

# **IENCsF1 TAI EVALUATION**

## **MJD 53304-53324 (26October-15November 2004)**

During the period MJD 53304.0-53324.0, 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 follows the prescriptions reported in [1].

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 Quadratic Zeeman shifts. The C-field was mapped just before and after the measurement run; the obtained result was used to correct the Zeeman shift. The fountain operation temperature was not changed during the run, but it was carefully surveyed to ensure the stability of the Blackbody radiation shift.

The correction values and related uncertainties are summarized in Table 1.

The values for Circular T are reported in Table 2.

[1] F. Levi, L. Lorini, D. Calonico, A. Godone, "IEN-CsF1 accuracy evaluation and Two-Way frequency comparison". IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 51, no. 10, pp. 1216-1224 (October 2004).

### Black Body Radiation

$$\Delta\nu_{\text{BBR}} = \beta (T/300)^4 \times [1+\varepsilon(T/300)^2]$$

$$\beta = (-1.711 \pm 0.003) \times 10^{-14}$$

$$\varepsilon = 0.014$$

$$T = 69.9 \pm 0.2 \text{ }^\circ\text{C} = 343.1 \pm 0.2 \text{ K}$$

$$\Delta\nu_{\text{BBR}} = (-2.98 \pm 0.01) \times 10^{-14}$$

### Gravitational Red Shift

$$\Delta\nu_{\text{RS}} = \gamma \times h$$

$$\gamma = 1.09 \times 10^{-16} \text{ m}^{-1}$$

$$h = 242 \pm 1 \text{ m}$$

$$\Delta\nu_{\text{RS}} = (2.64 \pm 0.01) \times 10^{-14}$$

### Zeeman Shift

$$\Delta\nu_{\text{Z}} = K \times B_0^2$$

$$K = 427.45 \text{ Hz/T}^2$$

$B_0$ , C-field, evaluated by a mapping procedure, as described in [1].

$$\Delta\nu_{\text{Z}} = (4.59 \pm 0.01) \times 10^{-14}$$

### Collisional Shift

$$\Delta\nu_{\text{C}} = (-0.15 \pm 0.1) \times 10^{-14}$$

Average value calculated on the fountain operation accumulated time in the period MJD 53304-53324. Evaluation as described in [1].

<b>Effect</b>	<b>Bias (<math>\sim 10^{-14}</math>)</b>	<b>Uncertainty (<math>\sim 10^{-14}</math>)</b>
2 <sup>nd</sup> order Zeeman Shift	4.59	0.01
Blackbody Radiation	-2.98	0.01
Gravitational Potential	2.64	0.01
Collisions	-0.15	0.1
<b>Total</b>	<b>4.10</b>	<b>0.1</b>

Table 1. Summary of corrected biases and uncertainty budget in IENCsF1, for the run MJD 53304-53324

<b>Ev. Period</b>	<b>y[IENCsF1-HM2]</b>	<b>uA</b>	<b>uB</b>	<b>ul/lab</b>
53304-53324	$+103.7 \times 10^{-15}$	$0.3 \times 10^{-15}$	$1.0 \times 10^{-15}$	$0.4 \times 10^{-15}$ (*)

Table 2. Final results of IENCsF1 evaluations

(\*) IENCsF1 Dead Time < 15% over the period MJD 53304-53324