Realization of the new UTC(OP) based on LNE-SYRTE atomic fountains

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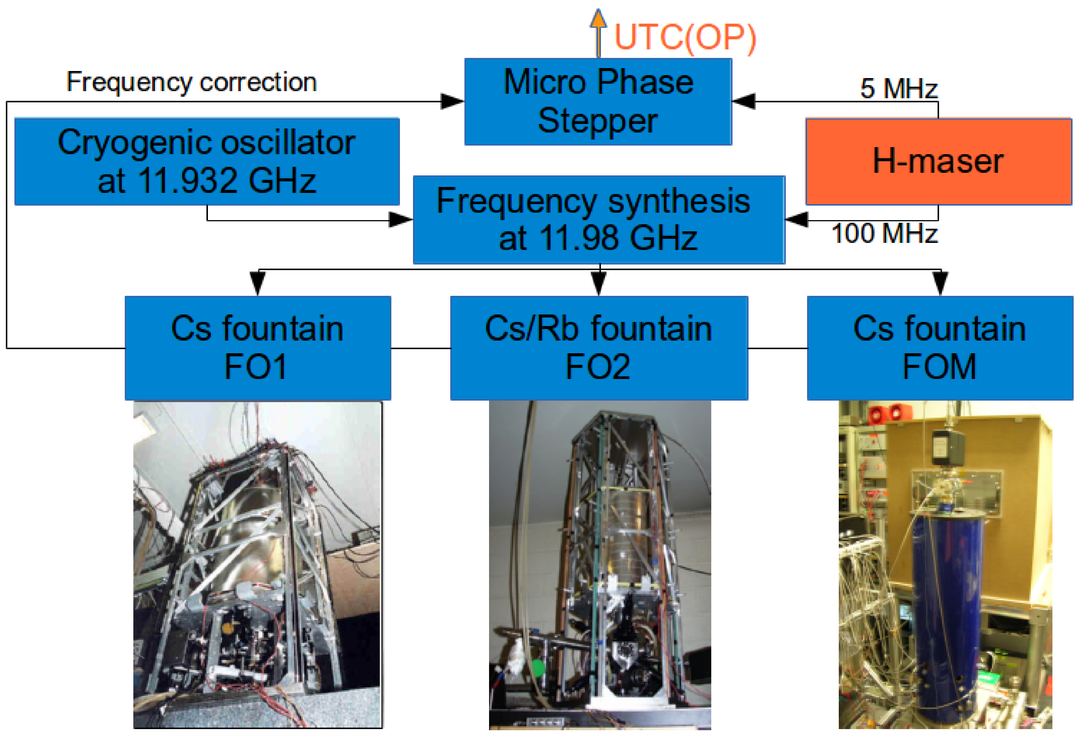
Introduction

UTC(OP) is a physical signal, the real time prediction for France of the Coordinated Universal Time (UTC) produced by the Observatoire de Paris. Since 29th October 2012, this signal is issued from a 5 MHz hydrogen maser signal frequency steered on the LNE-SYRTE atomic fountains.

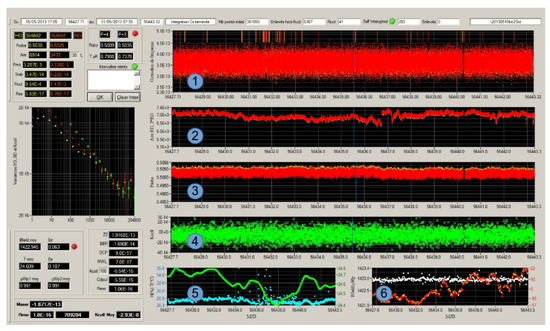
Simplified block diagram



Oscillating signal of the maser generates UTC, fountains measure the maser frequency to steer the frequency via the micro-phase stepper.

Automatic processing of fountain data

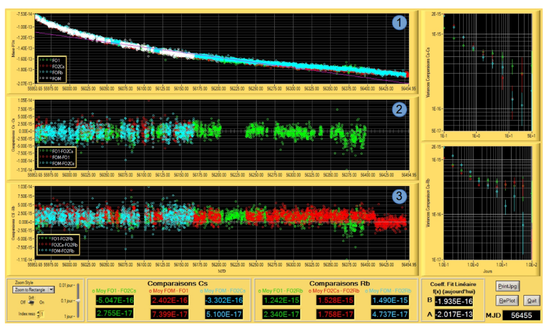
Hourly tasks



Plot of cycle by cycle data:

1. frequency corrections;
2. atoms number;
3. transition probabilities;
4. collision coefficient, K_{coll};
5. and 6. environment parameters: temperature, humidity, magnetic field, microwave power.

Daily tasks



Daily data processing for UTC(OP) steering, synchronous comparisons between fountains, data provision for TAI steering, ...

Operations:

- sorting data (outliers, anomalies in the operations of the fountains or of the metrological chain);
- computation and correction of systematic effects;
- recording of cycle by cycle corrected frequency data;
- averaging of frequency data sampled over synchronous periods of 0.01 and 0.1 d;
- synchronous comparisons between pairs of fountains.

Plot :

1. Maser-fountains frequency differences
2. Cs-Cs fountains frequency differences
3. Cs-Rb fountains frequency differences

Fountain's uncertainty budget:

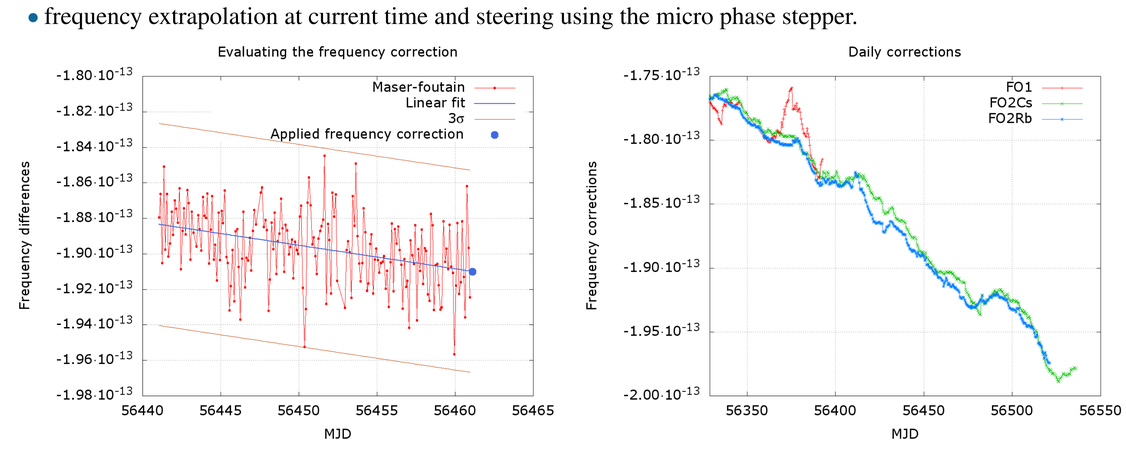
Corrections and uncertainties ($\times 10^{-16}$)

Systematic effects	FO1	FO2Cs	FOM	FO2Rb
Quadratic Zeeman Shift	-1274.5 ± 0.4	-1915.9 ± 0.3	-305.6 ± 1.2	-3465.5 ± 0.7
Blackbody radiation	172.6 ± 0.6	168.0 ± 0.6	165.6 ± 0.6	122.8 ± 1.3
Collisions and cavity pulling	70.5 ± 1.4	112.0 ± 1.2	28.6 ± 5.0	2.0 ± 2.5
Distributed cavity phase shift	-1.0 ± 2.7	-0.9 ± 0.9	-0.7 ± 1.6	0.4 ± 1.0
Spectral purity and leakage	< 1.0	< 0.5	< 0.4	< 0.5
Ramsey and Rabi pulling	< 1.0	< 0.1	< 0.1	< 0.1
Microwave lensing	-0.7 ± 0.7	-0.7 ± 0.7	-0.9 ± 0.9	0.7 ± 0.7
Second order Doppler shift	< 0.1	< 0.1	< 0.1	< 0.1
Background collision	< 0.3	< 1.0	< 1.0	< 1.0
Total	-1033.1 ± 3.5	-1637.5 ± 2.1	-113.0 ± 6.9	-3341.1 ± 3.3
Gravitational redshift	-68.7 ± 1.0	-65.4 ± 1.0	-69.3 ± 1.0	-65.4 ± 1.0

H-Maser frequency corrections

Every day:

- concatenation of the last 20 days of maser-fountain frequency differences data;
- rejection of $3 \times \sigma$ outliers and linear regression with the data;
- frequency extrapolation at current time and steering using the micro phase stepper.



Steering on UTC

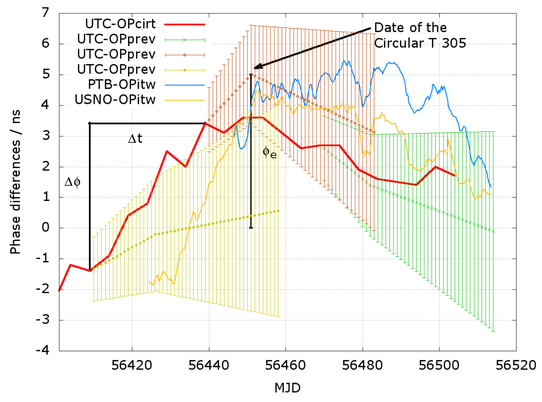
Circular T

Every month the BIPM publishes the phase differences in UTC – UTC(k) in the Circular T:

Date 2013 0h UTC	APR 27	MAY 2	MAY 7	MAY 12	MAY 17	MAY 22	MAY 27	Uncertainty/ns		Notes
MJD	56409	56414	56419	56424	56429	56434	56439	uA	uB	u
Laboratory k	[UTC-UTC(k)]/ns									
ONRJ (Rio de Janeiro)	-8.4	-9.3	-12.4	-7.1	-5.9	-8.9	-6.5	1.0	7.0	7.1
OP (Paris)	-1.4	-0.9	0.4	0.8	2.5	2.0	3.4	0.3	1.8	1.9
ORB (Bruxelles)	1.3	2.0	2.8	2.4	3.3	2.1	1.5	0.3	5.2	5.2
PL (Warszawa)	35.3	32.2	30.1	33.0	29.6	21.9	15.3	0.3	5.1	5.1
PTB (Braunschweig)	1.9	1.4	2.3	1.8	3.3	2.0	2.0	0.1	1.5	1.5
ROA (San Fernando)	-3.1	-3.3	-4.6	-7.2	-5.6	-5.0	-7.4	0.3	5.2	5.2

Excerpt from the CirT 305

Correction and prediction of UTC(OP)



From the latest Circular T

- Correction of the phase drift UTC-UTC(OP)

$$\nu_p = \frac{\Delta\phi}{\Delta t}$$

- Correction of the phase shift UTC-UTC(OP) extrapolated from the last BIPM computed value to the release date and distributed over 60 days

$$\phi_e \;\Rightarrow\; \nu_e = \frac{\phi_e}{60 \times 86400}$$

- The daily frequency correction is:

$$\nu_{\text{corr}} = -\nu_p - \nu_e$$

applied up to the release of next Circular T.

Comparison of UTC – UTC(k) [from BIPM Circular T]