



1. General Aspects

This report summarizes the activities of the EURAMET Technical Committee for Time and Frequency (TC-TF) during 2022 - 2023.

TC-TF at present has contact persons from 31 EURAMET member countries, and two contacts with observer status.

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. Recently, the coordinator is making a compilation of a compendium on anomalous results from GNSS receivers. Observations from UTC(PL) vs UTC(AOS) were presented in 2023 at the meeting. TC-TF participants are invited to share their experiences with the coordinator, so that they can be included in the compendium.

Coordinating institute: GUM (Poland); 10 participating partners.

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. In 2023, the G1/G2 calibration campaigns organized, or in progress, by PTB, ROA and LNE-SYRTE, over the period 2022 - 2023 were presented; in general, good results are achieved. The chair invited the

laboratories with uncalibrated receivers or with receivers that have been calibrated a long time ago to contact the G1 laboratories contact persons.

Coordinating institute: ROA (Spain); 16 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. A support group made up of 5 contact persons, was created to help the pilot laboratory in the organization of the comparison, the decision making, the preparation of the technical protocol, the analysis of the data and the preparation of the report. The writing of the Draft A report is still in progress (as of March 2023). It is expected to be distributed to the support group within about a month of the meeting.

Coordinating institute: GUM (Poland); 22 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 are to collect and discuss the experiences of laboratories within this area, and to describe the various solutions and their advantages and disadvantages. The project started in February 2021. Its completion was originally foreseen for April 2023, but this will be delayed. The next step in the project will be an investigation of the UTC(k) steering strategies. The TC-TF community will be asked to provide input with respect to their UTC(k) steering strategies. From this input, a working document will be prepared. Then, the TC-TF community will be asked to check the information and correct if necessary for the final report.

Coordinating institute: GUM (Poland); 29 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 66 contributing institutes worldwide. As of March 2023, 30 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 (30 in total so far), 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 writing of the Draft A report is still in progress (as of March 2023) 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 8 contact persons, including one new member, that carries out both internal and external (inter-RMO or JCRB) reviews of CMCs.

Changes since March 2022: the new or modified CMCs of BMM (Montenegro) and BEV (Austria) were reviewed internally and then by the JCRB. Most have been published, a few of BMM have required revision. Some CMCs of RISE (Sweden) were submitted to the KCDB for publication, being editorial changes that did not require JCRB review, and a few others with small technical changes related to last internal review were accepted by the chair, submitted to the JCRB for review. A few modified CMCs from ROA (Spain) have been submitted and reviewers have been contacted.

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/EPM 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), improved methods for time and frequency dissemination to users (Industry calls), or even high level time-base synchronisation needs in complex systems (Normative calls).

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

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

JRPs approved following the 2018 EMPIR 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 EMPIR calls:

20FUN01	TSCAC	Two-species composite atomic clocks Coordinator: Nils Huntemann (PTB)
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JRPs approved following the 2021 EPM calls:

21NRM02	Digital-IT	Metrology for digital substation instrumentation Coordinator: Jari Hällström (MIKES)
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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 worked at INRiM on the TiFOON project (18SIB06), while two researchers from ROA (Spain) spent 6 months at NPL and 12 months at LNE-SYRTE 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, TiFOON (18SIB06) held a 2-day stakeholder workshop in February 2021 on high-performance time and frequency transfer over optical networks. A discussion session at the end of each day collected feedback and ideas from the participants, addressing 4 questions: What applications are likely to benefit from high-performance T&F dissemination over fibre links, and when will they need it? What dissemination methods and network types would be most suitable to meet the needs of these applications? What steps are needed to enable high-performance fibre T&F dissemination methods to be set up and operated? What should the TiFOON project do to support this process? The ideas collected during those discussions have been summarised in a document ([TiFOON-workshop-summary.pdf](#)). Furthermore within the framework of the TiFOON project, a proposed draft EURAMET Technical Guide on combining T&F signals with data in DWDM networks was developed and presented at the TC-TF 2023 meeting for approval. Another example, ROCIT (18SIB05) held a final 2-day online workshop in October 2022, focusing on the findings and results of the project, which has been working towards many of the milestones in the international roadmap towards a redefinition of the SI second. Topics covered included improvements to the robustness and reliability of optical clocks, validation of optical clocks through international comparisons, and the use of optical clocks in International Atomic Time (TAI) and UTC(k) time scales.

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.

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 annual meeting of the TC-TF was held for the first time, since the covid-19 pandemic, in person at PTB in Braunschweig on 22 and 23 March 2023, with remote participation.

The meeting took place over a day and a half, followed by a visit to the TF laboratories of PTB, on the second day in the afternoon. About sixty people participated, half of them in person. In addition to EURAMET TC-TF contact persons and other representatives (EURAMET chairperson, EURAMET BoD and Secretariat), participants included guests (coordinators of EMPIR and EPM projects, EMN chairs, speakers on other projects), RMO TC-TF chairs from APMP, SIM and GULFMET, observers from SASO and INPL, representatives of the BIPM Time Department, a representative of the JCRB, and the chairman of the ITU-R WP 7A.



TC-TF meeting in March 2023 at PTB, Braunschweig

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) EPM update and calls 2023, update on Capacity Building activities;
- d) News from the JCRB;
- e) BIPM update in the treatment of not calibrated GNSS in UTC and CCTF Task Group final report on traceability to UTC from GNSS measurement;
- f) Report from ITU-R Working Party 7A;
- g) Reports on the active TC-TF projects, including that in support to the BIPM Key Comparison and that related the EURAMET Supplementary Comparison;
- h) Updates from EMNs relevant to TF (EMN for Quantum Technologies, present status of EMN for automated transport, EMN for Smart Electricity Grids);
- i) Reports on TF-related EMPIR and EPM projects: ROCIT, TiFOON, TSCAC and Digital-IT;
- j) Draft new project on comparison of phase noise measurement
- k) Laboratory news and any other projects (Jamming and spoofing of GNSS timing devices, Refimeve – recent progress, performance of real-time PPP time transfer);

l) Other activities (Digitalization, TWSTFT calibration campaign, direct comparison between absolute and relative calibration of GNSS stations, Follow-up on CE marking requirements, CMCs for NTP and PTP calibration, frequency measurements at 80 GHz).

The next annual meeting of the TC-TF will take place at LNE-SYRTE in Paris in 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 for automated transport (EMN-AutoTrap). Currently, an investigation is done for potential European stakeholders for such an EMN. Some NMIs have already indicated their interest, others interested to join this initiative can contact RISE. The TC-TF is in close contact on the topic.

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 on the agenda, 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 had the opportunity to consider it. This item has been discussed in recent TC-TF meetings and a proposal to link this with the revision of the roadmaps has been reported.

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 2023/2024

Some proposed actions are summarized below:

1. Development of DCCs: Carlos Pires (IPQ) was appointed as TC-TF representative in the TC-IM project 1448; comments or needs from the TC-TF can be sent to Carlos Pires;
2. Proposed EURAMET Technical Guide on TiFOON project - Combining T&F signals with data in DWDM networks. The meeting agreed to the proposal by Peter Whibberley (NPL) to circulate the draft document to all TC-TF members; comments should be sent to Peter and the TC-TF chair within a month;
3. Draft new project on comparison of phase noise measurement: the meeting approved the proposal for this new project and interested laboratories have expressed their views. Enrico Rubiola (LNE-LTFB, coordinator) will prepare the draft project and send it to the chair for distribution in early May 2023 to all TC-TF members for comment. The project will then be sent to the EURAMET Secretariat for registration as a new project. The project will also be submitted to the chair of the TC-EM for opinion;
4. TC-TF Roadmaps update and TC-TF perspective on EPM calls: the meeting agreed to have a working group and some laboratories expressed their interest to participate. This will be discussed among the chair and working group members.
5. Communications: there is a need for 2-3 volunteers for TC-TF representatives to the communications working group;
6. Research project No. 1146: the meeting agreed that the final report would be written and the project would be closed.

After 3 years of virtual annual meetings, the TC-TF was delighted with the resumption of face-to-face meetings, even if the meeting mode adopted in 2023 was the hybrid mode.

Joseph Achkar
EURAMET TC-TF Chair

