



1. General Aspects

This report summarizes the activities of the EURAMET Technical Committee for Time and Frequency (TC-TF) during 2021-2022.

TC-TF at present has contact persons from 30 EURAMET member countries, and one contact with observer status since May 2021.

A core aspect of the work of TC-TF is to support the generation of the international reference time scale, Coordinated Universal Time (UTC), by the BIPM under the single Key Comparison in Time & Frequency. Institutes participating in UTC generation provide both clock data and time transfer data regularly to the BIPM, and the TC-TF supports this activity by coordinating the calibration of GPS-based time transfer links. The BIPM Time Department therefore maintains close contacts with the TC and participates in its annual meetings.

2. Projects

There are currently 4 active projects within TC-TF:

Project 1152: *GNSS receiver performance monitoring*

The project started in 2010, and aims to investigate the long-term performance and stability of GNSS timing receivers. The methods for GNSS receiver performance monitoring consist of either common clock difference (CCD) or double clock difference (DCD) analysis. The technique adopted is to compare data from 2 or more receivers referenced to the same clock, and to investigate the environmental and other causes of changes observed in the differences between the receivers. The extended duration of the project enables it to obtain valuable information about the actual long-term behavior of GNSS receivers that contribute to the generation of UTC. In 2022, special cases observed by GUM and INRiM are presented in the TC-TF meeting.

Coordinating institute: GUM (Poland); 4 other participating partners; 1 further partner.

Project 1156: *GPS link calibrations in support of CCTF-K001.UTC*

The Key Comparison on the generation of UTC is dependent on accurate calibration of the time transfer links between participating institutes. The most widely used time transfer method is based on observations of GNSS satellite signals using dedicated timing receivers. To reduce its workload, the BIPM Time Department now only calibrates directly the GNSS timing receivers at a small number of institutes (the G1 laboratories) within each RMO. The G1 laboratories (LNE-SYRTE, PTB and ROA in the case of EURAMET) in turn carry out calibrations of the GNSS timing receivers at other institutes within the RMO, and the purpose of this project is to support the organization and coordination of regular calibration campaigns to ensure that all institutes are able to maintain the calibration status of their time transfer equipment. A much reduced number of calibrations were carried out in 2020 as a result of the pandemic, but the G1 institutes have upgraded their travelling GNSS receivers to enable calibration of Galileo signal delays in addition to GPS delays.

Coordinating institute: ROA (Spain); 16 other participating partners.

Project 1485: *Supplementary Comparison: Time Interval Measurements*

The purpose of this project is to support the first (and so far only) TC-TF Supplementary Comparison, discussed in more detail the next section. The project started in April 2019, following on from TC-TF

Project 1288 (Time interval comparison Pilot Study), which involved the development of portable delay standards and measurement protocols for use in time interval measurement intercomparisons. The devices developed under Project 1288 are being used in the Supplementary Comparison. Measurements started in December 2019 and the last measurement loop finished in November 2021. The draft A report is currently being written (as of March 2022) and will be circulated soon to the participants.

Coordinating institute: GUM (Poland); 21 other participating partners; 1 further partner.

Project 1519: *UTC(k) definition point and reference delay measurement strategies*

Time and frequency laboratories use a range of different approaches to defining a physical reference point for their local UTC(k) time scale. The choice made can facilitate some operations and make others more difficult, and can result in smaller or larger uncertainties. The aims of this project, which started in February 2021 and will continue until April 2023, are to collect and discuss the experiences of laboratories within this area, and to describe the various solutions and their advantages and disadvantages.

Coordinating institute: GUM (Poland); 29 other participating partners.

3. Comparisons

Within the Time and Frequency field there is only one Key Comparison, CCTF-K001.UTC, which is of indefinite duration and covers the computation of UTC by the BIPM. An essential aspect of this work is the regular submission of clock difference and time transfer data to the BIPM by approximately 70 contributing institutes worldwide. The majority of institutes represented in TC-TF participate in the KC.

The first EURAMET Supplementary Comparison (SC) in Time and Frequency started during 2019. It is registered with EURAMET as Project 1485 and by the KCDB as EURAMET.TF-S1. The SC aims to compare the time interval measurement capabilities of the participating institutes and is based on two types of travelling delay standards: optical fibre-based standards prepared by a Slovenian partner company, InLambda, in collaboration with SIQ (Slovenia), and an electronic delay standard developed by GUM.

The pilot laboratory for the SC is GUM (Poland), assisted by a support group of five other institutes. Because of the large number of participating institutes (24 in total), the comparison has been divided into three loops or “round robin” campaigns, with the travelling standards returning to the pilot laboratory in between each loop to be re-measured. The first loop started in December 2019 and was completed in early August 2020, after a delay of 12 weeks caused by restrictions to prevent the spread of Covid-19. The second loop finished in December 2020, and the third loop finished in November 2021. The draft A report is currently being written (as of March 2022) by the coordinator and will be circulated first to the support group, and after agreement from the support group, it will be circulated to the participants.

4. CMCs

TC-TF has an analysis working group of 6 contact persons that carries out both internal and external (inter-RMO or JCRB) reviews of CMCs.

Between June 2021 and March 2022, new or modified CMCs from IMBiH (Bosnia & Herzegovina), ILNAS (Luxembourg), RISE (Sweden) and BMM (Montenegro) were reviewed internally and then by the JCRB. Most have been published, a few from BMM have required revision and are now being

reviewed again. CMCs from GUM (Poland) and ROA (Spain) were also published, the latter being editorial changes that did not require JCRB review.

At the request of INRiM (Italy), 2 of their CMCs have been deleted from the BIPM KCDB. More recently, CMCs from BEV (Austria) have been submitted and are currently under review.

5. Activities of the Subcommittees

The TC-TF does not have any Sub-committees.

6. Participation in EMRP/ EMPIR

The TC-TF does not play as active a role in coordinating the submission of EMPIR PRTs as some of the other TCs as there are well-established links between institutes involved in the main areas of time and frequency research, and these institutes collaborate on PRT proposals in their areas of interest. These areas include fundamental research that could lead to the development of new types of clock or frequency standard (usually submitted to the Fundamental calls), research to improve the performance of optical clocks or high-accuracy clock comparison techniques (SI Broader Scope calls), or improved methods for time and frequency dissemination to users (Industry calls).

The TC maintains close contacts with the EMPIR projects that have significant time and frequency content, and progress reports are presented at the annual meetings of the TC-TF.

Active EMPIR projects in the time and frequency field, or that have a significant TF component, include the following:

JRPs approved following the 2017 calls:

17IND14	WRITE	White Rabbit industrial timing enhancement Coordinator: Davide Calonico (INRiM)
17FUN03	USOQS	Ultra-stable optical oscillators from quantum coherent and entangled systems Coordinator: Filippo Levi (INRiM)
17FUN07	CC4C	Coulomb crystals for clocks Coordinator: Ekkehard Peik (PTB)

JRPs approved following the 2018 calls:

18SIB05	ROCIT	Robust optical clocks for international timescales Coordinator: Helen Margolis (NPL)
18SIB06	TiFOON	Time and frequency over optical networks Coordinator: Jochen Kronjaeger (PTB)

JRPs approved following the 2020 calls:

20FUN01	TSCAC	Two-species composite atomic clocks Coordinator: Nils Huntemann (PTB)
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7. Capacity Building: Activities of the last year and future needs

Within the TF field, Researcher Mobility Grants (RMGs) have proved to be a useful mechanism for capacity building. Three researchers have been awarded RMG funding following the 2020 call: one will work at INRiM on the TiFOON project (18SIB06) starting in late 2021, while two researchers from ROA (Spain) will spend 6 months at NPL and 12 months at OBSPARIS respectively working on activities related to ROCIT (18SIB05).

The TC-TF has not run any training activities in recent years, in large part because the requirement for technical training in time and frequency in Europe is being met by other courses supported by the NMIs and DIs. These include events organized by EMPIR projects. For example, WRITE (17IND14) ran a 1-day online workshop on use of the White Rabbit protocol for time and frequency dissemination over fibre networks in September 2020, and TiFOON (18SIB06) held a 2-day online workshop on the current state-of-the-art in optical fibre TF transfer and applications of these high-performance methods during February 2021.

In addition, the week-long European Frequency and Time Seminar is held annually in Besançon (France), providing lectures and hands-on laboratory training delivered by TF experts from the EURAMET NMIs.

The BIPM organizes occasional workshops and training courses in the TF field, with support from the NMIs. A joint BIPM-APMP training course on time scales and algorithms was planned to take place in Thailand (open to worldwide participants), but it has been postponed due to the Covid-19 pandemic.

A meeting of the CCTF in March 2021 strongly supported a recommendation to increase the BIPM's CBKT activities in the TF area. The BIPM has responded with proposals to set up and maintain a website to share software tools and other resources of use to institutes contributing to UTC, to expand the training activities relevant to UTC, and to work with the RMOs to organize training workshops. The BIPM is setting up a programme of secondments from NMIs and DIs to help deliver these new initiatives. This extension of the BIPM's CBKT activities in TF should provide an excellent opportunity to increase the level of collaboration on CB between the BIPM and EURAMET.

8. Meetings

The TC-TF meets annually, usually in March. The 2022 meeting scheduled for March 24 and 25 was to be held face-to-face at LNE-SYRTE in Paris. Given the still worrying situation of the covid-19 pandemic, and in order to decide on the final organization of the annual EURAMET TC-TF meeting, a poll has been prepared and sent to contact persons to find out if they would be willing to travel to Paris if the possibility of meeting us in person is offered? According to the answers received (20 individual answers received), a majority was in favor of remote participation. Therefore the decision to switch to a completely remote meeting was retained using MS Teams.

The meeting was held over one full day and the morning of the second day. The online format enabled around 60 persons to attend all or part of the meeting, which is more than the usual attendance at a TC-TF annual meeting. In addition to the EURAMET TC contact persons and other representatives (EURAMET BoD and Secretariat), the participants included guests (EMPIR projects coordinators, EMN chairs, other projects), TC-TF Chairs from APMP and GULFMET, observers from SASO and INPL, representatives from the BIPM Time Department, a representative from the JCRB, the president of the CCTF and the chairman of ITU-R WP 7A.

The main topics covered during the meeting were:

- a) Report by the Chair on activities since the last meeting, including CMC changes and reviews;
- b) Report from the Board of Directors, and other EURAMET news;
- c) Update on EURAMET Capacity Building activities, and Communications;
- d) CCTF activity in preparation of the CGPM;
- e) News from the JCRB;
- f) Report of the Task Force on traceability to UTC from GNSS measurements;
- g) Report from ITU-R Working Party 7A;
- h) Updates from EMNs relevant to TF (Quantum Technologies, suggested EMN on Navigation and Synchronization);
- i) Reports on TF-related EMPIR projects: WRITE, USOQS, CC4C, ROCIT, TiFOON and TSCAC;
- j) Laboratory news and any other projects;
- k) Status reports on the active TC-TF projects, including a Supplementary comparison;
- l) Other activities (News from WG M4D, CE marking).

In the next two years, the annual meetings of the TC-TF are planned to take place in PTB, Braunschweig (2023) and LNE-SYRTE, Paris (2024).

9. Issues

Good contacts have been established with the EMNs that have a significant TF component, in particular those on Quantum Technologies (EMN-Q) and Smart Electricity Grids (EMN-SEG). The best way to maintain close links between the TC and EMNs seems to be to appoint a liaison person (not necessarily a TC contact person) who participates in the EMN and can report back to the TC. This procedure is working well in the case of EMN-SEG, although it can be a challenge to find suitable volunteers.

Other EMNs have a lower level of interest in time and frequency, for example those on Climate and Advanced Manufacturing. In these cases it will be more difficult to find a suitable liaison person, and a more ad-hoc approach might be needed.

There are significant sectors of the economy of interest to TF that are not at present well-represented by an EMN. These include telecommunications and Position, Navigation and Timing (PNT). Attempts to set up an EMN related to PNT have so far been unsuccessful. A proposal to focus on the geodesy sector as the primary user of high-performance PNT received mixed support. Now there is a new initiative: the focus is on autonomous transport themes including navigation, sensor performance, synchronization, artificial intelligence and machine learning. Some NMIs have already indicated their interest, others interested parties can join, the TC-TF will take a close interest.

10. Strategic Planning

The intended work to update the EURAMET roadmaps for TF in late 2020 did not in fact take place, in part because it seemed sensible to wait until the CCTF Working Group on Strategic Planning had completed the revision of its roadmap for the redefinition of the SI second. Revision of the TC-TF roadmaps is now more urgent, if only to bring them into line with the CCTF roadmap.

Experience has shown that developing a coordinated TF response to EMPIR calls continues to pose challenges, and TF PRTs are most often developed through direct discussions between interested

institutes. With the new EPM programme, a new strategy is proposed by EURAMET and the TC-TF has the opportunity to consider it. Ideas were suggested by the Chair during the 2022 meeting which would constitute a basis for future work for the TC in order to develop the TC-TF perspective on EPM calls.

A preparatory working group has been established by EURAMET to strengthen and improve communication from EURAMET TCs and EMNs. The focus will be on impact communications demonstrating the importance and benefits of metrology. Methods of communication will be webpages, sharepoints, newsletters, etc. The first steps will be to identify the key audience to target and to identify topics for internal & external TC communication. The TC-TF shall start to collect ideas for topics to be communicated.

11. Outlook for 2022/2023

Some proposed actions are summarized below:

1. Requirements for CE compliance of equipment: questionnaire submitted by Peter Whibberley for which feedback about how they are applied in laboratories is requested; the answers will be compiled and disseminated soon;
2. Updating the TC-TF Roadmaps from 2012 to a new version: there is a need for volunteers. Some persons have already indicated their interest to participate;
3. TC-TF perspective on EPM calls: there is a need to set up a working group for preparing for EPM calls;
4. Communications: there is a need for 2-3 volunteers for TC-TF representatives to the communications working group;
5. Development of DCCs: the Chair proposes to have a contact person from the TC-TF in WG M4D.

For the last 4 items, the chair will send out an e-mail to the TC-TF members.

After 3 years of virtual annual meetings, the TC-TF is looking forward to the resumption of face-to-face meetings. It is hoped this will be possible by early 2023.

Joseph Achkar
EURAMET TC-TF Chair

