

Annex 1

Operational procedures for a visit of the traveling equipment

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Revision history

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July 2022:	L. Tisserand (Update annex B for new equipment in B3TS and minor change in annex C and D) G. Tagliaferro (Recommendation to report PolaRx5TR option status added)
August 2022:	G. Tagliaferro (Correction of BP2G antenna name error)
March 2023:	L. Tisserand (Annex B and D update, interchanged GTR55 receivers)
May 2024:	L. Tisserand (Annex B update, TIC and PPS distribution changed, and TTS-5 receiver added)
January 2026:	L. Tisserand (Annex A update, Annex B antenna cables update)

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 BP1K TTS-4 receiver, and in Annex D for the BP25 GTR55 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 format¹.

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

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

should allow reporting them. If CGGTTS files are available from the local systems, they should be provided as well.

- 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;
 - **Just for Septentrio PolaRx5 receivers, the status of the “Enable compensation of PPS-in internal delay” option.**

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, Mesit GTR51 or GTR55, and Septentrio PolaRx5².
- The 1PPS-out defines the internal reference: see section 2.2.
Examples of such systems are Septentrio PolaRx2, PolaRx3, PolaRx4 or PolaRx5³ and Novatel OEM4, OEM5 or OEM6.
- Other cases: see section 2.3.
Examples of such systems are Ashtech Z12T metronome, PikTime TTS-4 or TTS-5.

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 E through I.

REFDLY=(delay between UTC(k) and PPSin) + (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 G.

2.1.3 Piktime TTS-3

No additional measurements necessary.

2.1.4 Septentrio PolaRx5

No additional measurements necessary.

“Enable compensation of PPS-in internal delay” receiver's option must be enabled, using the command: **setPPSINParameters**. [The status of this option should be reported in the Annex A.](#)

² With “compensation of PPS-in internal delay” option enabled

³ With “compensation of PPS-in internal delay” option disabled

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 Septentrio receiver, the internal reference is conventionally defined as 1PPS-out.

For PolaRx5, the “Enable compensation of PPS-in internal delay” receiver’s option must be disabled, using the command: **setPPSINParameters**. **The status of this option should be reported in the Annex A.**

- Synchronize the 1PPS output signal from the PolaRx receiver with the measurement latching epoch using the command: **setPPSPParameters**. This is done by setting the *TimeScale* argument of the **setPPSPParameters** 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 F.

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 I.

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 E)⁴.

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.**

⁴ This procedure should be reviewed by experts of the CCTF Working group on GNSS

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 or TTS-5

Only for 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 H.

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 receiver internal reference (the so-called REFDLY of the CGGTTS format).

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:	

Information on the system

	Local:	Travelling:
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		

Measured delays /ns

Please tick the correct box depending on the receiver (1)

	Local:	Travelling:
	REF point is PPSIN <input type="checkbox"/>	REF point is PPSIN <input type="checkbox"/>
• Delay from local UTC to receiver 1 PPS-in (REFDLY):		
• Optional Delay from local UTC to receiver 1 PPS-Out:		
	REF point is PPSOUT <input type="checkbox"/>	REF point is PPSOUT <input type="checkbox"/>
• Delay from local UTC to receiver 1 PPS-Out (REFDLY):		
• Optional Delay from local UTC to receiver 1 PPS-in:		
	REF point. TTS 4/5 <input type="checkbox"/>	REF point. TTS 4/5 <input type="checkbox"/>
• Delay from local UTC to receiver 1 PPS-in:		
• Delay from 1 PPS-in to 10 MHz input receiver:		
• Computed 1PPS frequency offset correction:		
• Computed REFIDLY by the receiver:		
	(Not to be filled)	REF point is calibration point <input type="checkbox"/>
• Delay from local UTC to traveling box calibration point:	(Not to be filled)	

	Other case <input type="checkbox"/>	Other case <input type="checkbox"/>
Please describe measurements and final REFDLY value		
• Antenna cable delay:		(2)
Splitter delay (if any):		(2)
Additional cable delay (if any):		(1)

Data used for the generation of CGGTTS files

Complete this section only if CGGTTS-format data were used for the calibration.
Please fill with the parameter values as configured in the receiver at the time of calibration

• INT DLY (GPS) /ns:	
• INT DLY (Galileo) /ns:	
• INT DLY (BDS) /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:	

General information

• Rise time of the local UTC pulse:	
• Is the laboratory air conditioned:	
Set temperature value and uncertainty:	
Set humidity value and uncertainty:	

Diagram of the experiment set-up:

Log of Events / Additional Information :

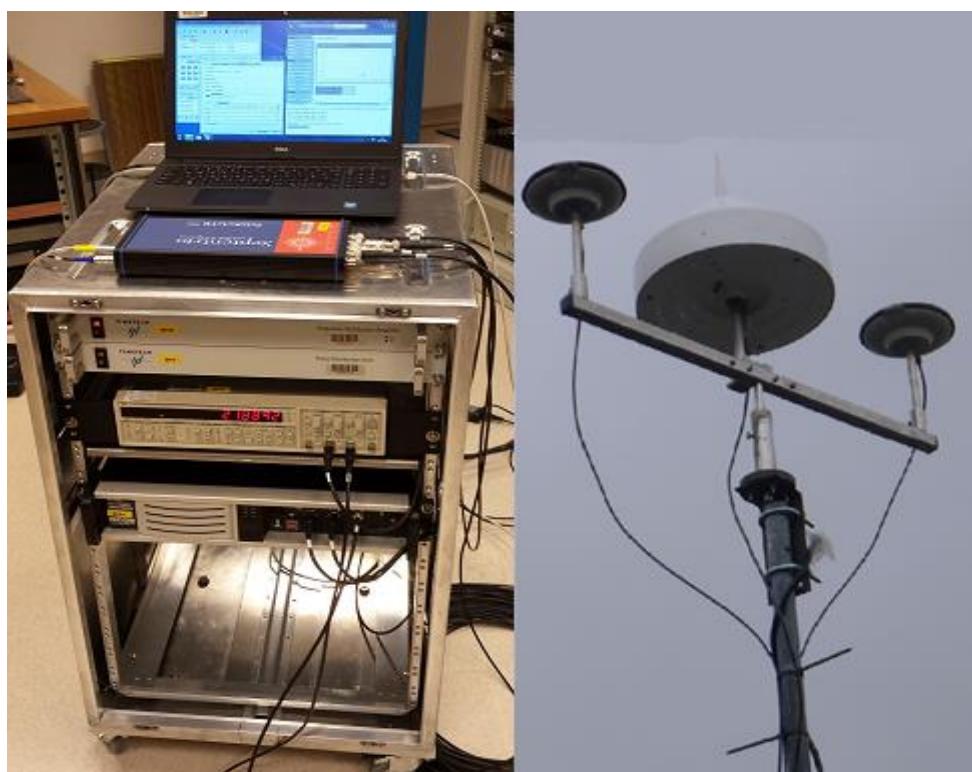
Annex B – Description and operation of the traveling system: B3TS (BIPM Time Transfer Traveling System)

a. List of the equipment

Designation	Maker	Serial Number	ID
GTR55 receiver	Mesit	2010001	BP2D
BP2D antenna cable (~50m)	Hytem	-	C222
BP2D antenna, GNSS-850	Novatel	NMLK17440001C	-
PolaRx5TR receiver	Septentrio	4701533	BP2G
BP2G antenna cable (~50m)	Hytem	-	C221
BP2G antenna, PolaNt Choke Ring B3/E6	Septentrio	6023	-
Frequency distributor	TimeTech	0024	BP1U
Pulse distributor	TimeTech	0048	BP2J
Time Interval Counter	Keysight	MY63280278	BP2K
Laptop Latitude E5500 (*)	Dell	GVVGD4J	-
antennas support	BIPM	-	AS-001
Coaxial cables	-	-	C141, C148, C153, C157, C149, C166, C155, C182, C183
Ethernet/USB cables	-	-	-
Power supply cables	-	-	-

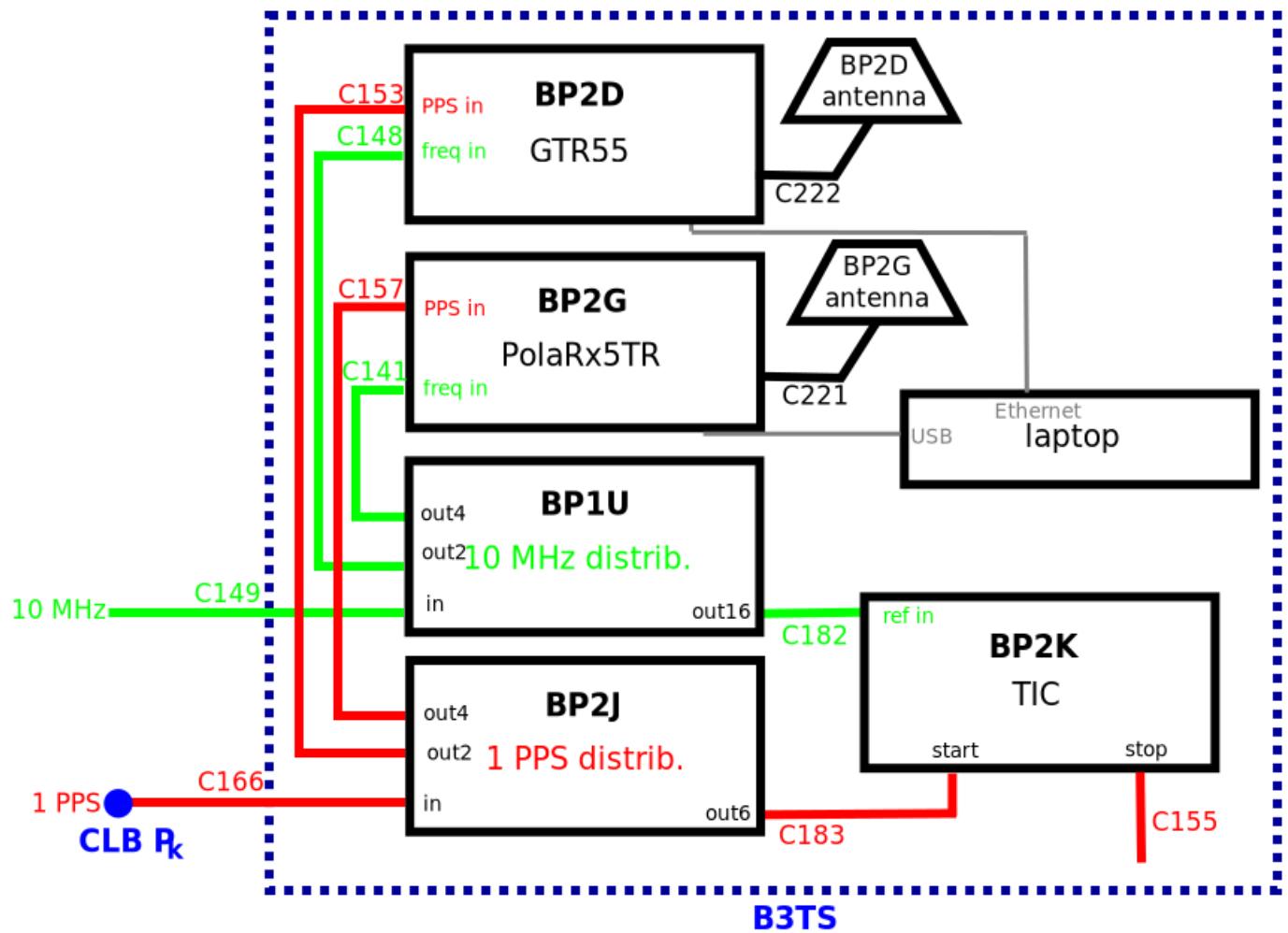
(*) removable battery not provided

b. Photo of B3TS



actual equipments may differ

c. B3TS hardware diagram

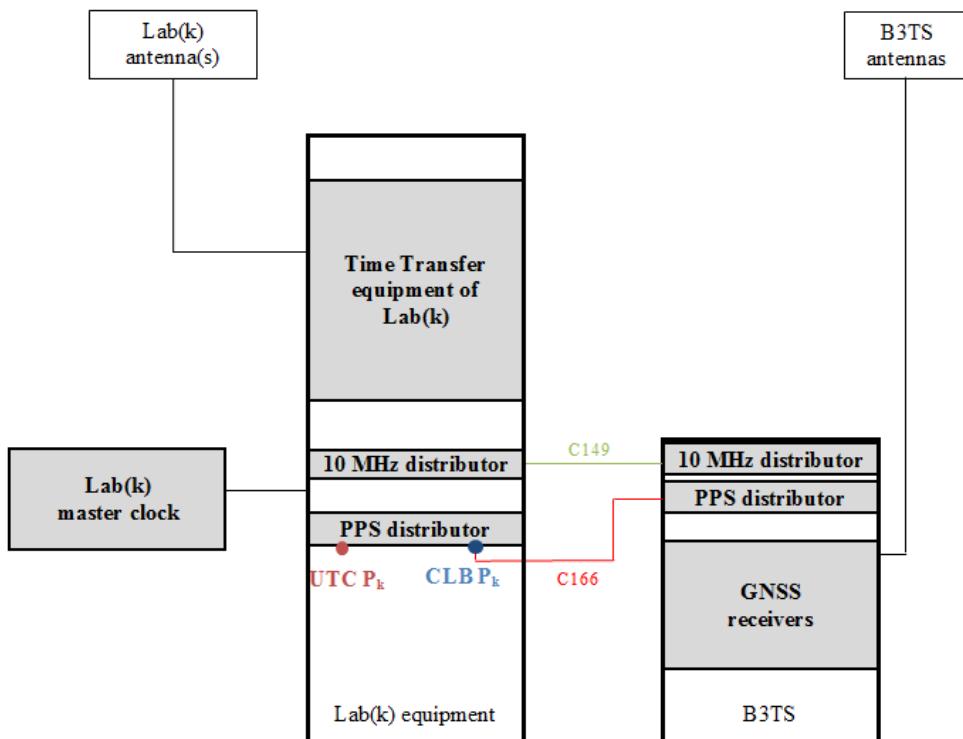


d. Relating the B3TS to the laboratory reference

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_k 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_k: Laboratory reference (the point defining UTC(k) for a laboratory participating to UTC).

CLB P_k: Connection point, 1 PPS, for the B3TS.

2. Delay Measurement

Measure the delay between the laboratory reference point (UTC P_k) and the 1 PPS input connector of the B3TS (CLB P_k).

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

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

No additional measurements are necessary for BP2G, the “compensation of PPS-in internal delay” receiver’s option is enabled by default.

e. GNSS receiver general information

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

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

The GTR55 receiver (BP2D) and the PolaRx5TR receiver (BP2G) can be operated by remote control through a web browser using the BIPM laptop.

BP2D must be connected to the BIPM laptop by Ethernet and BP2G must be connected by USB.

BIPM laptop information

The system is working under Linux.

Superuser for administrative privileges available on request.

Default user:

- username: bipm
- password: bipm

IP address: 172.16.124.31

WARNING:

The laptop is sent without battery in order to facilitate transportation, it must be used with the external power supply adaptor.

f. BP2D configuration (GTR55 receiver)

Receiver is connected by Ethernet to the BIPM laptop.

IP address: 172.16.124.32

BP2D operating system login

Superuser for administrative privileges available on request.

Default user:

- username: dicom
- password: dicom

Configuration and use information

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

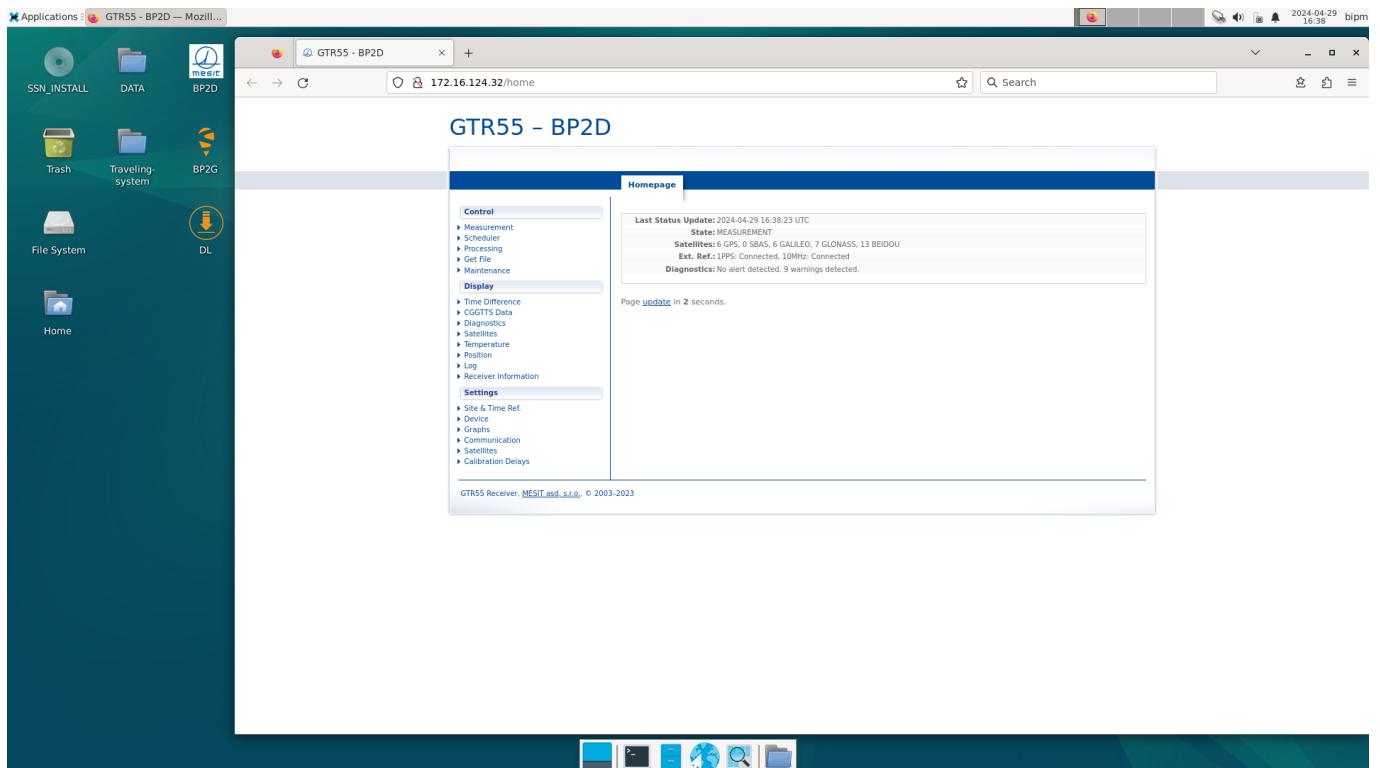
URL: <http://172.16.124.32/>

User interface access login:

- username: user
- password: user

A shortcut is available, click on the icon named “BP2D” on the desktop of BIPM laptop.

Then you should see the web page below:



Wait till the measurements starts (15 minutes approximately).
Please read GTR55 user's manual for more detailed information.

The receiver is preconfigured, so there is no need to change the default configuration.

Output data can be accessed via the web interface by clicking on the menu “Get File”, or locally inside path /var/lib/gtr/user/

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

g. BP2G configuration (PolaRx5TR receiver)

Receiver is connected by USB to the BIPM laptop.
IP address: 193.168.3.1

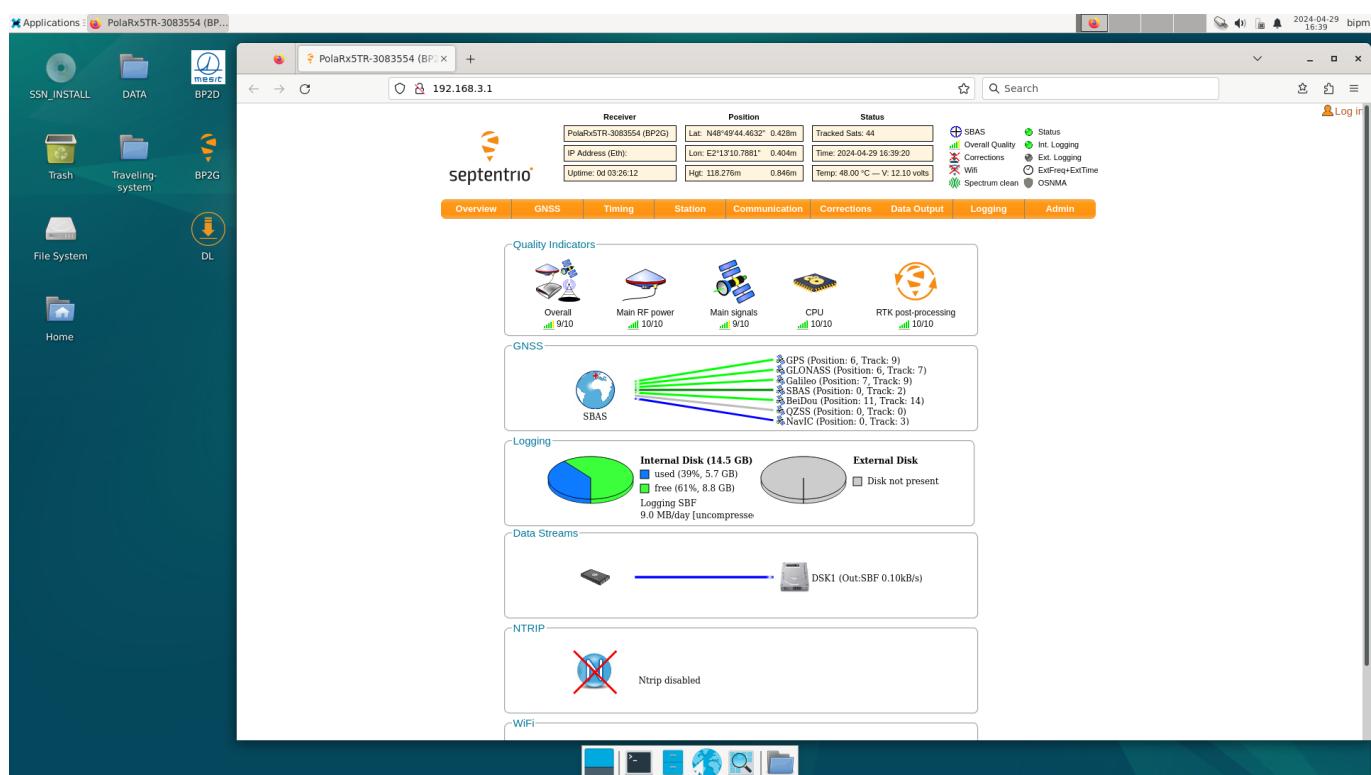
Configuration and use information

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

URL: <http://192.168.3.1/>

A shortcut is available, click on the icon named “BP2G” on the desktop of BIPM laptop.

Then you should see the web page below:



The receiver's option “compensation of PPS-in internal delay” is enabled by default.
Wait until calibration of the delay from PPS IN to the internal time reference. (20 minutes approximately).

Please read PolaRx5 user's manual for more detailed information.

The receiver is preconfigured, so there is no need to change the default configuration.

Output data can be accessed via the web interface by clicking on the menu “Logging” > “Disk Contents”, and inside tab named “Internal Disk” select “LOG1_BP2G” folder name.

To shut down the receiver press the power button on the rear panel of the receiver.

h. Output data files

The RINEX data files of both receivers have to be stored on the BIPM laptop.

A shortcut is available on the desktop of the BIPM laptop, click on the icon named “DL” to automatically upload files inside path /home/bipm/Desktop/DATA/.

It can also be done from a virtual terminal by running the script:
`/home/bipm/script/download_data.sh`

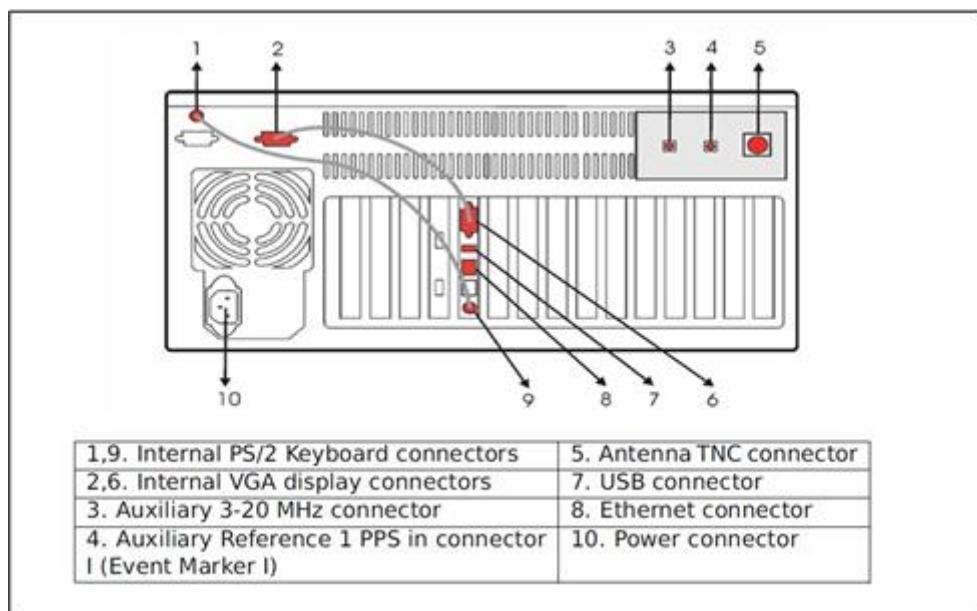
Annex C - Description and operation of the traveling system: BP1K (BIPM Time Transfer Traveling Receiver)

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)



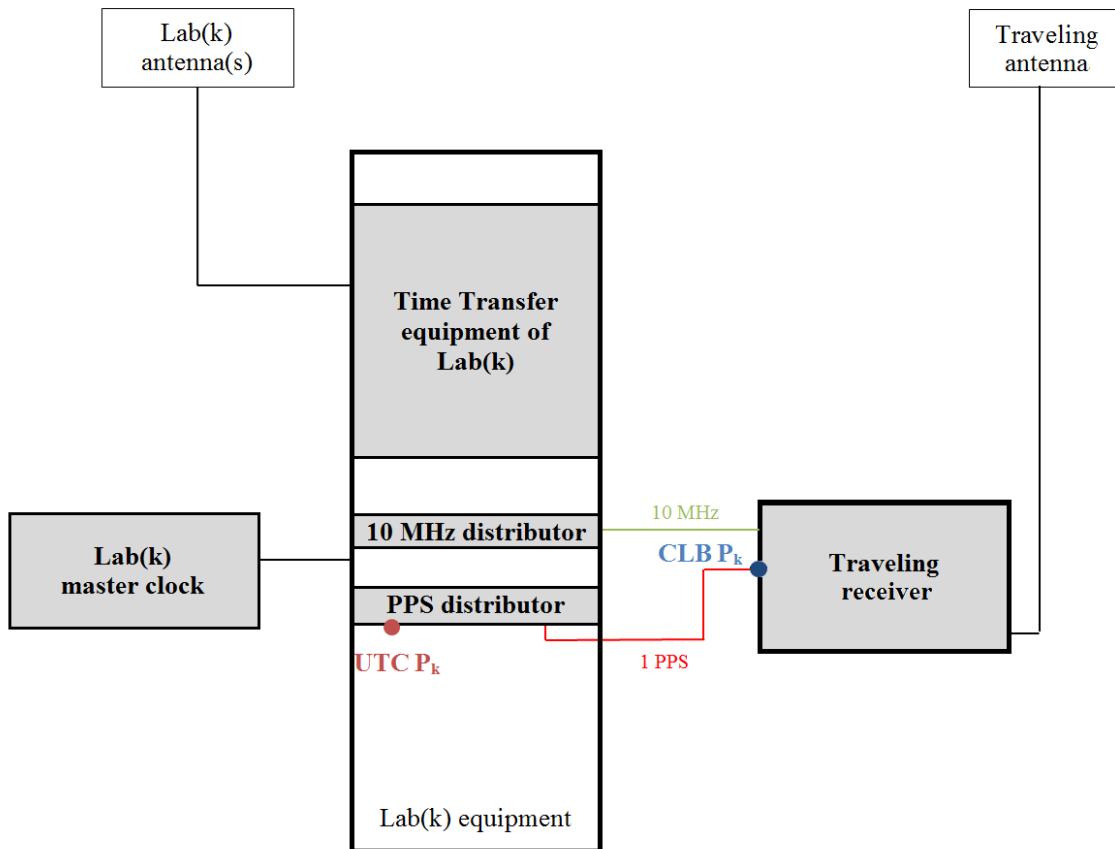
Power supply: AC 230 V 10%, 45 to 60 Hz, or AC 110 V 10%, 55 to 65 Hz

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_k 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_k: Laboratory reference (the point defining UTC(k) for a laboratory participating to UTC).
CLB P_k: Connection point, 1 PPS, for the BP1K input connector.

2. Delay Measurement

Measure the delay between the laboratory reference point (UTC P_k) and the 1 PPS input connector of the BP1K receiver (CLB P_k).

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_k) and the 5 or 10 MHz input connector of the BP1K receiver.

See Annex H 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: <https://webtai.bipm.org/ftp/pub/tai/publication/gnss-calibration/guidelines/travelling-system/bp1k.zip>.

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

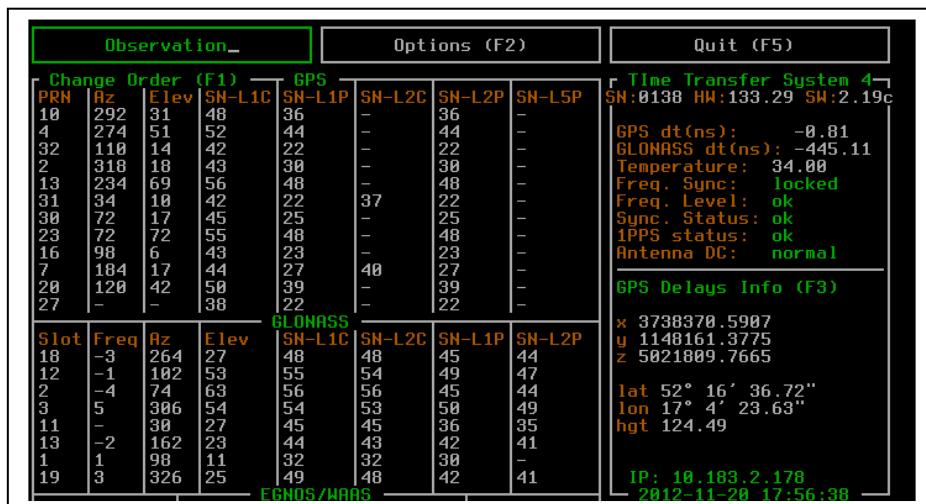
User information for web browser interface, configuration menu:

- username: admin
- password: tts3

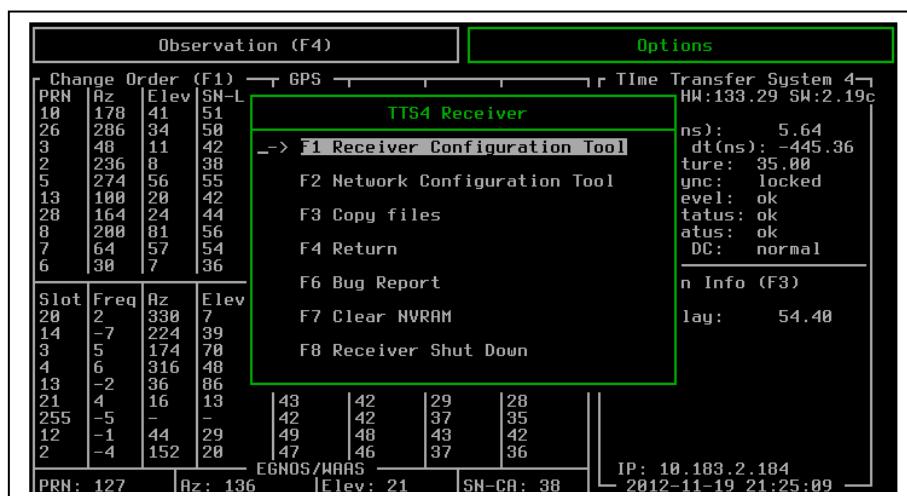
e. BP1K configuration

Configuration using touch screen and keyboard:

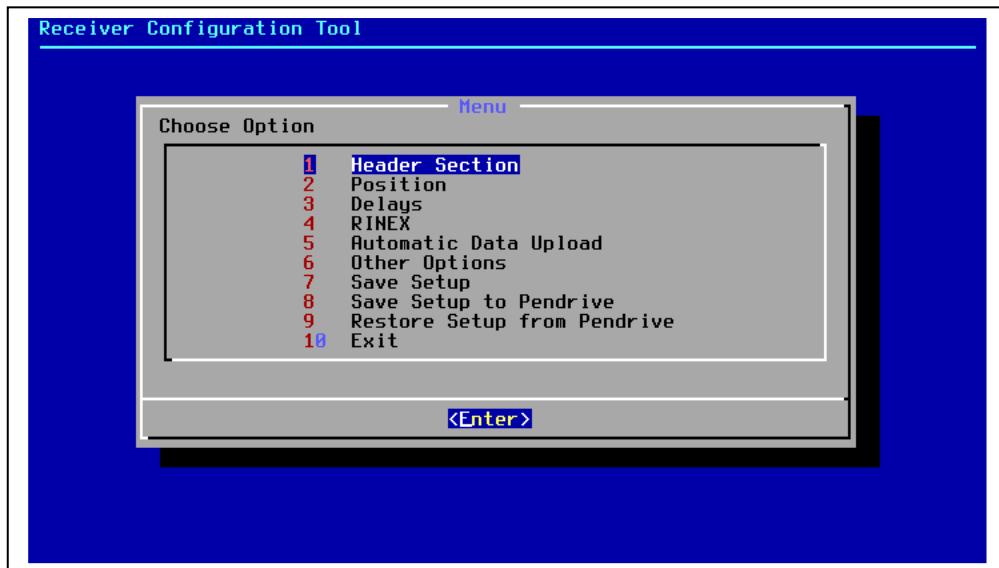
Press F2 touch on front panel (on touch screen or keyboard):



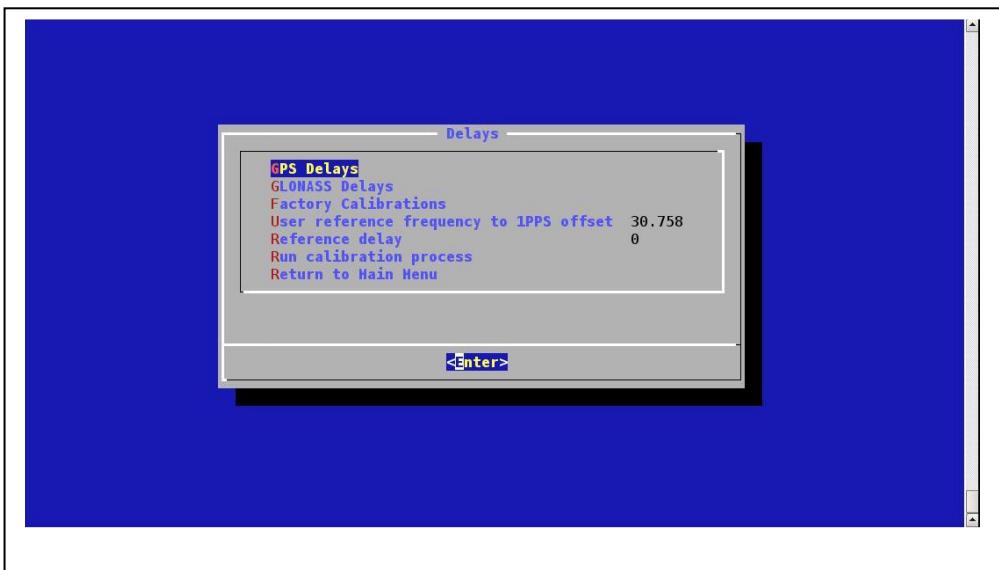
Then press F1 touch, menu “Receiver Configuration Tool”:



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



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

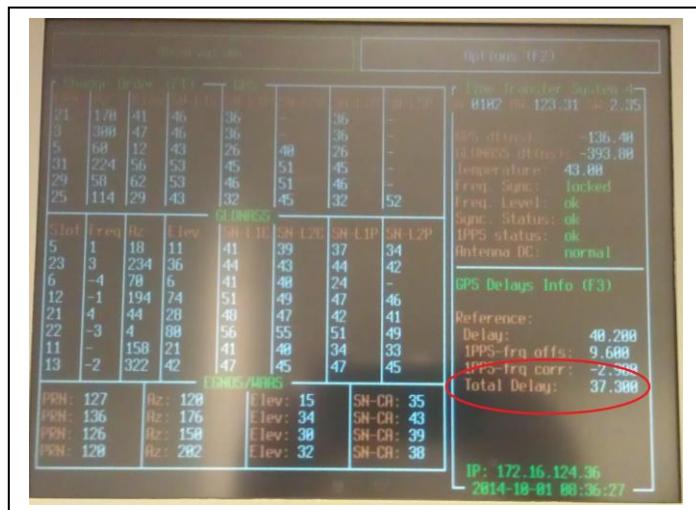


Introduce the delay from the laboratory reference UTC(k) to the 1PPS-in of the receiver in the field “Reference delay”.

Introduce the value of the delay between the 1 PPS input connector and the 5 or 10 MHz input connector of the BP1K receiver (see Annex H for measurement details) in the field “User reference frequency to 1 PPS offset”.

Then save configuration and after do “Clearing GNSS module NVRAM procedure”, see point **5.2.9** of the TTS-4 user’s manual.

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).

Please check the value of the "1PPS-freq offset corr", if it blinks red, or it is displayed in yellow color, read and follow instructions in the TTS-4 user’s manual, point **5.2.4**, “TTS-4 reference frequency to 1PPS offset”.

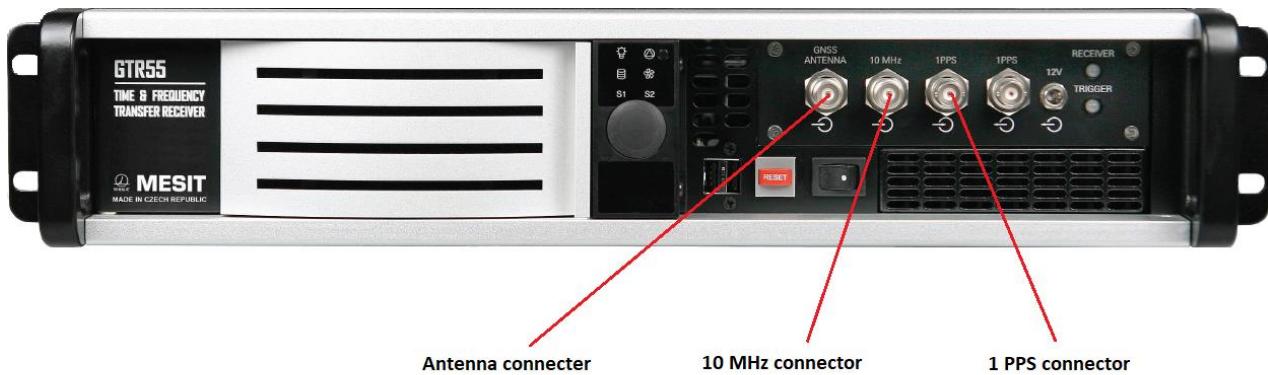
Annex D - Description and operation of the traveling system: BP25 (BIPM Time Transfer Traveling Receiver)

BP25 (Mesit GTR55 receiver)

a. List of the equipment

Designation	Maker	Serial Number	ID
GTR55 receiver	Mesit	1808001	BP25
BP25 antenna cable (~40m)	Hytem	-	C208
BP25 antenna, GNSS-850	Novatel	NMLK18070096N	-

b. Hardware connection diagram (front panel)

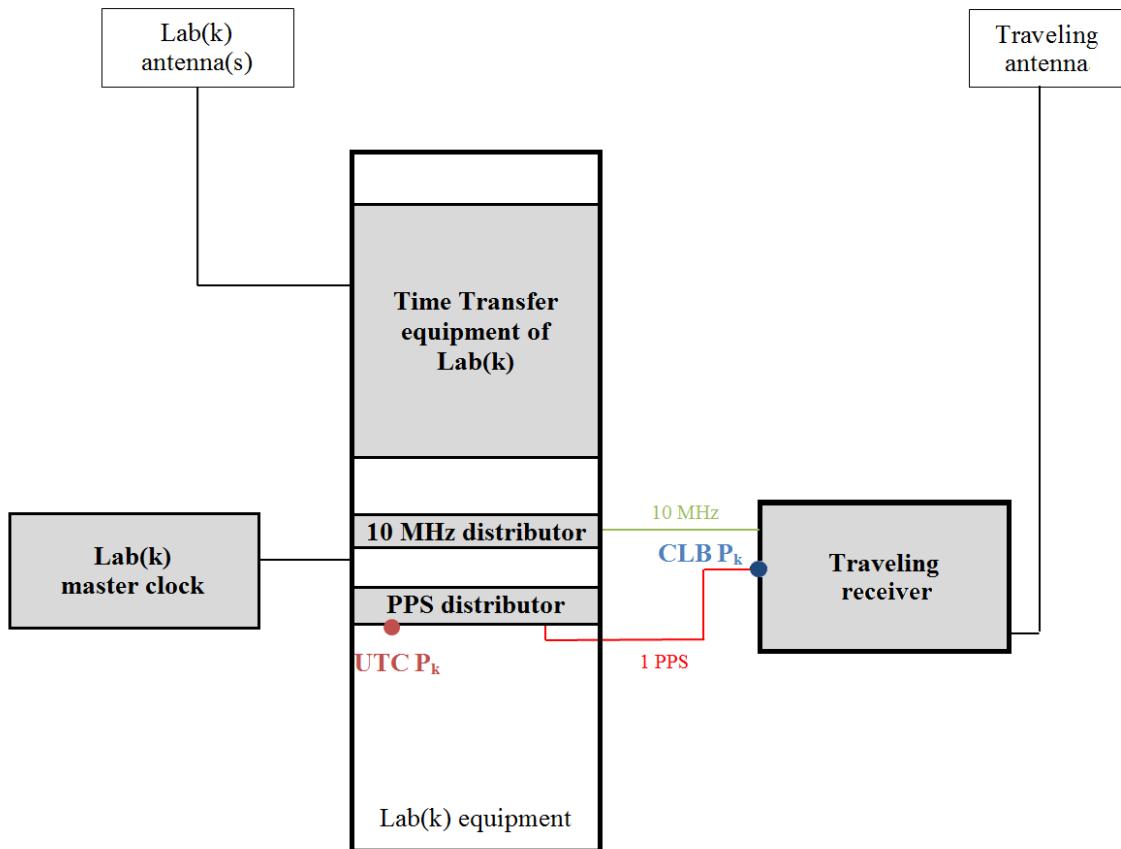


c. Relating the receiver to the laboratory reference

The BP25 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_k 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



2. Delay Measurement

Measure the delay between the laboratory reference point (UTC P_k) and the 1 PPS input connector of the BP25 receiver (CLB P_k).

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

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 receivers please read user's manual of the receiver which is available here:

<https://webtai.bipm.org/ftp/pub/tai/publication/gnss-calibration/guidelines/travelling-system/bp25.zip>.

The GTR55 receiver can be operated by remote control through a web browser or locally if you connect a screen and a keyboard to the receiver.

BP25 operating system login

Superuser for administrative privileges available on request.

Default user:

- username: dicom
- password: dicom

IP address (if operated remotely) : Ethernet configuration is DHCP by default.

Configuration and use information

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

URL:

- locally <http://localhost/>
- remotely: <http://<IP address>/>).

User web interface access login:

- username: user
- password: user

Then after login you should see the web page below:

GTR55 – BP25

update in 1 seconds.' The footer includes the text 'GTR55 Receiver, MESIT a.s., s.r.o., © 2003-2022, Rev. 1.10.11'." data-bbox="156 666 744 886"/>

Wait till the measurements starts (15 minutes approximately).
Please read GTR55 user's manual for more detailed information.

The receiver is preconfigured, so there is no need to change the default configuration.

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

WARNING:

Please record all RINEX files on an independent storage medium.

Output data (daily RINEX files) can be accessed via the web interface by clicking on the menu “Get File”, or locally inside path /var/lib/gtr/user/

Annex E - 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.

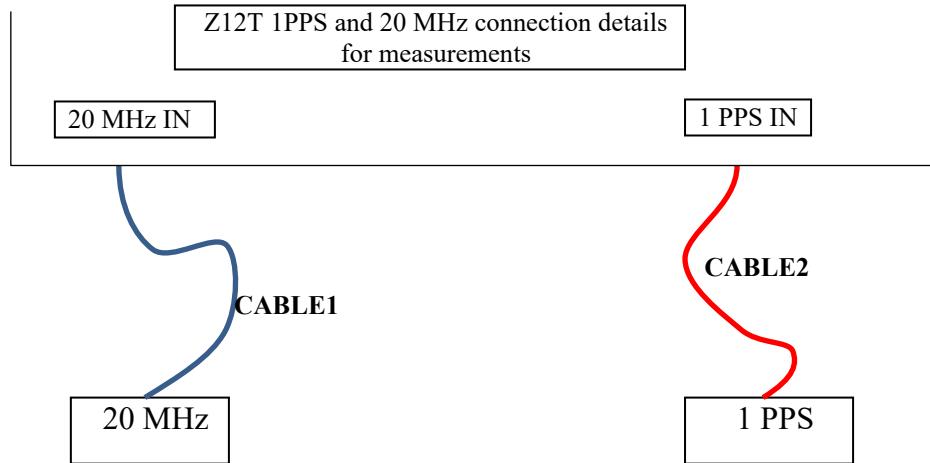


Figure 1. Example of connection between the local 20 MHz and 1PPS signals when the 20 MHz OUT is not available.

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.

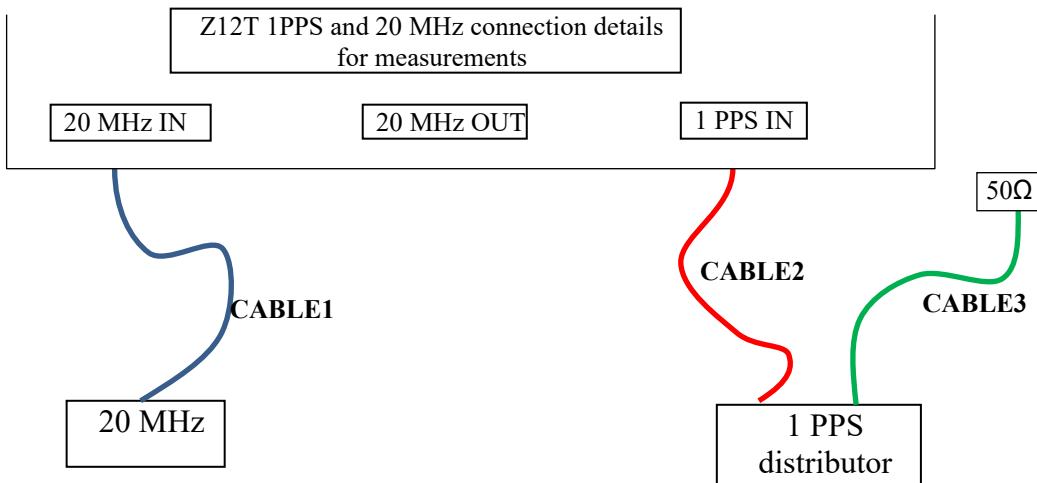


Figure 2. Example of setup for a receiver that has 20 MHz OUT available

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.

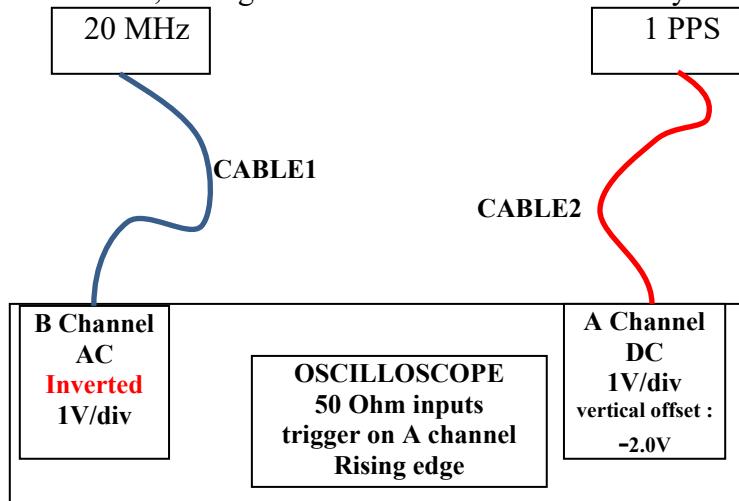


Figure 3: First setup for measurement 1)

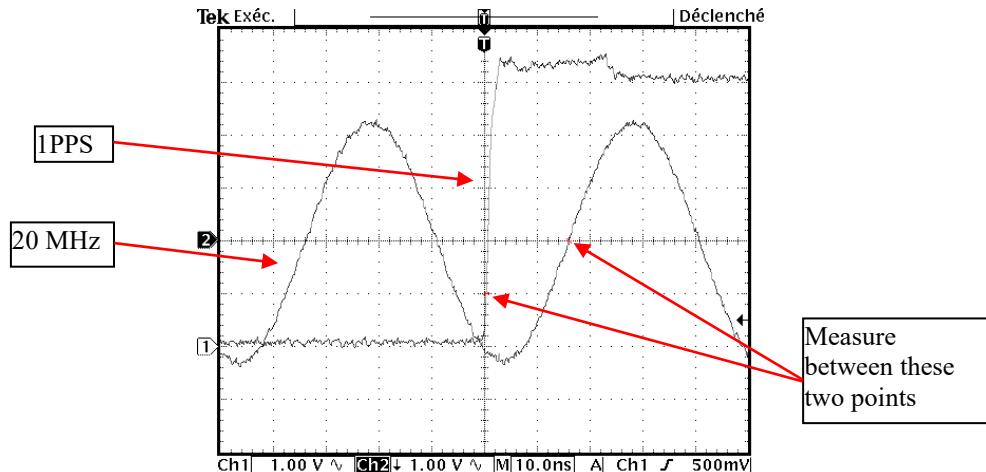


Figure 4: example of oscilloscope display using set-up shown in Figure 3

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 V on channel A (the PPS channel). This will put the 1.0V level in the middle of the screen. Use the cursors to check where the 1.0V level is. You should get a display like this one:

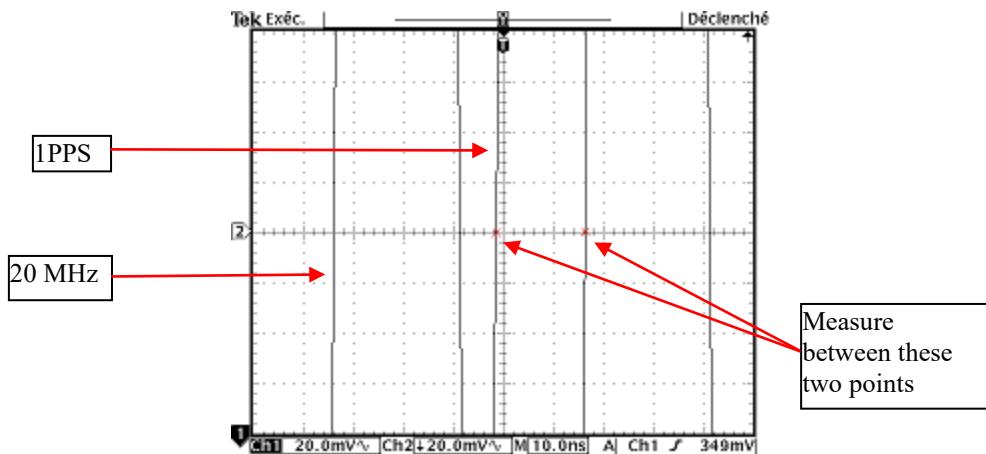


Figure 5: Measurement 1b: example of oscilloscope display using 20 mV range

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.

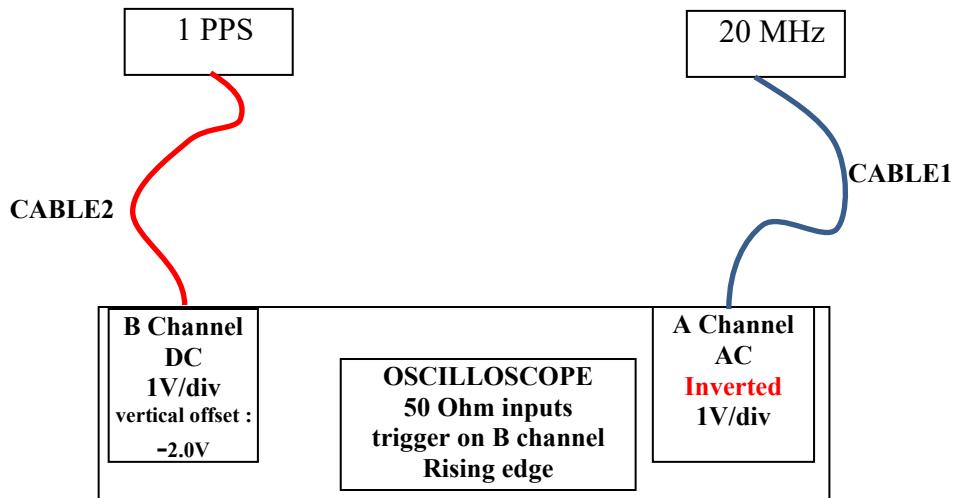


Figure 6: Measurement 1c: exchanged channel set-up

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.

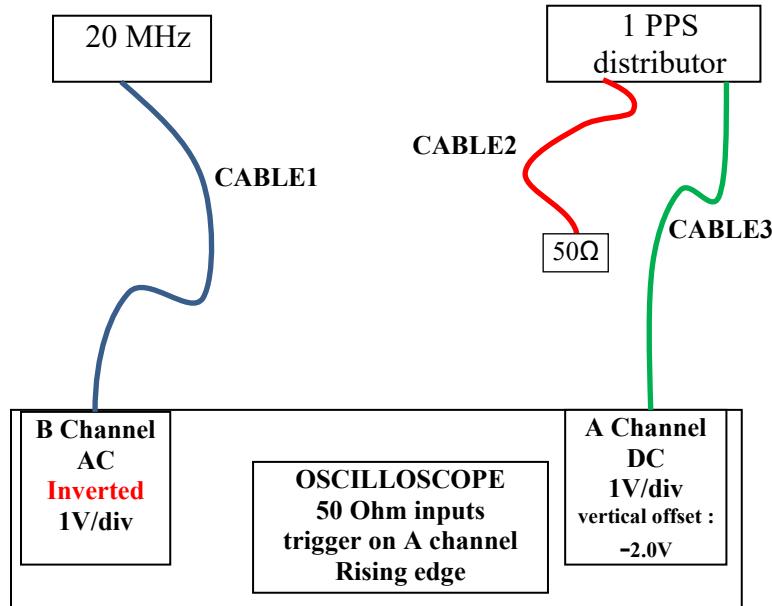


Figure 7. First set-up for measurement 2).

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.

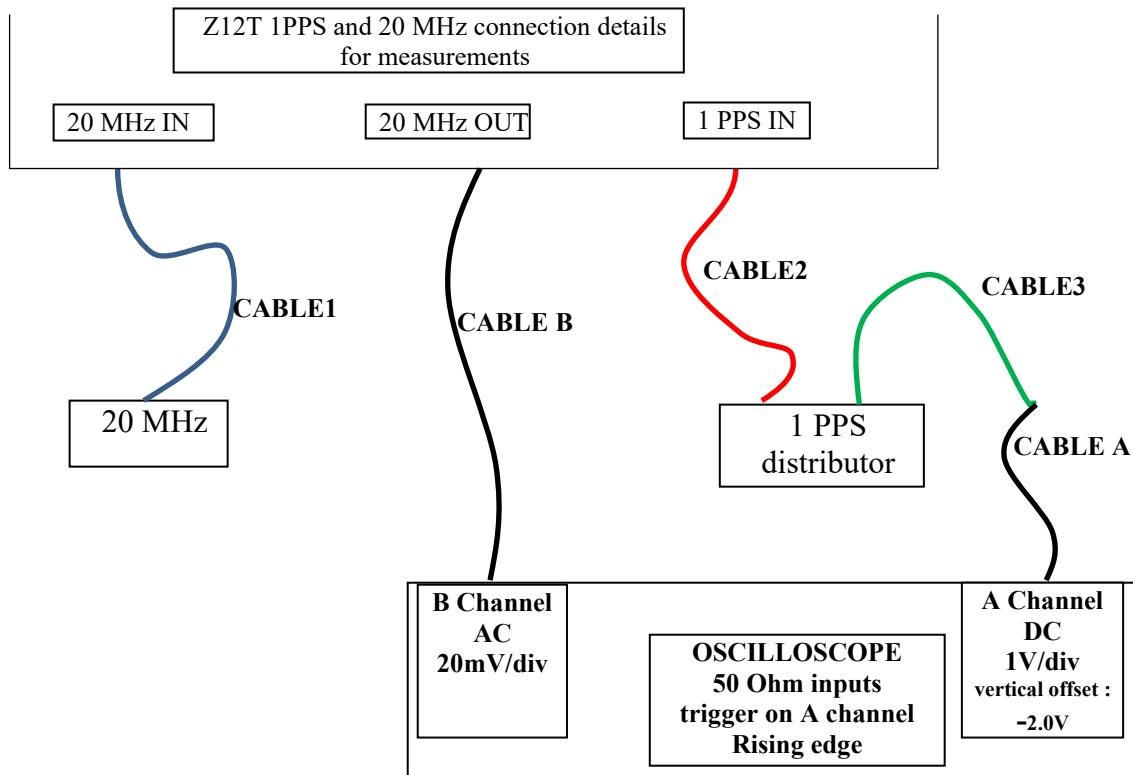


Figure 8. Second setup for Measurement 2). Note the use of phase matched cables (A and B)

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 F - 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.

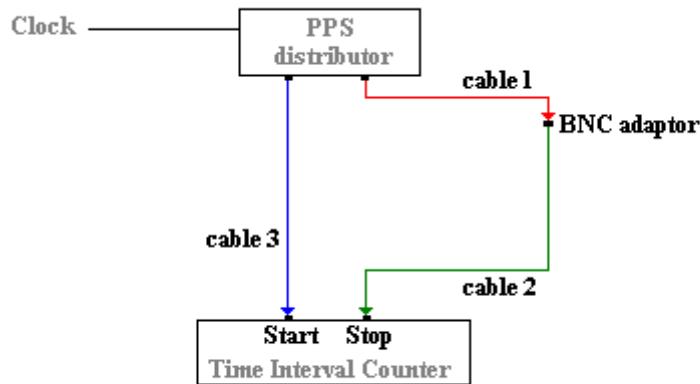


Figure 1: example of tare measurement set-up before and after operation

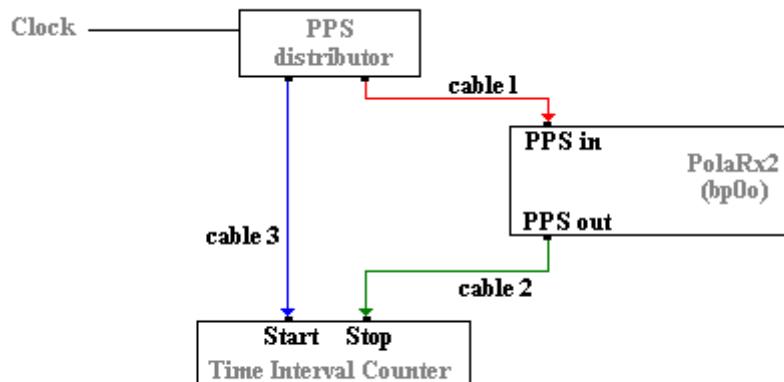


Figure 2: example of delay measurement set-up during operation

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 G - 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 H - TTS 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 or TTS-5 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 I - 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.

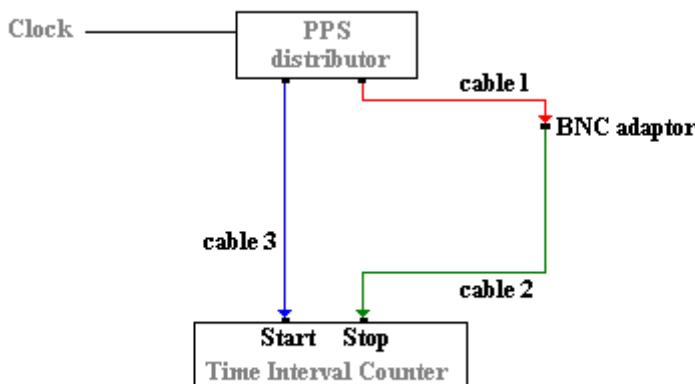


Figure 1. Determination of the tare of the measurement setup.

- 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.**

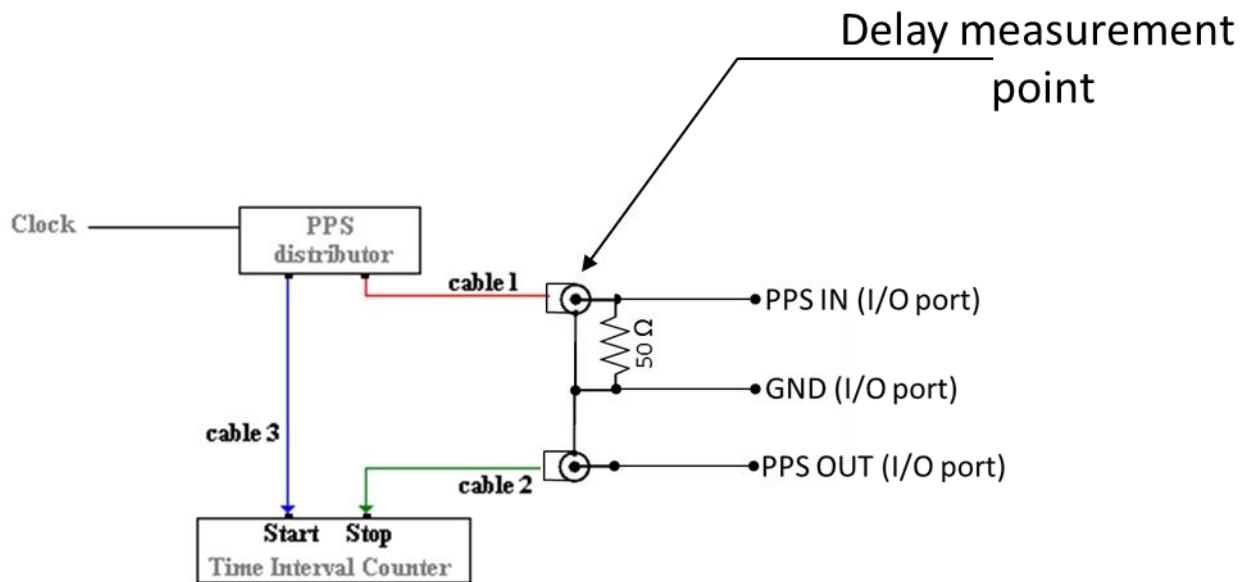


Figure 2. Setup to measure the delay between PPS OUT and PPS IN, tare included.

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 δ_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.

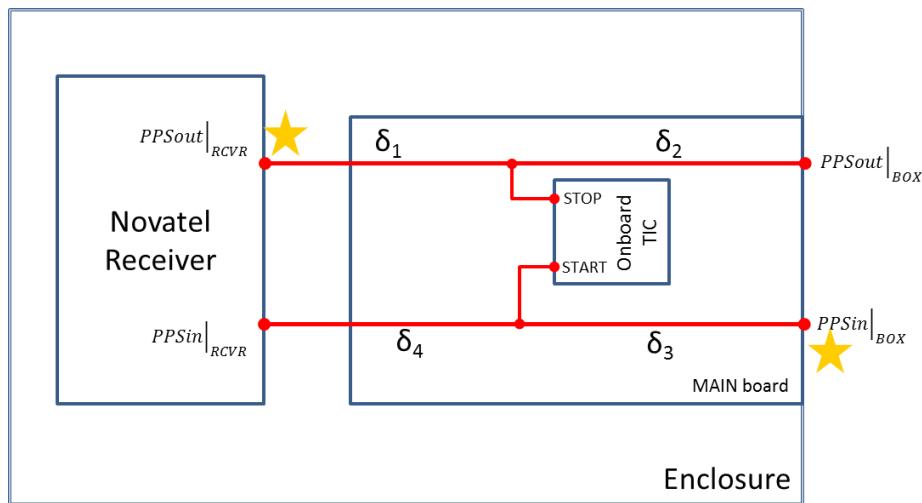


Figure 3. Conceptual diagram of the connections between the TIC included in the NIST-designed interface and the Novatel receiver. The output of the microcontroller included in the interface is the delay between PPS OUT and PPS IN at the locations indicated by the stars.

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