



## 1. General Aspects

This report summarises the activities of the EURAMET Technical Committee for Time and Frequency (TC-TF) during 2020-2021.

TC-TF at present has contact persons from 31 EURAMET member countries, including a representative from Hungary since December 2020. The Israeli National Physical Laboratory (INPL), which is a EURAMET Liaison Organisation, appointed a permanent observer to the TC-TF in 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 method 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 behaviour of GNSS receivers that contribute to the generation of UTC.

Coordinating institute: GUM (Poland); 4 other 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 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 organisation 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); 15 other participating partners.

### **Project 1485:** *Supplementary Comparison on 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 are expected to be completed during August 2021.

Coordinating institute: GUM (Poland); 22 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 & 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, and NSAI NML in Ireland started to do so for the first time in October 2020.

The first EURAMET Supplementary Comparison (SC) in Time & 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 2 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 5 other institutes. Because of the large number of participating institutes (24 in total), the comparison has been divided into 3 loops or “round robin” campaigns, with the travelling standards returning to the pilot lab 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 a third loop that will include the remaining participants is now in progress, with the standards expected to return to the pilot laboratory during August 2021.

### 4. CMCs

TC-TF has a working group of 7 contact persons that carries out both internal and external (inter-RMO or JCRB) reviews of CMCs.

Between September 2020 and May 2021, new or modified CMCs have been submitted for review by IMBiH (Bosnia & Herzegovina), ROA (Spain), ILNAS (Luxembourg), MBM (Montenegro) and GUM (Poland). A few of these were



modified CMCs to correct editorial errors that arose from the migration to KCDB 2.0, and were accepted without the need for JCRB review. The remainder are new or significantly modified CMCs that are currently in either internal RMO review or JCRB review.

No CMCs from other RMOs have been reviewed by TC-TF during the period.

## 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 & frequency field, or that have a significant TF component, include the following:

JRPs approved following the 2017 calls:

|                |               |  |
|----------------|---------------|--|
| <b>17FUN03</b> | USOQS         | <i>Ultra-stable optical oscillators from quantum coherent and entangled systems</i><br>Coordinator: Filippo Levi (INRIM) |
| <b>17FUN07</b> | CC4C          | <i>Coulomb crystals for clocks</i><br>Coordinator: Ekkehard Peik (PTB)   |
| <b>17IND14</b> | WRITE         | <i>White Rabbit industrial timing enhancement</i><br>Coordinator: Davide Calonico (INRIM)                                |
| <b>17IND06</b> | FutureGrid II | <i>Metrology for next-generation digital substation instrumentation</i><br>Coordinator: Enrico Mohns (PTB)               |

JRPs approved following the 2018 calls:

|                |        |  |
|----------------|--------|--|
| <b>18SIB05</b> | ROCIT  | <i>Robust optical clocks for international timescales</i><br>Coordinator: Helen Margolis (NPL) |
| <b>18SIB06</b> | TiFOON | <i>Time and frequency over optical networks</i>  |

Coordinator: Jochen Kronjaeger (NPL)

JRPs approved following the 2020 calls:

**20FUN01**      TSCAC      *Two-species composite atomic clocks*  
Coordinator: Nils Huntemann (PTB)

## 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 organised 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 organises occasional workshops and training courses in the TF field, with support from the NMIs. For instance, a joint BIPM-APMP training course on time scales and algorithms was planned to take place in Thailand on 1-3 July (open to worldwide participants), but it has been postponed due to the Covid-19 pandemic and may instead be held online.

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 BIP'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 2020 meeting was postponed due to the pandemic, then held online over 2 days in early July using MS Teams. Although this format worked well, it was hoped that the 2021 meeting could take place at PTB in February. By November 2020 it was clear that a physical meeting would not be possible in early 2021 and the annual TC-TF

meeting was again held online. The dates of the meeting were pushed back to 24-25 March to allow the outcomes of a CCTF meeting earlier that month to be presented and discussed.

The meeting was held over one full day and the morning of the second day. The online format enabled around 50 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, the participants included the TC-TF Chairs from APMP and AFRIMETS, 2 observers from SASO, Saudi Arabia (GULFMET), 2 observers from NIS, Egypt (AFRIMETS) and 3 representatives from the BIPM Time Department.

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;
- d) News from the BIPM Time Department on recent activities;
- e) News from the JCRB;
- f) Report from ITU-R Working Party 7A;
- g) Updates from EMNs relevant to TF (Advanced Manufacturing, Quantum Technologies, PNT and Geodesy, Smart Electricity Grids);
- h) Reports on TF-related EMPIR projects: CC4C, WRITE and TiFOON;
- i) Summary of the hot topics and Task Force reports presented to CCTF (including the redefinition of the SI second, leap seconds in UTC, traceability to UTC from GNSS signals, and resource sharing), followed by discussions;
- j) Proposals on GNSS absolute calibrations and extension of calibrations to Galileo receivers;
- k) Status reports on the active TC-TF projects, including the new project to collect and share experience of UTC(k) realisation;
- l) Status report on the active Supplementary Comparison on time interval measurement;
- m) Laboratory reports on other TF-related activities.

The next annual TC-TF meeting is expected to take place in February or March 2022, and will be held at a laboratory (to be decided) if travel restrictions for a large majority of the contact persons have been lifted by then. If a physical meeting is still not possible, it will again be held online.

## 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. The current intention is to focus instead on PNT applications in mobility and transport, in particular to autonomous vehicles, and if this EMN goes ahead TC-TF will maintain a close interest in it.

## 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.

There continue to be challenges in developing a coordinated TF response to EMPIR calls, and PRTs in the TF area are most often developed through direct discussions between interested institutes. The widespread acceptance of online meetings during 2020 may provide a mechanism to hold more focused meetings of the TC-TF at other times of the year on topics such as the formulation of PRTs.

BIPM proposals to extend its CBKT activities in the TF field offer the opportunity to strengthen links with the TC-TF, and to develop more joint BIPM/ EURAMET workshops and training courses.

## 11. Outlook for 2021/2022

The current TC-TF Chair, Peter Whibberley (NPL, UK) is coming to the end of his second 2-year term. Joseph Achkar (LNE-SYRTE, France) has been elected to become the next Chair and will take up the position at the General Assembly in June 2021.

The Supplementary Comparison on time interval measurement capabilities is continuing, despite some delays caused by the measures taken across Europe to restrict the spread of Covid-19, and the third and final measurement loop is expected to finish in August 2021.

After 2 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 2022.

Peter Whibberley  
EURAMET TC-TF Chair