



1. General Aspects

This report summarises the activities of the EURAMET Technical Committee for Time and Frequency (TC-TF) during 2019-2020.

TC-TF at present has contact persons from 29 EURAMET member countries.

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 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 3 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. During 2019, the 3 G1 labs within EURAMET all carried out campaigns that supported around 11 G2 institutes.

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 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.

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



3. Comparisons

Within the Time & Frequency field there is 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 & Frequency started during 2019, and is registered with EURAMET as Project 1485. New optical fibre-based travelling standards prepared by a Slovenian partner company, InLambda, in collaboration with SIQ (Slovenia), were thoroughly characterised at GUM (Poland) during 2017-2018 along with an electronic travelling delay standard developed by GUM. Both types of travelling standard are being used in the SC.

The technical protocol for the SC was prepared during 2019 and a support group of 5 other participating institutes was set up to assist the pilot laboratory. Because of the large number of participating institutes (23 including the pilot lab), 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 the restrictions to prevent the spread of Covid-19. The second loop began 2 weeks later.

4. CMCs

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

There has been little change to the EURAMET TF CMCs during 2019-2020. Revised CMCs from Bosnia and Herzegovina, France and Spain completed inter-RMO review and have all now been published in the KCDB. Publication of the CMCs from Spain was delayed by around 5 months due to the transition to the KCDB 2.0.

No TF CMCs from other RMOs has 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. However, the TC maintains close contacts with active EMPIR projects in the field and reports on many of them are presented at the annual meeting of the TC-TF. The active EMPIR projects closely related to Time & Frequency include the following:

JRPs approved following the 2015 calls, which completed during 2019:

15SIB03	OC18	<i>Optical clocks with 1E-18 uncertainty</i> Coordinator: Rachel Godun (NPL)
15SIB05	OFTEN	<i>Optical frequency transfer – a European network</i> Coordinator: Harald Schnatz (PTB)
15SIP04	TIMEFUNC	<i>Time synchronisation impact enabling future network communication</i> Coordinator: Erik Dierikx (VSL)

JRPs approved following the 2017 calls:

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

JRPs approved following the 2018 calls:

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

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. Two TF-related EMPIR projects advertised for RMG applicants in the 2020 call: 2 related to 18SIB05 ROCIT and one to 18SIB06 TiFOON.

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. For example:

- The BIPM organises occasional workshops and training courses in the TF field. These have included a workshop on advanced time and frequency transfer held at the BIPM on 10 October 2019, and a joint BIPM-APMP training course on time scales and algorithms that was planned to take place in Thailand on 1-3 July (open to worldwide participants) but has been postponed due to the Covid-19 pandemic.
- The week-long European Frequency and Time Seminar is held annually in Besançon (France), providing lectures and hands-on laboratory training.
- The EMPIR projects WRITE and TiFOON organised a joint 2-day workshop on optical fibre TF dissemination methods and applications that was to be held in Paris in March 2020. This

event was cancelled due to the spread of Covid-19, but WRITE will instead hold its training day online on 30 September 2020 and TiFOON is planning to run a similar event in early 2021.

- The successful one-week school on optical clocks in September 2018 organised through the OC18 EMPIR project is expected to be followed by similar optical clock schools in future years.

8. Meetings

The TC-TF meets annually, usually in March. The 2020 meeting was planned to be held at PTB over 10-11 March, with plenary sessions during the first day and morning of the second day, followed by laboratory tours. However, the rapid spread of Covid-19 across Europe during the weeks before the meeting led to a decision to postpone it.

A virtual or online TC meeting was instead held in early July, using MS Teams. A full day of presentations and discussions took place on 1 July, followed by a morning session on 8 July. The interval between the two dates allowed more contact persons to attend at least one session, and was also intended to give more time to update presentations based on the discussions in the first session.

The format appeared to work well. Around 35 persons attended part or all of the meeting, which is more than the usual attendance at a TC-TF annual meeting. In addition to the contact persons, the participants included a GULFMET observer from SASO (Saudi Arabia) and a representative from the BIPM Time Department.

The main topics covered during the meeting were:

- a) Report by the Chair on activities over the last year;
- b) Report on EURAMET Capacity Building ;
- c) Report from the Board of Directors, and other EURAMET news;
- d) News from the BIPM Time Department on recent activities;
- e) Laboratory status reports from several contact persons;
- f) Proposals to update the TF section of the EURAMET roadmap;
- g) Status updates from EMNs with relevance to TF, in particular EMN-SEG;
- h) Status reports on active TC-TF projects, and discussion of proposed new project;
- i) Status report on the active Supplementary Comparison;
- j) Updates on TF-related EMPIR projects;
- k) CMC changes and reviews, and introduction to KCDB 2.0;
- l) Update on EC proposals to promote the use of Galileo as a source of legal time;

The next annual TC-TF meeting is planned to take place at PTB Braunschweig over 24-25 February 2021 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 be held online on those days.

9. Issues

There remains some concern within the Time and Frequency community about the extent to which the existing or proposed EMNs cover industrial, commercial and scientific requirements for time and frequency (TF). TF is an underpinning technology that supports many sectors of the economy, but

only a few of these are represented by EMNs. Work to establish an EMN in the field of geodesy, surveying and positioning, provisionally called EMN-PNTG (Positioning, Navigation, Timing and Geodesy), has so far been unsuccessful, in part due to differences of opinion between the institutes involved.

Two of the established EMNs are of particular interest to the TC: EMN-Q (Quantum Technologies) and EMN-SEG (Smart Electricity Grids). It is proving to be a challenge to integrate TF expertise into these EMNs, although the presence of a dedicated contact person who is able to interact with both the EMN and the TC seems to be the most effective approach. There is potentially also some overlap with EMN-Climate, and a dialogue will be maintained with the relevant EMN contact person.

10. Strategic Planning

Work has begun to update the EURAMET road maps for TF, which have not been revised since 2012. A task group has been set up within the TC consisting of 4 contact persons, with the aim of completing the revised roadmaps in time to present them to the next annual meeting of the TC-TF in February 2021. The revision will take into account other related strategic planning activities in TF, such as the roadmap towards a new definition of the SI second developed by the CCTF Working Group on Strategic Planning.

Preparation of TF-related PRTs in response to EMPIR calls continues to be carried out largely through direct discussions between interested institutes, and there continues to be little interest in extending coordination through the TC-TF. The outcomes are generally successful, although the only SRT with a primary TF focus in 2019, SRT-w02 on support for an EMN on positioning, navigation, timing and geodesy, was not funded.

Three SRTs in the 2020 Fundamental call have a strong TF involvement (SRT-f02: Two-species composite atomic clocks; SRT-f12: Fundamental physical metrology with cold molecules; and SRT-f15: Non-classical approaches for quantum-enhanced metrology), highlighting the importance of TF optical clock research in fundamental physics.

11. Outlook for 2020/2021

The TC-TF Chair will change at the General Assembly in May 2021. A suitable candidate has offered to take up the position.

The Supplemental 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.

The next annual meeting of the TC-TF is scheduled for 24-25 February 2021. It will be held at PTB if a large majority of the contact persons are able to travel by then, otherwise will be held online.

Peter Whibberley
EURAMET TC-TF Chair