Towards Accurate Optical Fiber Time Transfer for UTC Generation

Z. Jiang and E.F. Arias
Time Department
Bureau International des Poids et Mesures

CCTF WG ATFT, 15 Sept 2015, BIPM
• Recommendation ATFT (draft) to CCTF2015

the BIPM participates actively in these (fibre link etc.) developments, notably by making preparations for exploiting, in time scale realization, clock comparison data issued from new time and frequency transfer methods.
Outline 2/2

• We focus on its use in UTC generation
  • Activities of the UTC laboratories
  • Attainable uncertainty
  • Applications
    • Short-term: validating the new and the most precise-accurate T/F technics
    • Long-term: UTC time transfer, UTC dissemination
**TWOTFT=Two-Way Optical-fiber T/F Transfer**

- **basic bidirectional:** Very similar to TWSTFT; temperature impact of picoseconds over hundreds km; self-calibration possible;

  Close reciprocity \( D_{AB} \approx D_{BA} \) in Two-Way time transfer

  ![Diagram](Fig. 1a)

  \[ \text{Lab}_A/\text{T}_A \rightarrow \text{Lab}_B/\text{T}_B \]

- **bidirectional with active delay stabilization:** feedback loop, with self-calibration and the stability of picoseconds

  Close reciprocity \( D_{AB} \approx D_{BA} \) in Two-Way time transfer

  ![Diagram](Fig. 1b)

  \[ \text{Lab}_A/\text{T}_A \rightarrow \text{Lab}_B/\text{T}_B \]
Activity in O.F. of the UTC labs/BIPM

- BIPM Technical Memorandum 253: > 80 papers, at least 18 UTC Labs actively involved: PTB, AOS, GUM, IPE, BEV, SP, MIKES, TL, NICT, NMIJ, NIM, INRIM, OP, NPL, NIST, NMIA, VSL and USNO;
- Several operational time/frequency links;
- AOS-PL, BEV-TP submit data to BIPM for monthly processing and publications;
- The attainable standard uncertainty < 120~200 ps;
- A study group, Optical fibre link for UTC, created in 2015
Applications of O.F. in UTC 1/2

- Validation of the new and the most precise technics, such as:
  - **Integer ambiguity PPP**, Petit et al. (2015), “$1 \times 10^{-16}$ frequency transfer by GPS PPP with integer ambiguity resolution”, *Metrologia* 52 *(BIPM,CLS ...*)
  - ... ...

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Applications of O.F. in UTC 2/2

- **Future applications and new challenges:**
  - Accurate time transfer for UTC generation
    - Configuration of the worldwide UTC network
    - Standardisation of data exchange format and data processing
    - Calibrations
    - Combination with the space based techniques
Fibre link UTC(AOS)-UTC(PL)

The real-time clock comparison between UTC(AOS) and UTC(PL) through a fibre link, [www.optime.org.pl/node/47](http://www.optime.org.pl/node/47)

420 km baseline 7 amplifiers, permanent operational
Total combined uncertainty 112 ps
Fibre link UTC(BEV)-UTC(TP)

550 km baseline with 7 amplifiers, permanent operational
Tdev 30 ps/20s
Noises, discontinuities, drifts and jumps $<< 1\text{ns}$.

In most cases, Caused by GPSPPP
Valid GNSS Calibrator with TWOTT over A-C

I: TWOTT self-calibration
(A-C)_{OF} = -2,046,196.23±0.15 ns

TTS4(AOS) Transceiver

UTCp(PL)

TTS4(PL)

II: GNSS (A-C)_{PL-TTS4} = (A-D)-(C-D) = -2,046,195.368 ns
GNSS (A-C)_{AoS-TTS4} = (B-C)-(B-A) = -2,046,195.958 ns

→ TWOTT-GNSS Calibration = I − II = 0.57±0.79 ns

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Consideration of its future Application in UTC

1) Standard data format
2) A new configuration and a new algorithm?
It is suggested adapting the **ITU TWSTFT** data format for **TWOTFT** (SATRE):
- All the data exchanges, processing, calibrations, and the related methodology and software can be kept almost the same;
- This will save huge time and man powers and speed up its applications (BIPM Tsoft);
- Adapted header
- Open points: Rcd 0.1 ps, Sagnac corr.

--- data body proposition (I) ---

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**A unique standard format** for all the TWOTT approaches
The UTC network configuration 1/2

Present structure based on GNSS and TWSTFT links

Unique pivot
The new UTC network configuration

with the **TWOTT** links ➔ comb. $U=0.1$ ns negligible
Thanks

for your attention

and to

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