in Mar., 2016 report period.