GNSS time transfer: receiver internal delay determination

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NIMT

kg

m

s

A

K

mol

cd

Outline

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

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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/

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2. NIMT time and frequency measurements

Time and frequency keeping

- Caesium frequency standard
- Hydrogen MASER

International time comparisons

- Dual frequency GPS receiver
- GNSS geodetic receiver
- GPS timing station
- GNSS CORS network

National time distributions

- Internet time server
- Frequency counters
- Time stamp
- Time and frequency calibration services

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2. NIMT time and frequency measurements

Second (s)

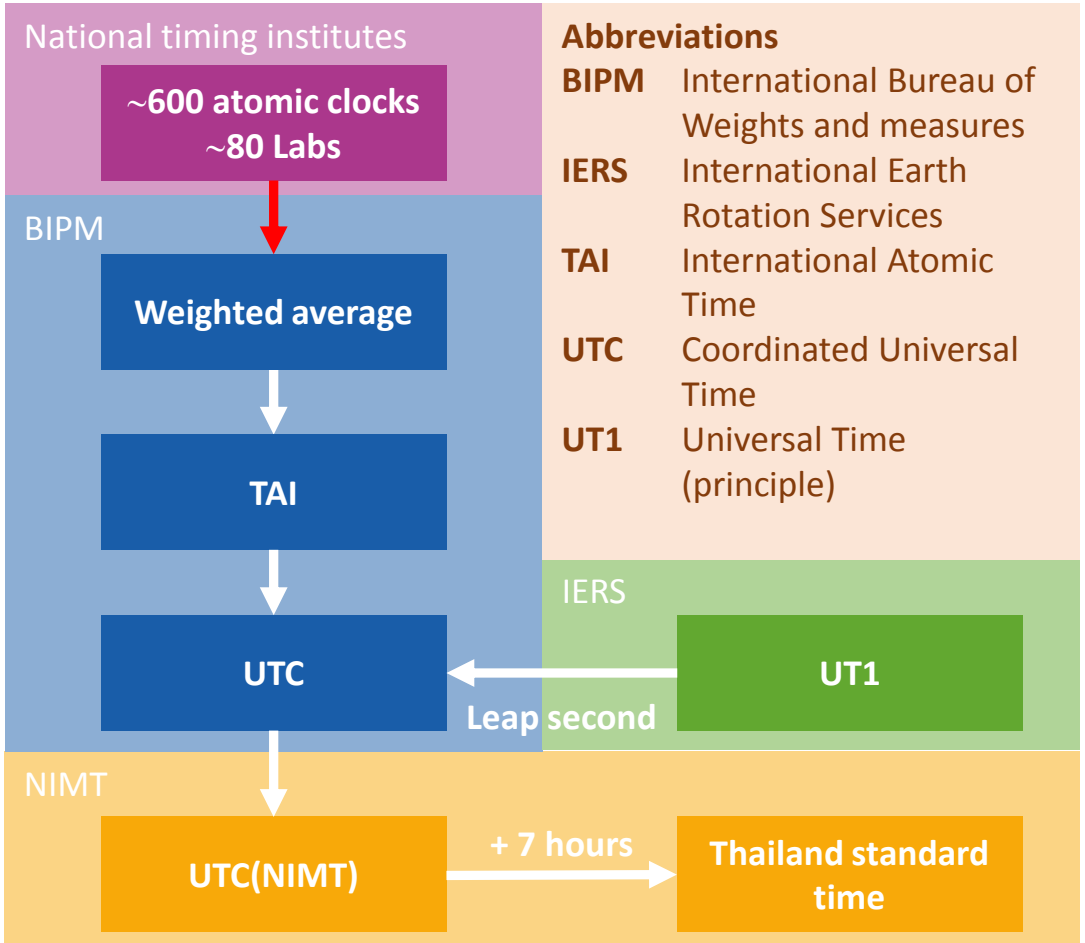
- The **second** is the International System (SI) base unit for time
- It is defined by fixed numerical value of the caesium frequency Δν
- Transition frequency of the caesium 133 atom is at 9,192,631,770 Hz

NIMT time and frequency lab aims to

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

NIMT contributions

- UTC (since 1997)
- UTCr (since 2012)



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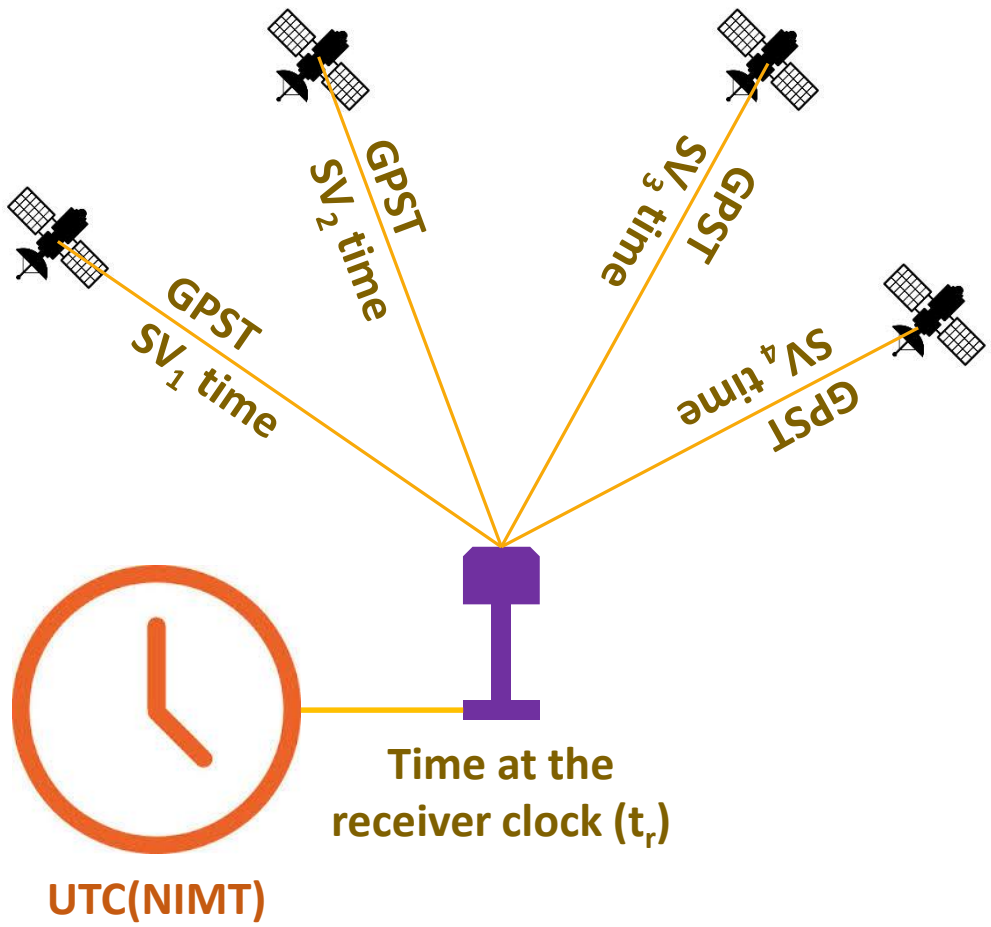
3. NIMT time and frequency measurements



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

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3. NIMT time and frequency measurements

Abbreviations
CGGTTS Common GPS GLONASS Time Transfer Standard

CGGTTS files

```
GGTTS GPS DATA FORMAT VERSION = 01
REV DATE = 1997-11-04
RCVR = NML Australia Topcon Euro-80 L1/L2
CH = 12
IMS = NML Euro-80 L1/L2 Pseudorange differences
LAB = NIMT (system #2)
X = -1150489.445  m
Y = 6080854.165 m
Z = 1537597.761  m
FRAME = ITRF2014 @ 2017/10/31
COMMENTS = Cal Id=1013-2017
INT DLY = 31.2 ns
CAB DLY = 165.4 ns
REF DLY = 7.07 ns
REF = UTC(NIMT)
CKSUM = DC
```

INT DLY = 31.2 ns (computed)

INT DLY = 42.9 ns

modelled troposphere

modelled ionosphere

measured ionosphere

PRN	CL	MJD	STTIME hhmmss	TRKL s	ELV .1dg	AZTH .1dg	REFSV .1ns	SRSV .1ps/s	REFGPS .1ns	SRGPS .1ps/s	DSG .1ns	IOE	MDTR .1ns	SMDT .1ps/s	MDIO .1ns	SMDI .1ps/s	MSIO .1ns	SMSI .1ps/s	ISG .1ns	CK
31	FF	58618	001000	780	261	396	-380949	+51	+501	+25	19	032	186	+17	96	+5	56	+18	25	2F
14	FF	58618	001000	780	474	947	+805175	-31	+567	-15	17	051	112	+4	65	+2	74	+25	19	16
26	FF	58618	001000	780	591	131	-2014529	-107	+557	-11	18	092	96	+8	57	+4	32	+13	13	21
16	FF	58618	001000	780	779	2770	+401751	+13	+567	-16	11	061	84	-0	51	-0	55	+33	8	FB
22	FF	58618	001000	780	462	2620	+7010052	+63	+591	-1	24	082	114	+2	66	+1	80	+48	33	08
3	FF	58618	001000	780	386	2893	-1878717	+3	+529	-2	12	088	132	-5	75	-2	49	+55	22	1A
32	FF	58618	001000	780	340	1150	+875625	-170	+540	-1	22	074	147	+17	82	+7	87	+72	42	31
23	FF	58618	001000	780	129	3235	+1862425	-12	+482	+4	21	090	363	-150	127	-16	98	+2	46	56
27	FF	58618	001000	780	315	1668	+1320703	+165	+523	+70	19	083	157	-29	86	-11	89	-77	18	84
31	FF	58618	002600	780	240	466	-380904	+57	+521	+31	21	032	201	+18	100	+5	90	+38	29	21

https://www1.bipm.org/cc/CCTF/Allowed/15/CCTF_01_36.pdf

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 ???**

kg m s A K mol cd

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

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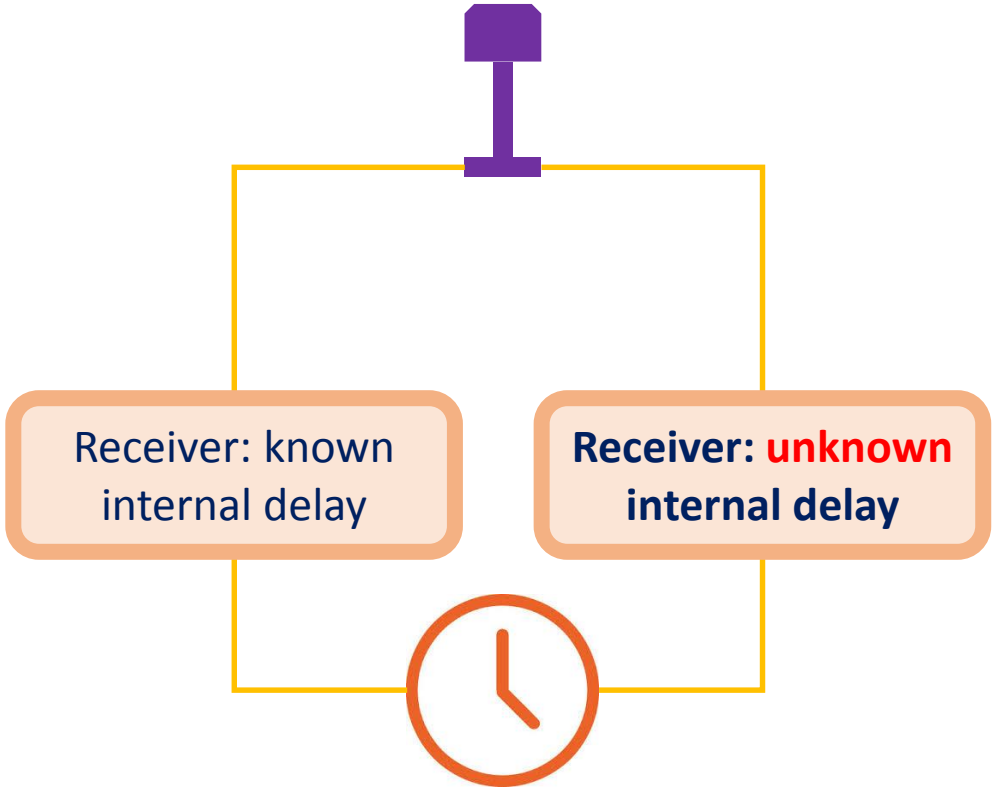
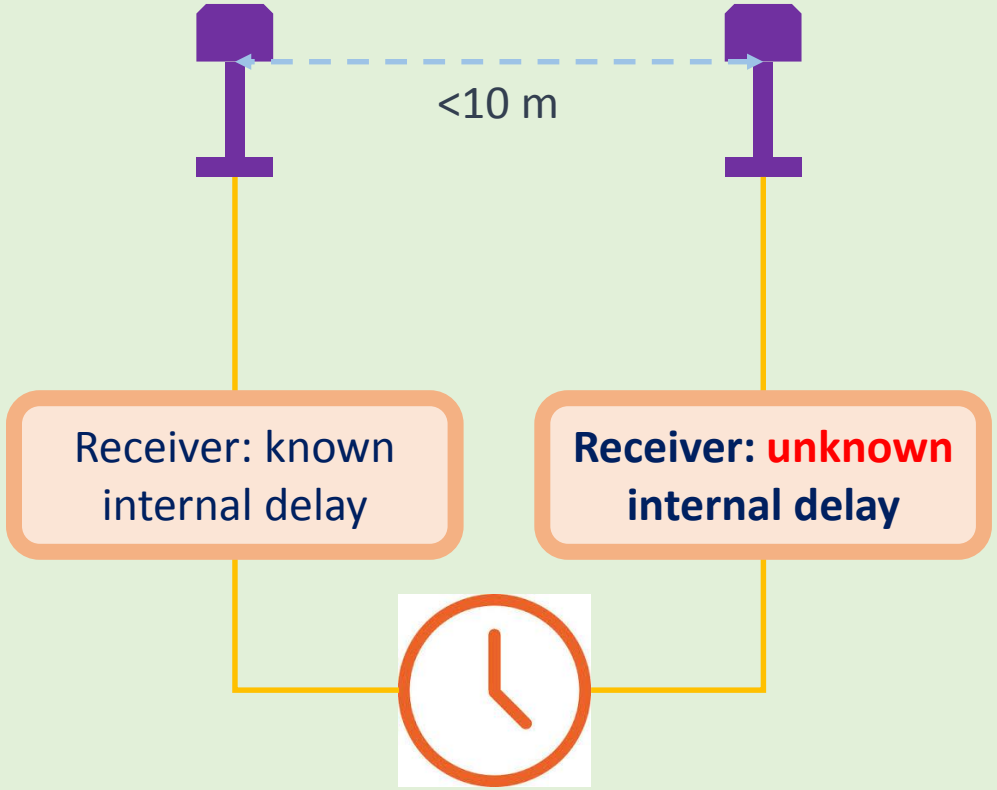
3. Receiver internal delay measurements

How receiver internal delay is determined?



Zero baseline determination



Short baseline determination

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3. Receiver internal delay measurements

Comparison method	Direct comparisons	Static Precise Point Positioning
Solutions	Receiver internal delay	• Receiver position • Receiver clock offsets • Zenith total delay
Software	None	Bernese GNSS Software version 5.2
Applied parameters	None	• IGS Earth Rotation Parameters • IGS satellite positions and clock offsets (sp3)
Tropospheric delay	None	• Saastamoinen • Global Pressure and Temperature

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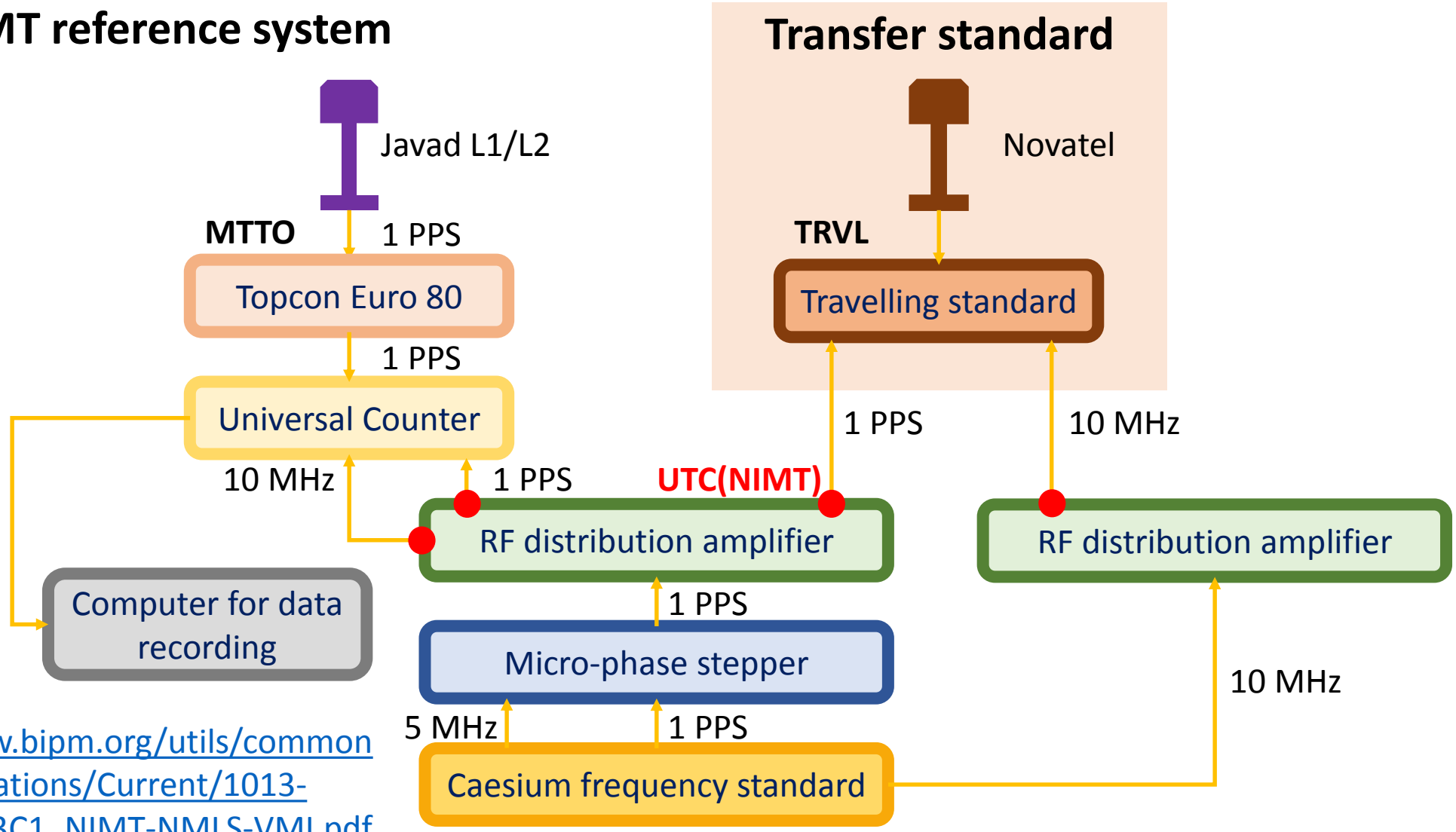
3. Receiver internal delay measurements: setup

NIMT reference system



https://www.bipm.org/utils/common/TimeCalibrations/Current/1013-2017_GPSP3C1_NIMT-NMLS-VMI.pdf

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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)

Parameters on C1	Time (ns)
Raw difference	-12.9
Reference delay	7.1
Cable delay	165.4
Internal delay	31.2

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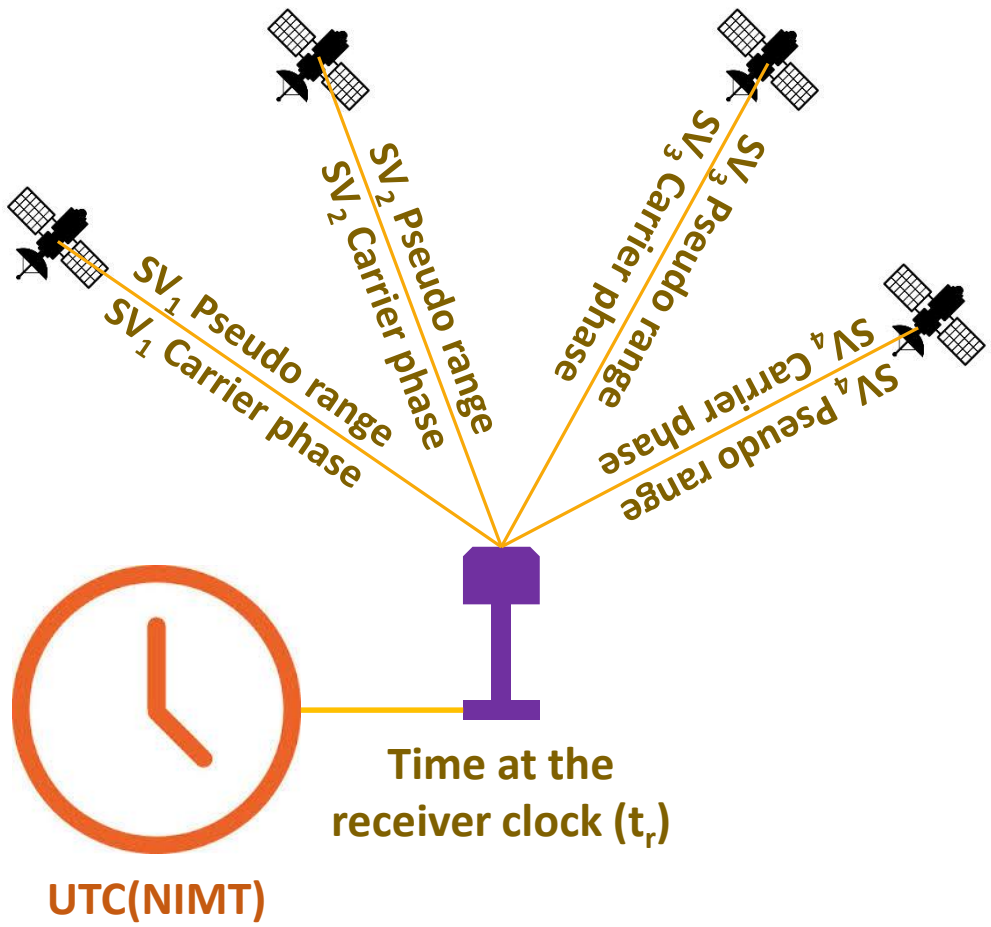
3. Receiver internal delay measurements: PPP



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

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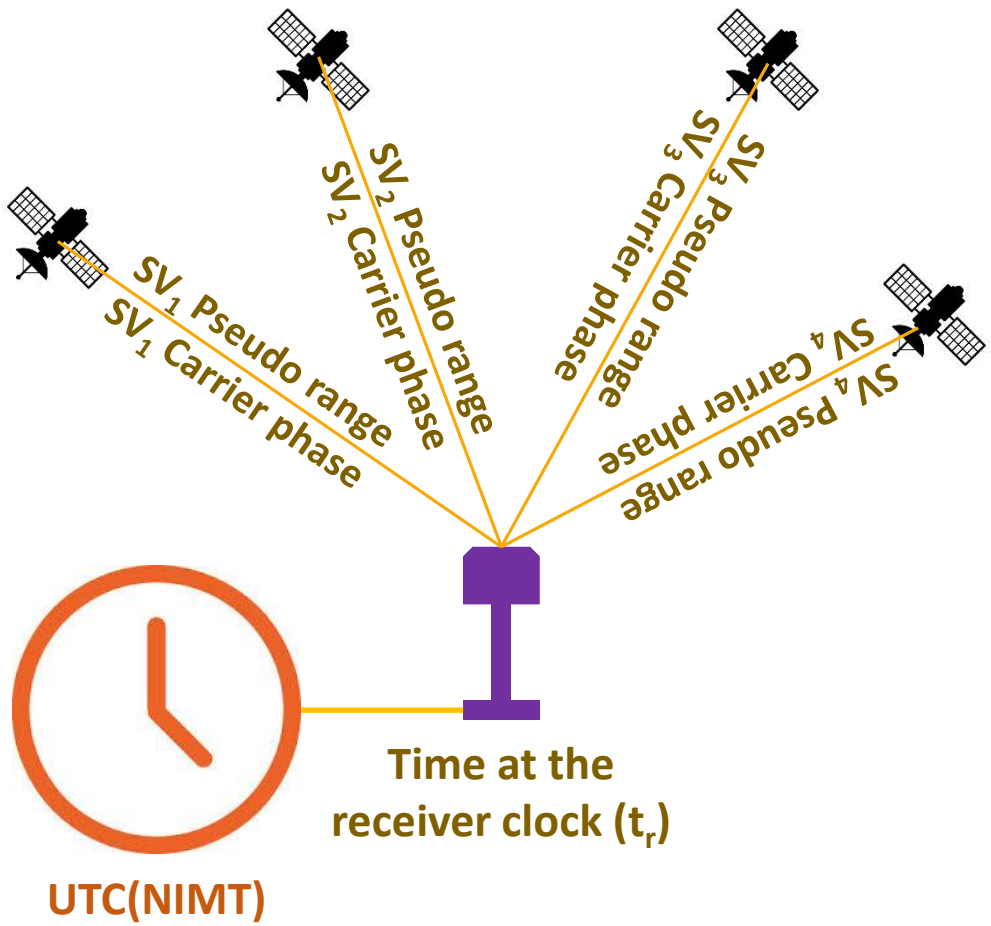
3. Receiver internal delay measurements: PPP



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

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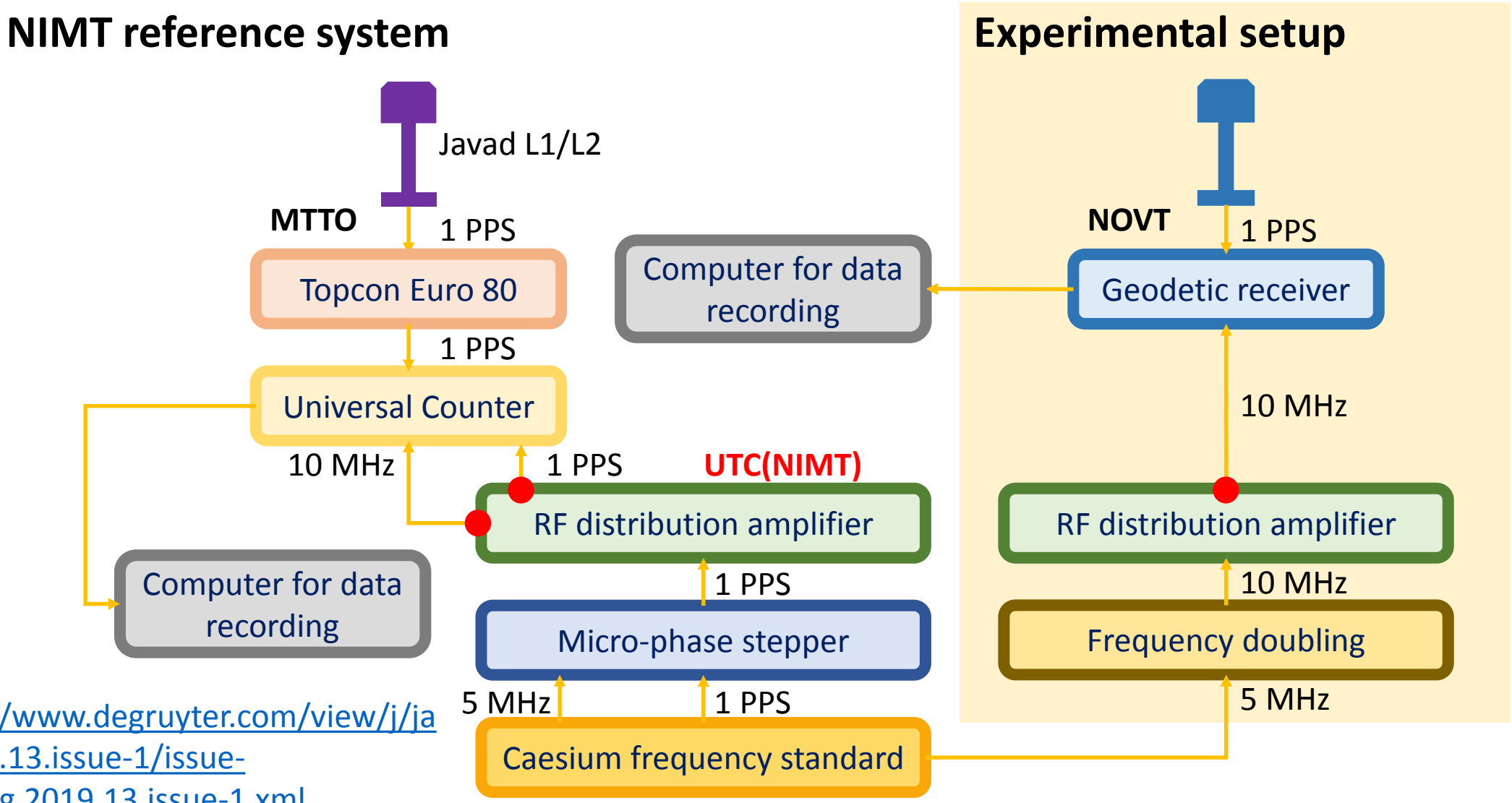
3. Receiver internal delay measurements: PPP



https://www.degruyter.com/view/j/jag.2019.13.issue-1/issue-files/jag.2019.13.issue-1.xml

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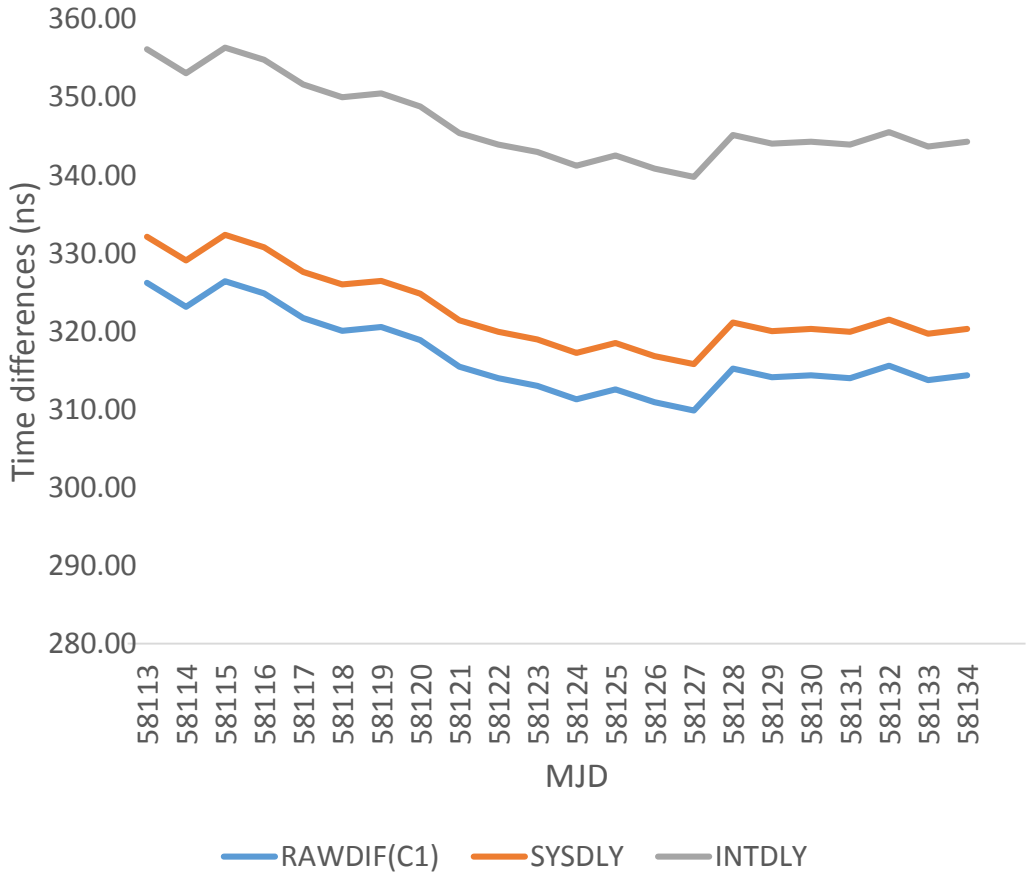
3. Receiver internal delay measurements: PPP



- 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.

Parameter on C1	Time (ns)
Raw difference	316.1
Reference delay	13.0
Cable delay	150.0
Systematic delay	322.0
Internal delay	346.0

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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)

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Acknowledgement

- United Nations Office for Outer Space Affairs
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- Asia-Pacific Metrology Programme
- Chulalongkorn University
- National Institute of Metrology (Thailand)

UNOOSA

USP
THE UNIVERSITY OF THE SOUTH PACIFIC

International Committee on Global Navigation Satellite Systems
ICG

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Thank you for your kind attentions!

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