SIM GNSS Travelling System: Measurement Procedure

Version 0

SIM Time and Frequency MWG5[⋆,†]

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Revision History

Version	Date	Who	Changes's description
0	April 2024	DAL	First version, all new

List of Acronyms

CAB DLY	Delay in the antenna cable
DUT	Device Under Test
CGGTTS	Common GNSS Generic Time Transfer Standard
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
INT DLY	Internal delay of GNSS receiver
INTI	Instituto Nacional de Tecnología Industrial
PPS	Pulse per second
REF DLY	Delay of the cable between the reference point and the PPS-in connector of a receiver
RINEX	Receiver Independent Exchange
SIM	Sistema Interamericano de Metrología
TDEV	Time deviation
UTC	Coordinated Universal Time

Table 1: Acronyms used in this procedure

Part I

Traveling System Operator Manual

1. Overview

The current procedure follows as much as possible the documents *BIPM guidelines for GNSS calibration* [3] and *How to get GNSS calibration for UTC(k) laboratories* [4].

As mentioned in [3], *All laboratories contributing to UTC are equipped with GNSS receivers, almost all of them providing the official time link, either by one-technique links (GPS or Galileo) [...]. The characterization of the delays in the time transfer equipment (here referred to as "calibration") is essential to the accuracy of time transfer and time dissemination. The set of GNSS equipment in laboratories used for time transfer in UTC needs to be calibrated, and the system is to be maintained through a programme of repeated calibrations over time.*

The calibration of a time and frequency station includes the measurement of several delays. They are depicted in figure 1 and explained afterwards.

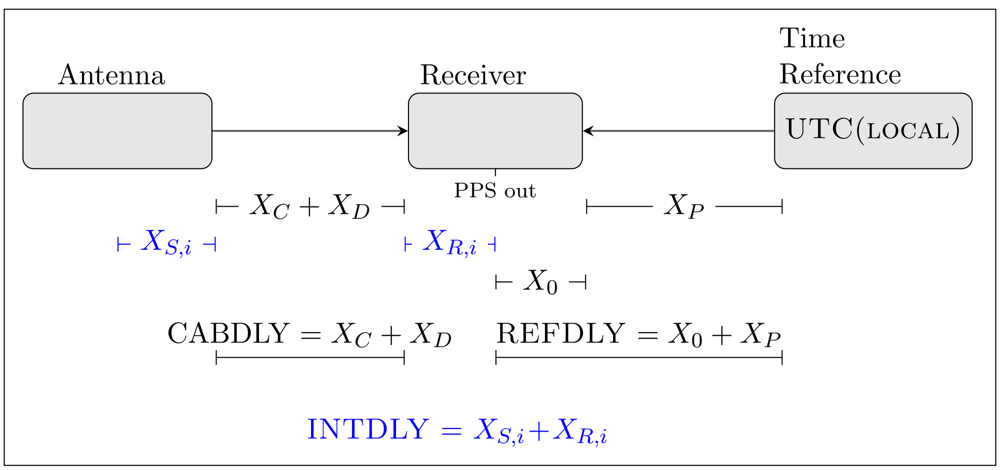


Figure 1: Definition of delays in a receiver station

1. **INT DLY** 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, f1 and f2.

   The following terms are considered frequency independent, i. e. no distinction is made for f1 and f2.

2. **CAB DLY** 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, $X_D = 0$.

3. **REF DLY** The sum $X_P + X_O$ represents the "REF DLY" field in the CGGTTS header. X_P corresponds to the delay of the cable between the laboratory reference point for local UTC and the 1 PPS-in connector of the receiver.

CABDLY and X_P are delays generated by cables which have to be measured by the visited laboratory.
The internal delay of the visited receiver will be determined by with the use of the traveling receiver and using the zero-baseline technique. (Figure 2)

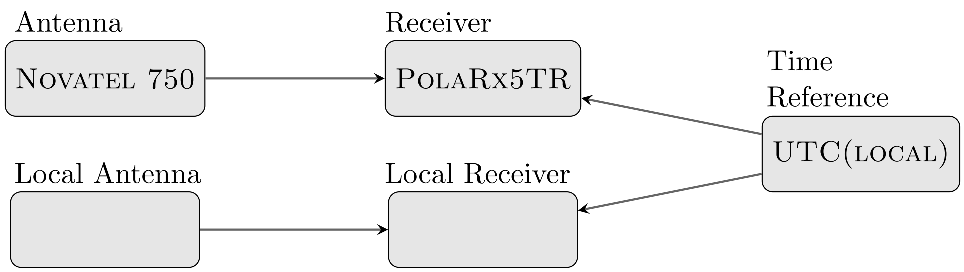


Figure 2: Zero baseline measurement

The difference of the total delay for a pair of co-located receivers is the sum of the delays incurred in the antenna cable (CABDLY) and the internal delay(INTDLY), minus the time offset at the latching point of the receiver as referenced to a fixed point, usually UTC(k)(REFDLY). The internal delay is comprised of both code- and frequency-dependent delays in the antenna and the receiver. After accounting for the baseline geometry, the difference in pseudoranges between a pair of receivers, say for P1, is given by

$$RAWDIF(P1)_{A-B} = \Delta CABDLY_{A-B} + \Delta INTDLY_{A-B} - \Delta REFDLY_{A-B} \tag{1.1}$$

2. Equipment

The SIM traveling is composed of the elements depicted in table 2.

Quantity	Element	Model	Serial Number
1	Laptop	Dell Latitude 7300	9SVR2R2
1	GNSS Receiver	PolaRx5TR	4701626
1	Frequency Counter	Berkeley Nucleonics 1105	TW00048101
1	GNSS Antenna	Novatel GNSS 750	10200001
1	Antenna Cable	LMR LW400	-
2	Cable	LMR 240	-
1	Case	Pelican 1690 Case	-

Table 2: System's elements.

2.1. SIM laptop

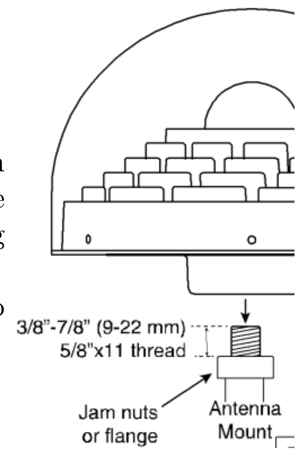
Please use the following to log in to the SIMr travelling System laptop:

Username: denali

Password: nistg2cal

2.2. Antenna

A robust pillar or mount with a 5/8" x 11 thread that extends between 3/8" and 7/8" (9 mm and 22 mm) is required to set up the antenna. The weight of the antenna is 7.6 kg. Please consider this fact when mounting it. Make sure the antenna has a clear view of the sky.
Connect one end of the antenna cable to the antenna and the other end to the rear-panel 'Main' socket on the PolaRx5TR.



Antenna mount. (From GNSS 750 manual)

2.3. Frequency Counter

The traveling frequency counter must be referenced the local 10 MHz reference.

2.4. GNSS receiver

Part II
Measurement Procedure

3. Cable Delays Measurements

The visited laboratory must inform CABDLY and REFDLY of the local receiver. This means that the laboratory will have to determine the delay of two cables and (depending on the receiver model), the value of X_0. The method sugested for this measurements is the depicted in figure 3.

Measurement 1) corresponds to a tare. Then the cable under test and a connector must be added to the channel 2 of the time interval counter. The measurement equation for this procedure is

$$Delay = [\text{Delay measured at 2)}] - [\text{Delay measured at 1)}] + corrections \tag{3.1}$$

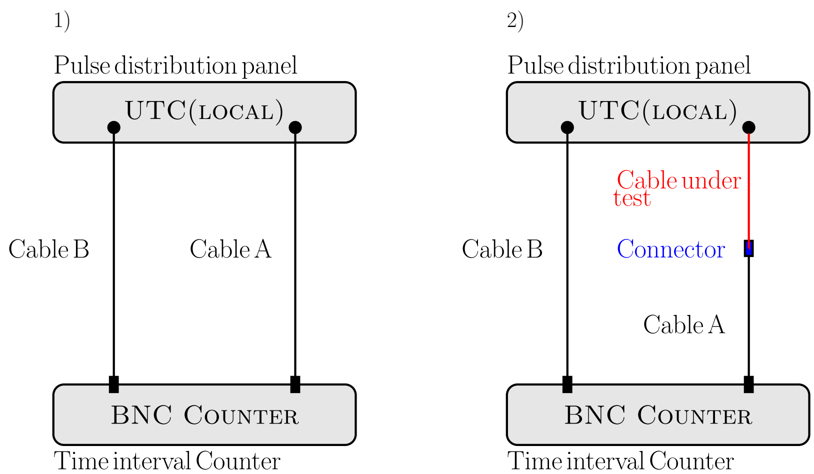


Figure 3: Measurement sequence for the determination of delays. Cable B must be conected to channel 1 of the counter.

The corrections are the estimated delay introduced by adaptator: -0.1 ns.

Cable delays must be measured using the counter included in the traveling system. By enabling the "RECALL 1" memory, 100 time interval measurements are done. To do this, press the *SAVE & RECALL* button from the front panel of the counter. Then select *Recall* and option 1 (This should be the only memory stored). Then press *Run Recall*.

In this configuration, a 1 V trigger level is applied on both channels, together with a DC coupling and a 50 Ω impedance.

The display will present the mean value of the delay between Channel 1 and Channel2, averaged over 100 measurements. The standard deviation is also shown.

If you cannot unmount the antenna cable to perform this measurement, the refelection technique explained in [1] is recommended. Please contact `luna@inti.gob.ar` in this case.

4. GNSS measurements with SIMr receiver

4.1. REF DLY ($X_0 + X_P$) Measurement

Before starting logging data of the traveling receiver, it is necessary to measure the value of the phase relationship between the 10 MHz reference and the 1PPS input (REF DLY). For that:

1. Connect the antenna cable, 10 MHz reference and the 1 PPS to the PolaRx5^{TR}receiver as shown in figure 4
2. Power the receiver on.
3. Connect Cable A to PPS out of PolaRx5^{TR}. Switch the receiver power. Wait for a few minutes for the receiver to lock with the external reference. A stable output of the TIC is indicative of a firm lock.
4. Turn on the WiFi by firmly ressing the front-panel WiFi button to turn on the WiFi modem.

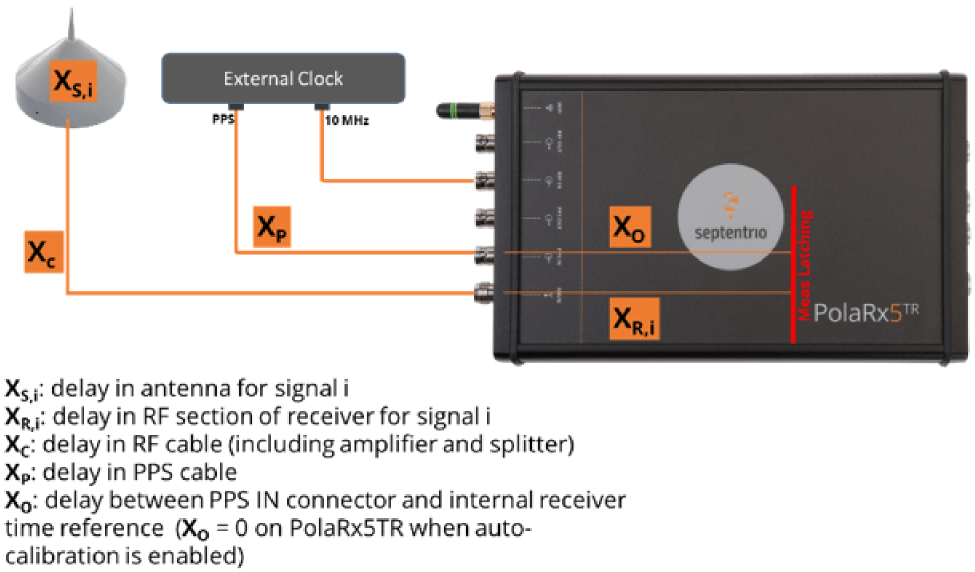


Figure 4: PolaRx5$^{\mathrm{TR}}$connections. From receiver user-interface.

5. Find the PolaRx5$^{\mathrm{TR}}$WiFi signal on the SIM laptop and click: **Connect**
6. When connected, open the web browser and go to the ip 192.168.20.1
7. Check if the PolaRx5$^{\mathrm{TR}}$is tracking satellites by selecting the 'GNSS' tab and then 'Satellites and Signals'. The SIMr should track between 15 and 25 GPS and Glonass satelites. The Carrier-to-Noise plot for the GPS should show about 3 satellites with an L1CA above 50 dB-Hz.

Please fill the table *Annex: REF DLY measurement* of the Appendix with the measurement results of steps a), b) and c) in figure 5

4.2. RAWDIFF Measurement

Once in the webpage of the PolaRx5$^{\mathrm{TR}}$, follow these steps to start a measurement:

- In the *Timing* section, make sure the option *Enable compensation of PPSIN internal delay* is OFF.
- Go to the *Logging* section and then click on the *Log Sessions* option.
- Then click on the *Create* button on any unused Log session.
- In the Edit Session section, assign a Session Name to the measurement.
- Go to the RINEX tab and click on the *Configure RINEX Logging* button. In this menu, select the GNSS measurements to log (usually only GPS constellation is enough) and click OK. In the *RINEX file duration* option, select 24 hours. For *Observation interval*, select 30 seconds.

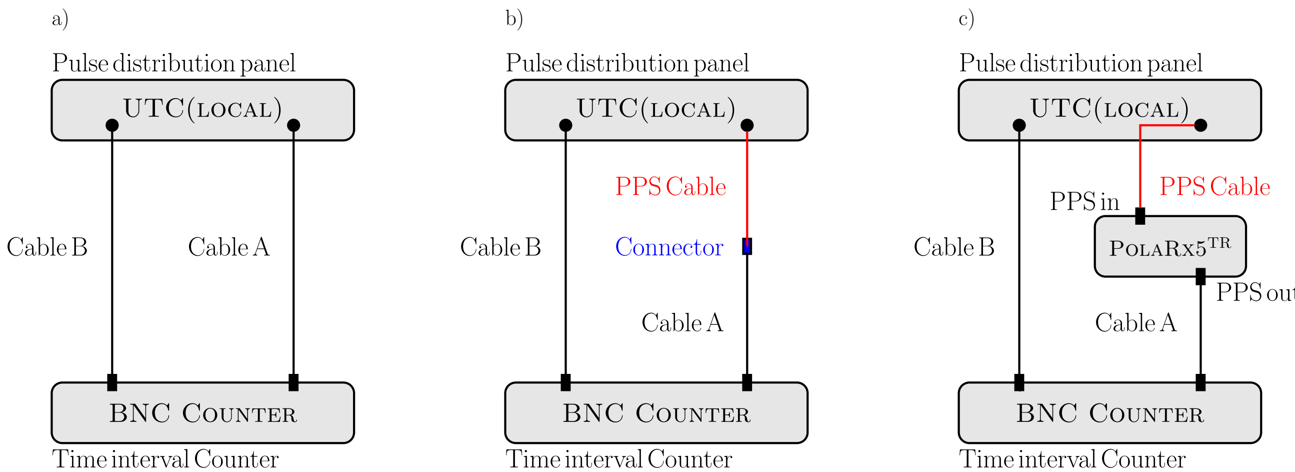


Figure 5: Measurement sequence for the determination of the value of phase relationship between the 10 MHz reference and the 1PPS input (X_0). The "PPS cable " is not part of the traveling system. Cable B must be connnected to channel 1 of the counter.

- Go to the CGGTTS tab and go to *Configure CGGTTS logging*. Select the GNSS constellation to log CGGTTS for (usually only GPS constellation is enough) and click OK.
- Finally, press OK on the *Edit Session LOG* menu.

After these steps, an active log session should be visible. (Figure 6).

After a few minutes, go to the *Logging* and select *Disk Contents*. You should see there the ongoing measurement. From the same menu, you will be able to download the data to the laptop after the 10 days of measurement.

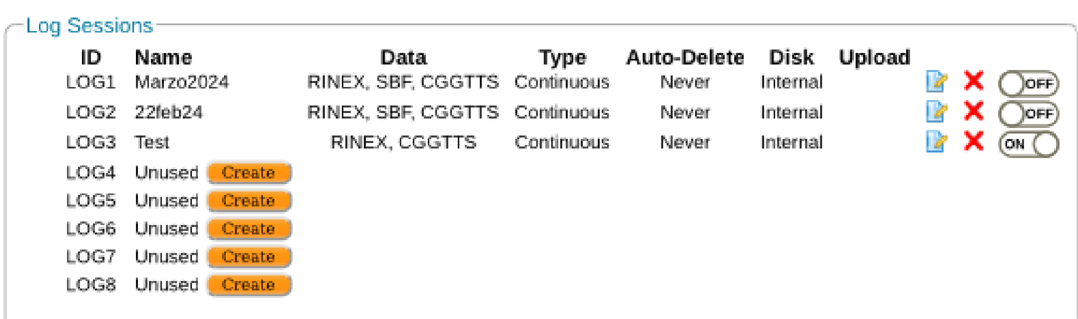


Figure 6: PolaRx5^{TR}connections. From receiver user-interface.

References

[1] Rovera, D., Abgrall, M., Uhrich, P., & Siccardi, M. (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.

[2] ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/doc-soft/

[3] https://webtai.bipm.org/ftp/pub/tai/publication/gnss-calibration/guidelines/bipmcalibration_guidelines_v40.pdf

[4] https://webtai.bipm.org/ftp/pub/tai/publication/gnss-calibration/guidelines/How-to-get-calibration-March2024.pdf

[5] BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP, and OIML. Evaluation of measurement data — An introduction to the “Guide to the expression of uncertainty in measurement” and related documents. Joint Committee for Guides in Metrology, JCGM 104:2009. https://www.bipm.org/documents/20126/2071204/JCGM_104_2009.pdf/19e0a96c-6cf3-a056-4634-4465c576e513

[6] JCGM 100:2008: Evaluation of measurement data — Guide to the expression of uncertainty in measurement https://www.bipm.org/documents/20126/2071204/JCGM_100_2008_E.pdf/cb0ef43f-baa5-11cf-3f85-4dcd86f77bd6

[7] https://webtai.bipm.org/ftp/pub/tai/Circular-T/cirt/cirt.434

[8] https://webtai.bipm.org/ftp/pub/tai/other-products/notes/explanatory_supplement_v0.6.pdf

Appendices

Annex: X0 measurement

Initial Measurement

Date:

Place:

Receiver (traveling or visited):

Temperature:

Measurement	Mean / ns	Standard deviation / ns
a)		
b)		
c)		

Final Measurement

Date:

Place:

Receiver (travelling or visited):

Temperature:

Measurement	Mean / ns	Standard deviation / ns
a)		
b)		
c)		

Laboratory		
Date and hour beginning of measurements		
Date and hour end of measurements		
Information of the system		
	Local	**Traveling**
4-character BIPM code		--
Receiver maker and type Receiver serial number		Septentrio PolaRx5TR
1 PPS trigger level /V		1
Antenna cable maker and type Phase stabilized cable (Y/N)		LMR-LW400 Times Microwave Systems
Cable length outside building /m		80 (estimated)
Antenna maker and type Antenna serial number		Novatel GNSS 750 10200001
Temperature if stabilized /°C		-
Measured delays / ns		
	Local	**Traveling**
Delay from local UTC to receiver 1 PPS-in (XP)		
Delay from 1 PPS-in to internal Reference (if different): (XO)		
Antenna cable delay (Xc)		328.7 ± 0.5
Splitter delay	-	-
Additional cable delay	-	-
Data used for the generation of CGGTTS files		
	Local	**Traveling**
INT DLY (GPS) /ns		
INT DLY (Galileo) /ns		
CAB DLY /ns		328.7
REF DLY /ns		
Coordinate reference frame		
Latitude or X /m		
Longitude or Y /m		
Height or Z /m		
General Information		
Rise time of local UTC pulse		
Air conditioning (Y/N)		
Set temperature value and uncertainty		
Set humidity value and uncertainty		