TC Chair Annual Report 2016 - 2017

TC for Time and Frequency (TF)
TC Chair: Ramiz Hamid
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1. General Aspects

Currently 30 countries are represented in the EURAMET Technical Committee for Time and Frequency and the list of contact persons is published on the EURAMET web site. These institutes contributed for the generation of the UTC time scale using more than 130 commercial Cs and H masers. The different CNSS receivers used during time scale generation and the results related to national time scales and uncertainties are published on BIPM web site. Several institutes used primary frequency standards which are used also for time scale generation. Traceable time and frequency information is disseminated using different methods. A list of time dissemination services is available on the BIPM web site. The main aims of research and development projects and comparisons are the development of new standards for time scale generation and industrial applications, dissemination of time and frequency information with low uncertainty, and the comparison of reference equipment for improvement of type B uncertainty in time scale generation. Information about ongoing projects and EMRP projects is given below. Especially for last 1 year EURAMET TCTF community mostly concentrated to the GNSS comparisons as G1 and G2 laboratories, time interval comparisons at few ps level using travel standards and high frequency oscilloscopes. Two important new EMPIR projects related development Optical Clocks with 10-18 uncertainty and improvement of optical frequency comparisons up to 10-19 level are started.

2. Projects

List of current main EURAMET project on TCTF is given below:

Project 1288, Time interval comparison Pilot Study, (Coordinator: MIRS)
Project 1156, GPS link calibrations in support of CCTF-K001.UTC, (Coordinator: ROA)
Project 1152, GNSS receiver performance monitoring,(Coordinator: GUM)

The work for the following projects is ongoing:

Project 1288, coordinated by MIRS is second stage of the EURAMET project 828. In the proposed Pilot Study project 1288, different travelling standards for time interval comparison are studied and prepared and cable box as provided from BEV will be investigated again. Necessary measurements on these travelling standards will be performed by Pilot Study participants (AGH and NIT (Poland), SIQ (Slowenia) UME (Turkey), SASO (SA). The Inter-Laboratory Comparison (ILC) Protocol (and especially measurement parameters and methods) will be correctly defined so as to enable to launch a EURAMET TF.TI-K2 to serve as a EURAMET Supplementary comparison.

3 delay standards developed by SIQ and InLambda and standards are now complete. They have nominal delays of 20 ns, 100 ns and 300 ns, based on temperature-stabilized optical fibers. An input trigger pulse is needed, and the delay has been found to vary slightly with the pulse parameters and trigger level. The GUM electronic delay standard is also now complete. It can give more delay values, up to microseconds, and is not sensitive to the parameters of the 10 MHz input signal. During 2016 the InLambda delay standards have been characterized by both SIQ and GUM, and the GUM standard by SASO. All performed well, and are ready for use in the intercomparison. SIQ recommended closing the project, and is preparing a final report and draft protocol for the intercomparison. Finally the tested travel standard

generates 127 different Time Intervals between 1 pps outputs (from 20 ns to 12 μs). Result of investigation show that expanded uncertainty of the travelling standard is about 3 ps. In the comparison which completed in this year by pilot study participant used two type of measurement equipment: high frequency oscilloscope and time interval counter. Comparison results show that, measurements with oscilloscope agree within a few ps, but measurement with time interval counter is very surprising and agrees within more than 100 ps. New related project with a supplemental comparison (SC) is planned.

Project 1156, led by ROA (ES) on performing regional campaigns of GPS (in the future GNSS) receiver characterization, in reaction to Recommendation 2 of CCTF 2009. To the calibration of receivers ROA, PTB, INRIM, OP and NPL were involved. Project, which started in May 2010 and now has 17 participating partners.

Currently in EURAMET TCTF as G1 laboratories are PTB, OP and ROA. G1 and G2 laboratory comparison organized by PTB as G1 are include following G2 laboratories: VSL, METAS, DLR and BEV. G1 and G2 laboratory comparison organized by ROA as G1 are include following G2 laboratories: UME, BIM, BOM, IMBH and INRIM. A G2 calibration campaign has recently started, concentrating on labs in south-east Europe. ROA travelling equipment currently used in comparison by G2 laboratories. ROA prepared report on the G1 and G2 calibrations organized by ROA under Project 1156. G1 calibrations were carried out successfully during 2013-15. OP and PTB then carried out G1-G2 calibrations, and an ROA calibration campaign was started in February 2016. The ROA travelling receiver visited 6 other labs in southern Europe before returning to ROA after 6 months, and the results have been analyzed. ROA has finished its part of the report, but there are still a few problems to resolve before it is published. Lessons learned included the need for great care in handling the antenna cable, the benefits of studying the results in real time, and the need to keep the number of visited labs small.

The reference receiver PT02 and back-up receiver PT03 is Ashtech Z-12T, while the travelling receiver PTBT (and its back-up) is a GTR50. A G1-G2 campaign involving 4 other labs with 11 receivers in total was carried out in spring 2016, but the closure measurements at PTB showed a jump of around 2 ns in the P1 delay of the travelling receiver, limiting the calibration uncertainties. Andreas showed that the PT03-PT02 common-clock difference displayed an annual variation of around 1 ns, probably due to the temperature instability of the antenna cable. PTB is currently running a calibration for ESTEC only, which is complicated by the need to use an existing installed antenna cable for the antenna.

Project 1152, led by GUM (PL) on studies of GPS receiver performance in dependence on environmental parameters. Results from GPS receiver comparisons studied in the project (currently receivers in BEV, UFE, GUM, SP and PTB) have been presented. In the TCTF-2017 GUM gave an update on recent progress in this project, which started in 2010 and aims to monitor the differences between 2 or more GNSS receivers referenced to the same clock. At DMDM, the L1C difference between TTS-2 and GTR50 receivers showed a clear annual variation of around 10 ns, which was initially identified as due to the temperature sensitivity of the GTR50 antenna. However, comparisons with a PolaRx2 calibration receiver from ROA showed that the problem is actually the TTS-2, but unusually the delay reduces as temperature increases.

3. Comparisons

Last 1 year two main comparisons were done in EURAMET TCTF.

First of them is pilot study time interval comparison (75 ns, 1.1 μs, 4.7 μs, 10.6 μs) under Project 1288. Second of them is GNSS comparison under Project 1156, GPS link calibrations in support of CCTF-K001.UTC for improvement of type B uncertainty with targeting value 2-3 ns in time scale generation.

4. CMCs

During 2016 IMBiH published its first CMCs, which have been reviewed and accepted, and are now in the KCDB. Revised CMCs prepared by ROA are currently undergoing intra-RMO review.

5. Activities of the Subcommittees

TC-TF has no sub-committees.

6. Participation in EMRP/ EMPIR

List of EMRP projects in TC-TF is given below:

- Optical clocks with 1E-18 uncertainty
- Optical frequency transfer- a European network

Short information about EMRP projects are given below:

EMPIR OC18: Optical clocks with 1E-18 uncertainty

- JRP Coordinator: Rachel Godun, NPL

The project was approved within the EMPIR 'SI broader scope' call in 2015 and will run for 3 years from May 2016.

The project aims to push optical clock development so that uncertainties at the 1E-18 level can be achieved in a workable measurement time of around 10000 s. The 12 partners include all of the European NMIs working on optical clock technologies, plus 3 universities. The first two work packages deal with improvements to stability. WP1 addresses laser stability and the transfer of that stability to the atoms, with a highlight being the PTB demonstration of laser instabilities a factor of 2 better than the previous state-of-the-art when locked to novel Si cavities cooled to 124 K. Methods for probing trapped atoms with sub-Hz resolution are being developed in WP2, including a new single-ion trap designed by NPL that is intended to minimise heating of the ion and give reliable operation. WP3 aims to reduce systematic uncertainties, with a room temperature vacuum system for Yb being designed at INRIM while PTB is developing a cryogenic system for Sr. The remaining technical work package, WP4, combines the results of the others with enhanced clock operation methods to achieve the 1E-18 targets. Recent work has included theoretical studies at LUH in Hannover into optimal operating parameters. Peter concluded by highlighting the planned 2nd School on Optical Clocks, which is being organised by INRIM and will be held in Italy in September 2018.

Optical frequency transfer- a European network (OFTEN)

- JRP Coordinator: Harald Schnatz, PTB

The motivation is to develop optical fibre links and methods for frequency comparisons between optical clocks at the 1E-19 level, cesium fountain comparisons, and frequency dissemination to non-NMI users. WP1 covers optical clock comparisons between SYRTE, PTB and NPL. Three 1-week campaigns are planned, with the next scheduled for summer 2017 if the SNR on the NPL-SYRTE fiber link can be improved. WP3 aims to establish frequent, and eventually automated, comparisons between Cs fountains on demand. It also includes work on an optical link between PTB, GUM (Warsaw) and AOS (Poznan) for evaluation of the Polish fountains. Other recent work is investigating methods to improve the instability of 1PPS, 10 MHz and 100 MHz dissemination over fiber. Novel and improved optical frequency transfer techniques are being developed under WP2. Recent progress has included software development for remote control and data logging of links, and improvement and evaluation of a range of key devices. As a result the Paris - Strasbourg link is much more robust and able to operate continuously over days. WP4 addresses optical frequency dissemination to users, such as two VLBI telescopes in Italy. Three test-bed networks are available and are being used to compare different approaches. Overall, good progress has been made in the first 9 months.

7. Capacity Building: Activities of the last year and future needs

For improvement of joint work capability and calibration services TCTF will continue work and applications related capacity building.

8. Meetings

The 2017 TC-TF meeting was on the 8-9 March 2017 at Real Instituto y Observatorio de la Armada (ROA), San Fernando, Spain. At this meeting, we discussed EURAMET projects, EMRP projects, CMCs and other new projects. The next annual meeting of the EURAMET Technical Committee for Time and Frequency plan in IPQ, Portugal.

9. Issues

European financial regulation and time traceability:

The new European regulations on time traceability in the financial sector (MiFID II) issued by the European Securities and Markets Authority (ESMA), which will come into effect on 3 January 2018. Within MiFID II, Regulatory Technical Standard (RTS) 25 specifies the requirements for clock synchronization, including a divergence from UTC of no more than 100 µs in the case of automated timestamps. As a result, many banks and trading venues are adopting PTP for time distribution within networks, but often still using GPS as the reference time source. NMIs should try to engage with their national finance regulators soon, to advise on the technical aspects of implementing the regulations, and mentioned the workshop for NMIs that NPL hosted in January 2017.

10. Strategic Planning

EIRAMET coordination prepared very important document „Strategic Research Agenda for Metrology in Europe“. This document also includes Time and Frequency Metrology strategy for next 10 year. Draft of this part prepared by TCTF chair based available documents, roadmaps. In short main strategy and targets are given below:

- The development of accurate ground atomic clocks

Target accuracy: from 10^{-14} - 10^{-15} to 10^{-17} - 10^{-18}

- Space applications of atomic clocks and time-frequency metrology

Target accuracy of clocks on space: $1x10^{-16}$ - $1x10^{-17}$ for next 10 years.

- Time and frequency dissemination and comparison

In ground $<10^{-18}$ and <0.1ns; In Space $<10^{-16}$ and <0.1ns

- Accurate time scale generation and traceability (from 7ns to <2 ns)

This strategy is important for redefinition of the second and for application in gravity wave detection, fundamental constant, gas detection, space, navigation and communication.

11. Outlook for 2017/2018

- Complete GNSS G1 – G2 Laboratory Comparisons.
- Start new supplemental comparison (SC) related time interval measurements.

Ramiz Hamid
TCTF Chair