TC-TF Annual Report 2012/2013 to the 2013 GA

13. May 2013

1. General Aspects

30 institutes have currently nominated Contact Persons in the EURAMET Technical Committee Time and Frequency. In 2012 and 2013 new delegates were nominated by Belgium, FYR Macedonia, Montenegro, and Spain.

On a wider international scale, scientific work in the TF field is very effectively coordinated by the BIPM Time Department. Out of the EURAMET member states, currently 32 institutes (NMIs, DIs, and other research institutes, including the European Space Agency / European Space Technology Centre) contribute directly to the realization of International Atomic Time TAI and Coordinated Universal Time UTC. They contribute clock data from in total 130 commercial caesium clocks and active hydrogen masers. They operate GPS time receivers for time comparisons, and some use in addition GLONASS receivers and equipment for two-way satellite time and frequency transfer through geostationary telecommunication satellites. During 2012 and 2013, NPL, LNE-SYRTE and PTB contributed with their primary frequency standards to the definition of the scale unit of TAI. Based on these inputs (complemented by NIST (USA) contributions) the scale unit of TAI agrees today with the defined duration of the second of the SI to better than one part in 10^{15}.

The European Satellite Navigation System Galileo has passed major steps towards its completion, with particular achievements regarding time and frequency services. They were proudly announced by European Space Agency (ESA)
(http://www.esa.int/Our_Activities/Navigation/Galileo_starts_to_tell_UTC_the_world_s_time),
and the European Commission
(http://ec.europa.eu/enterprise/newsroom/cf/itemdetail.cfm?item_id=6580&lang=de) “Punctuality is king's politeness : Galileo UTC time dissemination successfully tested”.

The progress is built upon the collaboration of five European timing institutions, all EURAMET members, and has been described by ESA as follows: “The offset between GST and UTC is currently estimated in Turin, Italy, by the Istituto Nazionale di Ricerca Metrologica (INRIM), where time measurements are performed every day with the most precise techniques available to check GST status. More recently INRIM has overseen the creation of a ‘Time Validation Facility’ for Galileo in collaboration with five other European time-measurement institutions: the Physikalisch-Technische Bundesanstalt in Germany, the National Physical Laboratory in the UK, the Systeme de References Temps Espace/Observatoire de Paris in France, the Real Instituto y Observatorio de la Armada in Spain and Observatoire Royale de Belgique. Each day, the most precise European clocks and national time scales are compared to Galileo System Time GST, and the offset compared to UTC is estimated and provided to the Galileo Control Centre. This offset is then uploaded to the Galileo satellites for transmission in the navigation message available to users.”

Ensuring the early interoperability of Europe’s satellite navigation with GPS, the four Galileo satellites have begun broadcasting the ‘offset’ between the parallel navigation systems’ timings, accurate to a few billionths of a second. With satellite navigation based around the highly accurate measurement of signal travel times, both Galileo and GPS have their own internal reference time systems used to synchronise all system clocks and signals. These time systems are not quite identical, with Galileo System Time being around 50 ns or less apart from GPS time.

Disseminating the offset will help enable the user receiver market to start making use of Galileo at this early stage, with only four Galileo satellites yet in orbit. Formally known as the GPS to Galileo time offset, GGTO, the accuracy of the offset is being benchmarked at five nanoseconds or less. Determination of GGTO is based on Galileo and GPS signal reception in the contributing timing institutes.

2. Projects

The work for the following projects is ongoing:

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1130, led by NPL (UK) on GPS disciplined oscillators. The objective is to produce a EURAMET Calibration Guide on the use of GPS disciplined oscillators in calibration laboratories. This work bases on an activity inherited from EA some years ago. Unfortunately, at a very late stage of the production of the “final” version in late 2012 TC-TF faced opposition against the content and spirit of the document so that the issue had to be brought again to the agenda in 2013. Most of the open issues, however, could be resolved in the meantime, so a final version can be expected during the first half of 2013 to become subject of formal approval.

1118, led by MIRS/SIQ, on involvement of the TCTF in EMRP calls.

The aim of the project is to coordinate consultations among TC-TF members in order to identify potential subjects and opportunities on replies to EMRP calls. Coordination included in the past consultation on proposed ideas for project topics, as well as identification of capacities and expressed roles in identified project cooperation. Applications out of the time and frequency community have been approved in the Calls Industry, SI Broader Scope and Excellence. In the remaining 2013 calls there is little chance for an active participation of researchers from the time and frequency field.
A survey of the active JRPs with T+F participation is given below.

1146, led by IPE (CZ) on time transfer using optical fibers;
This project was initially launched as a bilateral project. The work done in this Project is one part of the activities continued now in the frame of NEAT-FT.

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, PTB) have been presented, showing a range of anomalous behaviour – time jumps, drifts, etc. They are visible often as temporal disturbance during a day in the 16-min individual data. A clear strategy how to exclude such disturbances or a clear preference for a certain brand of receiver that might prove particularly immune could not yet be reached.

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. This subject is dealt with in the following section.

3. Comparisons

No EURAMET comparisons are currently in progress and none are foreseen which would easily fit to the scheme of EURAMET key or supplementary comparisons.

For many years the BIPM Time Department had organised international calibration campaigns for the GPS and more recently GLONASS receivers used by many laboratories for the inter-comparisons of their atomic clocks, which allow them to participate in the only time and frequency key comparison, CCTF-K001.UTC. Recommendation 2 of CCTF 2009 requests that RMOs and thus time and frequency laboratories take over part of the responsibility for these calibrations. In response to this, a new “GPS-calibration” (1156) project was started. In the frame of this project a scheme for documentation of the GNSS receiver inventory and the history of calibrations and the results obtained has been proposed and discussed at the 2010 TCTF meeting. There were concerns that such documentation would represent extra unnecessary bureaucratic work. This position was supported by BIPM whose representative announced a similar activity, but now on an international scale.

Unfortunately, there was standstill for many years. Today (May 2013) TC-TF is still waiting for instructions how calibrations should be performed and how reports should be delivered. In consequence only few links within Europe were calibrated (ROA-INRIM-NPL-OP-PTB, ESTEC-PTB, VSL-PTB) during 2012, and none of the results has been recognized by BIPM. More work and communications among the parties involved are needed to get an agreed procedure for reporting the data so that they might be used by BIPM.

4. CMCs

The organisation and analysis of comparisons and the review of Calibration and Measurement Capabilities (CMC) tables has played an important role in the work of the TC-TF during the last year. Anton Niessner (BEV, AU), Peter Whibberley (NPL, UK), and myself shared the work of reviewing the CMC tables coming from APMP (NIM and KRISS), and COOMET (Ukraine). Our analysis group noted certain discrepancies in interpretation of the entries, service categories etc., among the RMOs. In general, the process of the inter-RMO review of CMCs was noted as smooth and cooperative. The support of the jcrb Secretariat at BIPM is greatly appreciated.

SMD, the NMI of Belgium, requested that its CMC entries were greyed out in the KCDB because the succession from the previous responsible in the field to his successor was considered to provide insufficient evidence on the mastering of the technical problems involved in offering the various services.

5. Activities of the Sub-Committees

TC-TF has no sub-committees.

6. Participation in EMRP

<u>2010 call:</u>
IND14, Frequency - New generation of frequency standards for industry, Coordinator Patrick Gill (NPL)

Currently available commercial atomic clocks meet in part very stringent performance requirements. Applications span defense, security, aerospace, transportation, and the communications sector. The project aims at developing devices that are smaller and capable of operating in harsh environments, to be used in industrial environments. This project should improve the robustness and portability of atomic clocks and aims, inter alia, to qualify such clocks for use in satellites in space.

<u>2011 call:</u>
SIB02, NEAT-FT - Accurate time/frequency comparison and dissemination through optical telecommunication networks, Coordinator Harald Schnatz (PTB)

The aim of the project NEAT FT is to investigate new techniques for phase coherent comparison of remotely located optical clocks, separated by distances of up to 1500 km using optical fibre links. Within the scope of the JRP the equipment necessary for reliable operation of fibre links shall be developed and technological steps towards a full optical link infrastructure shall be demonstrated. Furthermore, the feasibility of a European fibre network connecting optical clocks in Europe shall be studied in close collaboration with potential fibre providers.

SIB04, Ion Clock - High-accuracy optical clocks with trapped ions, Coordinator Ekkehard Peik (PTB)

This JRP addresses the development of ultra - precise optical clocks using laser - cooled trapped ions. The combination of laser cooling and ion trapping provides an ideal spectroscopic system that permits the observation of unperturbed atomic frequencies, thus laying the foundation for atomic clocks of the highest accuracy. The realization of the unit of time plays a central role within the SI because of its unequalled precision and because it is also used in the realizations of other units, such as the metre, volt and ampere.

<u>2012 call:</u>
IND55, MCLOCKS - Compact microwave clocks for industrial applications, Coordinator Salvatore Micalizio (INRIM)

Atomic frequency standards provide the ultimate source of accuracy and stability for all modern communication, navigation and timekeeping systems. Commercially available devices are nowadays deployed in many strategic industrial fields. Vapour - cell clocks are particularly suited to fulfill industrial requirements. In fact, besides working in the microwave regime, vapour - cell clocks are compact, portable, reliable and operate with low power consumption and exhibit reasonably good frequency stability performances. All these properties have been demonstrated with commercial Rb clocks which have been deployed in ten thousands of copies. The JRP aims at developing similar clocks that have lower frequency instability and at preparing their industrialization. This would help to meet modern industrial demand and making the standards more suitable for modern technical applications.

SIB55, ITOC - International timescales with optical clocks, Coordinator Helen Margolis (NPL)

The possibility of a future redefinition of the second in terms of an optical transition frequency is being considered by the international metrology community. Nearly all information about the reproducibility of optical clocks comes, however, from independent absolute frequency measurements made in different laboratories, and is therefore limited by the uncertainty of the caesium primary standards. The work carried out within this JRP shall significantly improve upon this current state of the art by carrying out a tightly integrated program of frequency comparisons between European optical clocks at a level limited only by the accuracies of the clocks themselves. In this way a framework and procedures shall be established whereby the optical clocks can be integrated into international timescales. This JRP thus addresses the key steps that must be carried out before a redefinition of the second can occur, and will allow European NMIs to play an influential role in international debates on this matter

SIB60 Surveying: Metrology for long distance surveying, Coordinator Florian Pollinger (PTB)

The JRP unites metrologists, surveyors and geodesists to respond to the need for improvement in long-distance metrology. Surveyors or researchers in geosciences are facing the challenge of measuring distances over several hundreds of metres up to kilometres with uncertainties at the millimetre level and below. In general, two different measurement techniques are available for this task: one based on optical distance measurement, one on the reception and analysis of signals from Global Navigation Satellite Systems (GNSS). Both of them, however, are currently not capable of providing traceability to the SI definition of the metre with millimeter accuracy over the respective long distances in air. In the former case, the uncertainty is primarily limited by the imperfect knowledge of the index of refraction. In the latter case, the uncertainty is influenced by multiple effects, and is currently not even properly quantified to the required level. The same effects are also limiting GNSS-based time and frequency transfer. So a better understanding of the uncertainty of GNSS -based distance metrology may also help here.

EXL01, QESOCAS - Quantum engineered states for optical clocks and atomic sensors, Coordinator Sebastian Bize (SYRTE)

The stability of optical atomic clocks is currently limited by two factors which are the frequency noise of the laser used to probe the atomic system and the quantum projection noise that arises when detecting the state of this system. The JRP addresses these key factors that hamper progress towards uncertainties at the 10^{-18} level. Such performance in hand would be beneficial to most major applications of clocks and open the possibility of new applications. To tackle these two noise sources, in the JRP the possibility offered by quantum mechanics to create and exploit entangled states shall be investigated, showing quantum correlations between multiple atoms or ions, and to detect these states in a non-destructive manner. These states are referred to as Quantum Engineered States.

7. Meetings

The 2013 meeting took place at Real Instituto y Observatorio de la Armada at San Fernando during 18th and 19th March (local host Juan Palacio and Javier Galindo). Discussions during the meeting were very lively, and many delegates expressed their interest to support the ongoing projects by their active involvement. VSL (NL) has accepted to host the TC-TF meeting in 2014.

8. Issues

Waves have calmed down.

9. Outlook for 2013/2014

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My term as TC Chair will end in 2013. I am looking back gratefully to the collaboration among TC-Chairs, the friendly atmosphere during TC-Chair meetings and General Assemblies, and I wish those who remain in duty a successful and pleasant term. My successor will be Ramiz Hamid of UME, Turkey, whom I wish a lucky hand and the necessary patience in guiding the TC through the coming 4 years.

Dr. Andreas Bauch
PTB, Time Dissemination WG
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