Live demonstration 2: GNSS receiver operation, set up and calibration Part 1

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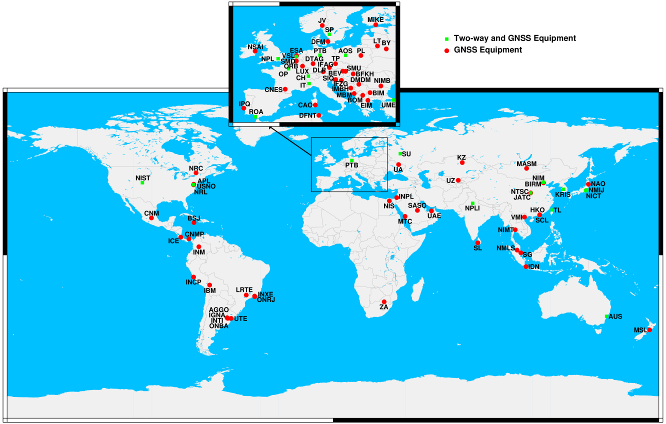
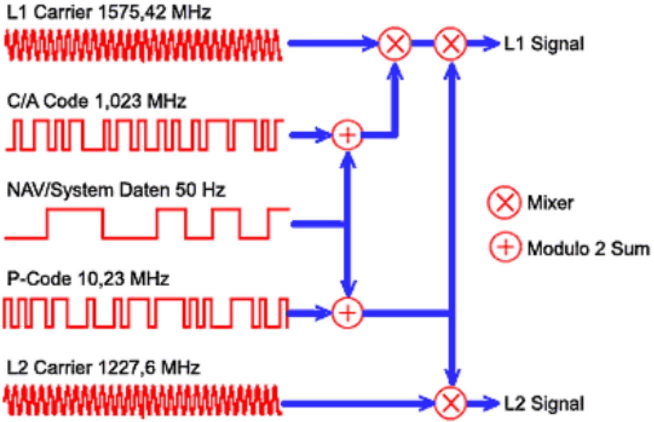
2025-May-08

Geographical distribution of the laboratories that contribute to TAI and time transfer equipment (2024)



GNSS signal structure



Circular T

BUREAU INTERNATIONAL DES POIDS ET MESURES
THE INTERGOVERNMENTAL ORGANIZATION ESTABLISHED BY THE METRE CONVENTION
PAVILLON DE BRETEUIL F-92312 SEVRES CEDEX TEL. +33 1 45 07 70 70 tai@bipm.org

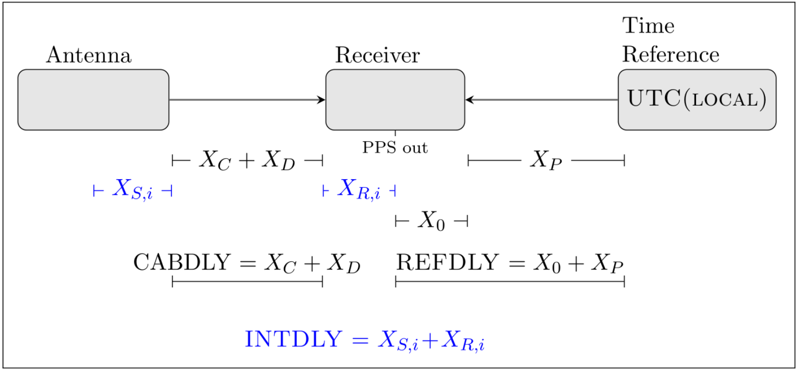
The contents of the sections of BIPM *Circular T* are fully described in the document " Explanatory supplement to BIPM Circular T " available at https://webtai.bipm.org/ftp/pub/tai/other-products/notes/explanatory_supplement_v0.8.pdf

1 - Difference between UTC and its local realizations UTC(k) and corresponding uncertainties. From 2017 January 1, 0h UTC, *TAI-UTC* = 37 s.

Date 2025 0h UTC			JAN 29	FEB 3	FEB 8	FEB 13	FEB 18	FEB 23	FEB 28	Uncertainty/ns		
		MJD	60704	60709	60714	60719	60724	60729	60734	u_A	u_B	u
Laboratory *k*						[*UTC-UTC*(*k*)]/ns						
AGGO	(La Plata)	123	458.7	452.1	452.9	445.6	459.8	446.8	427.9	0.7	2.9	3.0
AOS	(Borowiec)	123	-2.8	-2.6	-2.0	-1.5	-0.4	-0.8	-0.8	0.2	2.6	2.6
APL	(Laurel)	123	0.0	0.5	0.7	1.1	1.8	1.4	1.3	0.2	NC	-

- u_B uncertainty in Circular T is related to the calibration of the GNSS receiver.
- u_B increasases with time since last calibration! Calibration of GNSS stations for UTC (link)
  - until 10 years: $\max[0.4\sqrt{months} - 1, 0]$
  - 10 years: $u = 20ns$
  - After 10 years: 20 ns per year

Definition of delays in a receiver station



The internal delay, INTDLY, depends on the frequency and observable (C1, P1, P2, etc) of the GNSS constellation.

Delays of A Typical GNSS Station

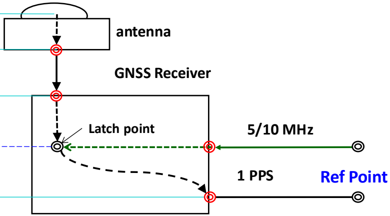
X_S: antenna delay

X_C: antenna cable delay

X_R: receiver hardware delay

X_O: the delay from the receiver 1PPS-in to latch point

X_P: the delay from the reference point to the 1 PPS-in of the receiver



CABDLY = X_C;
INTDLY = $X_S + X_R$
REFDLY = $X_O + X_P$
SYSDLY = CABDLY+INTDLY

Total delay (TOTDLY):
the total electronic delay between the phase center of the antenna and the time reference point
= CABDLY + INTDLY – REFDLY = SYSDLY - REFDLY

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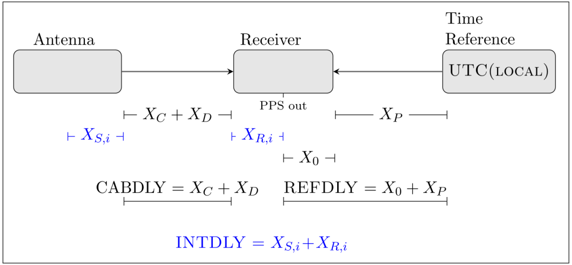
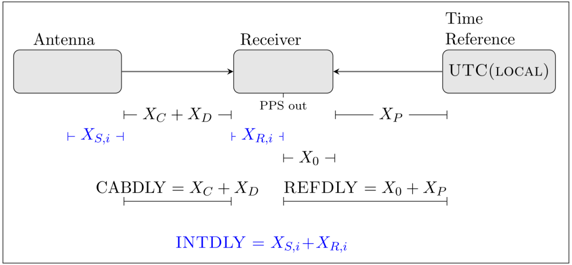
* Slide from Calvin S.Y. Lin, Telecommunication Laboratories, Taiwan

Definition of delays in a receiver station



INTdly The sum $X_R + X_S$ represents the "INT DLY" field in the CGGTTS header: X_R represents the receiver hardware delay, between a reference point whose definition depends on the receiver type and the internal time reference of the measurements. X_S represents the antenna delay, between the phase center and the antenna cable connector at the antenna body. We distinguish the two quantities for the two GPS frequencies, L1 and L2.

Definition of delays in a receiver station



CABdly The sum $X_C + X_D$ represents the "CAB DLY" field in the CGGTTS header. X_C corresponds to the delay of the long cable from the antenna to the input connector at either the antenna splitter or the receiver body directly. If a splitter is installed, X_D corresponds to the delay of the splitter and the small cable up to the receiver body. For a simple set-up with just an antenna cable, $X_D = 0$.

Definition of delays in a receiver station

Other definitions may appear in the literature:

- TOTdly = INTdly + CABdly -REFdly
- SYSdly = CABdly+INTdly

Absolute calibration (not covered here)

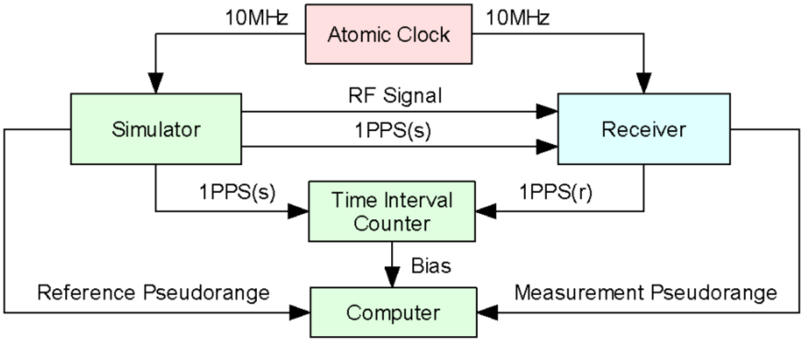
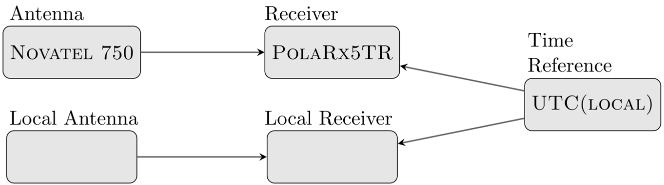


Figure 3. Principle of absolute calibration.

Zhu, F., Zhang, H., Huang, L., Li, X., & Feng, P. (2020). Research on Absolute Calibration of GNSS Receiver Delay through Clock-Steering Characterization. Sensors, 20(21), 6063. https://doi.org/10.3390/s20216063

Common-clock, zero baseline measurement



$$RAWDIF(P1)_{A-B} = \Delta CABDLY_{A-B} + \Delta INTDLY_{A-B} - \Delta REFDLY_{A-B} \tag{1}$$

International organization of calibrations: Absolute, G1, G2, third parties

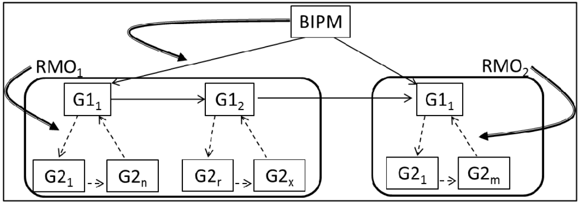


Figure 1: Schema of the GNSS calibration organization for the UTC generation. G1 and G2 refer to Group 1 and Group 2 laboratory, the curved arrows shows the organization responsibility. Solid arrows represent Group 1 trips and dashed arrows

- The selected G1 labs are calibrated by the BIPM every 2 years.
- Others are Group 2 labs. Calibration trips for G2 labs are performed under responsibility of each RMO.
- Each calibration report will be identified by a unique Cal_Id to be used as a reference for the calibration info.
- The calibration uncertainties uCAL for UTC links are set by the BIPM.

International organization of calibrations: Absolute, G1, G2, third parties

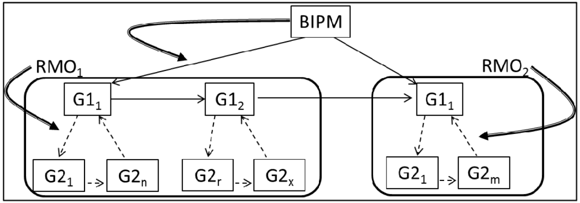


Figure 1: Schema of the GNSS calibration organization for the UTC generation. G1 and G2 refer to Group 1 and Group 2 laboratory, the curved arrows shows the organization responsibility. Solid arrows represent Group 1 trips and dashed arrows

References:

Guidelines for GNSS equipment calibration (link)

BIPM guidelines for GNSS calibration (link)

How-to-get-calibration-March2024.pdf (link)

Calibration procedure for G2 Labs

1. **Calibration trip with closure (CC)**: the G1 calibrates a GNSS traveling station G1-TS (GNSS receiver, cable and antenna) against its BIPM-calibrated reference, sends it to the G2, where G1-TS is installed, connected to UTC(k), and collects data for at least 4 days. Then the G1-TS is sent back to the G1 where closure measurements are performed against the G1 reference. $u \sim 2{,}5\,\text{ns}$.
2. **Direct calibration (DC)** The G2 sends its complete equipment (GNSS receiver, cable and antenna) to the G1. The G2 station is installed at G1 premises and collects data for at least 4 days, to be calibrated against the G1 reference. $u \sim 4\,\text{ns}$.
3. **Authorized third party (A3P)**, which can be a G2 laboratory, a manufacturer of GNSS receivers, or another entity e.g. a laboratory with absolute calibration (AC) facility. The A3P must have their calibration procedure first validated by the BIPM. In the A3P case, all procedures (CC, DC and AC) can be considered. The uncertainty for this A3P calibration will be validated by the BIPM, and will generally be between 5.0 and 7.0 ns.

Description of a Calibration trip with closure (CC)

How to request calibration

PROCEDURE FOR G2 UTC(k) LABORATORIES TO REQUEST A CALIBRATION:

see the list of contacts in RMOs and G1 labs here below

- If your RMO is covered by G1:
  Contact the TCTF G1 Coordinator, if exists. Otherwise contact a G1 laboratory of your RMO
  A G1 lab will organize a DC or a CC
- If there is no G1 laboratory in your RMO (i.e. AFRIMETS and GULFMET):
  contact either a G1 from another RMO or the BIPM that will help find a G1 or organize a DC
- In all cases, the practical aspects of the calibration trip (shipment, customs administrative procedures…) should be considered well in advance of the planned trip.

Group 1 laboratories and contact names (as of 2021)
The list of G1 contacts may be found in the membership of the WG GNSS at
https://www.bipm.org/fr/committees/cc/cctf/wg/cctf-wggnss

APMP TCTF G1 Coordinator: Michael Wouters Michael.Wouters@measurement.gov.au	**NICT** Ryuichi Ichikawa richi@nict.go.jp	**NIM** Zhiqiang Yang yangzq@nim.ac.cn	**TL** Shinn-Yan Lin sylin@cht.com.tw
EURAMET	**ROA** Carmen Velez cvelez@roa.es	**PTB** Florian Heimbach florian.heimbach@ptb.de	**OP (LNE-SYRTE)** Michel Abgrall michel.abgrall@obspm.fr
SIM	**NIST** Bijunath Patla brp1@nist.gov	**USNO** James Hanssen james.hanssen@navy.mil	

Hardware composing a travelling station (TS)

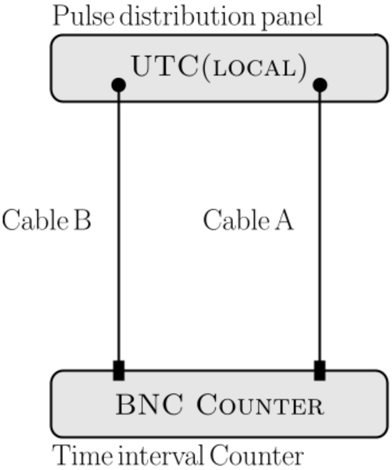
For a case of a Calibration trip with closure (CC), you will receive the following:

- **GNSS Receiver**
- **Antenna**
- **Time interval counter**
- **Antenna cable**
- **Laptop computer**
- Pelikan case + miscellaneous cables

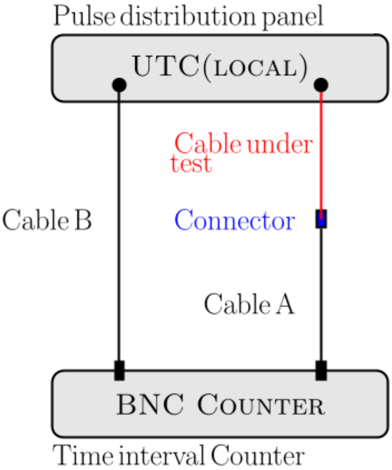
Hardware composing a travelling station (TS)

Measurement of antenna and cable delays

a)



b)



Measurement of antenna and cable delays

Some points to keep in mind

- When measuring with the TIC, use the same trigger level as in the receivers (Usually, 1 V)
- Lock the timebase of your counter to your UTC(k).
- Adapt the impedance to 50 Ω
- An oscilloscope is useful for this. Keep in mind that a 1 GHz bandwidth oscilloscope is needed to see the usual PPS pulses.
- The cable connected to the STOP channel of the counter, shold be longer that the other.
- Usually, around 100 measurements are taken for the computation of mean and std. dev.
- The delay introduced by the connector is usually estimated as 0,1 ns

Measurement of antenna and cable delays. TR Method

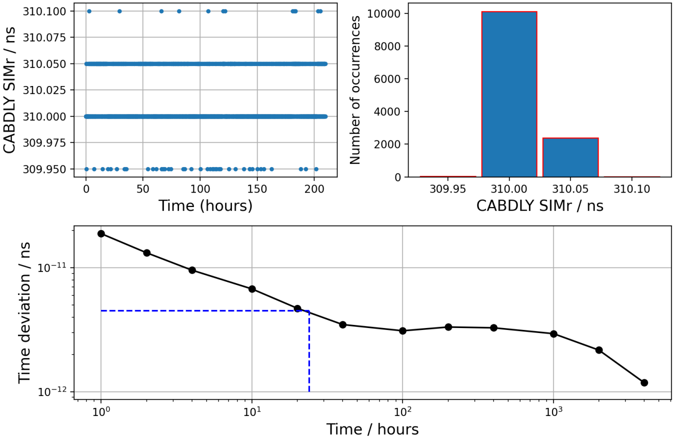
Rovera et. al., Techniques of antenna cable delay measurement for GPS time transfer, 2015 iFCS-EFTF

Measurement of antenna and cable delays

If the antenna cable cannot be unmounted, use the reflection technique:

- Rovera, D., et. al. (2015, April). Techniques of antenna cable delay measurement for GPS time transfer. In 2015 Joint Conference of the IEEE International Frequency Control Symposium & the European Frequency and Time Forum (pp. 239-244). IEEE.
- **An oscilloscope is useful for this. Keep in mind that a 1 GHz bandwidth oscilloscope is needed to see the usual PPS pulses.**
- Do not forget to disconnect the antenna for this measurement!

Antenna cable delay



REFdly: X0 + Xp

Measurement of the delay from reference point to the receiver latch point, $REFdly = X_P + X_O$
XP (delay from REF point to the 1 PPS-in of receiver): Measure the 1 PPS reference cable delay

REFdly: X0 + Xp

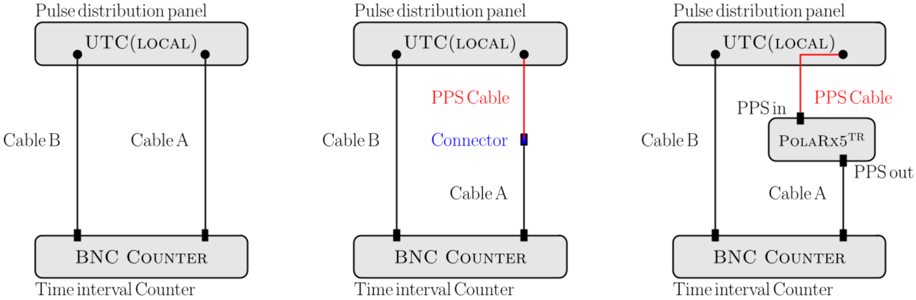
Measurement of the delay from reference point to the receiver latch point, $REFdly = X_P + X_O$
XP (delay from REF point to the 1 PPS-in of receiver): Measure the 1 PPS reference cable delay

XO (From 1 PPS−in to the latch point):

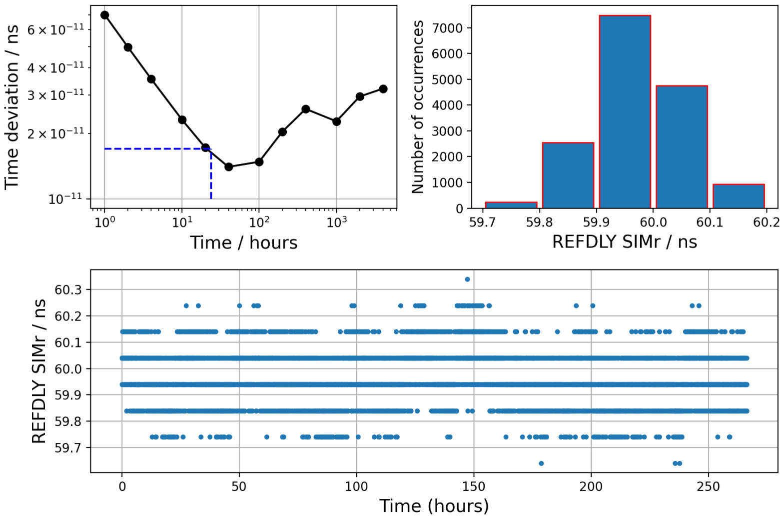
- **Case 1:** The latch point synced with input 1 PPS (Septentrio PolaRx5TR (set the auto compensation on), Piktime TTS−3, TTS−5, MESIT GTR-51/GTR/55), $X_O = 0$, *no need to measure.*
- **Case 2:** The latch point synced with the input frequency and 1 PPS, (PolaRx2, PolaRx3, PolaRx4, PolaRx5 (auto compensation off), Novatel OEM, OEM4, OEM5...), need to measure the REFDLY case by case, see the BIPM GNSS calibration Annex−1 for detail.

X0 output

REFDLY: X0 + Xp (Case 2)



Preliminary Measurements: REFDLY (X0 + Xp)



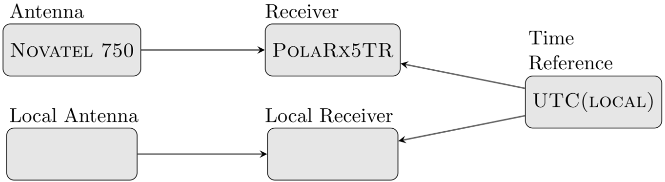
Placement of the antenna

Figure: Position of SIMr antenna with respect to the GTR antenna.

Placement of the antenna




Zero baseline Measurements



$$RAWDIF_{A-B} = \Delta CABDLY_{A-B} + \Delta INTDLY_{A-B} - \Delta REFDLY_{A-B} \quad (2)$$

RAWDIF measurements are for C1, P1, P2, etc. observables.

Report

- Once the measurements are done, you have to share the rawdifference (RINEX) data with the G1 laboratory.
- The measurement files for a single day can take up around 40 MB, depending on the configuration of the receiver.
- You will be asked to provide some information (Annex A)
- The G1 Laboratory will issue a report of the measurements and share it with you. READ IT CAREFULLY!

Annex A

Annex A - Information Sheet

Laboratory:	**INTI**
Date and hour of the beginning of measurements:	
Date and hour of the end of measurements:	

Information on the system

	Local:	**Traveling:**
4-character BIPM code	**INTI**	
Receiver maker and type: Receiver serial number:	DICOM GTR50 S/N: 1203120	
1 PPS trigger level /V:	1	
Antenna cable maker and type: Phase stabilized cable (Y/N):	BELDEN VENLO, HOLLAND 2010 50 ohm. Not stabilized	
Length outside the building /m:	5 (estimated)	
Antenna maker and type: Antenna serial number:	Novatel GPS-702	
Temperature (if stabilized) /°C	-	

Annex A

Measured delays /ns		
	Local:	**Traveling:**
Delay from local UTC to receiver 1 PPS-in (X_P)	8	
Delay from 1 PPS-in to internal Reference (if different): (X_O)	-	
Antenna cable delay: (X_C)	129.3	
Splitter delay (if any):	-	
Additional cable delay (if any):	-	

Data used for the generation of CGGTTS files	
INT DLY (or X_R+X_S) (GPS) /ns:	-30.8
INT DLY (or X_R+X_S) (Galileo) /ns:	-
CAB DLY (or X_C) /ns:	129.3
REF DLY (or X_P+X_O) /ns:	8
Coordinates reference frame:	WGS84
X /m:	2745680.77

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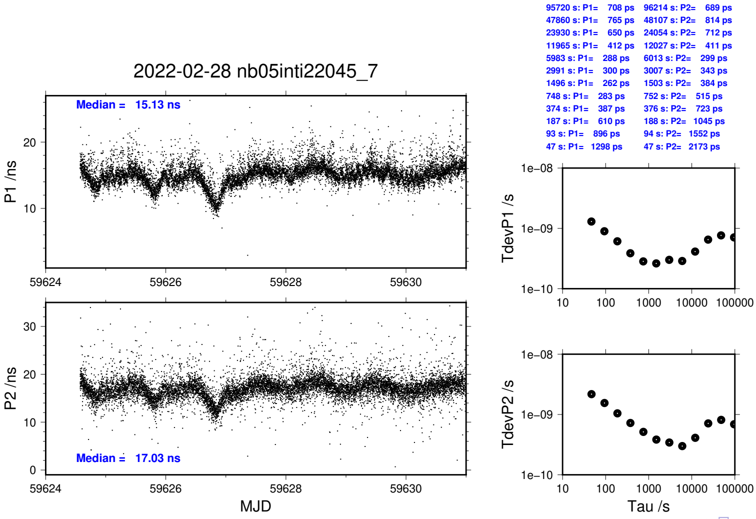
G1 laboratory report (example)



BIPM calibration report

1014-2021 V1.0 / 20220927

GPS calibration of AGGO, ONBA and INTI receivers with respect to NIST G1 (1014-2021)

Summary

From June 2021 to April 2022, the National Institute of Standards and Technology (NIST) conducted a trip to calibrate GPS equipment owned by the Argentinian-German Geodetic Observatory (AGGO), the Observatorio Naval Buenos Aires (ONBA) and the Instituto Nacional de Tecnología Industrial (INTI). The trip started and finished at the NIST, providing closure with respect to the NIST Group1 reference receiver NIST.
The operations and report of measurements are described in the report by NIST.

- **Final results for the calibrated systems**

The INTDLY values of the receivers given in Table 1 have been computed by NIST based on the results of the Group 1 trip 1001-2020 for NIST and should not be updated to reflect later changes in the conventional INTDLY values of the reference receiver.

For a P3/PPP UTC link A-B involving any Group 1 and any receiver in this trip, the uncertainty resulting from the calibration, U_b(A-B), is computed as

BIPM calibration report

$$U_B(A\text{-}B) = (U_{CAL0}^2 + \Delta U_{CAL}(A)^2 + \Delta U_{CAL}(B)^2)^{1/2} \quad (1)$$

where U_{CAL0} = 2.5 ns is the conventional Group 2 value, and where ΔU_{CAL} (generally zero) is specified for each system.

Changes in the set-up of the receivers after the calibration must be accounted for as described in section A.3.6 of the most recent Calibration guidelines in ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/guidelines/.

Table 1. Final P1/P2/C1 INTDLY values from the 1014-2021 exercise. Values of REFDLY and CABDLY during the calibration are also indicated for reference. All values are in ns date in YYYY/MM/DD format. "Meas. Date" refers to the first day of the differential calibration, to which the calibration results can be applied. "Impl. Date" is the MJD when the results should be implemented in the receiver.

System	BIPM ID	Meas. date	INTDLY C1	INTDLY P1	INTDLY P2	REF DLY	CAB DLY	Note	ΔU_{CAL}	Impl. date
TC_2	TC_2	2021/10/16	31.9	30.1	28.3	12.3	207.9		0.0	59850
ON__	ON__	2021/11/07	73.7	-	-	48.9	160.4	(1)	1.5	59850
INTI	INTI	2022/02/14	-37.3	-38.0	-23.0	8.0	129.3	(1)	1.5	59850

Notes:

(1) Significant systematics errors in the differential measurements

Version history

V1.0 2022/09/27: Publication of results from V1 of the NIST report.

Aplication of new calibration values

The BIPM will inform you by email when to apply the new values.
Example: Circular T 417 and 418:

Date 2022 0h UTC	AUG 28	SEP 2	SEP 7	SEP 12	SEP 17	SEP 22	SEP 27	Uncertainty/ns			Notes
MJD	59819	59824	59829	59834	59839	59844	59849	uA	uB	u	
Laboratory k				[UTC-UTC(k)]/ns							
AGGO (La Plata)	815.9	831.0	845.8	853.7	873.3	904.4	911.8	1.0	20.0	20.0	

Aplication of new calibration values

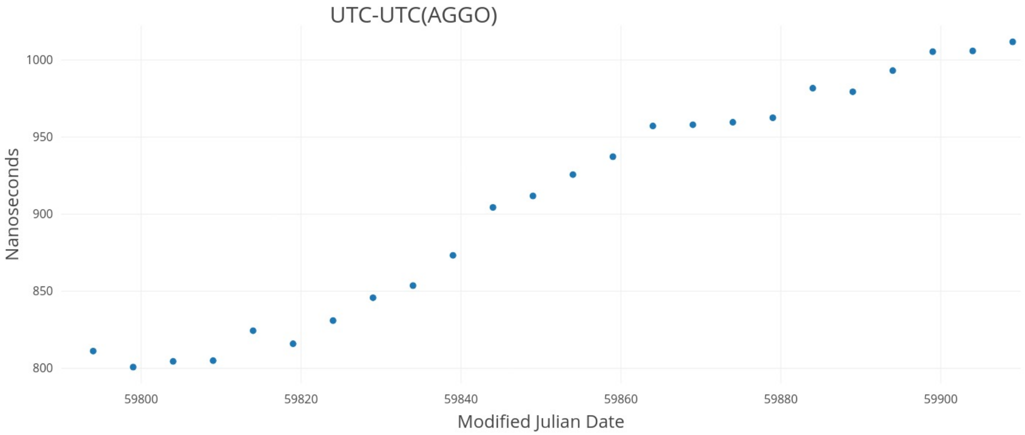
The BIPM will inform you by email when to apply the new values.
Example: Circular T 417 and 418:

Date 2022 0h UTC	AUG 28	SEP 2	SEP 7	SEP 12	SEP 17	SEP 22	SEP 27	Uncertainty/ns			Notes
MJD	59819	59824	59829	59834	59839	59844	59849	uA	uB	u	
Laboratory k				[UTC-UTC(k)]/ns							
AGGO (La Plata)	815.9	831.0	845.8	853.7	873.3	904.4	911.8	1.0	20.0	20.0	

Date 2022 0h UTC	SEP 27	OCT 2	OCT 7	OCT 12	OCT 17	OCT 22	OCT 27	Uncertainty/ns			Notes
MJD	59849	59854	59859	59864	59869	59874	59879	uA	uB	u	
Laboratory k				[UTC-UTC(k)]/ns							
AGGO (La Plata)	911.8	925.7	937.3	957.2	958.0	959.6	962.5	0.7	2.7	2.8	

Aplication of new calibration values

There should be no big step:



5 - Time links used for the computation of TAI, calibrations information and corresponding uncertainties.

Link	Type	Equipment	Cal_ID1	/ Cal_ID2	u_{Stb}/ns	u_{Cal}/ns	u_{Ag}/ns	Al/ns
AGGO/PTB	GPS P3	TC_2 /PT13	1014-2021	/ 1001-2022	0.7	3.0	1.6	
AOS /PTB	GPSPPP	AO_4 /PT13	1012-2024	/ 1001-2022	0.3	2.7	0.9	
APL /PTB	GPSPPP	AP04 /PT13	NC	/ 1001-2022	0.3	NC		

Example of CGGTTS header

```
CGGTTS     GENERIC DATA FORMAT VERSION = 2E
REV DATE = 2023-05-30
RCVR = PolaRx5TR (5.4.0)     sbf2cggtts-1.4.0
CH = 80
IMS = PolaRx5TR
LAB = nist
X = -1288398.600 m
Y = -4721697.050 m
Z = 4078625.450 m
FRAME = ITRF
COMMENTS = LS=18; ElMask=10deg; BIPM Cal_Id name: NISX
INT DLY = 28.8 ns (GPS P1),  26.6 ns (GPS P2)     CAL_ID = 1001-2022
CAB DLY = 275.5 ns
REF DLY = 121.8 ns
REF = UTC(NIST)
CKSUM = c6

SAT CL  MJD  STTIME TRKL ELV AZTH   REFSV      SRSV     REFSYS    SRSYS  DSG IOE MDTR SMDT MDIO SMDI MSIO SMSI ISG FR HC FRC CK
             hhmmss  s  .1dg .1dg   .1ns     .1ps/s     .1ns     .1ps/s .1ns     .1ns.1ps/s.1ns.1ps/s.1ns.1ps/s.1ns
G05 FF 60786 000200  780 165  599     2077929     25           21       14   27 103  231   77  450   41  450   41  19  0   0 L3P 00
```

Description of a Calibration from Authorized third party (A3P)

Description of an A3P calibration

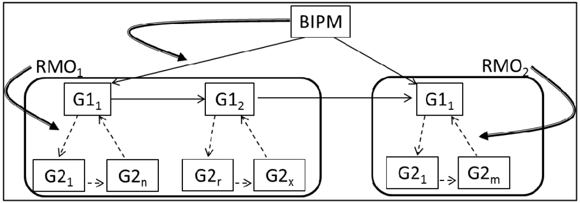
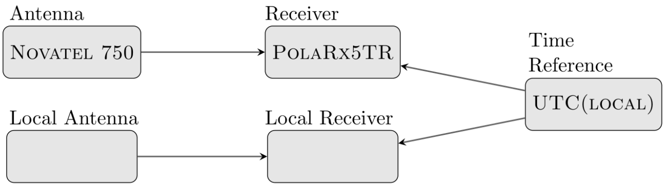


Figure 1: Schema of the GNSS calibration organization for the UTC generation. G1 and G2 refer to Group 1 and Group 2 laboratory, the curved arrows shows the organization responsibility. Solid arrows represent Group 1 trips and dashed arrows

Mainly two cases:

- You acquired a calibrated receiver.
- You acquired a receiver and want to perform an internal calibration

A3P calibration



$$RAWDIF_{A-B} = \Delta CABDLY_{A-B} + \Delta INTDLY_{A-B} - \Delta REFDLY_{A-B} \quad (3)$$

Start with a measurement of the cable delays of the DUT and a zero baseline measurement, like in a G2 calibration.

Processing of the RINEX files: DCLRINEX software

- Will be covered in detail in Part 2
- You will need to download the Navigation files. Go to: `https://cddis.nasa.gov/archive/gnss/data/daily/2024/brdc/`
- Example: BRDC00IGS_R_20241220000_01D_MN.rnx.gz

Some tools that may be needed:

- If files are Hatanaka compressed, use the codes in `https://terras.gsi.go.jp/ja/crx2rnx.html` to pre-process.
- If data intervals are not the same (1 s or 30 s), use the codes in `https://gnss.gfz-potsdam.de/services/gfzrnx` to adjust time intervals.
- If files do not have the duration (hourly vs daily), use also gfzrnx codes).

Excel sheet to calculate

Receptor A:	AGGO
Receptor B:	SIM

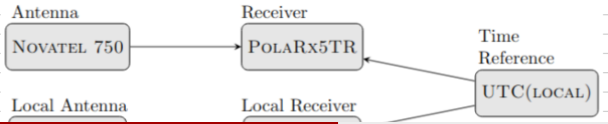
https://webtai.bipm.org/database/calib.html?calid=1014-2021

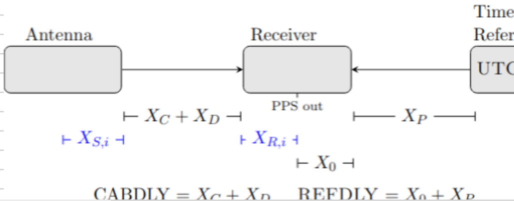
P1		
RawDiff (ns):	-109,44	
INT Dly A (ns):	30,1	
	CAB Dly (ns)	REF Dly (ns)
A	207,9	12,3
B	328,3	13,7
DeltaCab (ns):	-120,4	
DeltaRef (ns):	-1,4	
DeltaInt (ns):	9,56	
INT Dly B (ns):	20,54	

P2		
RawDiff (ns):	-108,87	
INT Dly A (ns):	28,3	
	CAB Dly (ns)	REF Dly (ns)
A	207,9	12,3
B	328,3	13,7
DeltaCab (ns):	-120,4	
DeltaRef (ns):	-1,4	
DeltaInt (ns):	10,13	
INT Dly B (ns):	18,17	

C1		
RawDiff (ns):	-109,75	
INT Dly A (ns):	31,9	
	CAB Dly (ns)	REF Dly (ns)
A	207,9	12,3
B	328,3	13,7
DeltaCab (ns):	-120,4	
DeltaRef (ns):	-1,4	
DeltaInt (ns):	9,25	
INT Dly B (ns):	22,65	

$$RAWDIF(P1)_{A-B} = \Delta CABDLY_{A-B} + \Delta INTDLY_{A-B} - \Delta REFDLY_{A-B}$$





Uncertainties

RAWDIF(P1)	0,1	RAWDIF(P2)	0,1	RAWDIF(C1)	0,1
INTI antenna position	0,05	INTI antenna position	0,05	INTI antenna position	0,05
SIMr antenna position	0,05	SIMr antenna position	0,05	SIMr antenna position	0,05
INTI multipath	0,2	INTI multipath	0,2	INTI multipath	0,2
SIMr multipath	0,2	SIMr multipath	0,2	SIMr multipath	0,2
REFDLY(AGGO)	0,1	REFDLY(AGGO)	0,1	REFDLY(AGGO)	0,1
REFDLY(SIM)	0,1	REFDLY(SIM)	0,1	REFDLY(SIM)	0,1
CABDLY(AGGO)	0,1	CABDLY(AGGO)	0,1	CABDLY(AGGO)	0,1
CABDLY(SIM)	0,1	CABDLY(SIM)	0,1	CABDLY(SIM)	0,1
ua	0,1		0,1		0,1
ub	0,4		0,4		0,4

Calibration Report (example)

Instituto Nacional de Tecnología Industrial
INTI

Ministerio de Economía Argentina

Secretaría de Industria y Desarrollo Productivo

GNSS Calibration Report

Cal_Id: 1-2024
Page 1 of 10

Element	**Object:** GNSS receiver and antenna **Manufacturer / Brand:** Septentrio / Novatel **Model :** PolaRx5TR / GNSS 750 **Serial Number:** 4701626 / 10200001
Required determinations	Calibration of internal delay of a GPS receiver
Calibration date	February de 2024

Calibration Report (example)

3.1 CABDLY and REFDLY measurement

The differences $\Delta CABDLY_{A-B}$ and $\Delta REFDLY_{A-B}$ for INTI(A) and SIMr(B) receivers are given in Table 2, referenced from Annexes at the end of this report. The measurement technique for the cable delays was the one described in [1] as *1 PPS TX technique*.

REFDLY(GTR)	REFDLY(polar)	CABDLY(GTR)	CABDLY(polar)	ΔREFDLY	ΔCABDLY
8.0	60.7	129.3	328.7	-52.7	-199.4

Table 2: REFDLY, CABDLY and their differences between receivers, in nanoseconds

3.2 INTDLY determination

The RINEX files for a pair of co-located receivers during the data acquisition period, MJD column in Table 3, are processed using *dclrinex* software provided by the BIPM that solves for the baseline between the phase centers of the two antennas from L1 and L2 phase differences [2]. Subsequently, the C1, P1 and P2 pseudorange differences are formed after accounting for the baseline. (Figure 5) IT IS IMPORTANT TO NOTICE THAT THE RINEX FILES GENERATED BY THE GTR50 ARE ALREADY CORRECTED FOR INTDLY, CABDLY AND INTDLY.

Pair A-B	MJD	RAWDIF(P1)	RAWDIF(P2)	RAWDIF(C1)
INTI-SIMr	60362-60369	-300.07	-297.2	-301.62

Table 3: Median of RAWDIF$_{A-B}$ between receivers, in nanoseconds. See figure 5 and text.

Pair A-B	MJD	$\Delta INTDLY(P1)$	$\Delta INTDLY(P1)$	$\Delta INTDLY(C1)$
INTI-SIMr	60362-60369	32.1	29.2	33.6

Calibration Report (example)

u^2_{ref} depicts the uncertainty in the reference receiver as detailed in circular T for the calibration period. I.e., the ageing term is included [7] [8].

Systematic and statistical uncertainties are assigned as given in Table 5.

Quantity	unc type	value / ns
RAWDIF(P1)	u_a	0.1
RAWDIF(P2)	u_a	0.1
RAWDIF(C1)	u_a	0.1
INTI antenna position	$u_{b,11}$	0.05
SIMr antenna position	$u_{b,12}$	0.05
INTI multipath	$u_{b,13}$	0.2
SIMr multipath	$u_{b,13}$	0.2
$\mathrm{REFDLY}_{\mathrm{GTR}}$	$u_{b,21}$	0.1
$\mathrm{REFDLY}_{\mathrm{polar}}$	$u_{b,22}$	0.1
$\mathrm{CABDLY}_{\mathrm{GTR}}$	$u_{b,31}$	0.1
$\mathrm{CABDLY}_{\mathrm{polar}}$	$u_{b,32}$	0.1
$\mathrm{INTDLY}_{\mathrm{GTR}}$	u_{ref}	1.7

Table 5: Uncertainty assigned for each station, k=1.

The combined uncertainty given in Table 6 is obtained by combining uncorrelated (assumed) uncertainties in quadrature

Receiver	Model	INTDLY(P1)	INTDLY(P2)	INTDLY(c1)
SIMr	PolaRx5TR	(32.1 ± 3.5) ns	(29.2 ± 3.5) ns	(33.6 ± 3.5) ns

Table 6: INTDLY values, with $k = 2$ uncertainties.

Application of the new calibration values

- Send the calibration report to the BIPM Time Department.
- Apply the changes when indicated.

That's all

Thank you!