GNSS time transfer: receiver internal delay determination

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Outline

1. NIMT
2. NIMT time and frequency measurements
3. Receiver internal delay measurements
4. Conclusions
1. NIMT

• Establish in 1 June 1998 under the ministry of science and technology
• Maintain and develop national measurement standards
• Provide national measurement infrastructure in Thailand
  • Provide measurement capability
  • Disseminate the accuracy of measurement standards
• Under ministry of higher education, science, research and innovation since 2 May 2019
• Locate in central Bangkok and Pathumthani

http://www.nimt.or.th/
# 2. NIMT time and frequency measurements

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<th>Time and frequency keeping</th>
<th>Caesium frequency standard</th>
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<td><strong>International time comparisons</strong></td>
<td><strong>Dual frequency GPS receiver</strong></td>
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<td><strong>GPS timing station</strong></td>
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<td><strong>GNSS geodetic receiver</strong></td>
<td><strong>GNSS CORS network</strong></td>
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<td><strong>Internet time server</strong></td>
<td><strong>Time stamp</strong></td>
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<td><strong>Frequency counters</strong></td>
<td><strong>Time and frequency calibration services</strong></td>
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</tbody>
</table>
2. NIMT time and frequency measurements

Second (s)

- The second is the International System (SI) base unit for time.
- It is defined by fixed numerical value of the caesium frequency $\Delta v$.
- Transition frequency of the caesium 133 atom is at 9,192,631,770 Hz.

NIMT time and frequency lab aims to

- Traceable to SI second.
- Determine UTC(NIMT) at highest accuracy as possible.

Abbreviations

- BIPM: International Bureau of Weights and Measures
- IERS: International Earth Rotation Services
- TAI: International Atomic Time
- UTC: Coordinated Universal Time
- UT1: Universal Time (principle)

NIMT contributions

- UTC (since 1997)
- UTCr (since 2012)
3. NIMT time and frequency measurements

**GNSS/GPS point positioning: time comparison**

- Known satellite and receiver positions
  - Broadcast ephemeris
  - Computed precise receiver (static)

- Observed data
  - GNSS/GPS observations
  - Time interval measurements

- Determined time offsets
  - GPST - $t_r$
  - SV - $t_r$

**Abbreviations**
- GPST: GPS System Time
- SV: Satellite Vehicle
3. NIMT time and frequency measurements

**CGGTTS files**

CGGTTS GPS DATA FORMAT VERSION = 01
REF DATE = 1997-11-04
RCVFR = NML Australia Topcon Euro-80 L1/L2
CH = 12
IPS = NML Euro-80 L1/L2 Pseudorange differences
LAB = NIMT (system #2)
X = 1156489.445 m
Y = 6068854.105 m
Z = 1537597.761 m
FNAV = ITRF2014 @ 2017/10/31
TSV = CAL 2013-2017

INT DLY = 31.2 ns
CAB DLY = 16.9 ns
REF DLY = 7.07 ns
REF = UTC(NIMT)
CKSYN = DC

**INT DLY = 31.2 ns (computed)**

**INT DLY = 42.9 ns**

**Abbreviations**

CGGTTS Common GPS GLONASS Time Transfer Standard

**REFSV** is corrected for:

- geometric delay
- modelled ionosphere
- modelled troposphere
- Sagnac effect
- relativistic effect due to the eccentricity of the GPS satellite’s orbit
- L1-L2 broadcast correction
- cable and reference delays
- receiver internal delay

**https://www1.bipm.org/cc/CCTF/Allowed/15/CCTF_01_36.pdf**
3. Receiver internal delay measurements

Why receiver internal delay has to be determined?

• **Generally** high grade geodetic receivers and antennas typically have minimum values of receiver internal delays.

• **Currently** timing receivers and antennas are also used as an international time link.

• **Needs** especially for international time comparisons and some high precision and accuracy applications.

• **Determined** by measured and estimated.

How receiver internal delay is determined?

• Applied appropriate combinations

• Inserted proper mathematical models for each observation errors and biases

• Determined with **suitable** algorithms
3. Receiver internal delay measurements

How receiver internal delay is determined?

Zero baseline determination

Receiver: known internal delay

Receiver: unknown internal delay

Short baseline determination

Receiver: known internal delay

Receiver: unknown internal delay

<10 m
3. Receiver internal delay measurements

<table>
<thead>
<tr>
<th>Comparison method</th>
<th>Direct comparisons</th>
<th>Static Precise Point Positioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solutions</td>
<td>Receiver internal delay</td>
<td>• Receiver position</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Receiver clock offsets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Zenith total delay</td>
</tr>
<tr>
<td>Software</td>
<td>None</td>
<td>Bernese GNSS Software version 5.2</td>
</tr>
<tr>
<td>Applied parameters</td>
<td>None</td>
<td>• IGS Earth Rotation Parameters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• IGS satellite positions and clock offsets (sp3)</td>
</tr>
<tr>
<td>Tropospheric delay</td>
<td>None</td>
<td>• Saastamoinen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Global Pressure and Temperature</td>
</tr>
</tbody>
</table>
3. Receiver internal delay measurements: setup

NIMT reference system

- Javad L1/L2
- MTTO
- Topcon Euro 80
- Universal Counter
- Computer for data recording
- UTC(NIMT)
- RF distribution amplifier
- Micro-phase stepper
- Caesium frequency standard
- 1 PPS
- 10 MHz
- 5 MHz
- 1 PPS
- 5 MHz
- 1 PPS

Transfer standard

- Novatel
- TRVL
- Travelling standard
- RF distribution amplifier
- 1 PPS
- 10 MHz

3. Receiver internal delay measurements: model

Raw difference of a particular code is determined as:

RAW = REFSV + MDIO + MDTR + INT DLY + CAB DLY – REF DLY

RAWDIF = median(RAW value of A – RAW value of B)

<table>
<thead>
<tr>
<th>Parameters on C1</th>
<th>Time (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw difference</td>
<td>-12.9</td>
</tr>
<tr>
<td>Reference delay</td>
<td>7.1</td>
</tr>
<tr>
<td>Cable delay</td>
<td>165.4</td>
</tr>
<tr>
<td>Internal delay</td>
<td>31.2</td>
</tr>
</tbody>
</table>
3. Receiver internal delay measurements: PPP

**GNSS/GPS precise point positioning: time comparison**

- Precise satellite orbits and satellite clocks
  - IGS computed orbits and clock offsets
- Receiver position
  - Computed precise receiver position
- Observed data
  - GNSS/GPS carrier phase observations
  - Dual frequency observations
  - Ionosphere-free combinations (L3)

**Abbreviations**

- IGS: International GNSS Services
- PPP: Precise Point Positioning
3. Receiver internal delay measurements: PPP

GNSS/GPS precise point positioning: time comparison

- Positioning method
  - Post-processing
  - Static positioning

- Software
  - Online processing services
  - RTKLib
  - Bernese GNSS processing

- Determined time offsets
  - GPST - $t_r$
  - IGS - $t_r$
3. Receiver internal delay measurements: PPP

**NIMT reference system**

- MTTO
  - Javad L1/L2
  - 1 PPS
  - Topcon Euro 80
  - Universal Counter
    - 10 MHz
    - 1 PPS
    - Computer for data recording
  - Micro-phase stepper
    - 5 MHz
    - 1 PPS
    - Caesium frequency standard

**Experimental setup**

- NOVT
  - 1 PPS
  - RF distribution amplifier
  - Geodetic receiver
    - 10 MHz
    - 1 PPS
  - RF distribution amplifier
  - Frequency doubling
    - 5 MHz
    - 1 PPS

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3. Receiver internal delay measurements: PPP

- Results are time differences between computed receiver delay of MTTO and NOVT with respected to GPST.
- The raw differences as of C1 codes for NOVT is then determined.

<table>
<thead>
<tr>
<th>Parameter on C1</th>
<th>Time (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw difference</td>
<td>316.1</td>
</tr>
<tr>
<td>Reference delay</td>
<td>13.0</td>
</tr>
<tr>
<td>Cable delay</td>
<td>150.0</td>
</tr>
<tr>
<td>Systematic delay</td>
<td>322.0</td>
</tr>
<tr>
<td>Internal delay</td>
<td>346.0</td>
</tr>
</tbody>
</table>
4. Conclusions

• NIMT uses GNSS and GPS for international time comparisons with the BIPM
• Geodetic techniques are applied to improve accuracy of international time transfer – receiver internal day determination
• GNSS receiver internal delay is determined in most timing laboratory as it is to resolve the receiver delays on navigation satellite observations on their codes
• The geodetic positioning mode of PPP is applied to determine the GNSS receiver internal delays for GPS C1 codes on L1C frequency band
• This is a preliminary stage before involving in the international time comparison scheme
• The goal is to improve the quality measures of Thailand time scales of UTC(NIMT)
Acknowledgement

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Thank you for your kind attentions!