Time and Frequency Activities
TL, Chinese Taipei

Huang-Tien LIN and Chia-Shu Liao

the 21st CCTF meeting
June 08-09, 2017
Where is TL?
TL is responsible for the time and frequency standard of Taiwan

An associate member of CGPM, and TL has attended CCTF meeting as a guest since 1999.

ITRI/CMS has joined in CCL and CCAUV as an Observer
1. Introduction
   T&F national standard, UTC(TL), TA(TL)

2. Precise time and frequency transfer
   GPS、TWSTFT, and Optical fiber

3. Time Dissemination Services
   NTP and speaking clock services

4. International Cooperation
   Workshops and Training activities

5. Publications
1. Introduction

**Reference clocks of TL**

- 10 Microsemi 5071A cesium clocks with high performance tubes
- 4 active Hydrogen masers located in the 4 EM shielding chambers with stabilized temperature (23±1°C) and humidity (50±5%).

**UTC(TL) & TA(TL)**

- TA(TL) is a weighted result of our cesium-clock ensemble. The output frequency of our master hydrogen maser is steered by a micro-phase-stepper (Microsemi AOG-110) to generate UTC(TL).
- The performance of UTC(TL) was checked by referring to TA(TL) and the Circular-T data to ensure its accuracy.
- The phase difference between UTC(TL) and UTC was kept within ±30 ns, and its stability is about 4E-15 with averaging time of 5 days.
- **Contribution to the calculation of TAI ~ about 1.3% (Ranked about 15)**
TL’s link on BIPM webpage

Associate: Chinese Taipei / Useful links

→ Metrology institutes
  BSMI** (Bureau of Standards, Metrology and Inspection)
  TL™ (Telecommunication Laboratories, ChungHwa Telecom Co., Ltd.)
  CMS™ (ITRI Center for Measurement Standards)
  INER™ (Institute of Nuclear Energy Research)
  NML (National Measurement Laboratory)

→ National legal metrology authorities
  Bureau of Standards, Metrology and Inspection (BSMI)

→ National accreditation bodies
  Taiwan Accreditation Foundation (TAF)

** Signatory of the CIPM MRA ; * Also participating in the CIPM MRA.
<table>
<thead>
<tr>
<th>Calibration or Measurement Service</th>
<th>Measurand Level or Range</th>
<th>Measurement Conditions/Independent Variable</th>
<th>Expanded Uncertainty</th>
<th>Is the expanded uncertainty a relative one?</th>
<th>NMI Service Identifier</th>
<th>Comments</th>
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<tbody>
<tr>
<td><strong>Time interval</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Time difference source</td>
<td>-1000 to 1000 s</td>
<td>1 PPS amplitude &gt; 0.5 V (50 Ω)</td>
<td>1.0 ns</td>
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<td>95%</td>
<td>No</td>
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<tr>
<td>Slew rate</td>
<td>&gt; 0.5 V/μs</td>
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<td>100 ns</td>
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<td>95%</td>
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<td>Local clock vs. UTC</td>
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<td>Slew rate</td>
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<td>Baseline length from TL &lt; 1000 km</td>
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<tr>
<td><strong>Frequency</strong></td>
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<td>Measurement time 86400 s</td>
<td>3.0E-12 Hz/Hz</td>
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<td>95%</td>
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<td>General frequency source</td>
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<td></td>
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<tr>
<td><strong>Frequency</strong></td>
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<td>95%</td>
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The contents of the sections of BIPM Circular T are fully described in the document "Explanatory supplement to BIPM Circular T" available at ftp://ftp2.bipm.org/pub/tai/publication/notes/explanatory_supplement_v0.1.pdf

1 - Difference between UTC and its local realizations UTC(k) and corresponding uncertainties.

From 2015 July 1, 0h UTC, TAI-UTC = 36 s. From 2017 January 1, 0h UTC, TAI-UTC = 37 s.

<table>
<thead>
<tr>
<th>Date 2016</th>
<th>0h UTC</th>
<th>SEP 28</th>
<th>OCT 3</th>
<th>OCT 8</th>
<th>OCT 13</th>
<th>OCT 18</th>
<th>OCT 23</th>
<th>OCT 28</th>
<th>Uncertainty/ns</th>
<th>Notes</th>
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<td>AOS (Borowiec)</td>
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<td>-0.2</td>
<td>0.9</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0</td>
<td>1.1</td>
<td>0.4</td>
<td>2.7</td>
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<td>2.5</td>
<td>2.1</td>
<td>0.8</td>
<td>-1.7</td>
<td>-2.7</td>
<td>-2.0</td>
<td>0.3</td>
<td>10.9</td>
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<td>AUS (Sydney)</td>
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<td>894.0</td>
<td>914.3</td>
<td>924.4</td>
<td>955.5</td>
<td>967.0</td>
<td>982.5</td>
<td>0.4</td>
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<td>20.0</td>
<td>23.4</td>
<td>24.1</td>
<td>26.2</td>
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<td>2.7</td>
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<td>9.1</td>
<td>9.7</td>
<td>10.2</td>
<td>10.6</td>
<td>0.3</td>
<td>2.2</td>
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<td>-14.0</td>
<td>-7.7</td>
<td>-2.9</td>
<td>2.1</td>
<td>9.4</td>
<td>0.3</td>
<td>5.8</td>
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<td>0.4</td>
<td>0.2</td>
<td>1.0</td>
<td>1.1</td>
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<td>VMI (Ha Noi)</td>
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<td>23.6</td>
<td>19.1</td>
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<td>19.9</td>
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<td>20.0</td>
<td>20.1 (3)</td>
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<td>1.3</td>
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<td>7.6</td>
<td>5.8</td>
<td>6.1</td>
<td>0.4</td>
<td>20.0</td>
<td>20.0</td>
</tr>
</tbody>
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Participate in the ongoing key comparison ~ CCTF-K001.UTC

- Report GPS measurement data continuously to BIPM
- Contribute to the generation of TAI and UTC
TL is one of the Group-1 Labs in APMP

Participated in BIPM Group-1 GPS calibration trip (Phase 1, March-September 2016), BIPM – TL – NICT – NIM – BIPM

Host Group-2 calibration campaign (February - May 2017, MEDEA ILC project) TL – NMIT – NMIM – VMI – TL
TL has been devoted to the TWSTFT activities since 2002, and established the first Europe-Asia (VSL-TL) link in 2003.

TL still maintains four earth stations for the TWSTFT experiments: Asia-Pacific link, Europe-Asia link, and North America-Asia link.
Two-Way Satellite Time and Frequency Transfer Experiment using Dual Pseudo-Random Noise (DPN) Codes

a DPN-based TWSTFT system.

Two narrow PRN coded signals are separated by 20 MHz

TDEV comparison between DPN and GPS PPP for the NICT-TL link

- Cooperation between NICT and TL in 2010
- the performance of DPN Results is as good as the GPS PPP results.
TL has been devoted to the development of TWSTFT SDR receiver since 2014.

The preliminary SDR experiments among TL, NICT and KRISS in 2015 showed good results.

The BIPM and CCTF WG on TWSTFT established a pilot study group (PSG) in 2016, to evaluate the feasibility of contributing SDR technology to UTC generation.

Up to now, the SDR receivers have been installed in many Labs, e.g., PTB, OP, NTSC, NIST, NIM, VNIIFTRI, INRiM, AOS, and METAS, ... etc.

Measurement results using SDR receivers show good stability. In particular, the diurnal phenomenon in several links was effectively reduced.
Pilot Study on applying SDR technology to UTC generation

March 2017
Comparison of TWSTFT results by using Conventional and SDR receiver

- Conventional receivers
- SDR receivers
Time transfer via optical fiber

TW time transfer experiment through a common-path optical fiber link

- provide good reciprocity in both directions
- common clock test through 25-km long spool of fiber

70 MHz, @cable

25 km SMF

SATRE MODEM 1

Tx1

E/O

O/E

Rx1

1310 nm

1310 nm

25 km SMF

SATRE MODEM 2

Tx2

E/O

O/E

Rx2

Ref 5 MHz

Ref 1 PPS

Time deviation (TDEV): 7 ps

frequency stability : 2E-16 (@ 1 day)
We have proposed a structure of OEO, based on optical fiber loops to act as a high-Q cavity, which can generate stable radio-frequencies (RF) signal.

- TIC was used to detect the time shifts between OEO output & the reference.
- TWSTFT modem was used to monitor the fiber delay.
The performance of time transfer through a mobile backhaul network was evaluated. With the support of IEEE 1588 v2 packets and Sync-E, very stable results were obtained. The accuracy of time transfer experiment is about 100 ns.
Microwave Frequency Measurement Capability

- The range of microwave frequency calibration at TL using a down-convert technique: 300 MHz ~ 26.5 GHz
- An active microwave amplifier doubler has been used to extend the upper limit of our system from 26.5 GHz to 40 GHz since 2014
- By using TL’s system, the frequency stability of the common clock test is about 3.0E-13 (carrier frequency 40 GHz; $\tau = 1$ sec)

Fig 1. Diagram of the microwave frequency measurement at TL using a down-convert technique

Fig 2. An active microwave amplifier doubler and a power supply
Since the end of 2015, TL has extended its frequency measurement capability from microwave (~40 GHz) to optical (1100~2200 nm, or 136~272 THz) field based on the fiber laser comb technology.
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NTP is the major time dissemination service of TL.

TL has provided this time synchronization service through Internet since June 1998.

In 2014, TL renewed its monitoring system to maintain the NTP services and record the request counts. The amount of NTP requests is more than two hundred million per day.

The request count of the NTP service from 2014 to 2016
TL has provided “117 speaking clock” service for more than 50 years, and the old system was replaced by an IPC-based digital system since 1994. The amount of speaking clock service is hundreds of thousands per day. Recently, a supporting system with protection and monitoring functions were developed to make the service running smoothly and reliably.

**the protecting sub-system**

- The sub-system with multi-time selecting and back up functions was designed to prevent any possible failure.

**the monitoring sub-system**

- Measure the input and output time error.
- Warning message alert operator in case an error happens.
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International cooperation activities:

Actively participated in the CCTF relative activities
CCTF TAI contribution labs
CCTF WG on MRA
CCTF WG on GNSS
CCTF WG on TWSTFT
CCTF WG on ATFT

21th Meeting of the CCTF WG on TWSTFT
Taipei, 5-6 September 2013
International workshops, training activities

TL is full member of APMP, and has actively participated in the TCTF activities

- Support the intra- and inter- RMO CMCs reviews for APMP WGMRA

- Since 2011:
  invited by KRISS, NICT, NMIJ, NIM, NMIM, RCM-LIPI as Peer reviewer

Workshops and Training activities:

2012 APMP TC initiative project – GPS calibration Exercise
2013 host ATF workshop (as joint sessions of AP-RASC’13 Conference)
2013 host 2013 APMP GA and TCTF meeting
2014 host ATF workshop (join with IEEE IFCS as a technical co-cosponsor)
2014 proposed MEDEA workshop on Participating in UTC (host by NIM)
2016 host MEDEA kickoff workshop on GPS time transfer and calibration techniques
2017 GPS Inter-Laboratory Comparison (ILS) – G2 calibration campaign (MEDEA) 
  Expert Site-Visit, and Concluding Workshop (MEDEA)

* MEDEA (Metrology-Enabling Developing Economies in Asia) : funding support by PTB
The ATF 2013 workshop was held as the joint sessions of commission-A in the AP-RASC’13 Conference.

- Sept. 3-6 ATF 2013 Workshop
  60 papers ~
  2 Plenary sessions, 8 Oral sessions, and one poster session

- Sept. 5-6 CCTF WG on TWSTFT meeting
Photos of the AP-RASC’13 Conference
2013 APMP GA and TCTF meeting
The ATF 2014 workshop is a technical co-sponsor of the symposium, so members of the APMP (Asia Pacific Metrology Programme), TCTF (Technical Committee on Time and Frequency), and NMIIs (National Measurement Institute) are also encouraged to submit abstracts. Paper selection and publication will follow past rules established by IEEE and the IFCS.
2014 Workshop on Participating in UTC (MEDEA project)

- Two-day workshop proposed by TL as a MEDEA project, and was held by NIM on 5-6 Nov., 2014

- MEDEA Workshop on “Participating in UTC”
  - To equip participants with the technical knowledge to participate in UTC
  - To hear what the needs of the participants are and inform further projects within the DEC
A series of training activities in **GPS time transfer and calibration techniques** were organized by TL in 2016-2017, to support the NMIs of APMP Developing Economies.

Training activities included **a kickoff workshop, inter-laboratory comparison (ILC), and site visits by experts** in the field.

**The kickoff workshop** was held from Sept. 27-29, 2016 at TL. More than 20 delegates from 15 NMIs participated the kickoff workshop.
The ILC {GNSS receiver calibration campaign) among NIMT (Thailand), NMIM(Malaysia), and VMI(Vietnam) started soon after the kickoff workshop, and the traveling system returned to TL around middle May, 2017. The ILC will be the first extended GPS receiver calibration campaign conducted within the APMP.

Three experts were invited to visit 3 Labs for providing on-site instructions.

Concluding Workshop
The ILC measurement results, the lessons learned from the ILC and the achievements of the expert site-visits, will be presented in the Workshop at TL on October 25-26, 2017.
~ Summary ~

- Maintain Stable Time and Frequency standard
  - Contribute to the generation of TAI and UTC (Ranked about 15)
  - Provide time dissemination services

- Devote to the research of time and frequency transfer technologies
  - One of the GPS calibration G1 Labs
  - Host the first extended GPS receiver calibration campaign within the APMP
  - TWSTFT DPN and SDR technologies

- Actively participate in the CCTF and APMP activities
  - Host meetings, workshops, and training activities
  - Act as a peer reviewer of many NMIs
  - Promote international cooperation
5. Publications - 1/4

Journal papers:


EI referenced papers:


Thank You for your kind attention!