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Federal Institute of Metrology METAS

METAS (CH) report to CCTF 2017

Report to the 21st session of the Consultative Committee for Time & Frequency (CCTF), 08-09 June 2017

15.05.2017

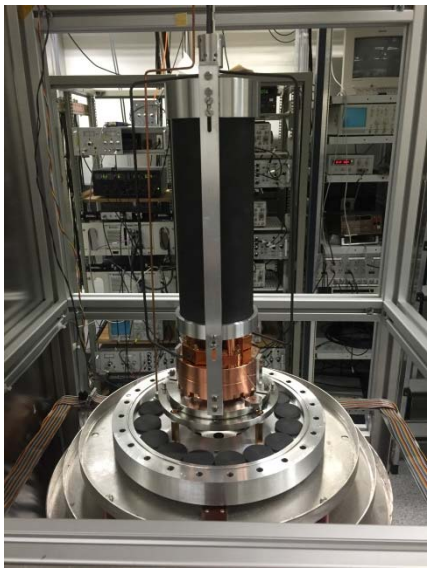
1 Clocks for TAI

1.1 Commercial clocks

METAS is currently operating three commercial cesium standards, one hydrogen maser and one passive hydrogen maser, which all contribute to the realization of the UTC(CH) time scale and to the computation of TAI.

1.2 FoCS-2 continuous beam primary frequency standard

Since the last report dated 09.2012, METAS continued working on the development and on the evaluation of the continuous Cs fountain primary standard FoCS-2. Major improvements were achieved with the new TE_{105} microwave cavity [11] and with the installation of a graphite shield to protect the atoms in the free flight zone from residual microwave leaks.



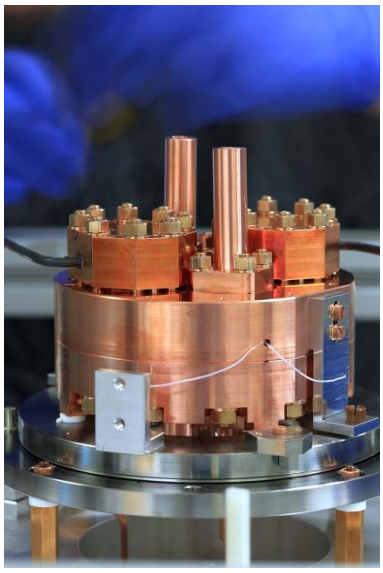


Fig. 1 (left) shows a view of the graphite shield placed on the top of the microwave cavity to protect the atoms in the free flight zone from residual microwave leaks. Fig.1 (right) shows the details of the microwave cavity with the two upper cutoffs and microwave input couplers.

An in depth evaluation of FoCs-2 led to the first complete uncertainty budget, which demonstrates a fractional frequency uncertainty of $1.99 \cdot 10^{-15}$ essentially limited by the type-A contributions, as shown in the table below.

Effect	**Frequency shift / 10^{-15}**	**Uncertainty / 10^{-15}**
Type-B		
2nd order Zeeman	23.59	0.21
Gravity	59.76	0.05
Blackbody radiation	-16.76	0.04
Microwave purity	0.00	0.05
Light shift (from source)	-0.16	0.04
Cavity pulling	0.00	<0.01
Rabi and Ramsey pulling	0.05	0.1
Majorana transitions	0.00	0.50
Type-A		
End-to-end	2.17	0.27
DCPS	0.00	1.02
Collisions Cs-Cs	-1.91	1.47
Light shift (from detection)	-0.10	0.41
Microwave leakage	0.00	0.47
Total Type-B	66.57	0.23
Total Type-A	0.16	1.98
Total	**66.73**	**1.99**

Table 1. Uncertainty budget of FoCS-2 (relative standard uncertainties).

A first one month calibration of TAI was performed between MJD 57809 and MJD 57839 (March 2017, Circular T 351) and yields $d = (-0.83 \pm 2.00) \cdot 10^{-15}$. $d = -(y_{\mathrm{TAI}} - y_{\mathrm{PFS}})$ is defined as the duration of the measured TAI scale unit relative to the SI second realized by the primary standard. The uncertainty budget of the comparison FoCS-2 vs TAI is detailed in the table below. The uncertainties are specified using the same definitions as Circular T. Our result is consistent with the other primary standards since for that particular month the estimation by BIPM of the duration of the TAI scale unit versus the SI second was $d = (-0.75 \pm 0.22) \cdot 10^{-15}$.

Contribution	**Fractional Frequency Uncertainty / 10^{-15}**
FoCS-2 u_{A}	1.98
FoCS-2 u_{B}	0.23
Link to local clock $u_{(\mathrm{l/lab})}$	0.07
Link to TAI $u_{(\mathrm{l/TAI})}$	0.20
Total uncertainty u_{tot}	2.00

Table 2 Uncertainty budget of comparison FoCS-2 vs TAI (relative standard uncertainties).

An article is in preparation for publication in Metrologia with a detailed report of the first evaluation of FoCS-2 [1]. The next step for METAS will be to apply with the CCTF WG-PSFS and

with the BIPM in order to contribute officially to the monthly calibration of TAI published in Circular T.

2 *Timescales* generation

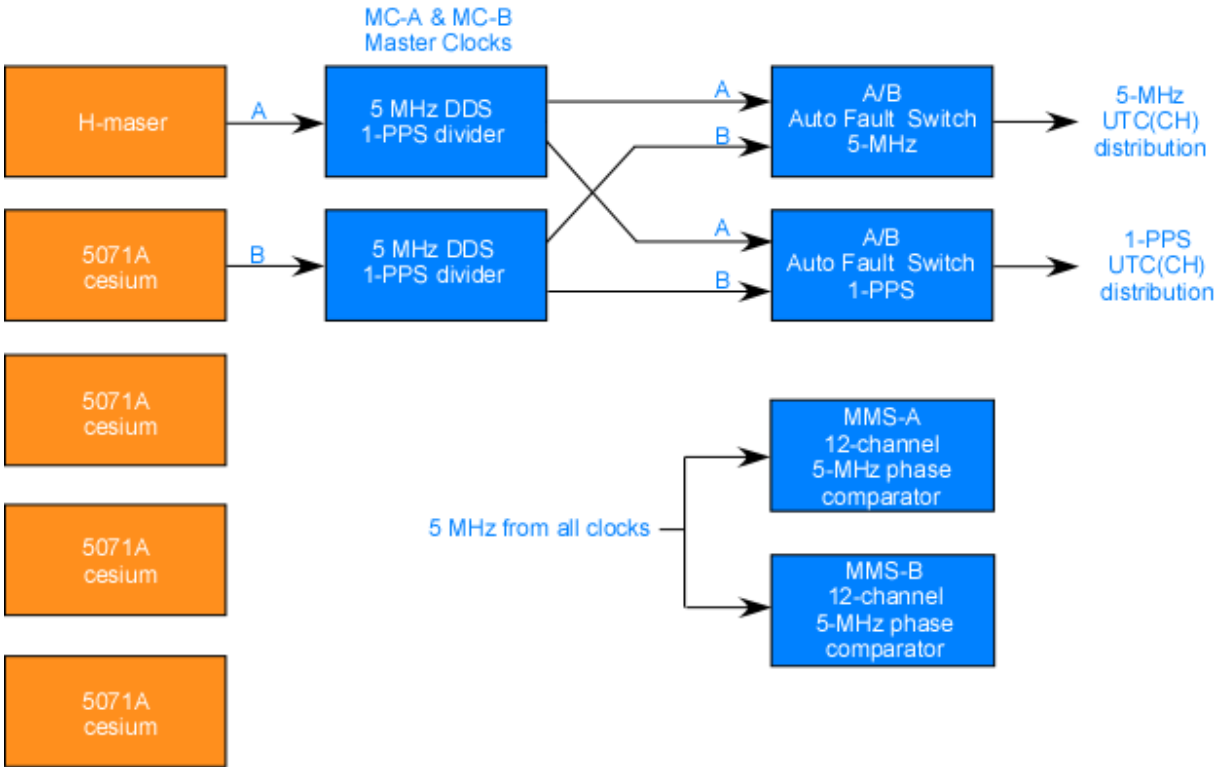


Fig. 2. Hardware architecture of the ART time scale generation system.

The ART (Autotime Real Time) time scale generation system was commissioned in 2011 and described in our 09.2012 report to CCTF. With the ART system, all local comparisons are consistent within 100 ps and the total uncertainty on the measurements traceable to UTC is 1 ns, limited by the accuracy of the TWSTFT TAI link. The type A uncertainty on the TAI link published in Circular T is 300 ps, which implies a contribution to the fractional frequency uncertainty of 2×10^{-16} over one month when a comparison FoCS-2 vs TAI is performed.

3 International comparisons

The official link for the TAI international comparisons is a TWSTFT station. The METAS TWSTFT link was last calibrated in November 2012 using the Timetech TWSTFT mobile station [9]. In the frame of the ongoing activities within the WG-TWSTFT, a digital modem was installed at METAS and is now operational.

METAS also operates two GPS receivers. Station CH00 (WAB1) has a Septentrio PolaRx3 receiver. Station CH01 (WAB2) has an Ashtech Z-XII-T receiver and is an official IGS station. The GPS receivers are used as backups for the TWSTFT TAI link.

4 Time dissemination

The Swiss time code transmitter HBG was decommissioned at the end of 2011. METAS operates several public NTP servers for low accuracy time dissemination. High-accuracy remote access to UTC(CH) is possible via GNSS PPP or GNSS Common-View techniques.

5 Conferences and publications

[1] A. Jallageas, L. Devenoges, M. Petersen, J. Morel, L.-G. Bernier, P. Thomann, T.Südmeyer. “First uncertainty evaluation of the FoCS-2 primary frequency standard”, under preparation for submission to Metrologia.

[2] L. Devenoges, G. Di Domenico, A. Stefanov, A. Jallageas, J. Morel, T. Südmeyer, P. Thomann, “Measurement of the magnetic field profile in the atomic fountain clock FoCS-2 using Zeeman spectroscopy”, Metrologia **54**, 239-246, (2017).

[3] L.-G. Bernier, D. Stalder, J. Morel, J. Kucera, S. Dahinden, “Traceable Calibration of a Phase Noise Standard”, Proc. of the 48th PTTI meeting, Monterey, Jan. 30-1, (2017).

[4] A. Jallageas, L. Devenoges, M. Petersen, J. Morel, L.-G. Bernier, P. Thomann, T. Südmeyer, “Status and prospect of the Swiss Continuous Cs fountain FoCS-2”, Journal of Physics : Conference Series 723 (2016).

[5] Z. Jiang, D. Piester, C. Schlunegger, E. Dierikx, V. Zahng, J. Galindo, D. Matsakis, „The 2015 TWSTFT calibration for UTC and related time links“, EFTF 2016, York, 4th-7th April.

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[7] A. Jallageas, L. Devenoges, M. Petersen, L.-G. Bernier, P. Thomann, T. Südmeyer, J. Morel, “Studies of electromagnetic frequency shift on FoCS-2”, EFTF 2015, Denver, 14-16 April.

[8] A.Jallageas, L. Devenoges, M. Petersen, J. Morel, L.-G. Bernier, P. Thomann, T. Südmeyer, “Status and prospect of the Swiss Continuous CS fountain FoCS-2”, FSM 2015, 8th Symposium on Frequency Standards and Metrology, Potsdam, 14-16 April, (2015).

[9] A. Jallageas, L. Devenoges, M. Petersen, L.-G. Bernier, P. Thomann, T. Südmeyer, J. Morel, “Evaluation of microwave leakage and magnetic field inhomogeneity in the continuous fountain atomic clock FoCS-2”, EFTF 2014, Neuchâtel, 23rd-26th June.

[10] Th. Feldmann, A. Balu, S. Liu, W. Schafer, J. Achkar, A, Kanj, A. Bauch, J. Becker, D. Piester, C. Schlunegger, J. Morel, “TWSTFT calibration involving four sites using a mobile station on a trailer”, Proc. Joint EFTF/IFCS, Prague, 21-25 July, (2013).

[11] L. Devenoges, G. Di Domenico, A. Jallageas, A. Stefanov, P. Thomann, L.-G.Bernier, J. Morel, “Design and realization of a low gradient microwave cavity for a continuous atomic fountain clock”, Proc. Joint EFTF/IFCS, Prague, 21-25 July, (2013).