Calibration of geodetic-type receivers
version 5

Guidelines and operational procedures
using the traveling BIPM receiver

Table of Contents

This document provides the necessary information to perform differential calibration of geodetic-type receivers using one of the traveling receivers of the BIPM. Section 1 and 2 apply to the traveling equipment while section 3 describes measurements to be performed on the traveling receiver as well as on the receiver under calibration. Ashtech Z12-T and Septentrio PolaRx2 are considered in this version, and new types of receivers will be added as necessary.

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 3)

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

1.2 Traveling PolaRx2 receiver (BP0O)

Equipment supplied:
- Not Applicable

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

2. General information

2.1 Hardware connection

To properly configure the traveling receiver:
- Z12-T (BP0C) see annex 1
- PolaRx2 (BP0O) see annex 4

2.2 Data acquisition

Before starting operation of the traveling receiver:
- Z12-T (BP0C) see annex 2
- PolaRx2 (BP0O) see annex 5

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 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 6.

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.

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, 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 1
Traveling Z12T Hardware connection

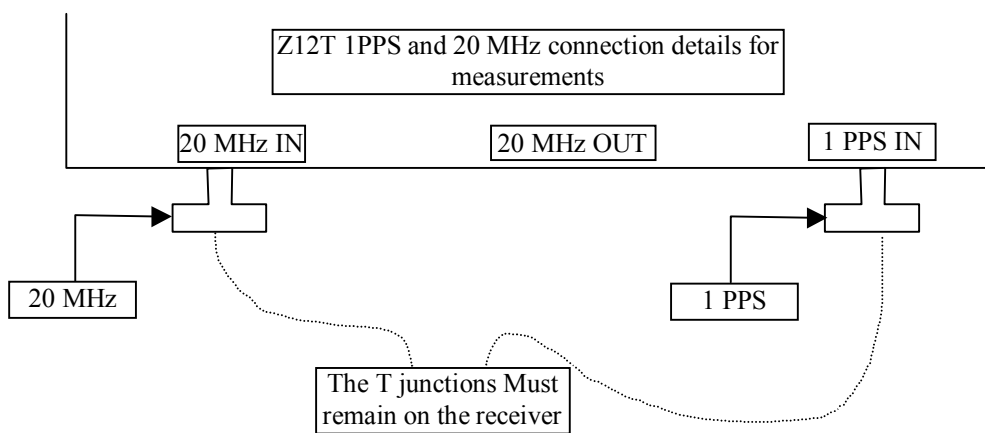Please use the frequency doubler if possible.
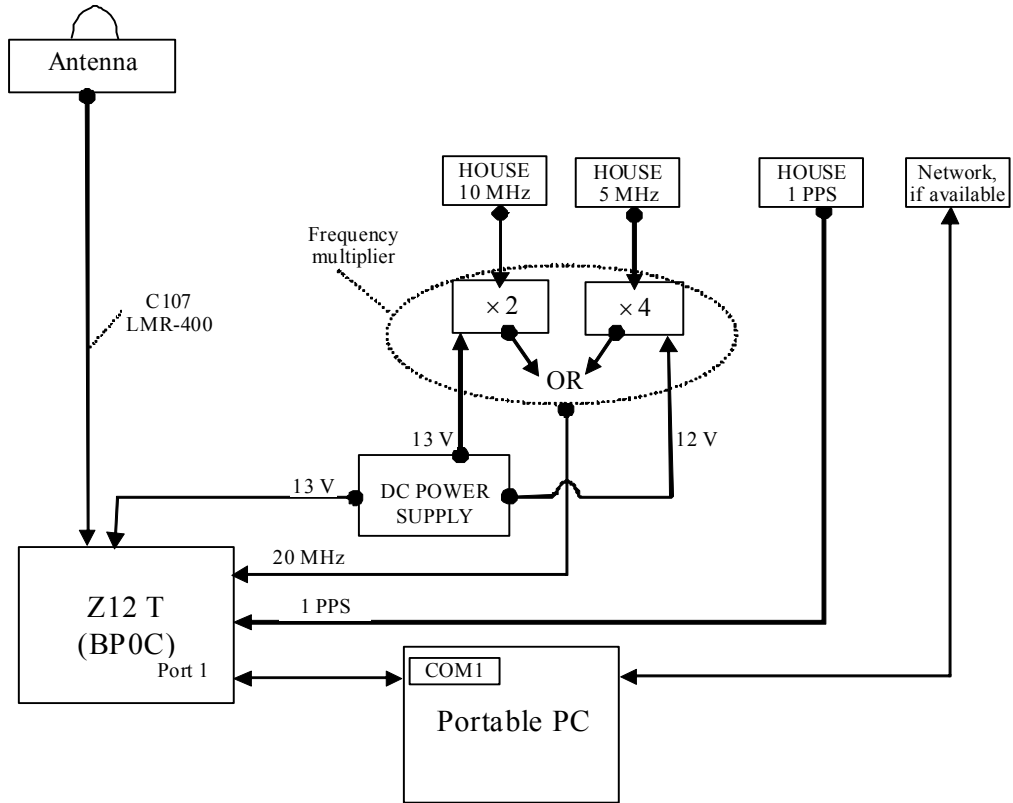
Figure 1: short baseline set-up

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

ANNEX 2
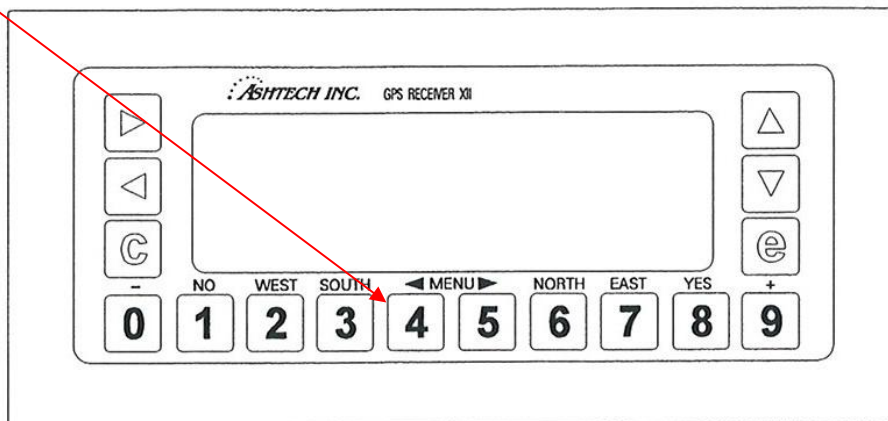# Traveling Z12T Data acquisition

The user account of the portable computer is:

      Login: "user"
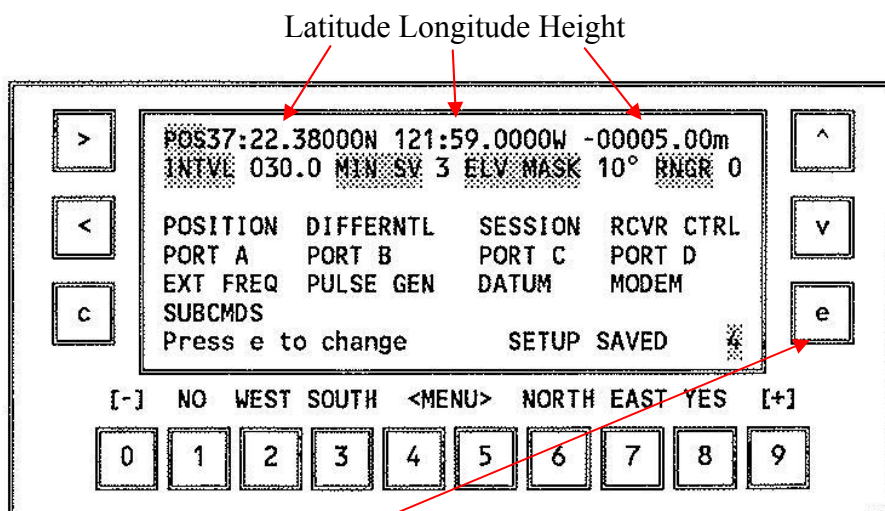
      Password: " " (empty)

Beforehand Z12-T configuration :

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).

Latitude Longitude Height

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.
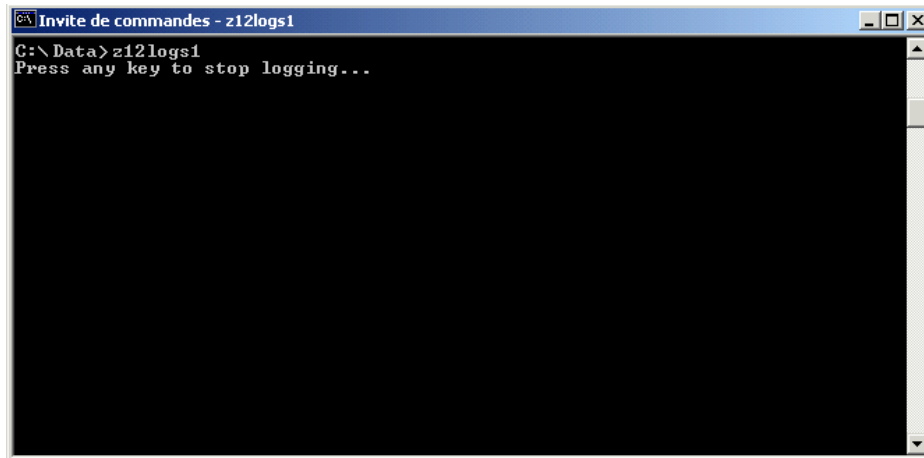After being started, it will record daily binary files of RS-232 stream from the Z12T.

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

Z12T acquisition

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").
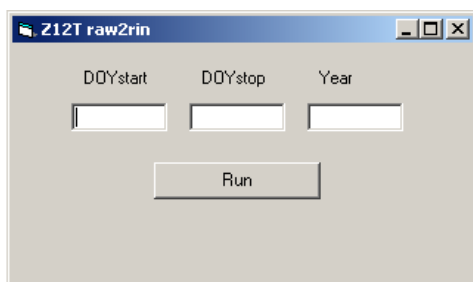
Raw data conversion to rinex data:

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.

Z12T raw2rin

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 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.
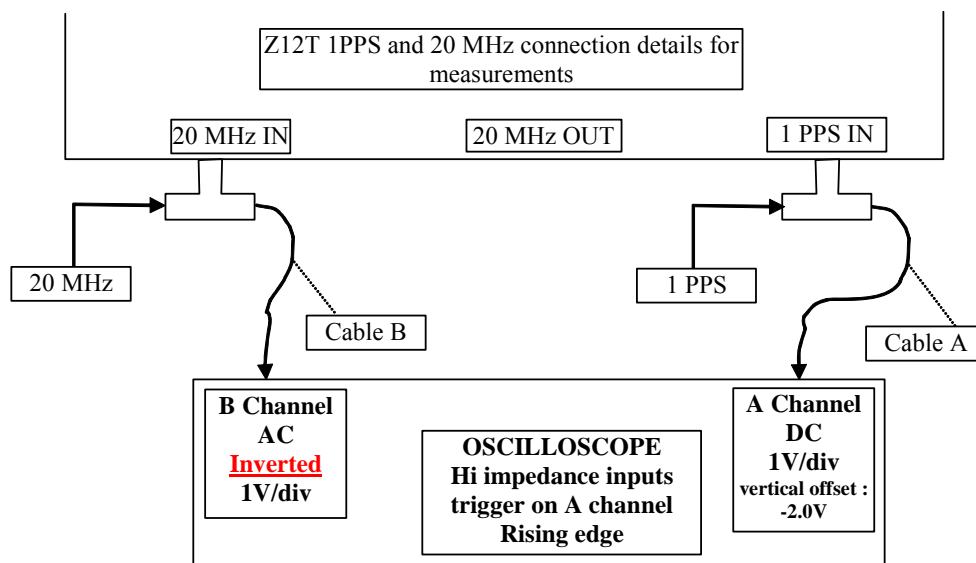Use a time base of 10ns/div, the signals will then be easier to identify.
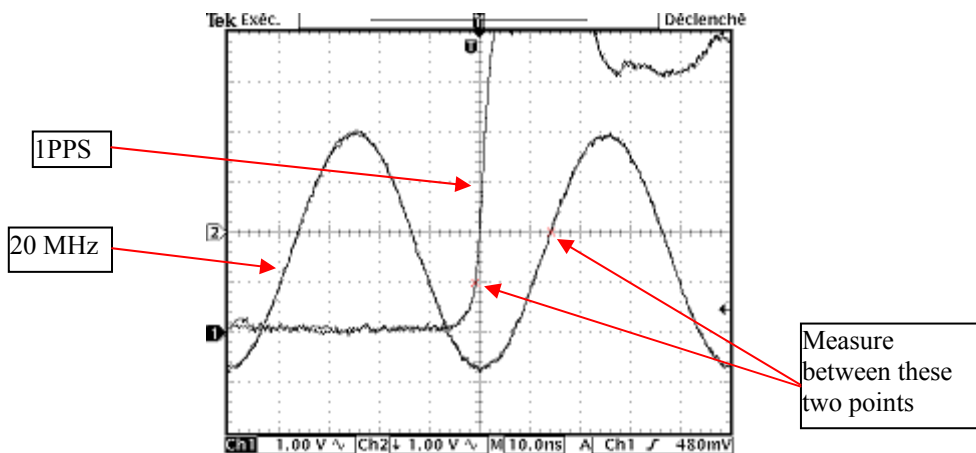
Figure 1: measurement (3.1-1) set-up

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:
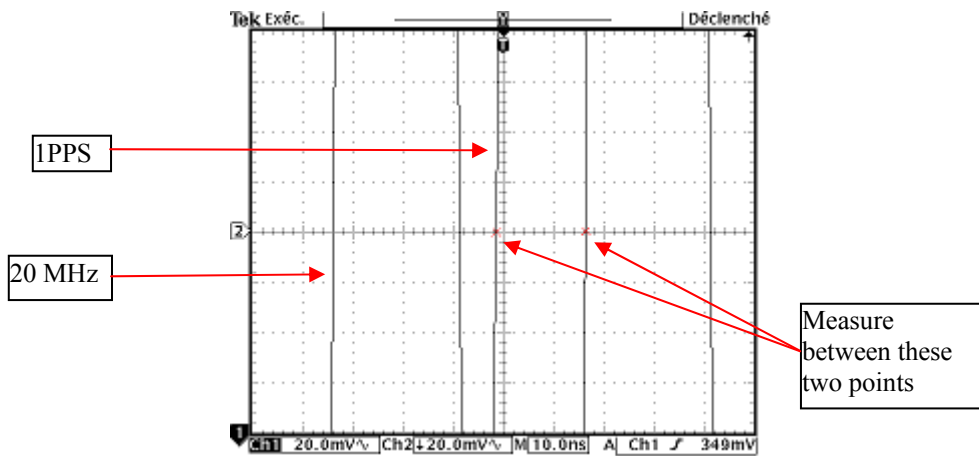

Figure 3: example of oscilloscope display using 20 mV range

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
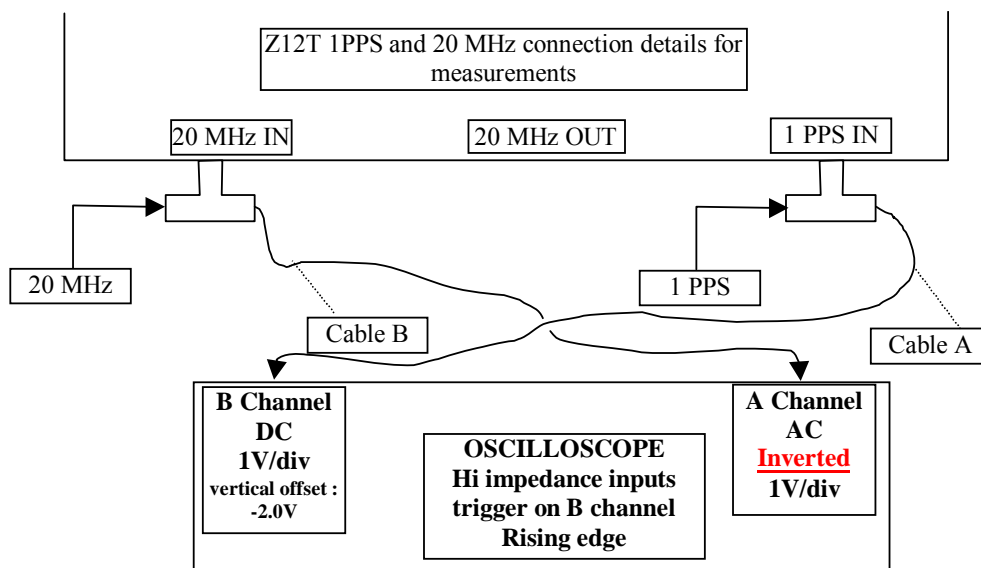Interchange the channels and measure again

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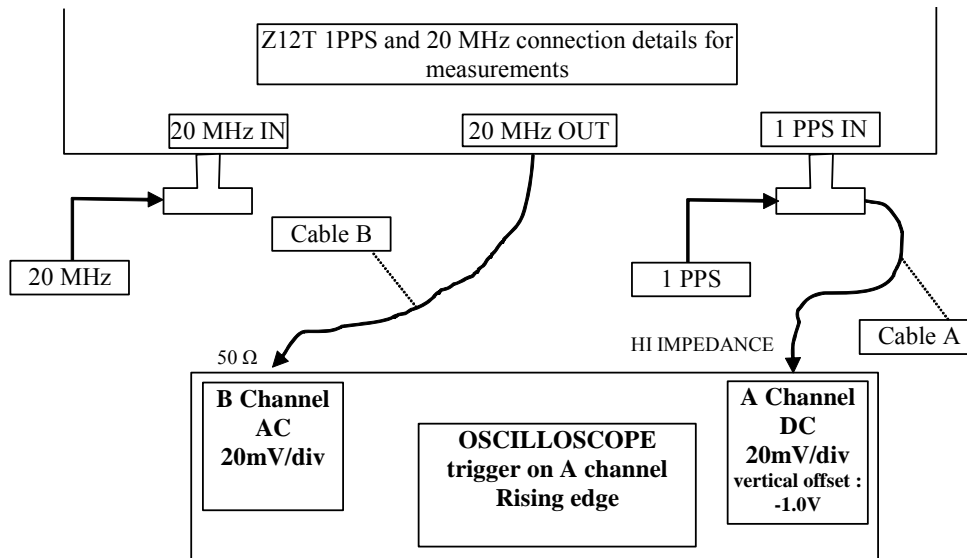
Figure 5: measurement (3.1-2) set-up

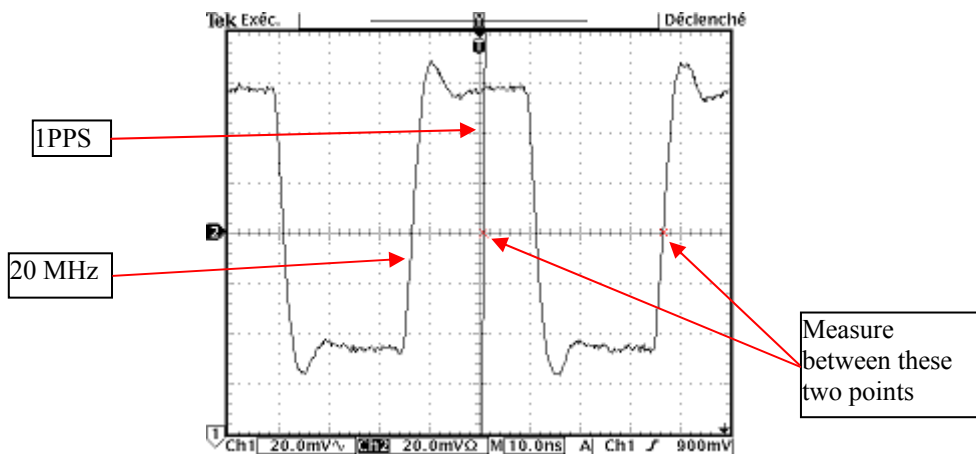You should obtain a result like the figure 6.

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.
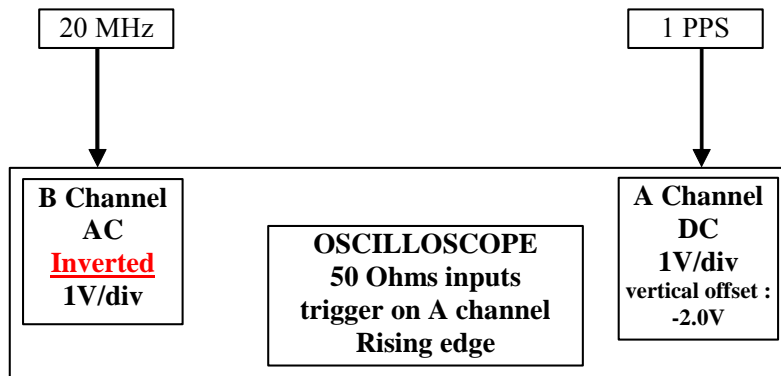Use a time base of 10ns/div, the signals will then be easier to identify.
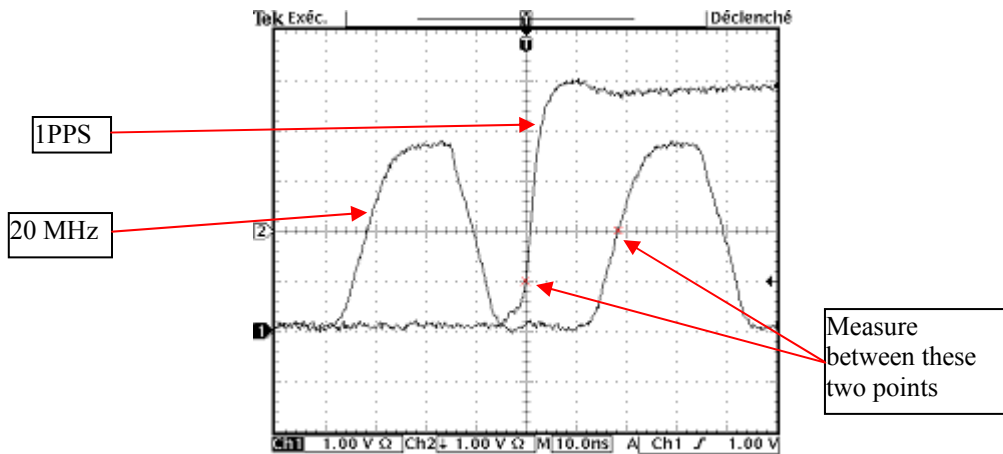

Figure 7: measurement (3.1-3) set-up

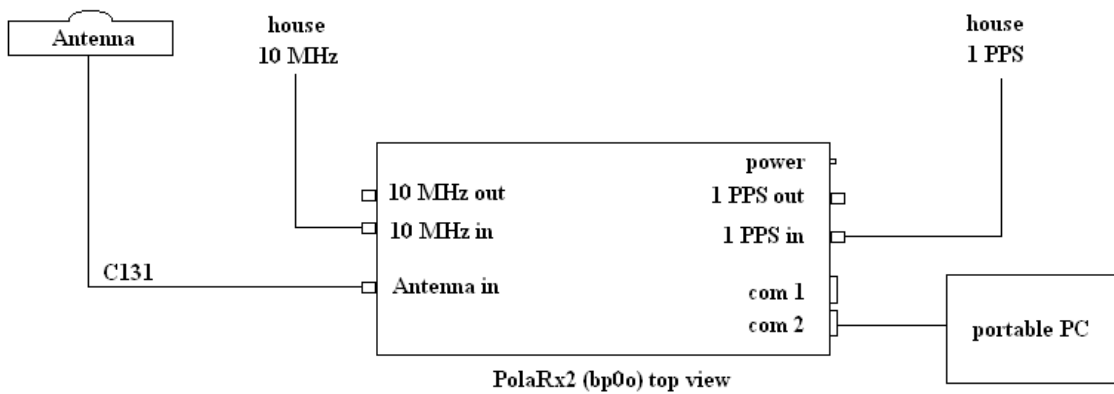Figure 8: example of oscilloscope display using this set-up

ANNEX 4
Traveling PolaRx2 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

PolaRx2 (bp0o) top view

ANNEX 5
Traveling PolaRx2 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.
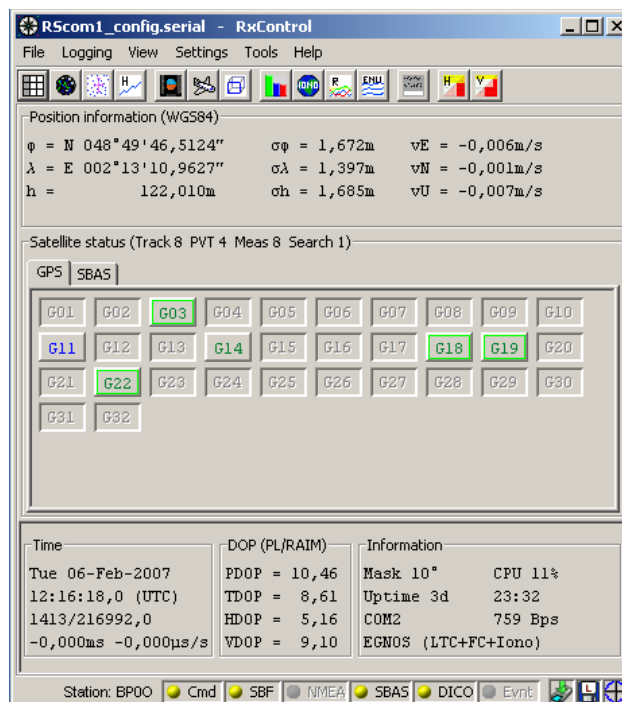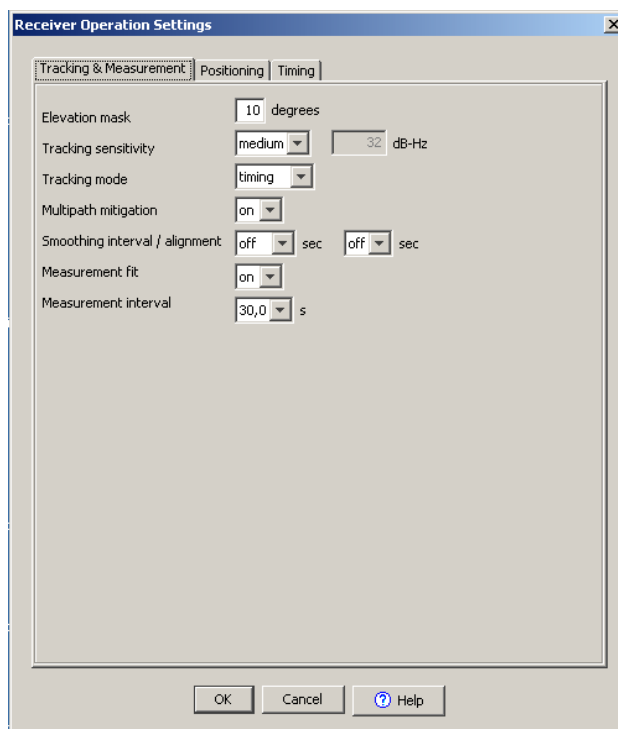

RxControl

This screen should appear on the screen.

Select connection named "RScom1_config.serial" and press OK.
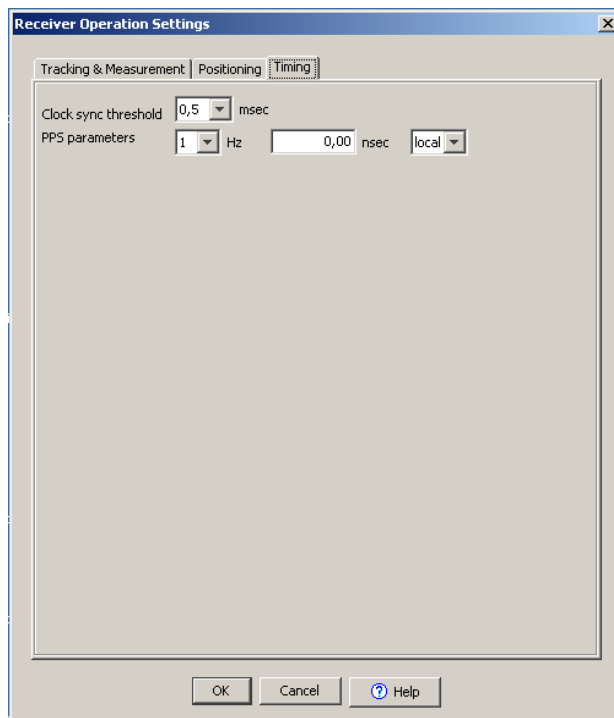
This screen should appear on the screen.

In the "Settings" menu, start by checking the "Receiver Operation".

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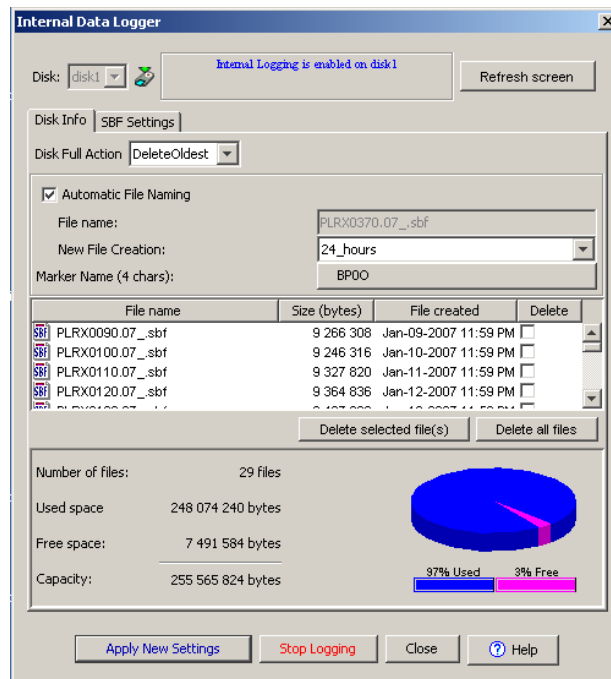

On this tab "Timing", make sure to have the same values :
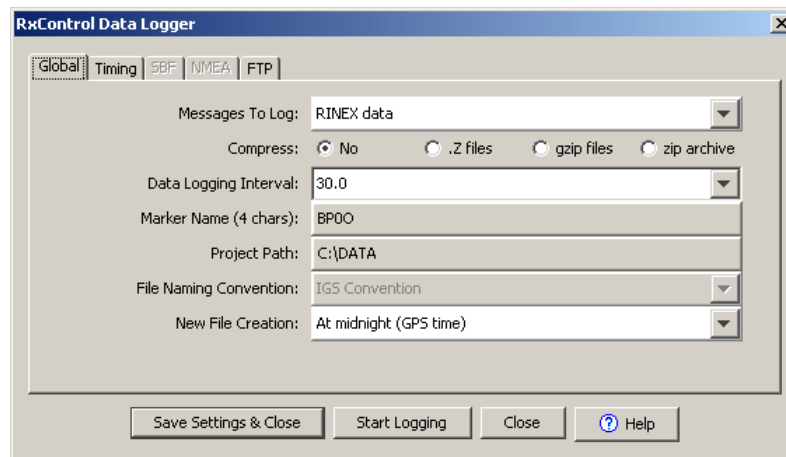

Press OK.

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 6
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.
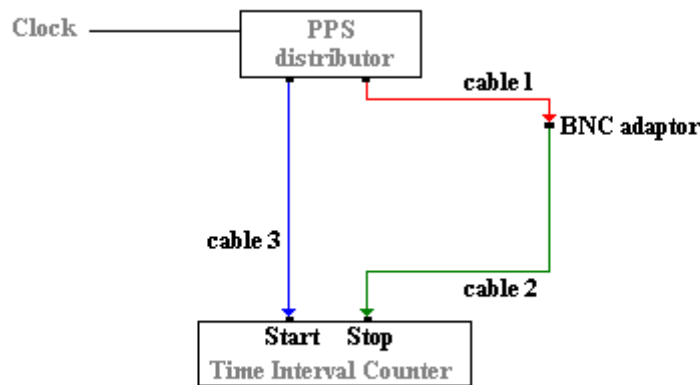

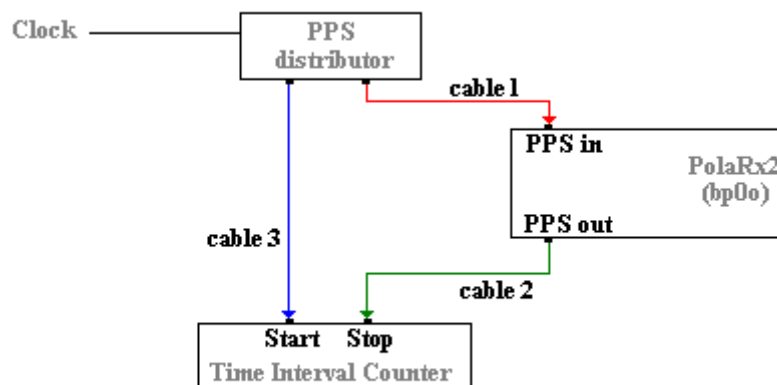Figure 1: example of tare measurement set-up before and after operation

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 7
Revision history of this document

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