# Calibration of geodetic-type receivers
# version 6

# Guidelines and operational procedures
# using the travelling BIPM receiver

**<u>Table of Contents</u>**

This document provides the necessary information to perform differential calibration of geodetic-type receivers using one of the traveling receivers of the BIPM. Procedures are established for four types of receivers: Ashtech Z12-T, Septentrio PolaRx2, Dicom GTR50 and Javad JPS E_GGD, however the BIPM traveling receiver may be only an Ashtech Z12-T, Septentrio PolaRx2 or Dicom GTR50.

Section 1 and 2 apply to the traveling equipment and the user should select the section applicable, according to the traveling receiver. Section 3 describes measurements to be performed (except in some cases) both on the traveling receiver and on the receiver under calibration.

## 1. Description of the equipment

1.1 Traveling Z12-T receiver (BP0C)

Equipment supplied:
- Ashtech Z12-T (serial number LP02944),
- Antenna Ashtech choke ring (serial number CR15373)
- Antenna cable about 50m long (number C107)
- Alimentation TTI EX752M (serial number 230378)
- Portable PC Dell Latitude ATG D620 (model PP18L, P/N YY327A01)
- Frequency doubler (if 20 MHz is to be generated from 10 MHz)
- Frequency quadrupler (if 20 MHz is to be generated from 5 MHz)
- cable A and cable B for Z12T measurement (see annex A.3)

Other non-supplied necessary equipment:
- Oscilloscope (for Z12T “20MHz input/PPS input” phase measurement)

1.2 Traveling PolaRx2 receiver (BP0O)

Equipment supplied:
- Septentrio PolaRx2 (serial number 1327)
- Antenna Ashtech choke ring (serial number CR6200323008)
- Antenna cable about 50m long (number C131)
- Portable PC TOSHIBA TECRA S1 (serial number 93808215G)

Other non-supplied necessary equipment:
- Time Interval Counter (for PolaRx2 “PPS input/PPS output” delay measurement)

1.3 Traveling GTR50 receiver (BP0U)

Equipment supplied:
- Dicom GTR50 (serial number 0801068)
- Antenna Novatel GPS-702 GG (serial number NAE07460010)
- Antenna cable about 50m long (number C134)

Other non-supplied necessary equipment:
- Computer screen and keyboard (for initial receiver configuration)

## 2. General information

2.1 Hardware connection

To properly configure the traveling receiver:

- Z12-T (BP0C) see annex A.1
- PolaRx2 (BP0O) see annex B.1
- GTR50 (BP0U) see annex C.1

2.2 Data acquisition

Before starting operation of the traveling receiver:

- Z12-T (BP0C) see annex A.2
- PolaRx2 (BP0O) see annex B.2
- GTR50 (BP0U) see annex C.2

## 3. Relating the internal reference to the laboratory reference

The procedure to relate the internal reference to the laboratory reference is presented below. It should be carried out at the beginning and the end of the experiment (to check for stability and possible mistake), for the two systems.

3.1 Ashtech Z12-T

See a more detailed description in annex A.3.

3.1-0) Check the oscilloscope: one should obtain the same results when measuring a delay with different ranges (1V or 20 mV). Also when reversing channels.

3.1-1) Measure the delay between the laboratory reference 1PPS @ 1V and the 20 MHz in (inverted, positive zero crossing) (oscilloscope range 1V).
**Note: This measurement is a back-up measurement.** The measurement 3.1-3 will be used by default.

3.1-2) 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]

3.1-3) Additional measurement: similar to 3.1-1) but connecting the cable of 20 MHz in and 1 PPS in 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.**

3.1-4) Provide a plot of the oscilloscope screen (for all measurements for the each Z12-T system).

3.2 Septentrio PolaRx2

See a more detailed description in annex B.3.

3.2-0) Synchronize the 1PPS output signal from the PolaRx2 receiver with the measurement latching epoch using the command:
“SetPPSParameters 1 0 local” (or equivalently “spp 1 0 3”)

3.2-1) Measure the delay between the 1PPS-in and 1PPS-out. The result should be between 213.0 and 246.3 ns (+/- 2ns) for firmware version 2.3 and higher.

3.3 Dicom GTR50

As the 1 PPS input is the reference of the GTR50 measurements, no extra measurement is needed.
For the receiver under calibration, it is however necessary to check and report the values of some parameters, see details in annex C.3.

3.4 Javad (type JPS E_GGD)

When the receiver under calibration is a Javad (type JPS E_GGD), see a detailed description of the procedure in annex D.3.

## 4. Measurements for differential calibration of total (internal + antenna) delay

The two systems are set-up independently (2 antennas). The input frequency and the 1 PPS in for the two systems are derived from the same reference.

Four days to one week of measurements are taken with a 30s data interval and stored in daily Rinex files.

## 5. Data report

The following information should be provided:

- A figure describing the actual set-up with indication of all measured delays.
- Results of measurements described in section 3 (at the beginning and end of the experiment).
- Precise coordinates for the phase centers of the two antennas: The relative positions should be known with an uncertainty of one cm [at most a few cm]. If impossible, the BIPM will compute coordinates from the Rinex files.
- A log of events.

The data from the two receivers are to be provided in daily RINEX files. For safety reasons, all files 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).

The BIPM receiver data are stored on the traveling PC.
The data from the laboratory receiver may also be stored on the traveling PC.

# Annex A.1
# Traveling Z12T (BP0C) hardware connection

Please use the frequency doubler if possible.

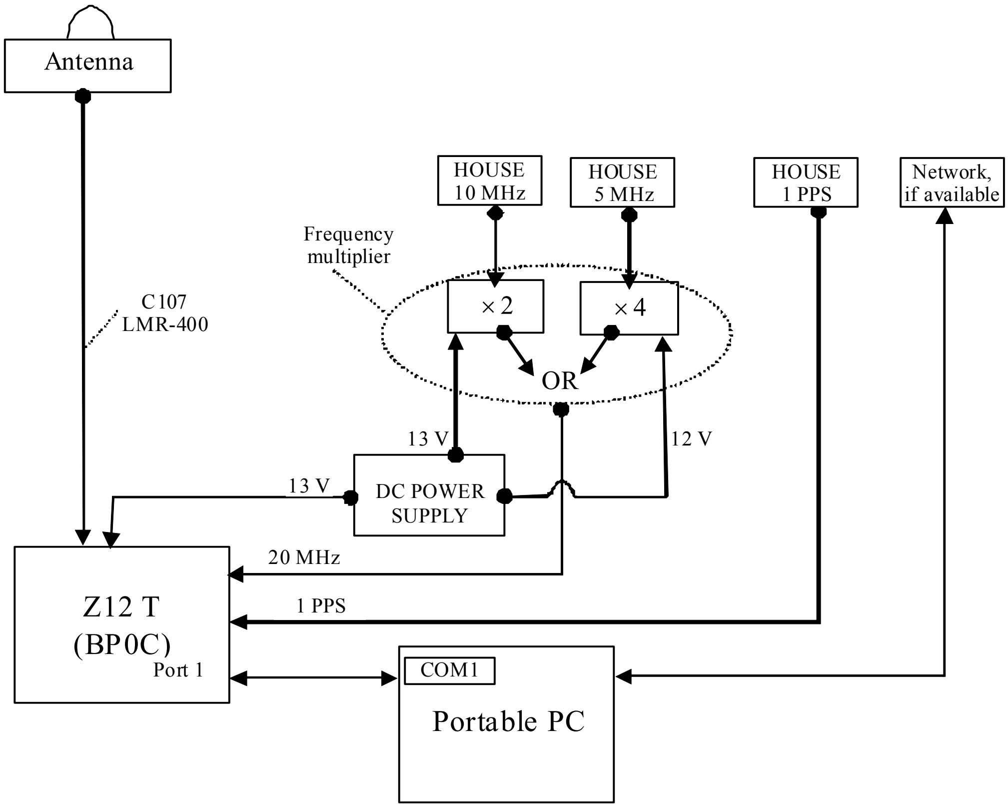



Figure 1: short baseline set-up

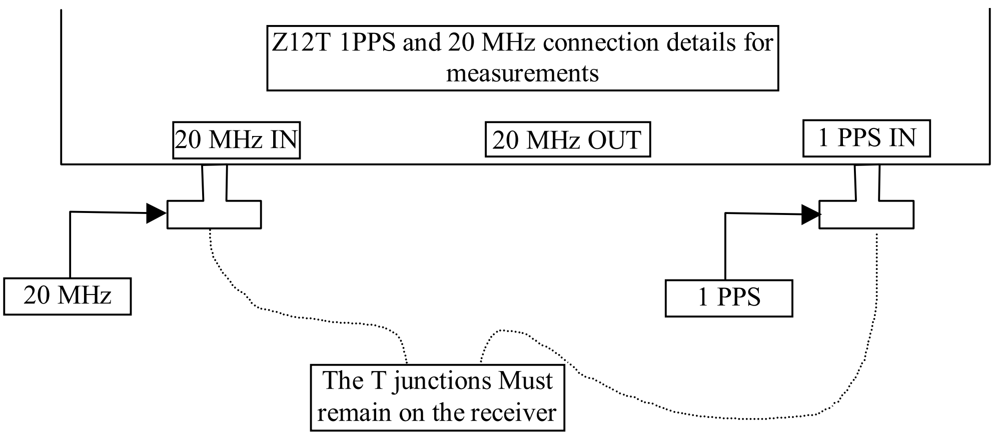



Figure 2: 1PPS and 20 MHz input and output close up

# Annex A.2
# Traveling Z12T (BP0C) data acquisition

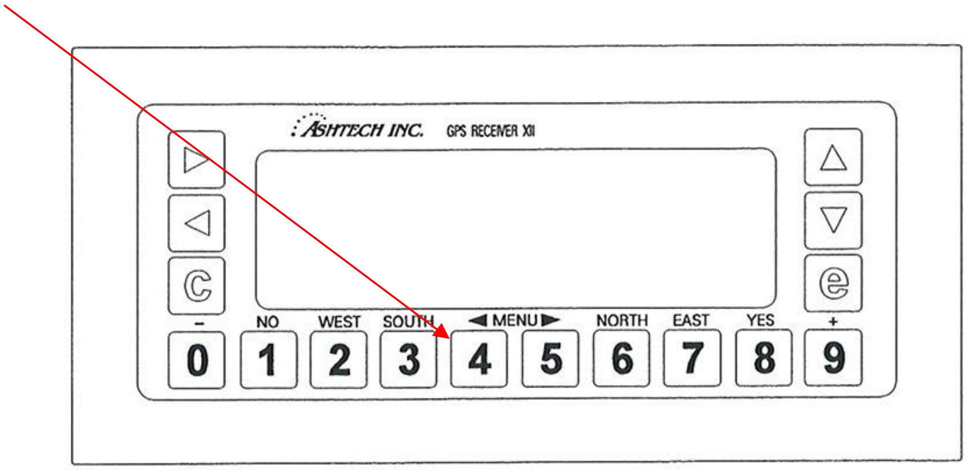
The user account of the portable computer is:

Login: “user”

Password: “ ” (empty)

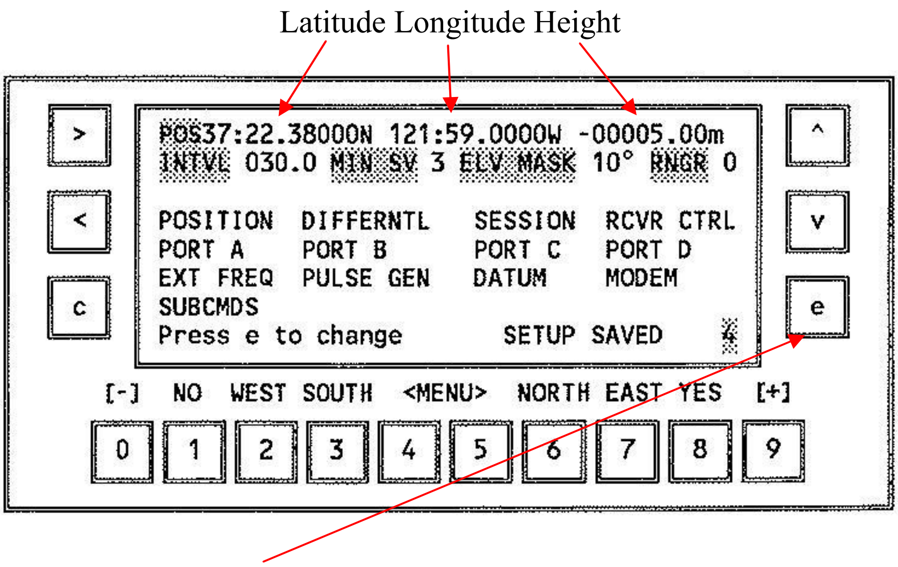
<u>Beforehand Z12-T configuration :</u>

Press button “4” of the receiver.




The next screen will appear.

You have to record the coordinates of the BIPM antenna in this menu (“POS” line).




To proceed you have to press red button “e” to enter in edition mode.

Use blue button “►”, “◄”, “▲”, “▼” to move the curseur in the menu and numerical white button to modify the values.

Once coordinates are changed press button “e” to record your changes.

If you have mistaken press red button “c” to abandon changes.

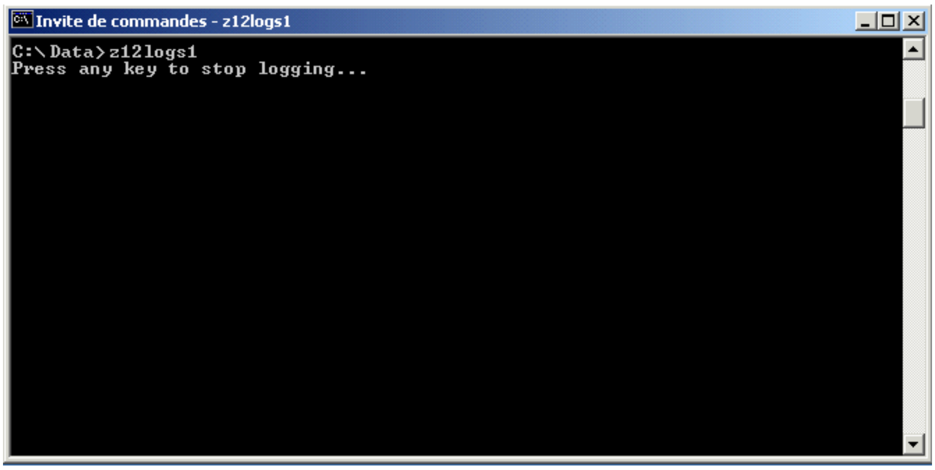
Other parameters (which are already recorded in the receiver) can be accessible in this menu and are:
- "INTVL": 30.0
- "ELV MASK": 10°
- "PORT A" subscreen:
    - "REAL-TIME": ON, "Baud Rate": 38400
    - "REAL-TIME" subscreen:
        - Binary mode
        - "MBEN": ON
        - "PBEN": ON
        - "SNAV": ON
- "EXT FREQ": 00.0

Raw data file acquisition:

The acquisition software of the traveling receiver is z12logs version 0.4.
After being started, it will record daily binary files of RS-232 stream from the Z12T.

To start the acquisition, launch the icon below by double-clicking on it on the desktop of the PC.


This will open a MS-DOS command console in directory "C:\Data".
Enter "z12logs1.exe" command to start the record of binary data:




A daily binary file, named z12t**DOY**0.r**YY**, will be created in directory "C:\Data" (where DOY is the day of year and YY is the 2 last digits of the year).

WARNING:
- If you run "z12logs1.exe" more than one time in a day, the previous output file will be overwritten, so please rename the previous file before start again "z12logs1.exe" command.
- If message "Timeout!" appear on the console check if Z12T receiver tracks satellites and relaunch "z12logs1.exe".
- When the change of year will occur you have to stop and start again "z12logs1.exe" command to take into account this change, otherwise the extension of binary file will not change

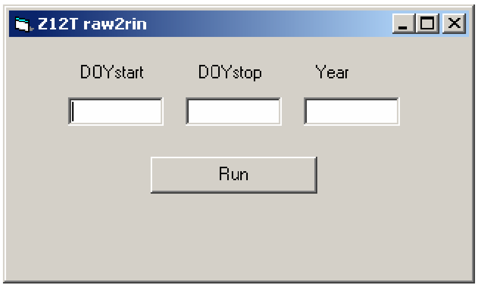
(ie: extension will be “*.r08” instead of “*.r09”).

Raw data conversion to rinex data:

If you want convert binary files to rinex files you can run software “Z12T raw2rin” independently of the acquisition software. This software use TEQC software from UNAVCO.

Launch the icon below by double-clicking on it on the desktop of the PC.


This will open this screen:




Fill the empty fields and click on “Run”.
The ouput is a set of daily rinex files located in directory “C:\Data”.

# Annex A.3
# Z12T measurement detailed procedure

Measurements 3.1-1 and 3.1-2 do not affect the receiver operation. Measurements 3.1-3 should be performed before starting the operation and after ending operation.
The T junctions must remain on the Z12T receiver during all the calibration period.
Please note the use of two phase matched external cables (cable A and cable B).
They are provided but, if for any reason you are using other cables, please make sure they are phased matched at the level of 0.1 ns.

MEASUREMENT 3.1-1:
Set-up your oscilloscope as stated on the following figure. The trigger level is not critical.
Use a time base of 10ns/div, the signals will then be easier to identify.

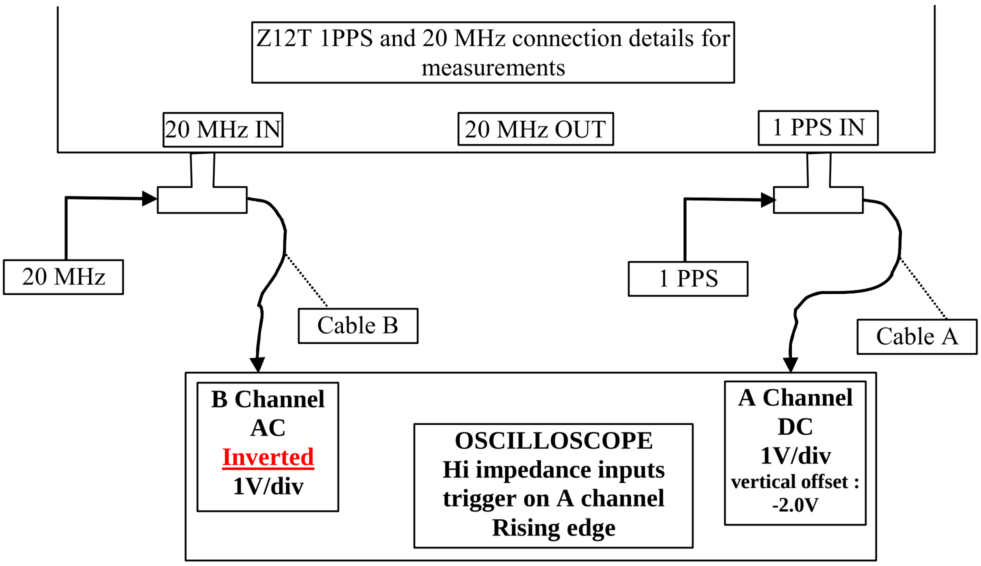



Figure 1: measurement (3.1-1) set-up

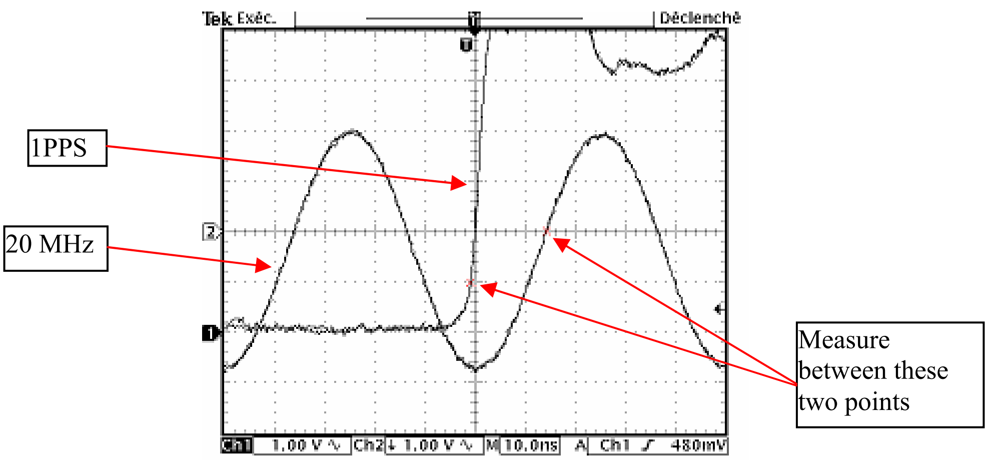



Figure 2: example of oscilloscope display using this set-up

Measure the phase difference between the 1PPS 1V crossing and the following inverted 20 MHz RISING EDGE ZERO crossing as shown on figure 2.

**This first measurement is important because you can check if the configuration correspond to the receiver setup.**
**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 first measurement in this range.**

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

Use this configuration 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:

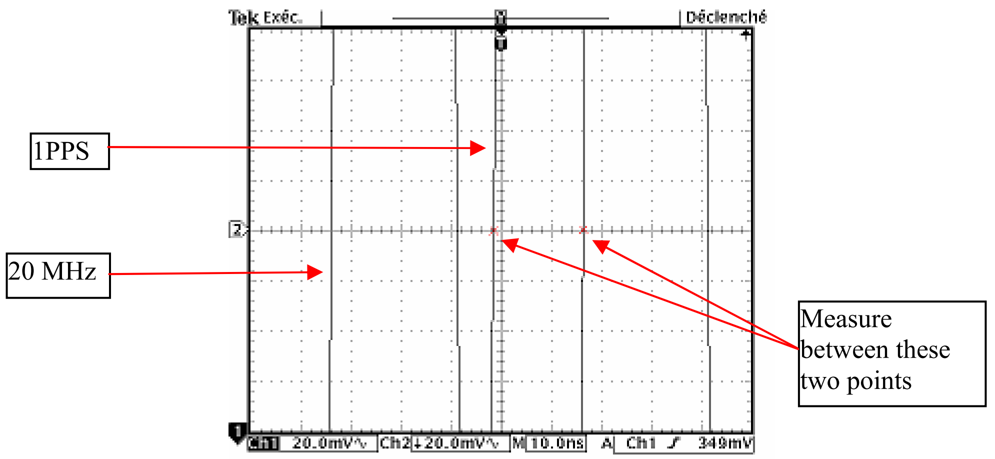



Figure 3: example of oscilloscope display using 20 mV range

Measure the same delay, The result should be the same (within the cursor uncertainty) as the one using the 1V/div range. If you don't measure the same value try to use another oscilloscope.

There is still a set-up to try to validate the oscilloscope measurements.
Set the vertical range back to 1V/div. remove vertical offset values
Interchange the channels and measure again

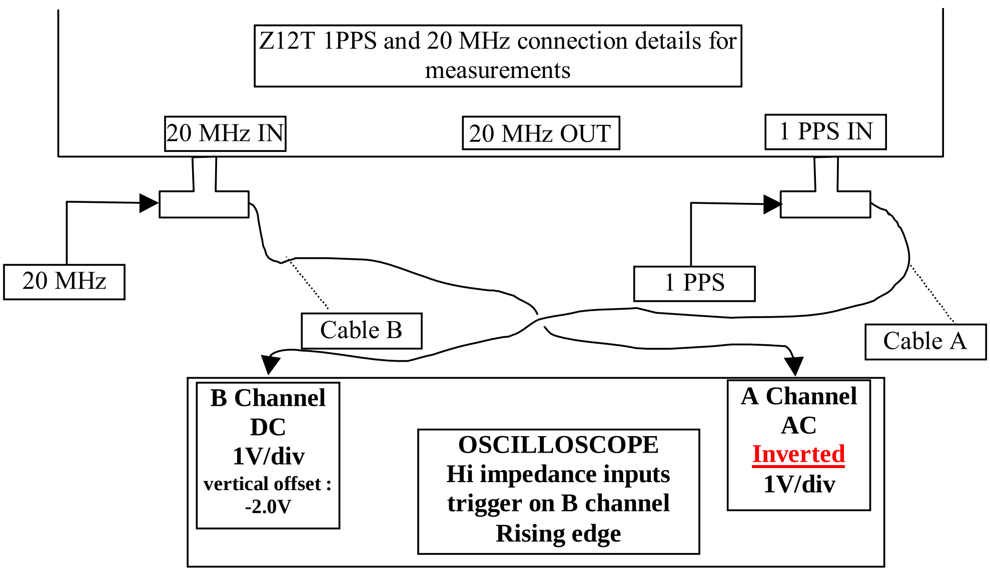



Figure 4: exchanged channel set-up

With this setup, you should get a plot equivalent to the figure 2
The measurement should give the same value as the others (within cursor uncertainty).
If not, take the average between this value and the one measured at the same range before exchanging channels.

MEASUREMENT 3.1-2:
Set-up your oscilloscope as stated on the following figure. The trigger level is not critical.
Use a time base of 10ns/div, the signals will then be easier to identify.

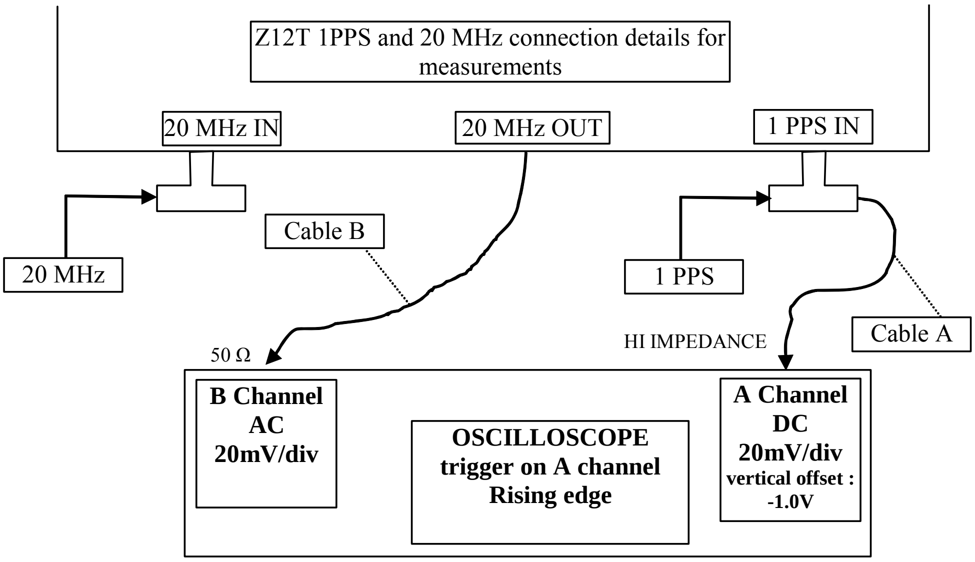



Figure 5: measurement (3.1-2) set-up

You should obtain a result like the figure 6.

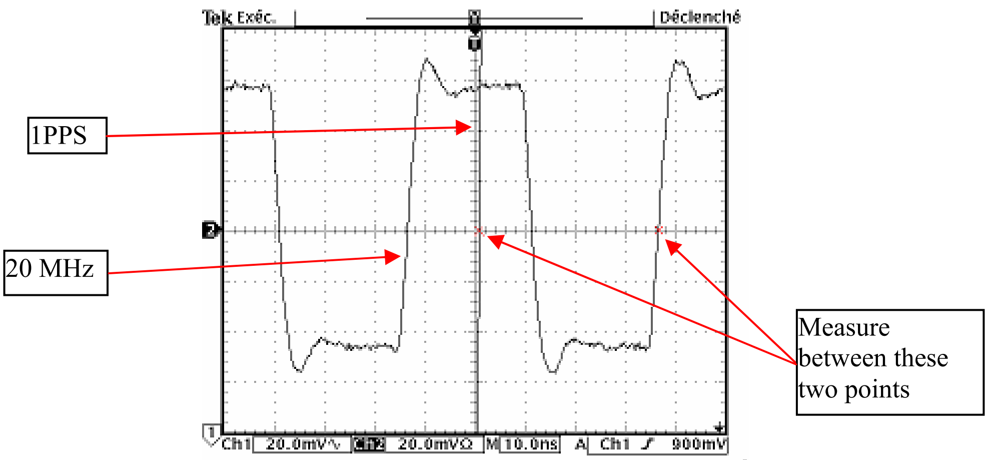



Figure 6: example of oscilloscope display

Measure the phase difference between the 1PPS 1V crossing and the following 20 MHz RISING EDGE ZERO crossing as shown on figure 6.
Do a measurement with exchanged channels if necessary.

The difference between measurement (3.1-1) and (3.1-2) should be 18.2 ns (within combined cursor measurement uncertainties).

MEASUREMENT 3.1-3:

Set-up your oscilloscope as stated on the following figure. The trigger level is not critical.
Use a time base of 10ns/div, the signals will then be easier to identify.

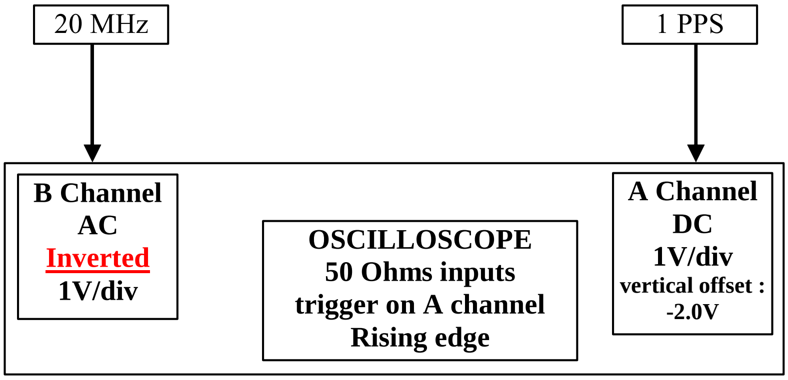



Figure 7: measurement (3.1-3) set-up

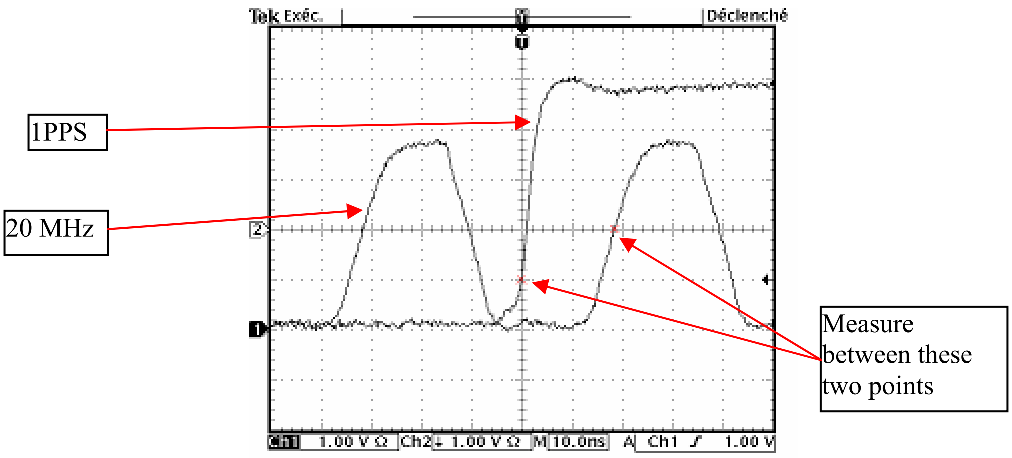
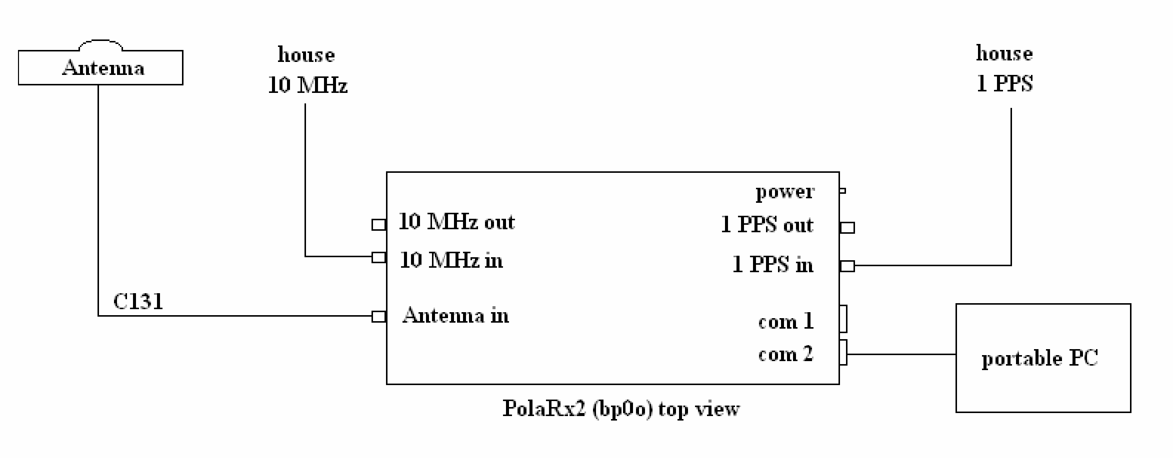



Figure 8: example of oscilloscope display using this set-up

# Annex B.1
# Traveling PolaRx2 (BP0O) hardware connection

The BNC/SMA adapters must remain on the traveling PolaRx2 receiver.
The 10 MHz signal must be sinusoidal with a peak-to-peak amplitude ranging from 0.4V to 1.5V on 50Ω.
Some Attenuators are provided if needed.

Figure 1: short baseline set-up

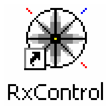


# Annex B.2
# Traveling PolaRx2 (BP0O) data acquisition

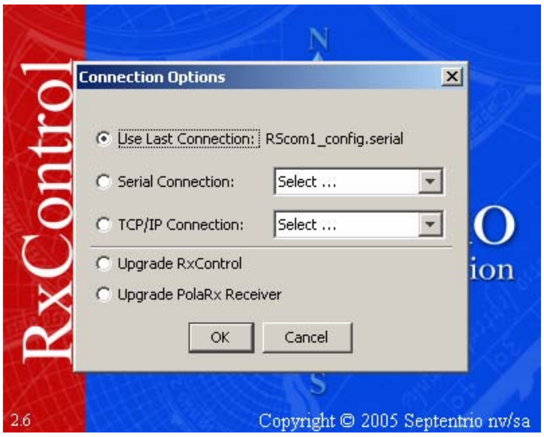
The software of the traveling receiver is RxControl version 2.6.
More details can be found on portable computer in path “C:\DOCS”.

The user account of the computer is:
Login: “administrator”
Password: “ ” (empty)

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

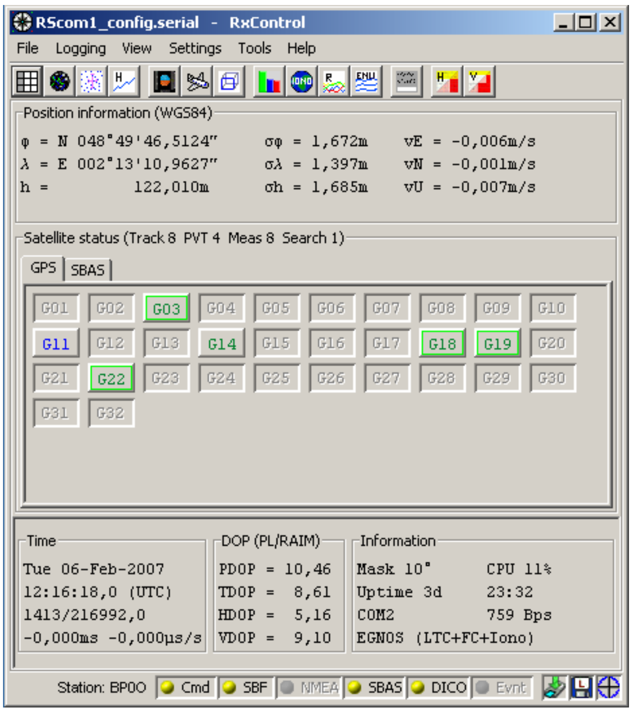



This screen should appear on the screen.



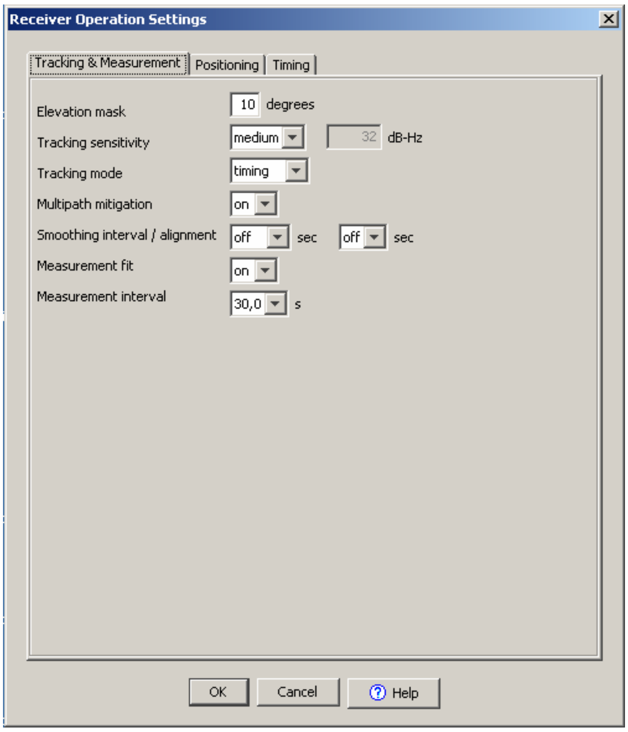

Select connection named “RScom1_config.serial” and press OK.

This screen should appear on the screen.

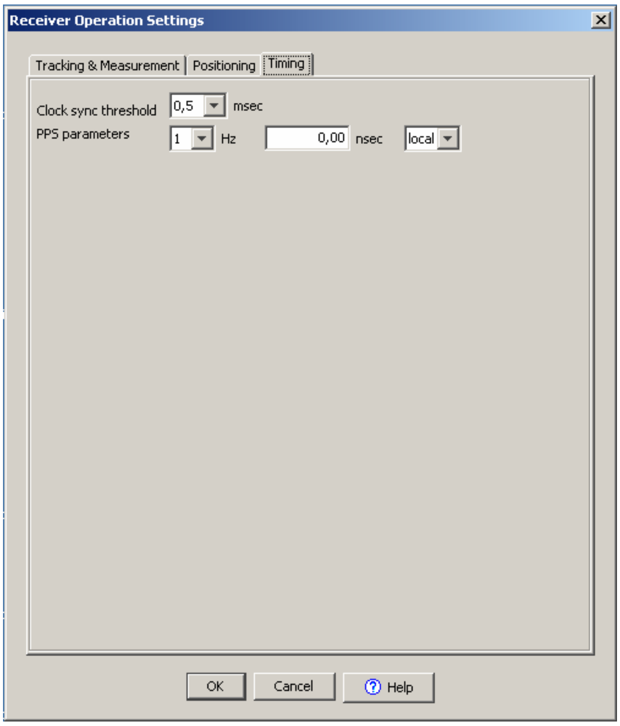


In the “Settings” menu, start by checking the “Receiver Operation”.

On this tab “Tracking & Measurement”, make sure to have the same values :



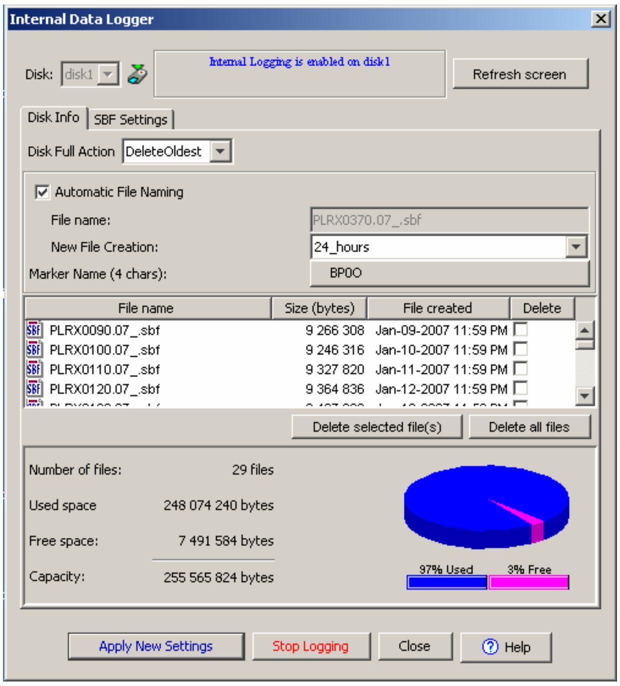

On this tab “Timing”, make sure to have the same values :




Press OK.

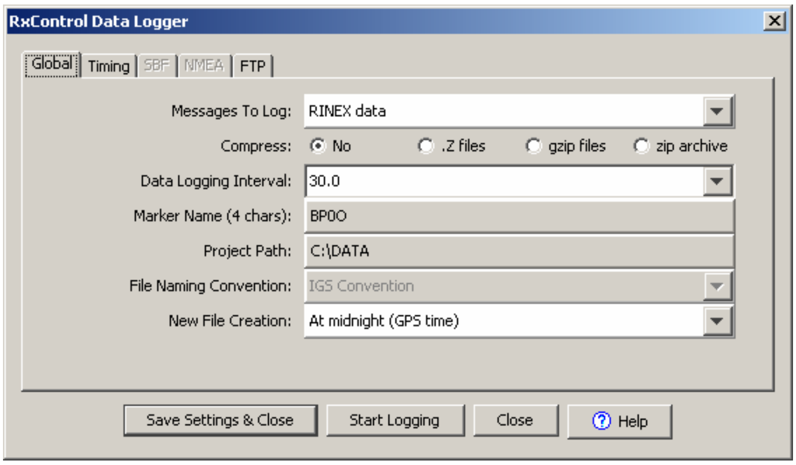
In the “Logging” menu, start by checking the “Internal Logger”.

On this screen, make sure to have the same values and press “Start Logging” :




In the “Logging” menu, check the “RxControl Logger”.

On this screen, make sure to have the same values and press “Start Logging” :




At all times files except the one of the current day are accessible and transferable from the directory “C:\DATA”.

At the end of the stay in your laboratory just exit from the “File” menu.

# Annex B.3
# PolaRx2 measurement detailed procedure

Measurement of the delay between the 1 PPS input connector
and the 1 PPS output connector of the PolaRx2 receiver.

MEASUREMENT 3.2-1:

In order to avoid disturbing the equipment during operation, one solution is to perform a tare of your set-up without PolaRx2 receiver before starting the operation and after ending operation.
Please set your Time Interval Counter with a trigger level of 0.5 volts under 50 ohms.

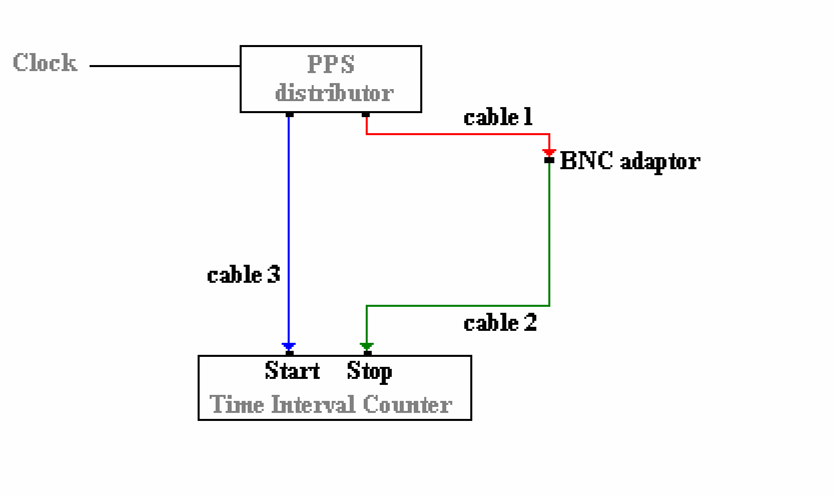



Figure 1: example of tare measurement set-up before and after operation

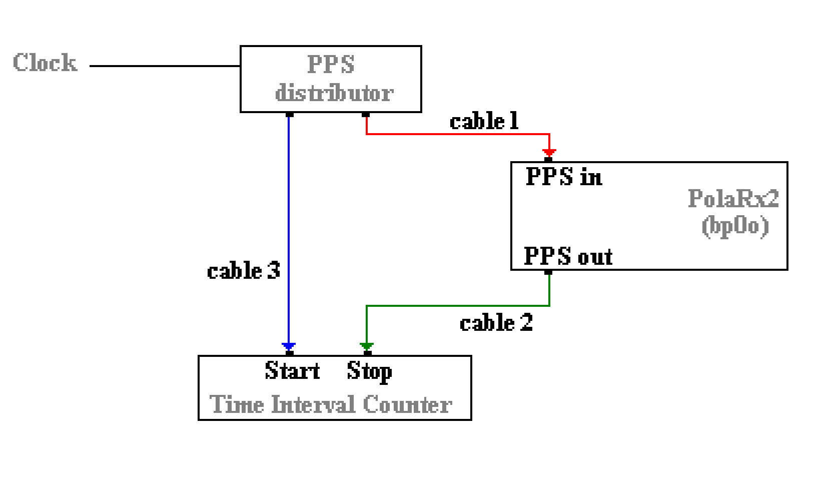



Figure 2: example of delay measurement set-up during operation

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) and should be between 213.0 and 246.3 ns (+/- 2ns) for firmware version 2.3 and higher.

# Annex C.1
# Traveling GTR50 (BP0U) hardware connection/configuration

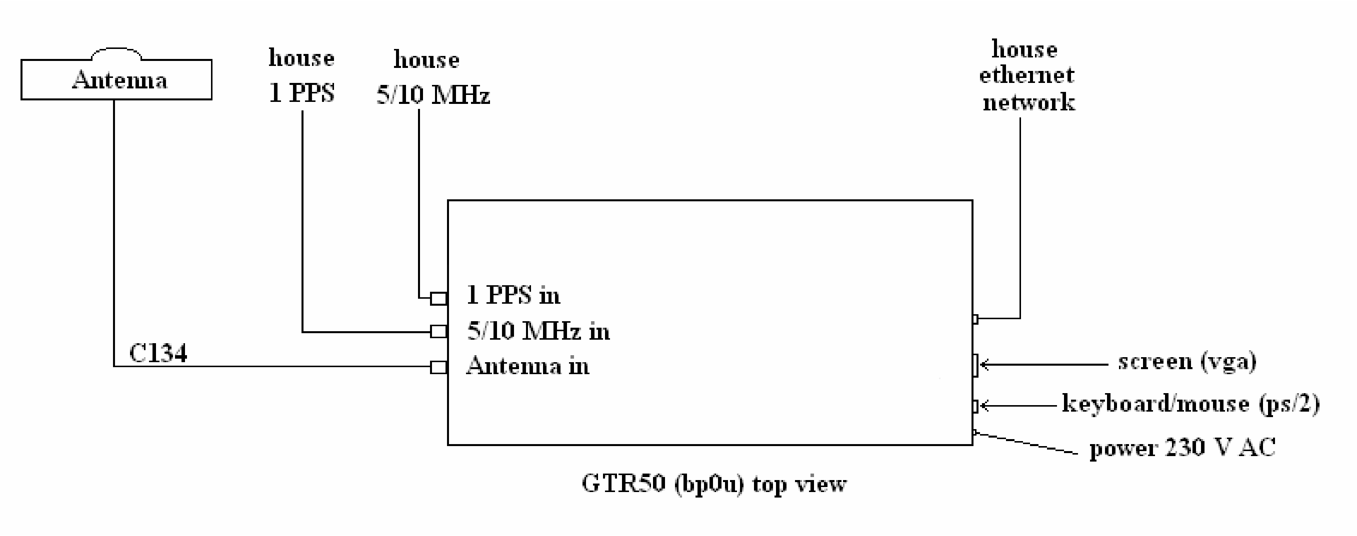



Figure 1: short baseline set-up

Initial receiver configuration:

The receiver is working under LINUX and operates by remote control through a web browser, so after the first boot of the receiver you have to configure the IP address of the receiver.

To do this (in case of trouble please make contact with person in charge of IT):

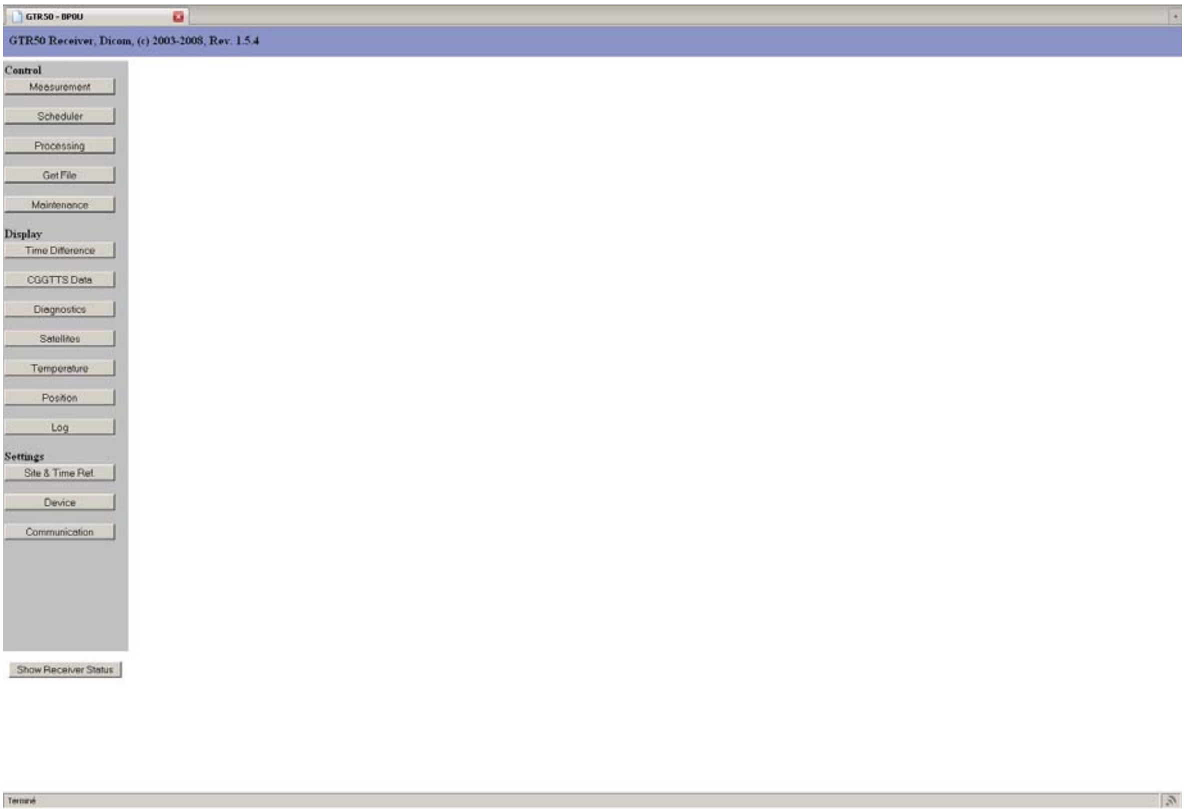
- connect a screen and keyboard to the receiver
- boot the receiver
- type ALT+F1 to switch to first virtual terminal
- login as root (login: root, password: KLdpO472007H)
- enter command "system-config-network"
- select “Ethernet” then “Configure”
- change/modify “Ethernet configuration”, DHCP or static IP are available
- apply change by enter command "service network restart"
- exit virtual terminal by enter command “logout”

After this operation you can remove screen and keyboard.

# Annex C.2
# Traveling GTR50 (BP0U) data acquisition

Open a web browser and enter URL: “http://<IP address>/GTR50/”
After the login field appears, enter user name “user” and password “user”.

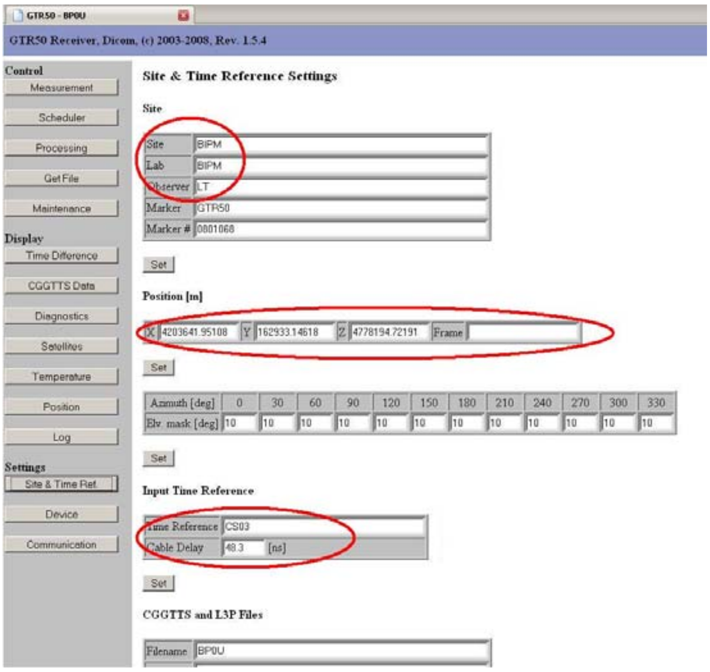
You should see the web page below:




Buttons visible above in web interface are called below “menu button”.

GTR50 configuration:

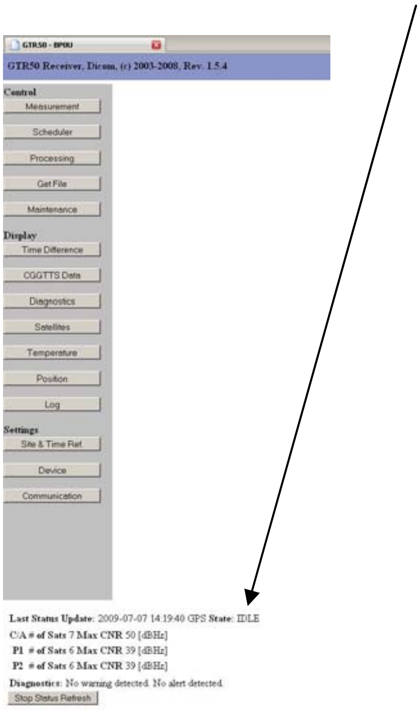
Click on the menu button “Site & Time Ref.” to display screen below:




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

GTR50 data acquisition:

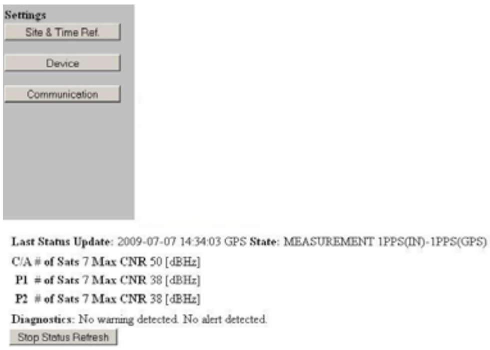
Before start the measurement you have to wait “IDLE” state of the receiver.




To check the status of the receiver click on the menu button “Show Receiver Status”.

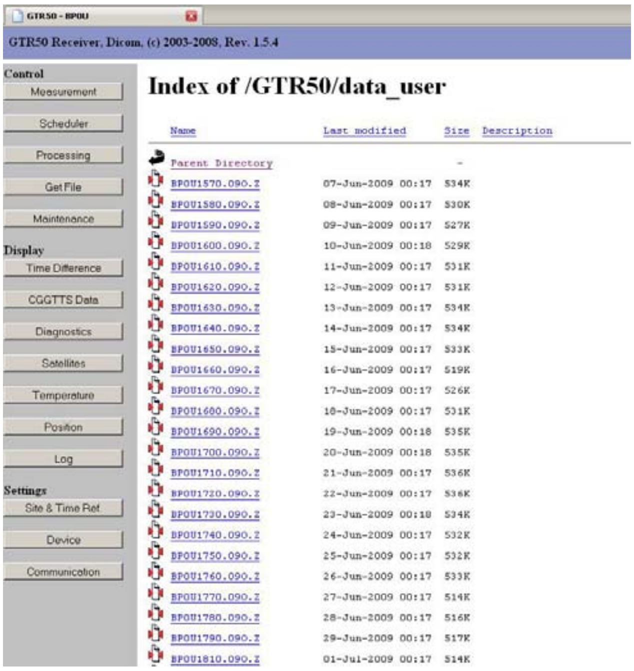
When the receiver is in “IDLE” state click on the menu button “Measurement”, then click on “Start Measurement”.

Once it’s done receiver state should be “MEASUREMENT 1PPS(IN)-1PPS(GPS)”




GTR50 data:

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




WARNING:
Oldest data (>30 days) are automatically removed, so don’t forget to record all files on an independent storage medium.

GTR50 shutdown:

Click on the menu button “Maintenance”, then click on button “GTR50 shutdown”

# Annex C.3
# GTR50 measurement detailed procedure

As the 1 PPS input is the reference of the GTR50 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:

For 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

For 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

# Annex D.1
# Javad: Hardware connection/configuration

The main connections of the receiver are shown in Figure 1.

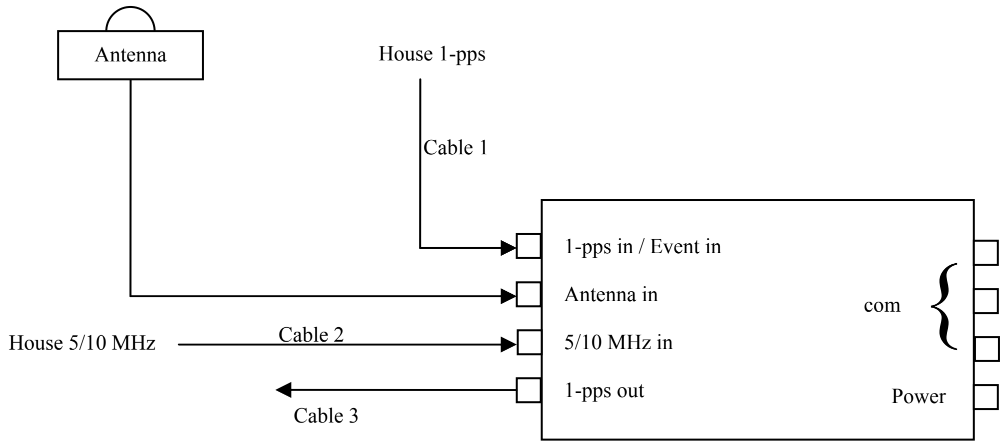



Figure 1: **Main connections of receiver**

1. The reference frequency input must be a 5/10-MHz sinusoidal signal with a peak-to-peak amplitude ranging from 0.5V to 3.0V in 50 Ω. Make sure that the receiver is locked to the frequency input and that the receiver is not adjusting its internal oscillator's frequency (OFF-mode), see Figure 2.

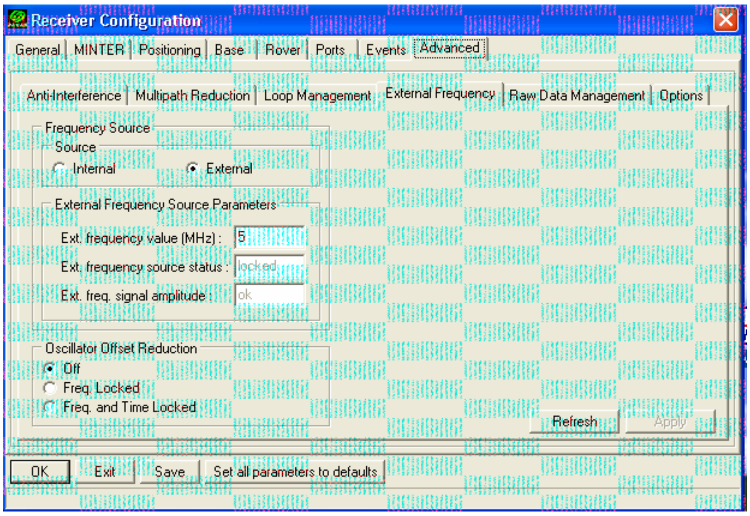



Figure 2: **Configuration of frequency input using software PCVU (see Annex D.2)**

2. The 1-pps input should be coherent with the reference frequency and with an amplitude of less than about 3 V peak-to-peak in 50 Ω. Make sure that the receiver clock is synchronized to the positive going pulse of the external 1-pps and not tied to any reference time scale, see Figure 3.

3. The connector of the 1-pps output is defined as the internal reference of the receiver clock. Make sure that the 1-pps output is set to ON, that the positive going pulse is chosen and not tied to any reference time scale, see Figure 3.

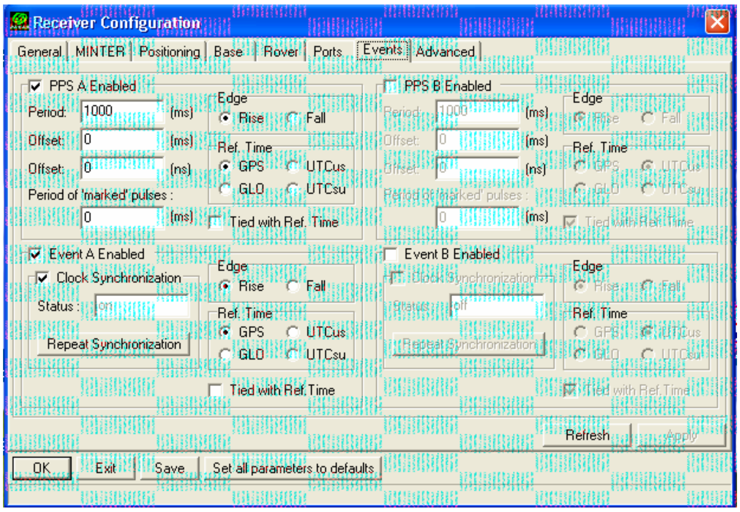



Figure 3: **Configuration of 1-pps output and 1-pps input (Event) using software PCVU (see Annex D.2)**

4. The input power should be between 4.75 VDC and 28 VDC.

# Annex D.2
# Javad: Data acquisition

To collect and download data from the Javad receiver use either the software “jlogger”, available from http://facility.unavco.org/software/download_transfer/other/other.html, on a Linux computer or “PCVU”, available from http://www.javad.com/jns/index.html, on a Windows computer (see Figure 4). Software for transfer jps-files to rinex-files are also available from these sites.

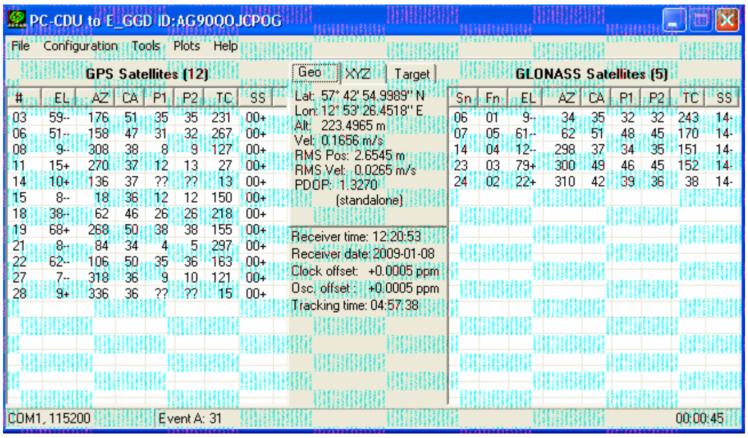



Figure 4: **General view of receiver connected to software PCVU**

The computer must be connected to one of the available com-ports (serial RS232/USB/Ethernet) available from the receiver. The software is also used to configure the receiver. A manual (GRIL reference guide) of the receiver is available from http://www.javad.com/jns/index.html. Figure 5 shows an example of configuring real-time logging using the PCVU software.

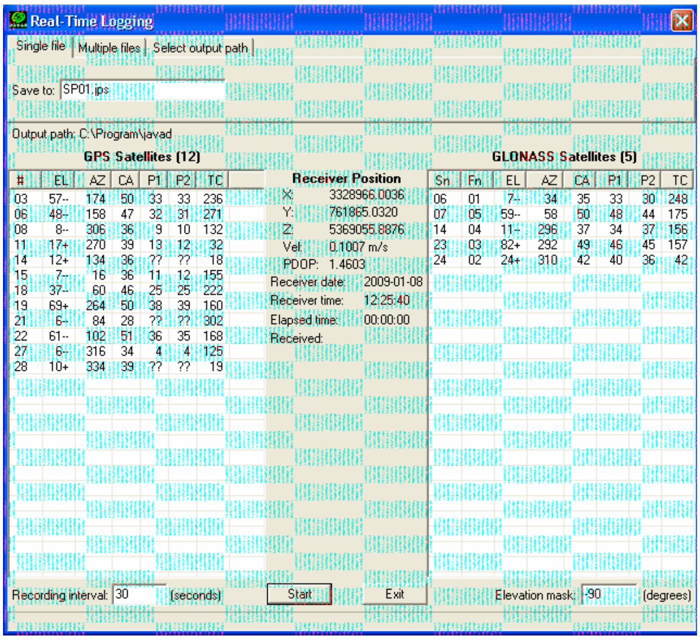



Figure 5: **Data logging using software PCVU**

# Annex D.3
# Javad: Measurement detailed procedure

Javad receiver functionality:

- The 1-pps output is related (with an unknown but constant time offset) to the internal clock of the receiver (if configured correctly, see Figures 2 and 3).

- The internal clock of the receiver is synchronized at start-up (or manually at any time) to the first positive going zero-crossing of the frequency input, derived from the 5/10-MHz input, that follows the 1-pps input (if configured correctly, see Figures 2 and 3). After synchronization, the internal clock of the receiver is disciplined to the 5/10-MHz frequency input.

- During normal operation and with correct configurations as above, the 1-pps output follows the internal clock of the receiver.

- The internal delay in the receiver depends on the phase difference between the 1-pps input and the 5/10-MHz input. As long as the phase difference is constant, the internal delay is constant (here neglecting changes in the internal delay due to other effects such as temperature or component ageing). The effective internal delay, as measured by the 1-pps output minus the 1-pps input, may in fact be negative.

- Any change in the phase difference between the 1-pps input and the 5/10-MHz input will change the effective internal delay in the receiver referenced to the 1-pps output. Any change in the internal delay may be calibrated by continuously measuring the 1-pps output of the receiver relative to a reference time scale.

Recommended measurements:

<u>MEASUREMENT 3.3-1:</u>

Since the synchronization of the internal receiver clock is made to the frequency input and since the effective internal delay in the receiver is sensitive to the actual phase difference between the 1-pps input and the 5/10-MHz frequency input, this phase difference must be measured in order to relate the 1-pps output to the 1-pps input (see Figure 6). We recommend to do this before and after operation.

Put your Time Interval Counter with a trigger level of 1.0 V and DC-coupling on the start channel for the 1-pps pulse and 0.0 V and AC-coupling on the stop channel for the 5/10-MHz signal. Set both channels to 50 Ω load.

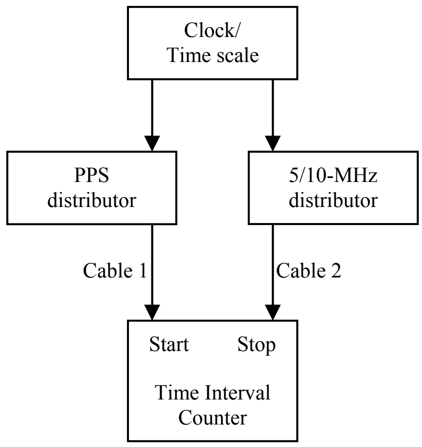



Figure 6: **Example of delay measurements of the phase difference between the receiver 1-pps input (cable 1) and receiver 5/10-MHz input (cable 2) before and after operation**

<u>MEASUREMENT 3.3-2:</u>

This measurement estimates the delay of the 1-pps input connector and the 1-pps output connector of the Javad receiver (see Figure 7), the so called tare delay. We recommend to do this before and after operation.

Put your Time Interval Counter with a trigger level of 1.0 V, DC-coupling and 50 Ω load on both the start and stop channel.

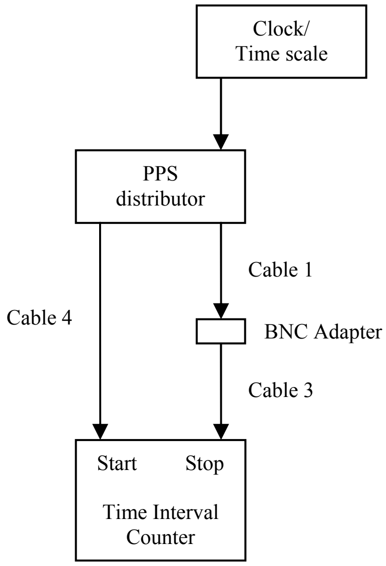



Figure 7: **Example of delay measurements of the time interval difference (the tare delay) between the reference pulse (cable 4) and the receiver 1-pps input (cable 1) + the receiver 1-pps output (cable 3) before and after operation**

MEASUREMENT 3.3-3:

This measurement is performed during operation (see Figure 8).

Put your Time Interval Counter with a trigger level of 1.0 V, DC-coupling and 50 Ω load on both the start and stop channel.

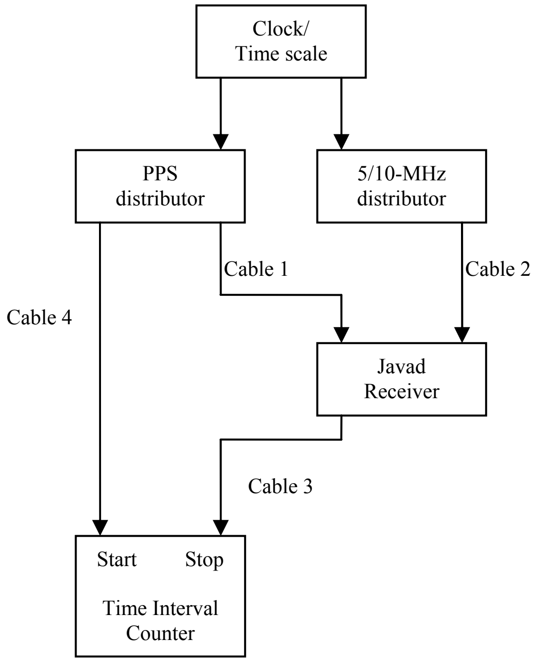



Figure 8: **Example of delay measurements of the time interval difference between the reference pulse (cable 4) and the receiver 1-pps output (cable 3) during operation**

The delay between the receiver 1-pps input and 1-pps output is equivalent to the delay measured in the third set-up (see Figure 8) minus the tare delay (average of the initial tare and the final tare and corrected for the extra BNC-connector, see Figure 7). This result is only valid for the measured delay of the 1-pps input and 5/10-MHz input (see Figure 6).

# Annex E
# Revision history of this document

| | |
|---|---|
| Version 1: | Describing the calibration of Ashtech Z12-T receivers<br>Calibration using the traveling BIPM Z12-T receiver<br>G. Petit, P. Moussay, December 2000 |
| Version 2-b: | Modification<br>G. Petit, P. Moussay, June 2001 |
| Version 2-c: | Modification<br>G. Petit, L. Tisserand, October 2001 |
| Version 2-d: | Modification<br>G. Petit, L. Tisserand, September 2003 |
| Version 2-e: | Modification<br>G. Petit, L. Tisserand, April 2005 |
| Version 3: | Also includes the calibration of Septentrio PolaRx2<br>G. Petit, L. Tisserand, May 2006 |
| Version 4: | Calibration using the traveling BIPM PolaRx2 receiver<br>G. Petit, L. Tisserand, February 2007 |
| Version 4-b: | Modification<br>G. Petit, L. Tisserand, February 2007 |
| Version 5: | Considers different traveling BIPM receivers, and different calibrated equipments (Ashtech Z12-T and Septentrio PolaRx2)<br>G. Petit, L. Tisserand, December 2008 |
| Version 6: | Addition of traveling GTR50 BIPM receiver and Javad JPS E_GGD receiver<br>G. Petit, L. Tisserand, K. Jaldehag, August 2009 |