IENCsF1 TAI EVALUATION
MJD 53089-53099 (25March-4April 2004)
MJD 53154-53174 (29May-18June2004)

During the periods MJD 53089-53099 and MJD 53154-53174, IEN has evaluated the frequency of its Hydrogen Maser IEN-HM2 (BIPM code 1401102) using the Cs fountain IEN-CsF1.

The evaluation procedure of the fountain standard is the same for both the evaluation runs and follows the procedures reported in [1], except for the collisional shift measurement.

In the period MJD 53089-53099, the fountain was operated varying the number of loaded atoms each 24 hours of measurement. The zero atom intercept of the frequency vs. atom number plot is then the frequency at which the fountain would operate in the absence of the collisions. In order to evaluate the drift of the maser independently from the collisional shift variation, we measured four times the frequency of the maser in the same loading configuration. The drift of the Maser is then evaluated by a weighted linear fit at (1±2)e-16/day. The frequency data are then drift corrected and the zero atom density intercept is evaluated with a weighted linear fit.

In the period MJD 53154-53174 the collisional shift was corrected using the differential technique reported in [1]. The sensitivity of the IEN-CsF1 frequency versus the number of detected atoms has been evaluated with two differential measurements, performed just before and after the reported evaluation period.

The frequency values, already corrected for the collisions shift, have then been corrected for the Blackbody radiation, Gravitational and Zeeman shifts. The G-field was mapped before each measurement run; the obtained result was used to correct the Zeeman shift. The fountain operation temperature was not changed between the two runs, but it was carefully surveyed to ensure the stability of the Blackbody radiation shift.

Final values for Circular T are reported in Table 3.

Period MJD 53089-53099

$\langle y(IENCsF1) - y(IENHM2) \rangle = +1.098 \times 10^{-13}$ (value corrected only for the collisional shift)
$u_A = 6 \times 10^{-16}$

Black Body Radiation Shift
$\Delta\nu_{BBR} = \beta\,(T/300)^4 \times [1+\varepsilon(T/300)^2]$
$\beta = (-1.711 \pm 0.003) \times 10^{-14}$
$\varepsilon = 0.014$
$T = 70.0 \pm 0.2\ ^\circ C = 343.1 \pm 0.2\ K$
$\Delta\nu_{BBR} = (-2.98 \pm 0.07) \times 10^{-14}$

Gravitational Red Shift Shift
$\Delta\nu_{RS} = \gamma \times h$
$\gamma = 1.09 \times 10^{-16}\ m^{-1}$
$h = 242 \pm 1\ m$
$\Delta\nu_{RS} = (2.64 \pm 0.01) \times 10^{-14}$

Zeeman Shift
$\Delta\nu_Z = K \times B_0^2$
$K = 427.45\ Hz/T^2$
B_0, C-field, evaluated with a mapping procedure, as described in [1].
$\Delta\nu_Z = (4.71 \pm 0.01) \times 10^{-14}$

Effect	Bias ($\times 10^{-14}$)	Uncertainty ($\times 10^{-14}$)
2nd order Zeeman Shift	4.71	0.004
Blackbody Radiation	-2.98	0.007
Gravitational Potential	2.64	0.01
Collisions	(*)	0.065
Other Effects	-	0.1
Total	4.37	0.12

Table 1. Summary of corrected biases and uncertainty budget in IENCsF1, for the run MJD 53089-53099.

(*) The collisional shift is corrected for each 24 hours run. The related uncertainty is reported as Type B uncertainty.

Period MJD 53154-53174

$\langle y(IENCsF1) - y(IENHM2) \rangle = +1.186 \times 10^{-13}$
$u_A = 3 \times 10^{-16}$

Black Body Radiation
$\Delta\nu_{BBR} = \beta\ (T/300)^4 \times [1+\varepsilon(T/300)^2]$
$\beta = (-1.711 \pm 0.003) \times 10^{-14}$
$\varepsilon = 0.014$
$T = 70.0 \pm 0.2\ °C = 343.1 \pm 0.2\ K$
$\Delta\nu_{BBR} = (-2.98 \pm 0.07) \times 10^{-14}$

Gravitational Red Shift
$\Delta\nu_{RS} = \gamma \times h$
$\gamma = 1.09 \times 10^{-16}\ m^{-1}$
$h = 242 \pm 1\ m$
$\Delta\nu_{RS} = (2.64 \pm 0.01) \times 10^{-14}$

Zeeman Shift
$\Delta\nu_Z = K \times B_0^2$
$K = 427.45\ Hz/T^2$
B_0, C-field, evaluated by a mapping procedure, as described in [1].
$\Delta\nu_Z = (4.61 \pm 0.01) \times 10^{-14}$

Collisional Shift
$\Delta\nu_C = (-0.24 \pm 0.07) \times 10^{-14}$
Evaluation as described in [1]

Effect	Bias ($\times 10^{-14}$)	Uncertainty ($\times 10^{-14}$)
2nd order Zeeman Shift	4.61	0.004
Blackbody Radiation	-2.98	0.007
Gravitational Potential	2.64	0.01
Collisions	-0.24	0.07
Other Effects	-	0.1
Total	4.03	0.12

Table 2. Summary of corrected biases and uncertainty budget in IENCsF1, for the run MJD 53154-53174

Ev. Period	y[IENCsF1-HM2]	uA	uB	ul/lab
53089-53099	$+66.1 \times 10^{-15}$	0.6×10^{-15}	1.2×10^{-15}	0.4×10^{-15} [2]
53154-53174	$+78.3 \times 10^{-15}$	0.3×10^{-15}	1.2×10^{-15}	0.3×10^{-15} [3]

Table 3. Final results of IENCsF1 evaluations

References

[1] F. Levi et al. "IENCsF1 accuracy evaluation and two way frequency comparison" Proceedings of the joint meeting EFTF/FCS, Tampa, 2003. pp.199-204

[2] IENCSF1 Dead Time < 2% over the period MJD 53089-53099

[3] IENCSF1 Dead Time < 10% over the period MJD 53154-53174