

# Annex 1

## Operational procedures for a visit of the traveling equipment

### Table of Contents

1. General information on the realization of one visit .....	2
2. Definitions and measurement procedures for local GNSS systems .....	3
Annex A - Information Sheet .....	6
Annex B – Description and operation of the traveling system: B3TS .....	9
Annex C - Description and operation of the traveling system: BP1K .....	16
Annex D - Z12T measurement procedure .....	21
Annex E - PolaRx measurement procedure .....	25
Annex F - GTR measurement procedure .....	27
Annex G - TTS-4 measurement procedure .....	28
Annex H - Novatel measurement procedure .....	29

### Revision history

July 2013:	G. Petit, W. Lewandowski, Z. Jiang, F. Arias, L. Tisserand
April 2014:	G. Petit, W. Lewandowski, Z. Jiang, F. Arias, L. Tisserand
October 2014:	G. Petit, Z. Jiang, F. Arias, L. Tisserand
November 2014:	S. Römisch
January 2015:	G. Petit (edition, without significant change)
February 2015:	L. Tisserand (move point 3 to Annex B & C and update)
June 2015:	L. Tisserand (Annex D update)
February 2016:	L. Tisserand (Annex B update)
August 2017:	L. Tisserand (Annex B & C update)
October 2018:	L. Tisserand (Adding receivers PolaRx5, GTR55 & update Annex E, F; Update annex B for new equipment in B3TS; mention possibility of Galileo measurements)
March 2019:	L. Tisserand (Update annex B for new equipment in B3TS)

This document provides the necessary information to perform measurements during the visit of the traveling equipment. It is established for “Group 1” calibration trips which are organized by the BIPM using BIPM traveling equipment. It could be expanded, with the necessary changes, to any traveling equipment e.g. as would be used for “Group 2” calibration trips performed by RMOs or individual laboratories.

## 1. General information on the realization of one visit

The traveling system should be set-up according to the following general rules:

- The location of its antenna should take into account the multipath environment (reflecting surfaces), masks. It should be oriented according to manufacturer specs.
- The provided antenna cable should be used; connectors must be tightened;
- The receiver should be in the same environment as the local receivers;
- The input frequency and the 1 PPS in should be derived from the same reference as for the local systems; the cables provided with the traveling equipment should be used for transporting the 1 PPS and the frequency.

The necessary measurements to relate the laboratory reference (in general UTC(k)) to the reference point (“internal reference”) of the traveling and local receivers should be carried out at the beginning and end of the visit and reported (see Annex A). See section 2 for the definitions and measurement procedures relative to local systems considered. These measurements will provide the “REFDLY” value to be used in the CGGTTS format.

For the BIPM traveling systems, a complete description including the operations for proper set-up can be found in Annex B for the system B3TS that includes two receivers, and in Annex C for the BPIK TTS-4 receiver. The measurements necessary to link the laboratory reference to the internal reference of each receiver are described in the annex relevant to each receiver.

If possible, the antenna cable delay of the local systems should be measured and reported (see Annex A). **In general such measurements should be done before the installation of the system; it is not recommended to disturb the set-up of an operational equipment to measure the antenna cable delay. Although this option is accepted, it is not recommended to use a splitter to feed more than one receiver.** If reported, it will provide the “CABDLY” value in the CGGTTS format and the calibration result will be relative to the system (receiver + antenna) and will provide the “INTDLY” value in the CGGTTS format. If not reported, the calibration result will be relative to the total system (receiver + antenna cable + antenna) **and will be reported as SYSDLY in the CGGTTS V2E format<sup>1</sup>.**

The relative positions between the local and traveling antennas should be known with an uncertainty of order (at most) a few cm.

- When Rinex files are available, **the relative positions will be determined during the analysis and no special measurement is necessary.**
- When Rinex files are not available, local topographic measurements from the traveling antenna to the local antenna should be carried out and reported (Annex A).

Four days to one week of measurements should be taken:

- For the calibration of geodetic-type receivers (providing at least GPS P1/P2 codes, also GPS C1 code and Galileo E1/E5a codes if planned in the trip), the measurements are done with a 30s data interval and stored in daily RINEX files. If Galileo codes are to be reported, the RINEX format should allow reporting them. If CGGTTS files are available from the local systems, they should be provided as well.

---

<sup>1</sup> If the CGGTTS V2 format is used, the result will appear in the “INTDLY” value with the “CABDLY” value set to zero.

- For the calibration of multi-channel receivers (GPS C1 code only), the measurements are stored in CGGTTS files.

For safety reasons, the data from the traveling and local systems should be recorded on an independent storage medium and kept by the laboratory until the end of the calibration trip. They should also be sent electronically to the BIPM (or made available on a server).

Information of connection on the BIPM FTP server:

- URL address: tai.bipm.org

- Username/Password: the same FTP account than for UTC/UTCr data submission

Put files in remote directory /temp/TRIP\_ID/LABO where TRIP\_ID is the identifier of the calibration trip and where LABO is the acronym of the laboratory.

The following information should be provided in annex A:

- The information sheet (one for each local system) including:
  - Information on the systems;
  - Measured delays from the local UTC(k) to the internal reference, at the beginning and end of the visit;
  - Measured antenna cable delay, if possible;
  - Parameters used for the generation of CGGTTS files, if available (these parameters should also appear in the CGGTTS header);
  - **All measured values should be accompanied by an estimated uncertainty (one standard deviation) and should be given with a numeric precision well below the estimated uncertainty to mitigate rounding errors at a later stage.**
- One diagram describing the actual set-up, for both the traveling and the local systems, with indication of all measured delays,
- A log of events,
- Additional information:
  - Details on the measurements from the local UTC(k) to the internal reference, at the beginning and end of the visit;
  - local topographical measurements, if needed;

## 2. Definitions and measurement procedures for local GNSS systems

The procedure to relate the internal reference of the system to the laboratory reference is presented below. It should be carried out at the beginning and the end of the visit (to check for stability and possible mistake), for the all systems. Three types of systems are defined ([the list of described systems will be updated as information becomes available](#)):

- The internal reference is the 1PPS-in: see section 2.1.  
Examples of such systems are all C/A only receivers, PikTime TTS-3, Dicom GTR50 or GTR51, and Mesit GTR51 or GTR55.
- The 1PPS-out defines the internal reference: see section 2.2.  
Examples of such systems are Septentrio PolaRx2, PolaRx3, PolaRx4 or PolaRx5 and Novatel OEM4, OEM5 or OEM6.
- Other cases: see section 2.3.  
Examples of such systems are Ashtech Z12T metronome, PikTime TTS-4.

In all cases, the delay from the laboratory reference UTC(k) to the 1PPS-in at the receiver's input should be measured and reported. To perform this measurement a time interval counter with sub-nanosecond precision should be used, and the set-up of inputs of the time interval counter should be: trigger level 1.0 V, DC, 50 Ω, rising edge. The measurement of the delay between the PPS-in at the receiver's input and its internal reference point (defined according to the list below) will be performed according to the instructions detailed in Annex D through H.

$REFDLY = (\text{delay between UTC(k) and PPSin}) + (\text{delay between PPSin and Receiver's internal reference point})$ .

## 2.1 Internal reference is 1PPS-in

### 2.1.1 C/A only receivers

No additional measurements necessary.

### 2.1.2 Dicom GTR50 or GTR51, Mesit GTR51 or GTR55

No additional measurements necessary.

It is however necessary to check and report the values of some parameters, see details in Annex F.

### 2.1.3 Piktime TTS-3

No additional measurements necessary.

## 2.2 Internal reference defined by 1PPS-out

### 2.2.1 Septentrio PolaRx2, PolaRx3, PolaRx4 or PolaRx5

For PolaRx2 with firmware 2.3 and higher, the internal reference has been defined by Septentrio as 1PPS-out - 8.7 ns. This definition is retained for continuity with past results.

For PolaRx3, PolaRx4 and PolaRx5, the internal reference is conventionally defined as 1PPS-out.

- Synchronize the 1PPS output signal from the PolaRx receiver with the measurement latching epoch using the command: **setPPSParameters**. This is done by setting the *TimeScale* argument of the **setPPSParameters** command to "Local" for PolaRx2 receiver, or "RxClock" for PolaRx3, PolaRx4, PolaRx5 receiver.
- Measure the delay between the 1PPS-in and 1PPS-out.

See a more detailed description in Annex E.

### 2.2.2 Novatel OEM4, OEM5 or OEM6

While the internal reference for Novatel receivers is not explicitly defined, "the 1PPS strobe timing is directly tied by hardware to the receiver time" (from Novatel Application Note 15), making PPS out the best choice for it. For all the receivers' families mentioned above, the following commands must be issued to the receiver to set it up correctly:

- **ppscontrol enable positive 1.0 0** (enables PPS out as a positive pulse)
- **markcontrol mark1 enable positive 0 0** (enables the PPS in as a positive pulse)
- **adjust1pps mark once** (brings PPS out close to PPS in, just once)

At this point the delay between PPS out and PPS in at the receiver's input can be measured. See details in Annex H.

## 2.3 Other cases

### 2.3.1 Ashtech Z12-T

The internal reference had been defined by Ashtech as the 20 MHz-in inverted, first positive zero crossing following the 1PPS-in, delayed by 15.8 ns. This definition is retained for continuity with past results.

The measurement procedure is the following (see a more detailed description in Annex D)<sup>2</sup>.

Measurement 1) Measures the delay between the laboratory reference 1PPS @ 1V and the 20 MHz in (inverted, zero crossing) connecting them directly to the oscilloscope.

This should be performed before starting and after stopping operation. **Note: This measurement will be used to compute the calibration results.**

Measurement 2) Measure the delay between the laboratory reference 1PPS @ 1V vs. 20 MHz out (positive zero crossing) (oscilloscope range 20 mV). **Note: 20 MHz out is not available on all systems.** [20 MHz out should trail inverted 20 MHz in by 18.2 ns]

### 2.3.2 PikTime TTS-4

Only for TTS-4 receiver software not older than version 2.35 and which has been factory calibrated by the manufacturer.

The phase difference between the laboratory reference 1 PPS and the 5 or 10 MHz reference frequency at the receiver's inputs has to be measured.

For the measurement procedure see detailed instructions in Annex G.

The obtained result has to be introduced into the receiver configuration as "User reference frequency to 1PPS offset" in order to allow the receiver to generate the value that PikTime names "Total delay", which is the delay from the laboratory reference UTC(k) to the TTS-4 internal reference (the so-called REFDFLY of the CGGTTS format).

---

<sup>2</sup> [This procedure should be reviewed by experts of the CCTF Working group on GNSS](#)

## Annex A - Information Sheet

(to be repeated for each calibrated system)

Laboratory:		
Date and hour of the beginning of measurements:		
Date and hour of the end of measurements:		
<b>Information on the system</b>		
	<b>Local:</b>	<b>Travelling:</b>
4-character BIPM code		
• Receiver maker and type: Receiver serial number:		
1 PPS trigger level /V:		
• Antenna cable maker and type: Phase stabilised cable (Y/N):		
Length outside the building /m:		
• Antenna maker and type: Antenna serial number:		
Temperature (if stabilised) /°C		
<b>Measured delays /ns</b>		
(if needed fill box "Additional Information" below)		
	<b>Local:</b>	<b>Travelling:</b>
• Delay from local UTC to receiver 1 PPS-in:		
Delay from 1 PPS-in to internal Reference (if different): <small>(see section 2 for details)</small>		
• Antenna cable delay:		(1)
Splitter delay (if any):		(1)
Additional cable delay (if any):		(1)
<b>Data used for the generation of CGGTTS files</b>		
• INT DLY (GPS) /ns:		
• INT DLY (Galileo) /ns:		
• INT DLY (GLONASS) /ns:		
• CAB DLY /ns:		
• REF DLY /ns:		
• Coordinates reference frame:		
Latitude or X /m:		
Longitude or Y /m:		
Height or Z /m:		
<b>General information</b>		
• Rise time of the local UTC pulse:		
• Is the laboratory air conditioned:		
Set temperature value and uncertainty:		
Set humidity value and uncertainty:		

**(1) For a trip with closure, not needed if the traveling equipment is used in the same set-up throughout.**

**Diagram of the experiment set-up:**

**Log of Events / Additional Information :**



## Annex B – Description and operation of the traveling system: B3TS (BIPM Time Transfer Traveling System)

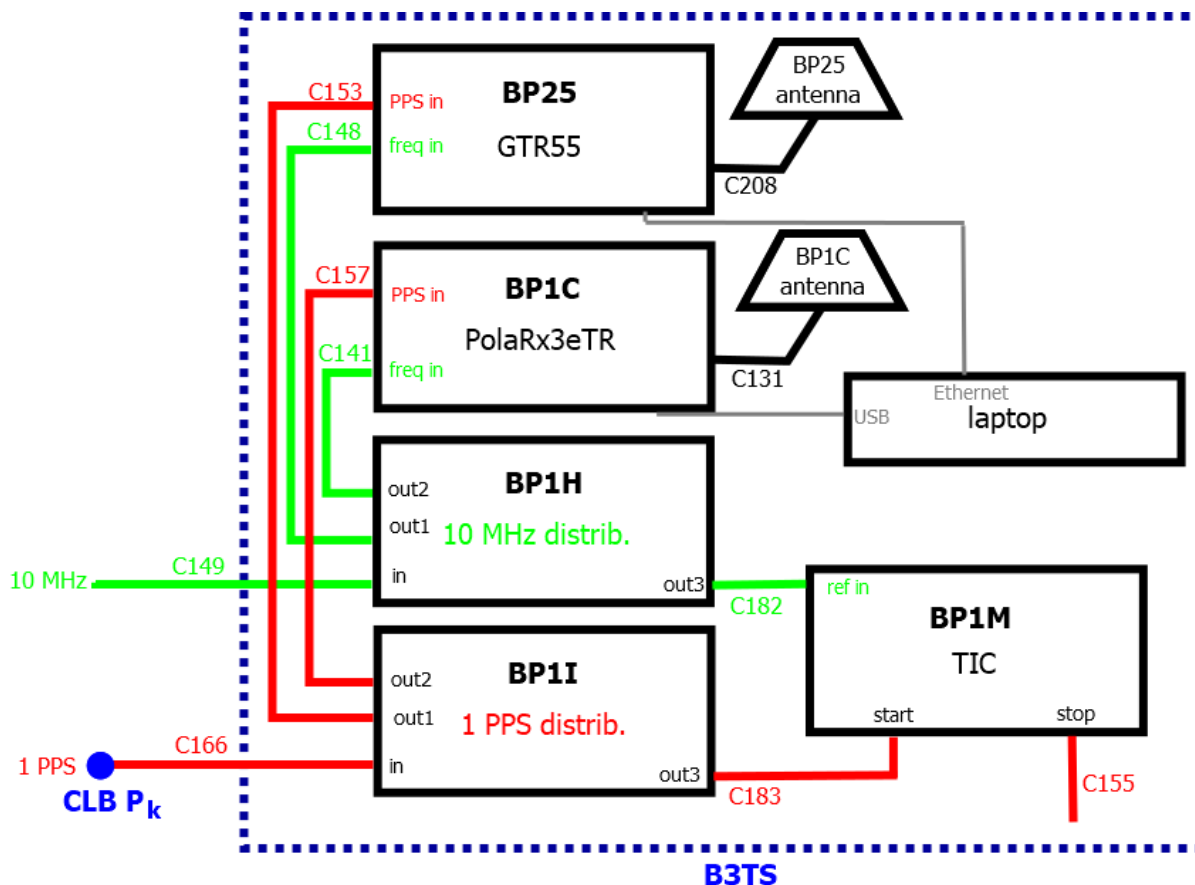
### a. List of the equipment

Designation	Maker	Serial Number	ID
GTR55 receiver	Mesit	1808001	BP25
Antenna cable	-	-	C208
Antenna GNSS-850	Novatel	NMLK18070096N	BP25 antenna
PolaRx3eTR receiver	Septentrio	S9000169176	BP1C
Antenna cable	-	-	C131
Antenna choke ring	Ashtech	CR6200323008	BP1C antenna
Frequency distributor	TimeTech	0039	BP1H
Pulse distributor	TimeTech	0157	BP1I
Time Interval Counter	Stanford Research System	5482	BP1M
Laptop Latitude 3550	Dell	FWC2042	-
antennas support	BIPM	-	AS-001
Coaxial cables	-	-	C141, C148, C153, C157, C149, C166, C155, C182, C183
Ethernet/USB cables	-	-	-
Power supply cables	-	-	-

### b. Photo of B3TS



**c. Hardware connection diagram**



Power supply: 100-240 V AC, 50-60 Hz

**WARNING:**

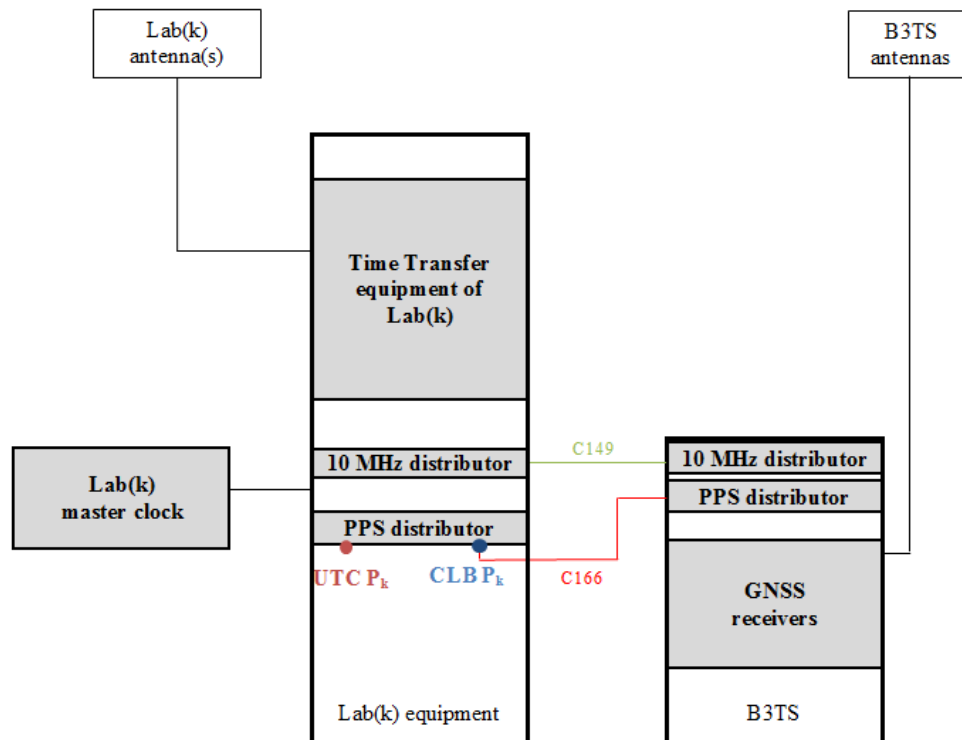
Time Interval counter (BP1M), use a 1 A fuse for 100/120V and a 1/2 A fuse for 220/240V. Both fuses are provided with equipment. Before turning on it, disconnect the power cord, open the fuse holder cover door and rotate the fuse-pull lever to remove the fuse. Remove the small printed circuit board and select the operating voltage by orienting the printed circuit board to position the desired voltage to be visible when pushed firmly into its slot. Rotate the fuse-pull lever back into its normal position and insert the correct fuse into the fuse holder.

**d. Relating the B3TS to the laboratory reference**

The B3TS has to be connected to the signals of the master clock of the laboratory and it is suggested each laboratory fix a PPS output point, namely CLB P<sub>k</sub> as shown in the figure below, for the calibration purpose.

At least the master GNSS receiver of the laboratory has to be connected to the same signals. Setups of other time transfer equipment vs. to the master one together with the measurement data are to be reported to BIPM in the calibration tour.

## 1. Hardware connection diagram



**UTC P<sub>k</sub>**: Laboratory reference (the point defining UTC(k) for a laboratory participating to UTC).

**CLB P<sub>k</sub>**: Connection point, 1 PPS, for the B3TS.

## 2. Delay Measurement

Measure the delay between the laboratory reference point (UTC P<sub>k</sub>) and the 1 PPS input connector of the B3TS (CLB P<sub>k</sub>).

Please set your Time Interval Counter with input parameter: trigger level 1.0 V, 50 Ω, DC, rising edge.

In addition the “PPS in/PPS out” delay of the PolaRx3eTR receiver (BP1C) has to be measured. See Annex E for detailed measurement instructions.

It should be carried out at the beginning and the end of the experiment (to check for stability and possible mistake).

### e. GNSS receiver general information

For more details information about receivers please read user’s manuals of the receivers which are available here:

<ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/guidelines/travelling-system/b3ts/>.

The GTR55 receiver can be operated by remote control through a web browser, and the PolaRx3eTR using a dedicated software, using BIPM laptop.

BIPM laptop information:

- username: bipm
- password: bipm
- IP: 172.16.124.1

#### f. BP25 configuration (GTR55 receiver)

- BP25 operating system login:

Superuser for administrative privileges:

- username: root
- password: gtr55receiver

Default user:

- username: dicom
- password: dicom

- IP address:

BP25: 172.16.124.31

- Configuration and use information:

To operate the receiver you have to use a web browser.

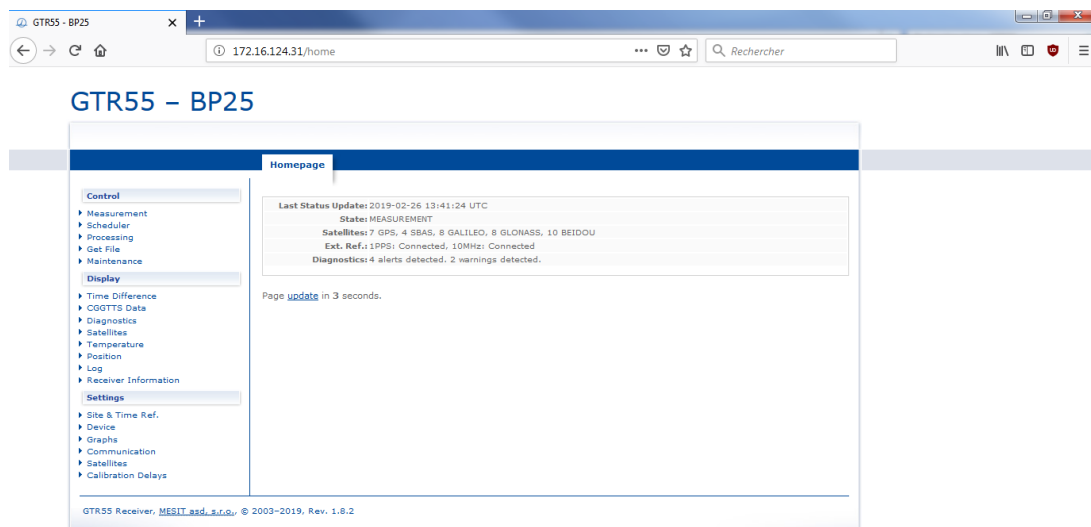
URL: <http://<IP address>/> (here <http://172.16.124.31/>).

Or launch icon named BP25, located on windows desktop of BIPM laptop.

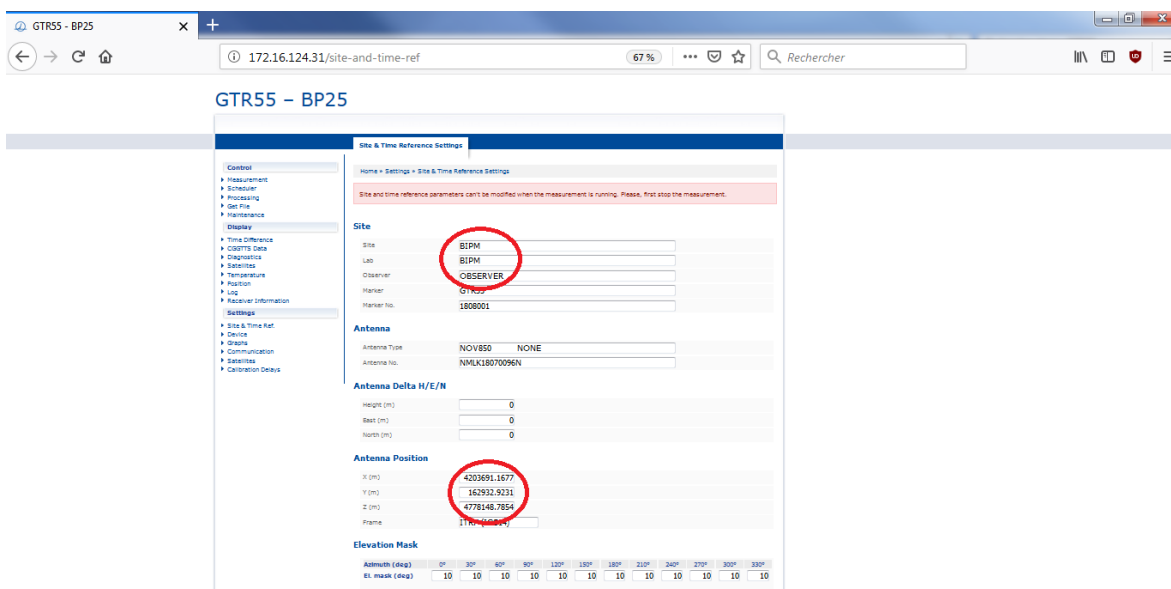
User interface access login:

- username: user
- password: user

Then you should see the web page below:



Click in the left menu on “Site & Time Ref.” to display screen below:



Change/fill fields inside red circle above, in frame named “Site” and “Antenna Position”.

Wait till the measurements starts (15 minutes approximately).

Output data can be accessed via the web interface by clicking on the menu “Get File”.

**WARNING:**

Oldest data (>30 days) are automatically removed, so don't forget to record all files on an independent storage medium (i.e. inside directory C:\data\BP25 of BIPM laptop).

To shut down the receiver click on the menu button “Maintenance”, then click on button “GTR55 shutdown”.

**g. BP1C configuration (PolaRx3eTR receiver)**

**WARNING:**


The peak-to-peak voltage value of the 10 MHz input signal should not exceed 1 Volts on 50 Ohms, please use attenuators if needed.

The 10 MHz and 1 PPS signals have to be connected before starting the receiver.

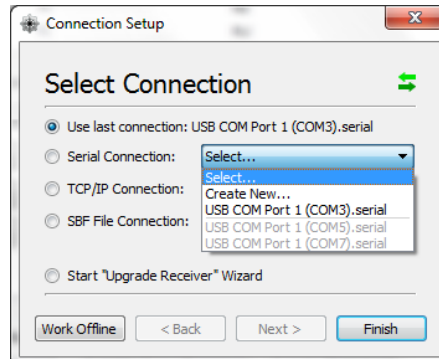
The receiver and dedicated software on BIPM laptop are pre-configured.  
The software is RxControl.

The PPS output of the receiver is configured to be synchronized with the internal receiver time.

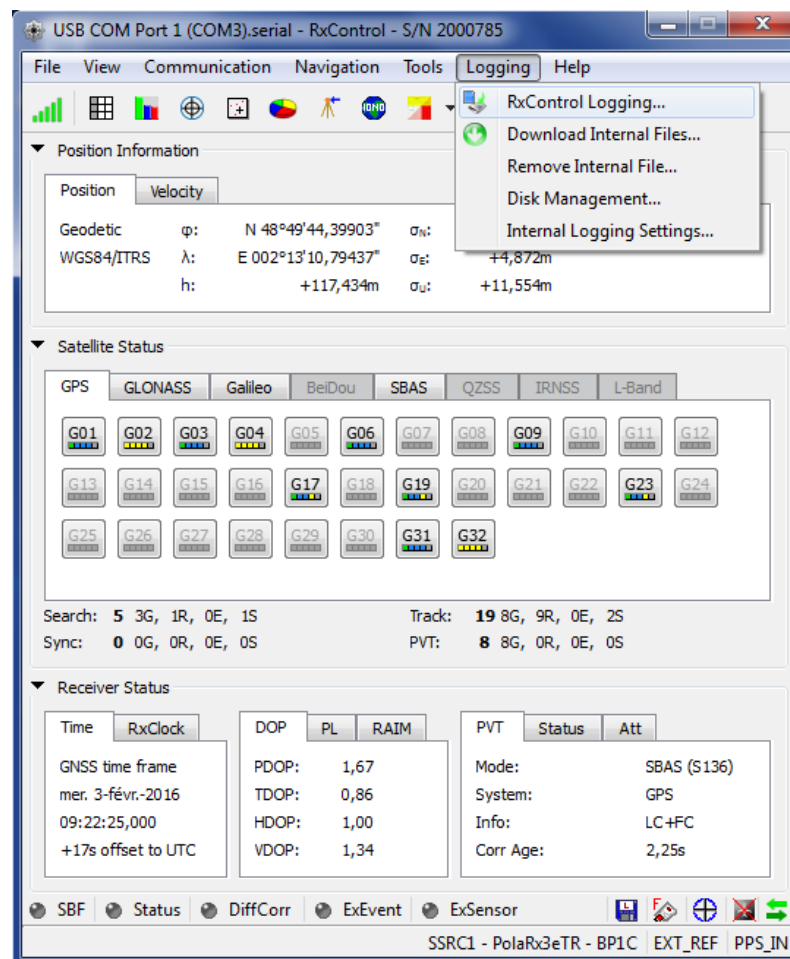
- Configuration and use information

Launch the RxControl software by double-clicking on this icon  situated on the desktop of the BIPM laptop.

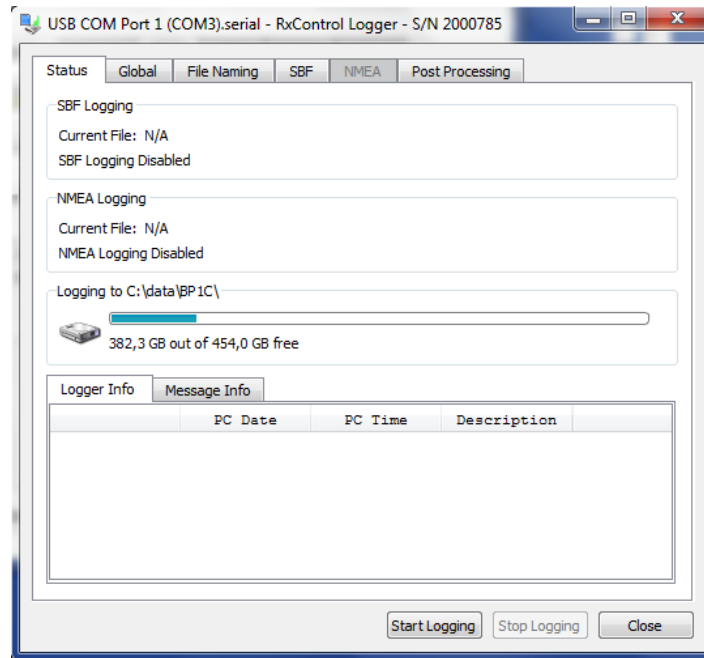
In “Serial Connection” select the highlighted “USB COM Port 1” and click on “Finish”.



In the “Logging” menu, click on “RxControl Logging”.



Then click on “Start Logging”.



Data are stored inside directory C:\data\BP1C\ on Laptop.

To shut down the receiver, first click on “Stop logging” in “RxControl Logging” window and after exit software, then turn off the receiver.

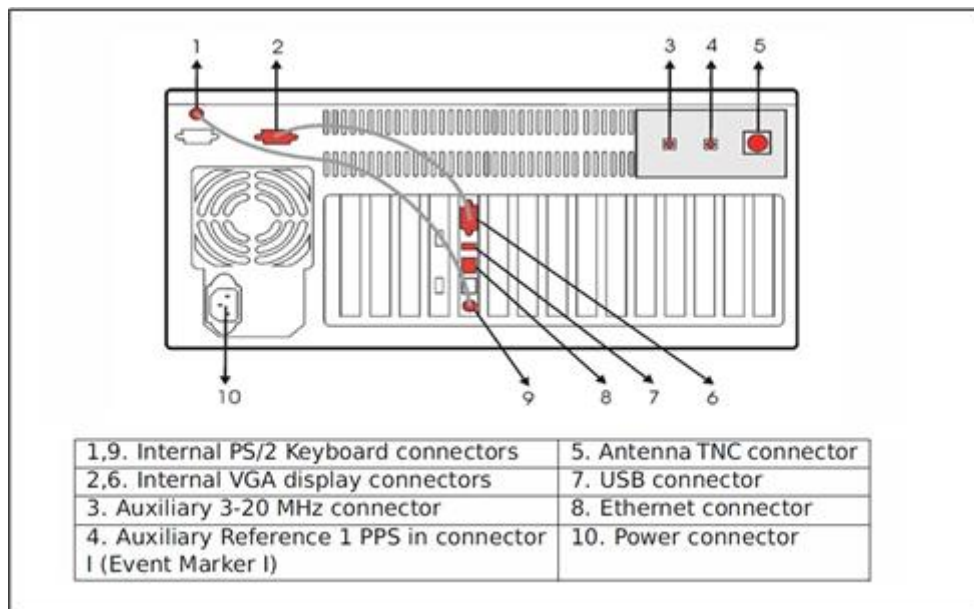
## Annex C - Description and operation of the traveling system: BP1K (BIPM Time Transfer Traveling Receiver)

### BP1K (PikTime TTS-4 receiver)

**a. List of the equipment**

Designation	Maker	Serial Number	ID
TTS-4 receiver	PikTime	136	BP1K
Antenna cable	PikTime	-	C188
Antenna RingAnt-G3T	Javad	00526	BP1K antenna
VGA, PS/2 cables	-	-	KK, QQ2

**b. Hardware connection diagram (rear panel)**



Power supply: AC 230 V 10%, 45 to 60 Hz, or AC 110 V 10%, 55 to 65 Hz

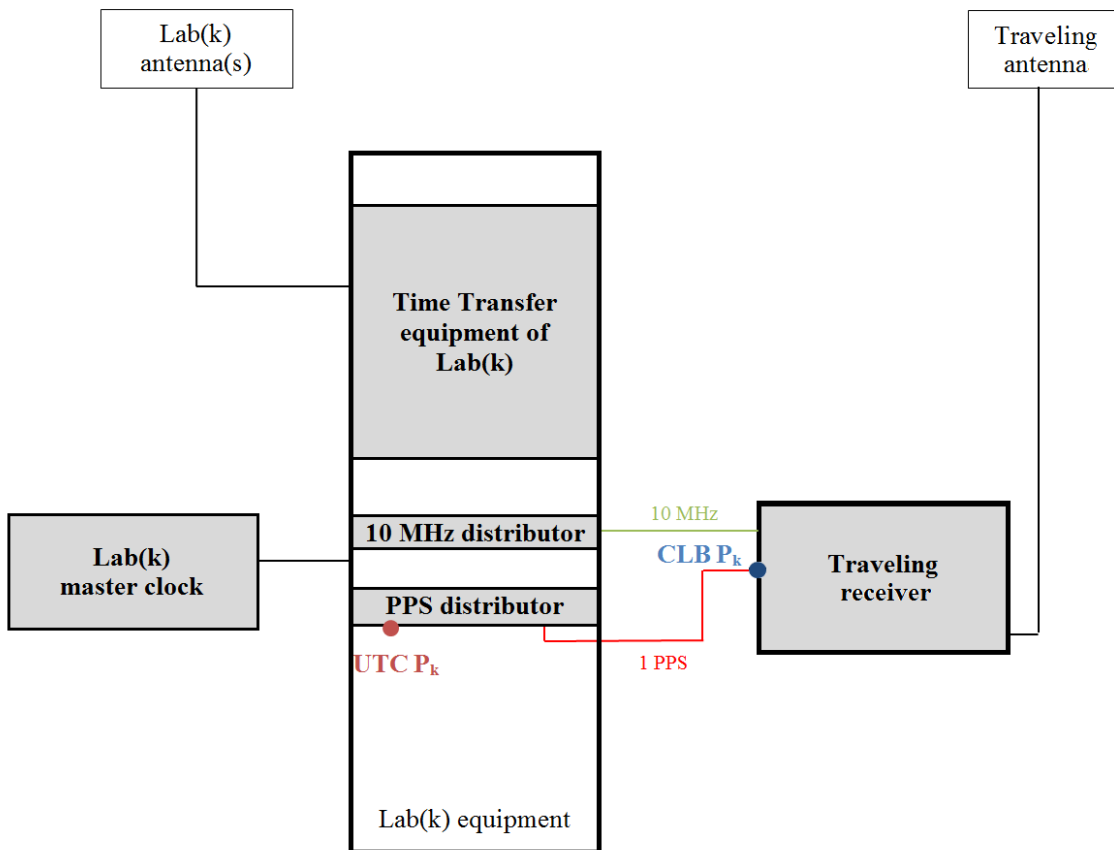
**c. Relating the receiver to the laboratory reference**

The BP1K receiver has to be connected to the signals of the master clock of the laboratory and it is suggested each laboratory fix a PPS output point, namely CLB P<sub>k</sub> as shown in the figure below, for the calibration purpose.

At least the master GNSS receiver of the laboratory has to be connected to the same signals. Setups of other time transfer equipment vs. to the master one together with the measurement data are to be reported to BIPM in the calibration tour.



## 1. Hardware connection diagram



**UTC P<sub>k</sub>**: Laboratory reference (the point defining UTC(k) for a laboratory participating to UTC).  
**CLB P<sub>k</sub>**: Connection point, 1 PPS, for the BP1K input connector.

## 2. Delay Measurement

Measure the delay between the laboratory reference point (UTC P<sub>k</sub>) and the 1 PPS input connector of the BP1K receiver (CLB P<sub>k</sub>).

Please set your Time Interval Counter with input parameter: trigger level 1.0 V, 50 Ω, DC, rising edge.

In addition measure the delay between the 1 PPS input connector (CLB P<sub>k</sub>) and the 5 or 10 MHz input connector of the BP1K receiver.

See Annex G for detailed measurement instructions.

It should be carried out at the beginning and the end of the experiment (to check for stability and possible mistake).

### d. **General information**

For more details information about receiver please read user's manual which is available here:  
<ftp://ftp2.bipm.org/pub/tai/publication/gnss-calibration/guidelines/travelling-system/bp1k/>.

The TTS-4 receiver can be operated by remote control through a web browser or locally using the touch screen and keyboard.

Superuser for administrative privileges of operating system:

- username: root
- password: tts3receiver

User information for web browser interface, general access:

- username: tts3
- password: tts3

User information for web browser interface, configuration menu:

- username: admin
- password: tts3

### e. BP1K configuration

Configuration using touch screen and keyboard:

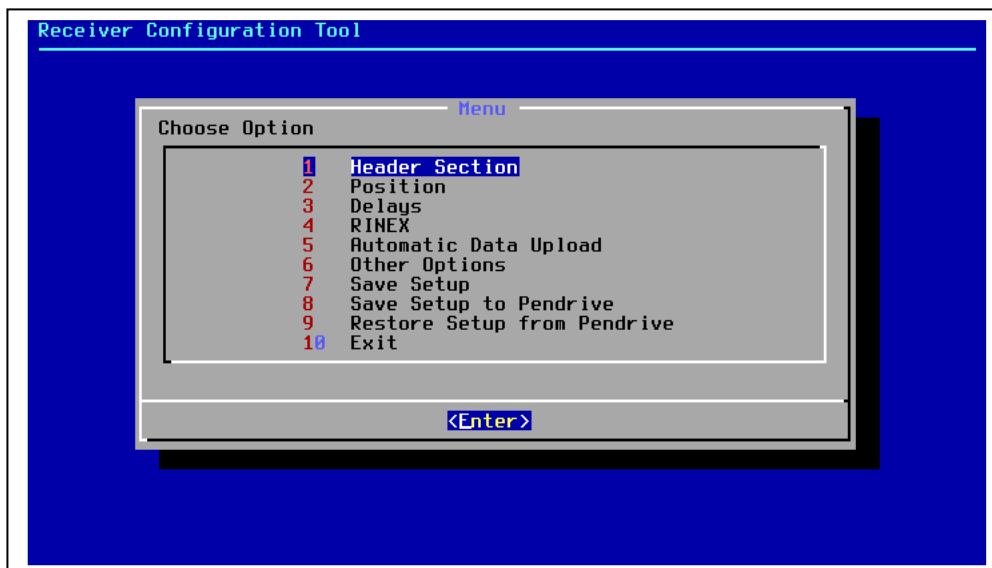
Press F2 touch on front panel (on touch screen or keyboard):

Observation_				Options (F2)				Quit (F5)			
Change Order (F1)				GPS				Time Transfer System 4			
PRN	Az	Elev	SN-L1C	SN-L1P	SN-L2C	SN-L2P	SN-L5P	SN:0138	HW:133.29	SN:2.19c	
10	292	31	48	36	-	36	-	GPS dt(ns):	-0.81		
4	274	51	52	44	-	44	-	GLONASS dt(ns):	-445.11		
32	110	14	42	22	-	22	-	Temperature:	34.00		
2	318	18	43	30	-	30	-	Freq. Sync:	locked		
13	234	69	56	48	-	48	-	Freq. Level:	ok		
31	34	18	42	22	37	22	-	Sync. Status:	ok		
30	72	17	45	25	-	25	-	1PPS status:	ok		
23	72	72	55	48	-	48	-	Antenna DC:	normal		
16	98	6	43	23	-	23	-	GPS Delays Info (F3)			
7	184	17	44	27	40	27	-	x	3738370.5907		
20	120	42	50	39	-	39	-	y	1140161.3775		
27	-	-	38	22	-	22	-	z	5021809.7665		
GNSS				GLONASS				lat 52° 16' 36.72"			
Slot	Freq	Az	Elev	SN-L1C	SN-L2C	SN-L1P	SN-L2P	lon 17° 4' 23.63"			
18	-3	264	27	48	48	45	44	hgt 124.49			
12	-1	102	53	55	54	49	47	IP: 10.183.2.178			
2	-4	74	63	56	56	45	44	2012-11-20 17:56:38			
3	-	306	54	54	53	50	49				
11	-	30	27	45	45	36	35				
13	-2	162	23	44	43	42	41				
1	1	98	11	32	32	30	-				
19	3	326	25	49	48	42	41				
EGNOS/WAAS											

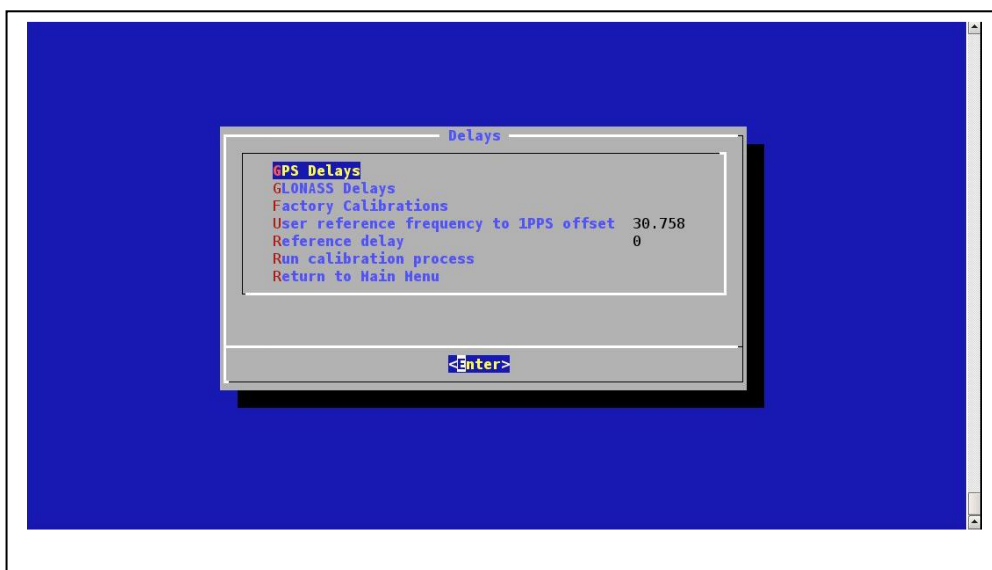
Then press F1 touch, menu "Receiver Configuration Tool":

Observation (F4)				Options							
Change Order (F1)				GPS				Time Transfer System 4			
PRN	Az	Elev	SN-L1C	SN-L1P	SN-L2C	SN-L2P	SN-L5P	SN:0138	HW:133.29	SN:2.19c	
10	178	41	51	36	-	36	-	GPS dt(ns):	5.64		
26	286	34	50	44	-	44	-	dt(ns):	-445.36		
3	48	11	42	22	-	22	-	Temperature:	35.00		
2	236	8	38	30	-	30	-	unc:	locked		
5	274	56	55	48	-	48	-	evel:	ok		
13	100	20	42	22	-	22	-	tatus:	ok		
28	164	24	44	25	-	25	-	atus:	ok		
8	200	81	56	48	-	48	-	DC:	normal		
7	64	57	54	23	-	23	-	n Info (F3)			
6	38	7	36	27	40	27	-	lay:	54.40		
GNSS				GLONASS				lat 52° 16' 36.72"			
Slot	Freq	Az	Elev	SN-L1C	SN-L2C	SN-L1P	SN-L2P	lon 17° 4' 23.63"			
20	2	330	7	43	42	29	28	hgt 124.49			
14	-7	224	39	42	42	37	35	IP: 10.183.2.184			
3	5	174	78	49	48	43	42	2012-11-19 21:25:09			
4	6	316	48	47	46	37	36				
13	-2	36	86								
21	4	16	13								
255	-5	-	-								
12	-1	44	29								
2	-4	152	20								
EGNOS/WAAS											
PRN:	127	Az:	136	Elev:	21	SN-CR:	38				

Select menu 2 “Position” and introduce the antenna coordinates:



Then return to main menu and select menu 3 “Delays”, the screen below appear:

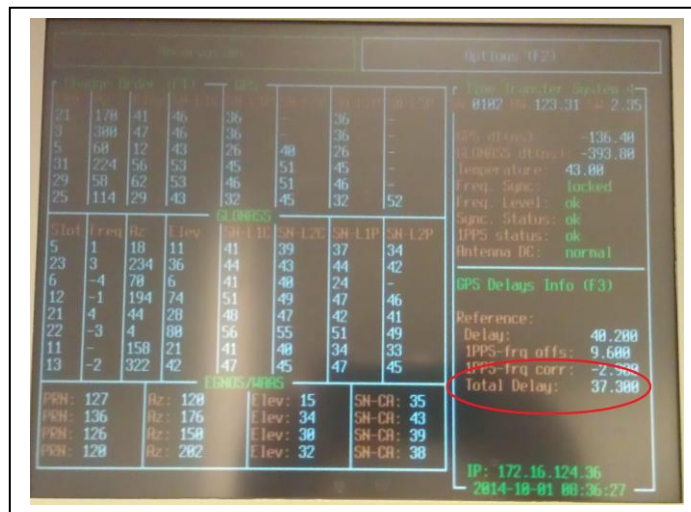


Introduce the delay from the laboratory reference UTC(k) to the 1PPS-in of the receiver in the field “Reference delay”.

Introduce the value of the delay between the 1 PPS input connector and the 5 or 10 MHz input connector of the BPIK receiver (see Annex G for measurement details) in the field “User reference frequency to 1 PPS offset”.

Then save configuration and restart TTS-4 observation process.

Once it's done return to the main screen and press F3 on the front panel of the receiver to get the value of "Total Delay" (inside the red circle below):



This "Total Delay" stands for the delay from the laboratory reference UTC(k) to the TTS-4 internal delay (the so-called REFDLY of the CGGTTS format).

## Annex D - Z12T measurement procedure

This procedure should be reviewed by experts of the CCTF Working group on GNSS

For Measurement 1), it is very important to connect the 20 MHz and the PPS signal to the oscilloscope using the same cables that will be used in the receiver's setup: this way, the calibration point for this delay is at the input ports of the receiver.

**For all measurements the impedance setting on both channels of the oscilloscope must be 50 Ohms.** In Figure 1 is shown an example where the two cables connecting the 20MHz and the 1PPS signal to the receiver are called CABLE1 and CABLE2. This example refers to a receiver that doesn't have 20 MHz OUT available.

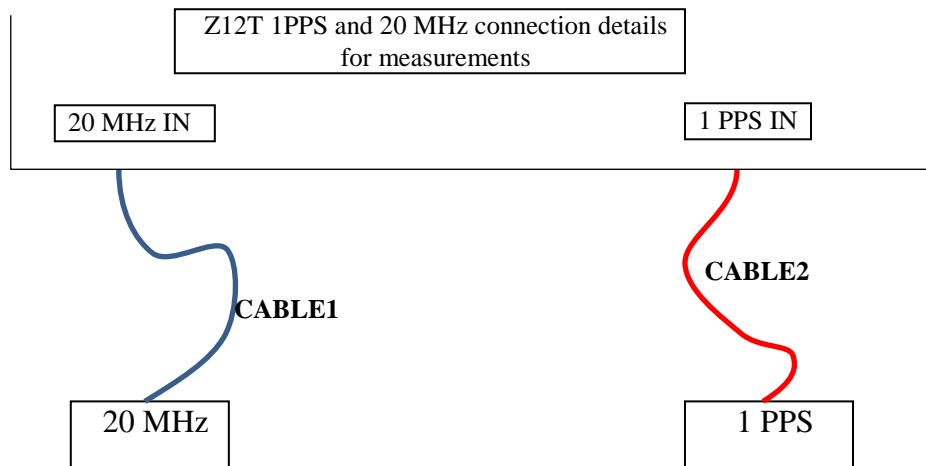


Figure 1. Example of connection between the local 20 MHz and 1PPS signals when the 20 MHz OUT is not available.

If a 20 MHz OUT signal is available from the receiver, it is desirable to perform also Measurement 2). From the comparison between measurement 1) and 2) it is possible to verify the delay between 20 MHz OUT and 20 MHz IN.

To perform Measurement 2) a second PPS signal (coherent with the first one) is needed, as shown in the example in Figure 2.

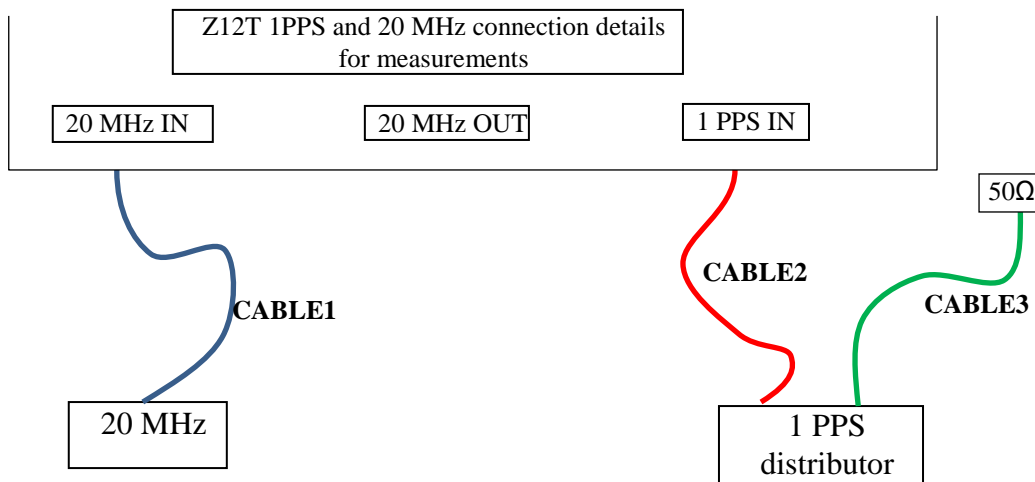


Figure 2. Example of setup for a receiver that has 20 MHz OUT available

All the measurements should be performed before starting the calibration and after ending the calibration.

MEASUREMENT 1):

- a. Set-up your oscilloscope as shown in Figure 3. The trigger level is not critical. Use a time base of 10ns/div, the signals will then be easier to identify.

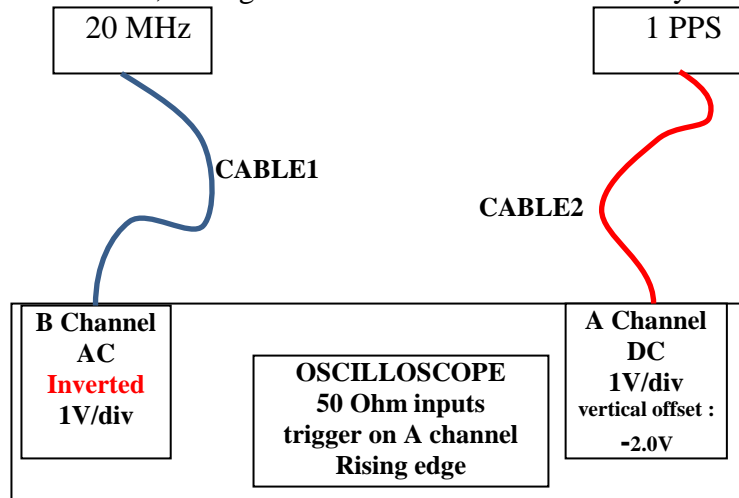


Figure 3: First setup for measurement 1)

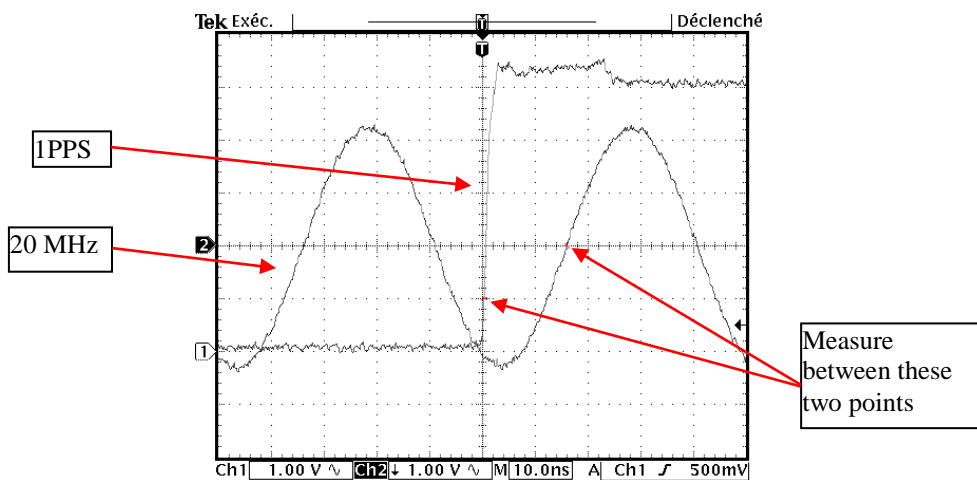


Figure 4: example of oscilloscope display using set-up shown in Figure 3

Measure the phase difference between the 1PPS 1V crossing and the following inverted 20 MHz rising-edge zero crossing as shown on Figure 4.

**This measurement is important because you can check if the relation between the 20 MHz and the 1PPS signal is appropriate for the receiver.**

**For a receiver in “rising edge sampling”, the measurement value should be between 5 and 20 ns. For a receiver in “falling edge sampling”, the measurement value should be between 30 and 45 ns. If the measurement value is not in the indicate range, add a delay line in the 20Mhz line to force this measurement in this range.**

Examples below are for “rising edge sampling”, which is the usual setup of a receiver.

- b. Use this measurement to check your oscilloscope measurement:

Change the range of both channels to 20mV. Make sure to apply a vertical offset of  $-1.0\text{ V}$  on channel A (the PPS channel). This will put the  $1.0\text{V}$  level in the middle of the screen. Use the cursors to check where the  $1.0\text{V}$  level is. You should get a display like this one:

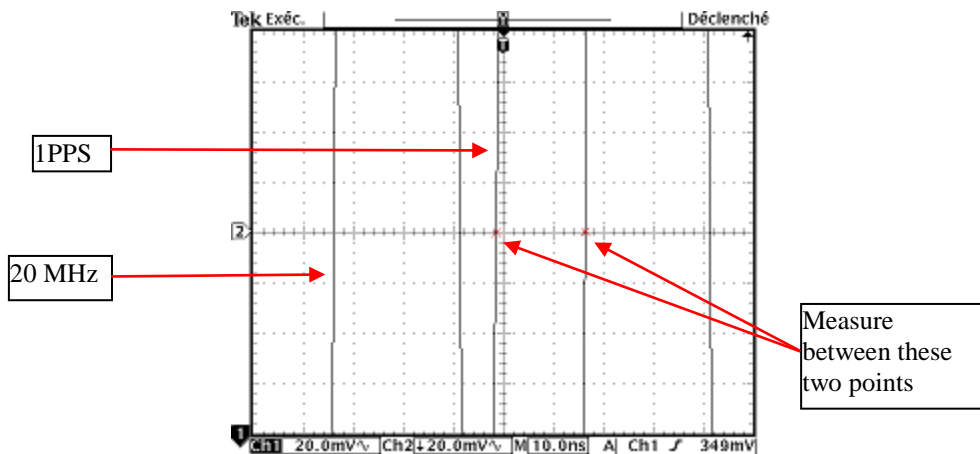


Figure 5: Measurement 1b: example of oscilloscope display using 20 mV range

Measure the same delay, the result should be the same (within the cursor uncertainty) as the one obtained in measurement 1a. If you don't measure the same value try to use another oscilloscope.

- c. There is still another way to validate the oscilloscope measurements. Interchange the channels and measure again using the setup shown in Figure 6.

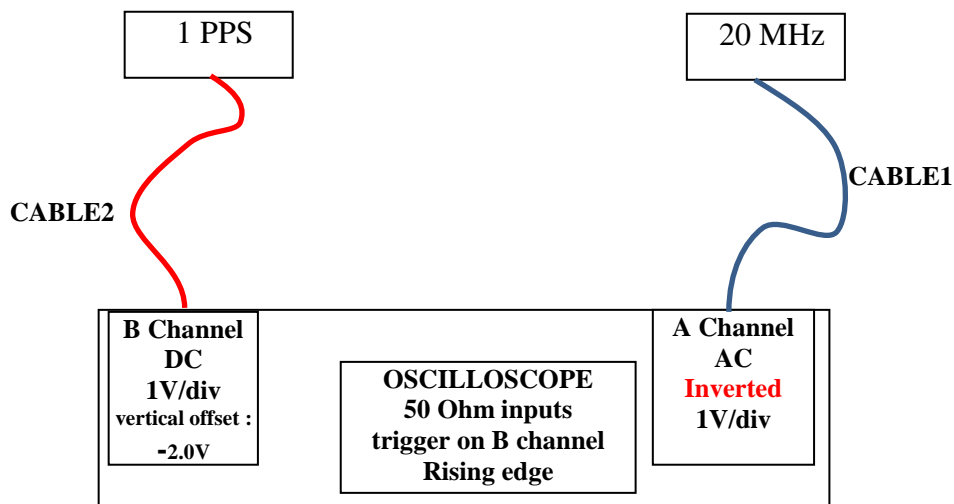


Figure 6: Measurement 1c: exchanged channel set-up

With this setup, you should get a plot equivalent to the Figure 4. The measurement should give the same value as the others (within cursor uncertainty). If not, take the average between this value and measurement 1a.

### MEASUREMENT 2):

This measurement is to be performed only if the receiver has a 20 MHz OUT available.

- a. This measurement is performed in the same way of Measurement 1a, but the setup is slightly different, as shown in Figure 7. Note the use of CABLE3.

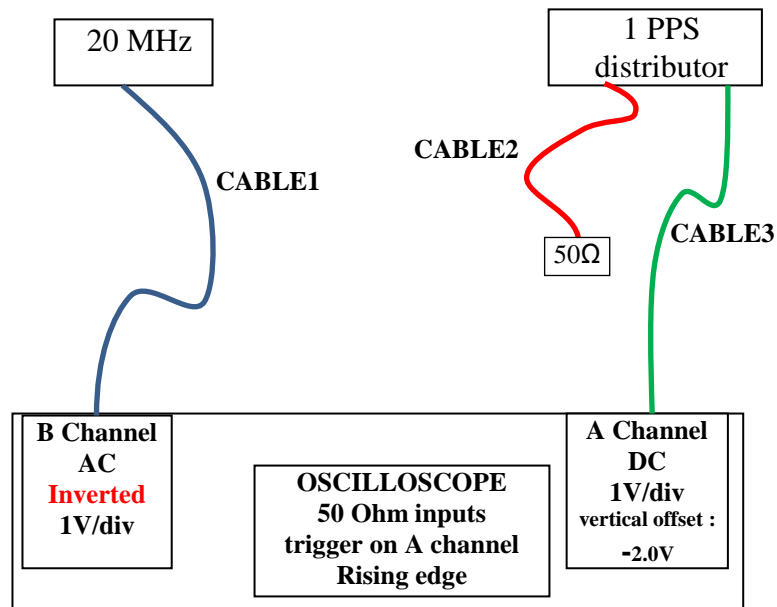


Figure 7. First set-up for measurement 2).

The oscilloscope has been verified during the previous measurements, so it is not necessary to do so now.

- b. This measurement needs the set-up shown in Figure 8. Note the use of two phase-matched cables (cable A and Cable B) provided by BIPM.

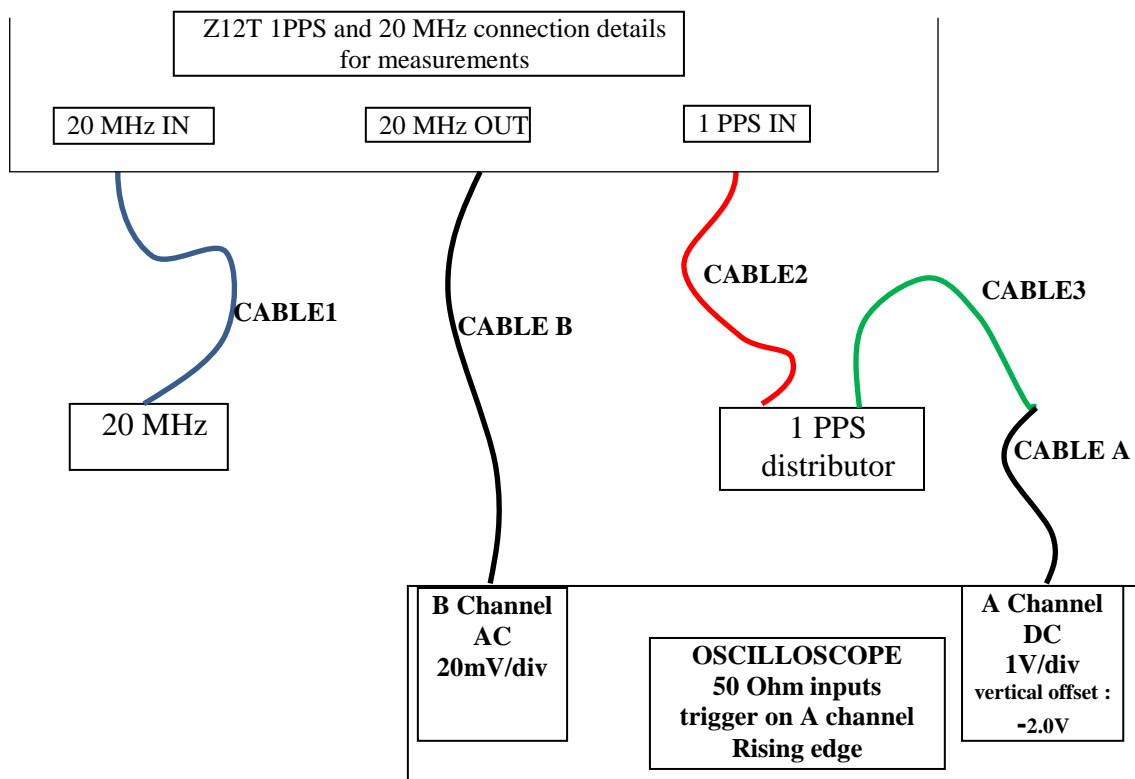


Figure 8. Second setup for Measurement 2). Note the use of phase matched cables (A and B)

The difference between Measurement 2a and 2b should be 18.2 ns (within combined cursor measurement uncertainties).

Provide a plot of the oscilloscope screen for all measurements for the each Z12-T system.



## Annex E - PolaRx measurement procedure

This procedure should be reviewed by experts of the CCTF Working group on GNSS

Measurement of the delay between the 1 PPS input connector and the 1 PPS output connector of the PolaRx receiver.

### MEASUREMENT:

In order to avoid disturbing the equipment during operation, one solution is to perform a tare of your set-up without PolaRx receiver before starting the operation and after ending operation. Please set your Time Interval Counter with a trigger level of 1 volt under 50 ohms.

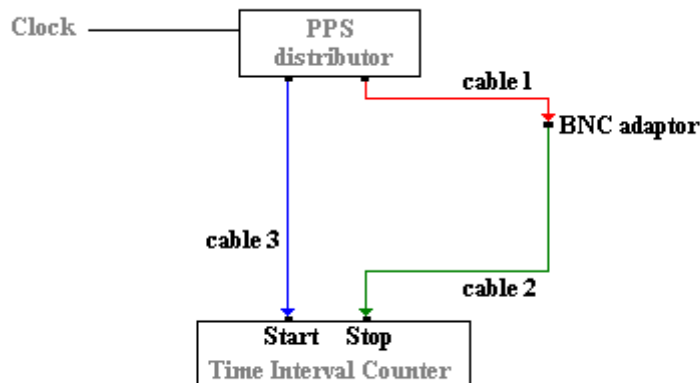


Figure 1: example of tare measurement set-up before and after operation

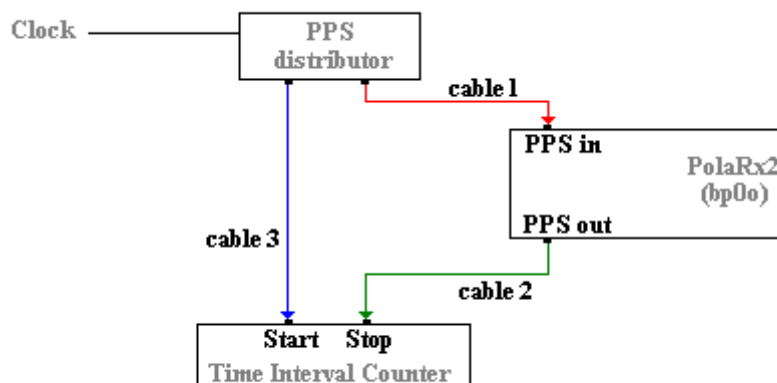


Figure 2: example of delay measurement set-up during operation

The delay between 1 PPS input and 1 PPS output is equivalent to the delay measured in the second set-up (see Figure 2) minus the tare delay (average of the initial tare and the final tare, see Figure 1).

#### PolaRx2 receiver:

The delay between the 1 PPS input connector and the latching measurements in the receiver is between 221.7 and 255.0 ns (+/- 2ns).

The delay between the internal measurement latching and the 1 PPS output connector is dependent on the firmware version:

- firmware version 2.2 : delay 58 ns
- firmware 2.3 and higher : delay of -8.7 ns (the 1 PPS output pulse comes sooner than the measurement latching)

#### PolaRx3 receiver:

The PPS output connector is synchronized with the internal measurement latching and the result should be between 180.0 and 213.0 ns (+/- 5ns).

#### PolaRx4 receiver:

The PPS output connector is synchronized with the internal measurement latching and the result should be between 130.3 and 150.3 ns (+/- 2ns).

#### PolaRx5 receiver:

The PPS output connector is synchronized with the internal measurement latching and the result should be between 20 ns and 60 ns.

## Annex F - GTR measurement procedure

As the 1 PPS input is the reference of the GTR measurements, no extra measurement is needed.

For the receiver under calibration, it is however necessary to check and report the values of the following parameters:

### GTR50 version 1.5:

In file /opt/GTR50/data/config\_lck:

- Int\_dly0
- AMR\_cor
- Dif\_dly
- Cab\_dly

Via the web interface “Settings / Site & Time Ref. / Input time reference”:

- Cable delay

### GTR50 version 1.6:

In file /opt/GTR50/data/config\_lck:

- Int\_dly
- P1C1\_dif
- P1P2\_dif

Via the web interface “Settings / Site & Time Ref. site”:

- Cable delay
- Reference delay

### GTR51/GTR55:

Via the web interface “Settings / Site & Time Ref.”:

- Input Time Reference Delay
- Antenna Cable Delay

Via the web interface “Settings / Calibration Delays”, report all “Int dly” values.

## **Annex G - TTS-4 measurement procedure**

**This procedure should be reviewed by experts of the CCTF Working group on GNSS**

Measurement of the delay between the 1 PPS input connector and the 5 or 10 MHz input connector of the TTS-4 receiver.

### MEASUREMENT:

This measurement can be done using oscilloscope, or time & frequency counter with sub-nanosecond precision.

Procedure using a time & frequency counter:

#### 1. Set-up the counter inputs:

- start (input A), trigger level 1.0 Volt, DC, 50 Ohms,
- stop (input B), trigger level 0.0 Volt, AC, 50 Ohms,
- time interval measurement mode.

#### 2. Connect:

- 1 PPS cable to start input of the counter
- reference frequency cable to stop input of the counter

#### 3. Measure the delay between the 1 PPS and the 5 or 10 MHz signals.

## Annex H - Novatel measurement procedure

This procedure should be reviewed by experts of the CCTF Working group on GNSS

Measurement of the delay between the 1 PPS input and the 1 PPS output of the Novatel receiver.

The possibility to synchronize the receiver time to an external PPS signal (PPS IN) and a PPS output signal representing the receiver's time (PPS OUT) are available for all Novatel receivers using OEM4, OEMV and OEM6 engines via the I/O port. Different enclosures (PropakG2, PropakV3, FlexpakG2 and Flexpak6) have different pinouts as described below:

	PropakG2, PropakV3, FlexpakG2	Flexpak6
PPS IN	I/O port pin 4	I/O port pin 11
PPS OUT	I/O port pin 2	I/O port pin 15
GND	I/O port pin 9	I/O port pin 5

The connection of coaxial cables to the pins of the I/O port of the receiver must be done with care, interfacing properly with the TTL-compatible signal expected by PPS IN and provided by PPS OUT (see details in Figure 2). NIST uses a custom-made interface that includes a time interval counter and records the PPS OUT minus PPS IN on a text file. The two cases, one for a standalone receiver and the other one for the NIST case, will be described below.

All measurements should be made before and after the calibration session.

### STANDALONE MEASUREMENT

The time interval counter settings should be:

- Trigger level 1V
  - Impedance 50 Ohms.
- a. This first measurement allows determining the tare of the measurement setup, as shown in Figure 1.

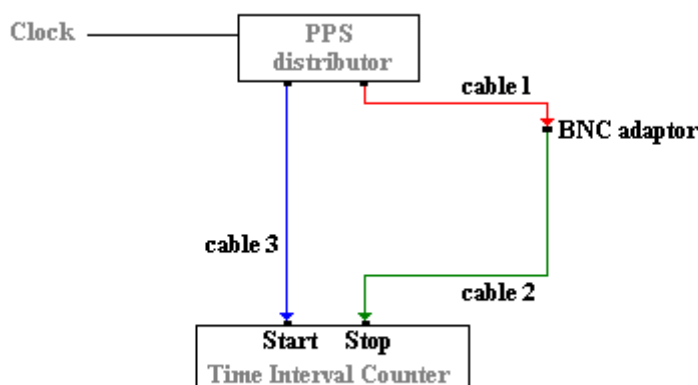


Figure 1. Determination of the tare of the measurement setup.

- b. This measurement provides the PPS OUT minus the PPS IN, with tare included. The setup is shown in Figure 2: **note the details of the connection between the I/O port pins and the coaxial cables used for the measurement. The length of the connection between the I/O port pins and the two coaxial cables (cable 1 and cable 2) is not included in the measurement so it should be as short as possible.**

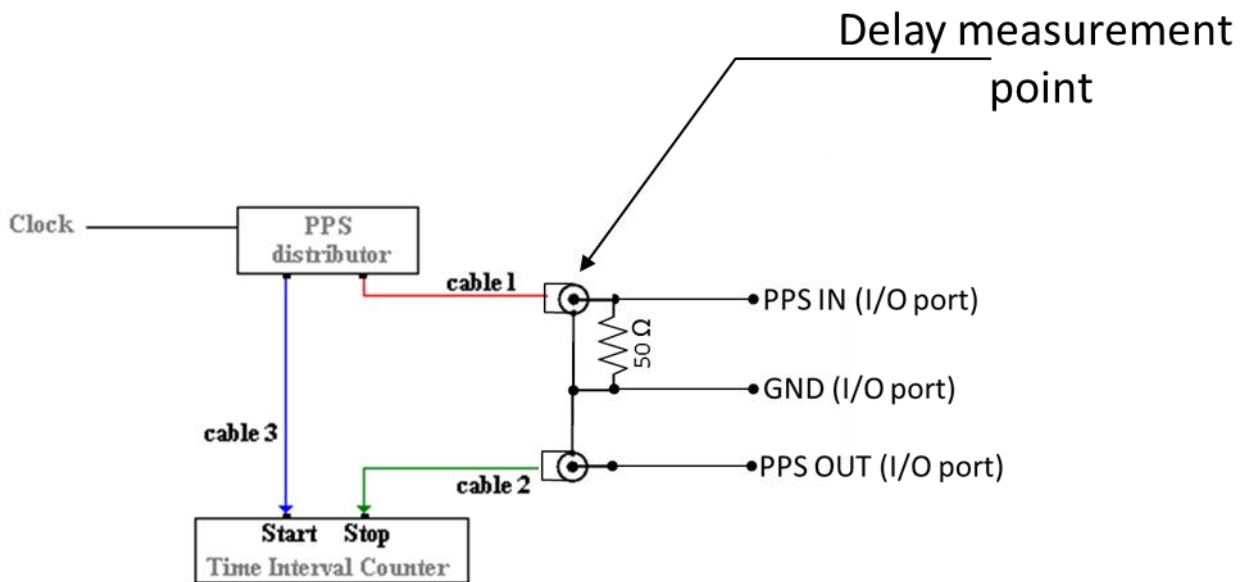


Figure 2. Setup to measure the delay between PPS OUT and PPS IN, tare included.

The delay between PPS OUT and PPS IN is the difference between Measurement b and a.

### NIST MEASUREMENT

The relationship between the NIST-designed interface and the PPS IN and PPS OUT for the Novatel receiver is illustrated in the conceptual diagram in Figure 3. The static delays  $\delta_n$  ( $n=1, 2, 3, 4$ ) indicated in the diagram are measured and their value is programmed in the microcontroller that manages the interface and logs the measurements from the onboard Time Interval Counter (TIC). The microcontroller outputs a string of ASCII characters via a RS-232 port which include the delay between PPS OUT and PPS IN at the locations indicated by the stars in Figure 3.

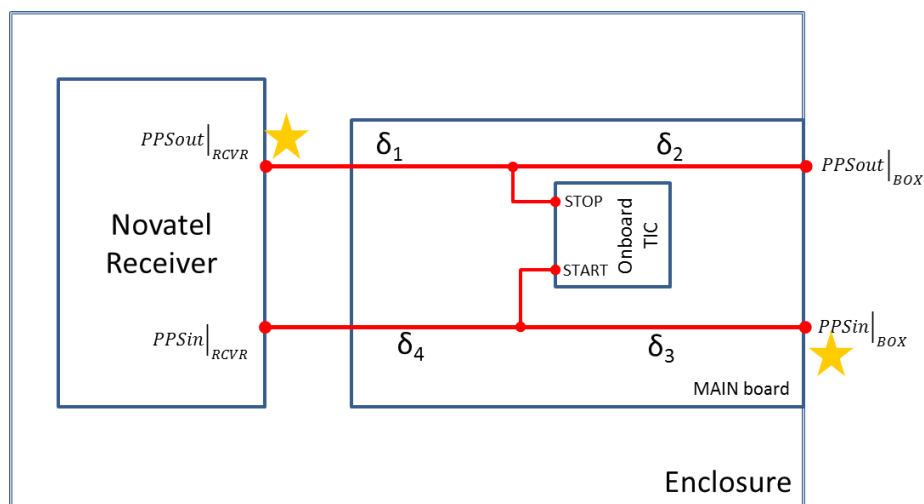


Figure 3. Conceptual diagram of the connections between the TIC included in the NIST-designed interface and the Novatel receiver. The output of the microcontroller included in the interface is the delay between PPS OUT and PPS IN at the locations indicated by the stars.

The measurements of the delay as described above are performed at regular intervals (usually every 100 seconds) for the duration for the calibration procedure.