PIK TIME SYSTEMS®

TTS-4

Time Transfer System-4

Installation and operation guide

2014

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Contents

1 Specification

Parameter	Value
Supported navigation systems	GPS, GLONASS, Galileo, WAAS/Egnos
Number of channels	216
Supported frequencies	GPS: L1, L2, L5 GLONASS: L1,L2 option: L3 GALILEO: E1, E5A , option: E5B, altBoc
Supported codes	GPS: L1C, L2C, L1P, L2P, L5P GLONASS: L1C, L2C, L1P, L2P option: L3 GALILEO: E1, E5A , option: E5B, altBoc
Data type	Code and Carrier
Data output format	CGGTTS, RINEX
Data availability	CGGTTS : 30 sec after each 13 min. observation session finished RINEX: real time
Power supply	AC 230 V 10%, 45 to 60 Hz, or AC 110 V 10%, 55 to 65 Hz
Reference Input Signals	Frequency: 3 - 20 MHz 1 PPS input

2 Package contents and pre-installation notes

The TTS-4 system is delivered in a single wooden crate, with stickers on its side marking the top of the crate. Inside each crate, the following should always be present:

- TTS-4 system wrapped in a polystyrene protection,
- the ordered antenna type[1]
- the antenna cable,
- USB Keyboard,
- TTS-4 manual (i.e. this file, printed + CD).

Please note, that the crate size is 69cm×69cm×77cm, and it weights about 45kg. Before picking up the package, please consider its size and weight. Please also note, that the crates should not be placed on each other during transport.
Before the receiver is installed, the following issues should be taken care of:

- Antenna installation point (providing: unobstructed view of the sky, no metal elements appearance, separation of multiple antennas, see also sec. *Antenna Installation* (p.8)).
- Antenna mounting pole preparation[1].
- The antenna-receiver cable path, with respect to the ordered cable length, and to the maximal bending radius of the cable: 1 inch for $^1/_4$ inch cable diameter, and 1,25 inch for $^1/_2$ inch cable diameter (please note, that these are extreme values, and that each section of the cable should be bended only once).

On customers request, PikTime Systems may also advice on setting up of the TTS-4 laboratory stand.

3 Quick start manual

Please make sure, that you read the section *Package contents* (p.4) before you pick up the receiver. There are additional issues to be taken care of, before installation.
After you unpack the receiver, please place it in desired location, and continue to install it using the diagram presented in fig. 1. Than, please configure it using the diagram presented at fig. 2.

[1] Please note, that antennas mounting pole is not included. Due to the variety of roof types and mounting arrangements it is not possible to work out one good solution, matching every user requirements. PikTime Systems recommends using metal poles with threaded bolt fitting standard geodetic $^5/_8$ inch threaded mount.

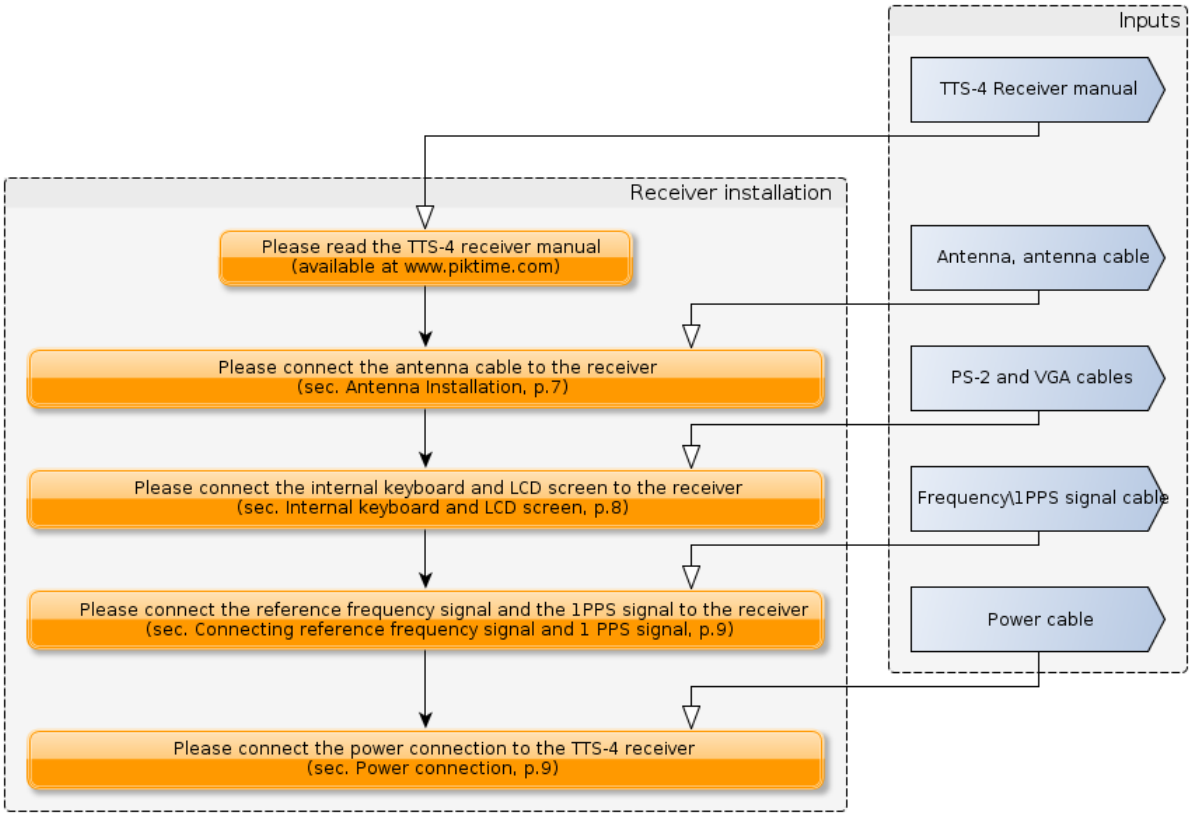


Figure 1: TTS-4 receiver installation diagram

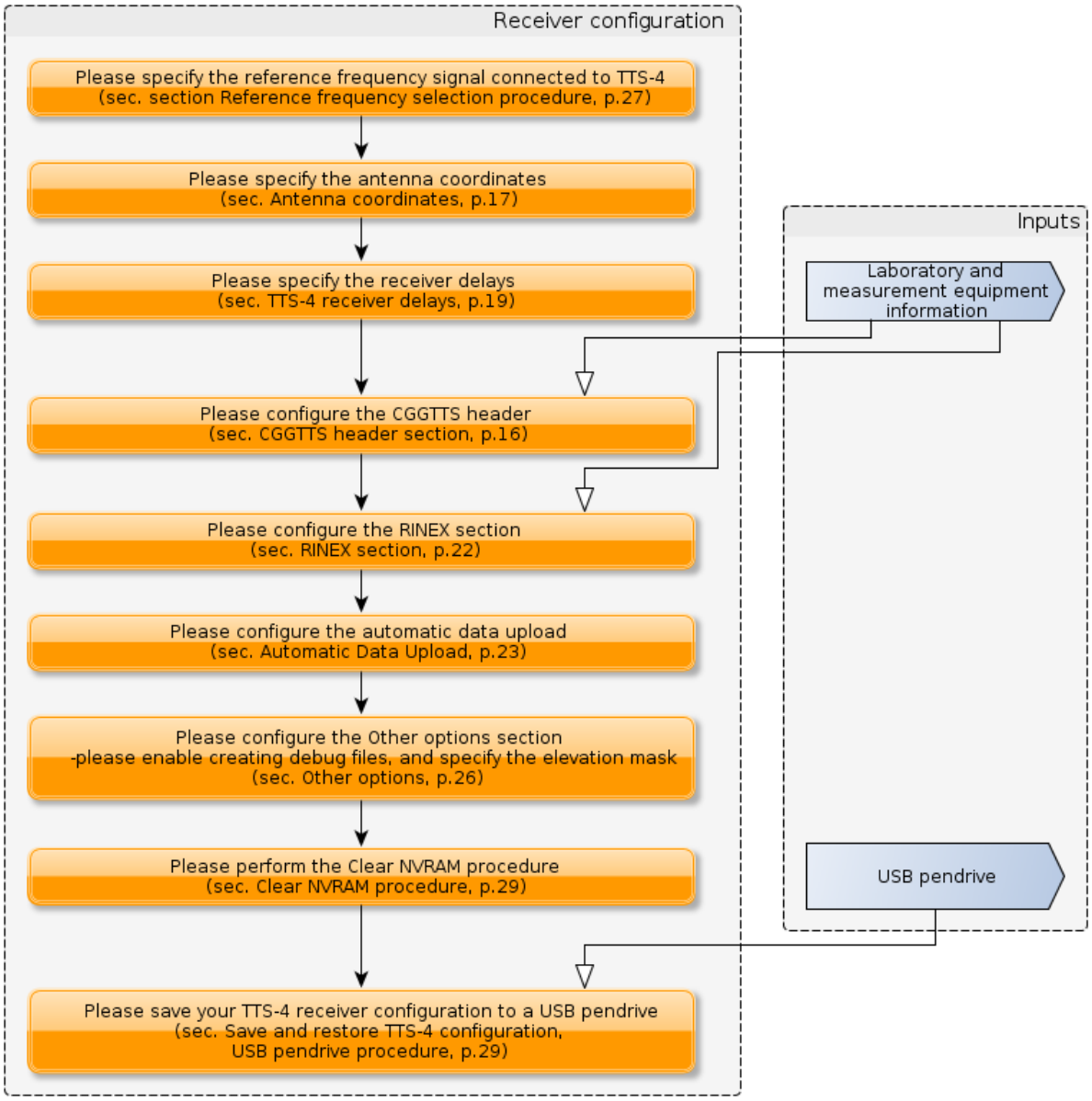


Figure 2: TTS-4 receiver configuration diagram

4 Receiver installation

This chapter guides you through the TTS-4 receiver installation. The following steps are covered: *Rear panel description* (p.7), *Antenna installation* (p.8), *Internal keyboard and LCD screen installation* (p.10), *Connecting reference frequency signal and 1 PPS signal* (p.11) and *Power connection* (p.11).

4.1 Rear panel description

The correct connection of all the signals to the TTS-4 receiver is essential for its proper operation. Figure 3 presents a receiver rear panel diagram. A short description of all connectors marked in the diagram is provided in table 1.

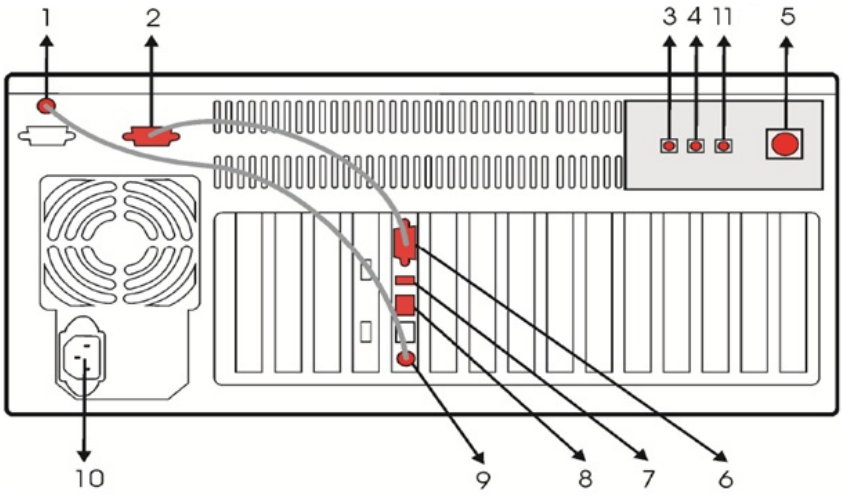


Figure 3: TTS-4 receiver rear panel diagram

1,9. Internal PS/2 Keyboard connectors	5. Antenna TNC connector
2,6. Internal VGA display connectors	7. USB connector
3. Auxiliary 3-20 MHz connector	8. Ethernet connector
4. Auxiliary Reference 1 PPS in connector I (Event Marker I)	10. Power connector
11. 1 PPS out connector	

Table 1: Connectors in fig. 3 description.

Depending on the TTS-4 receiver version, the rear panel may be equipped with the PPS out connector, or not. The TTS-4 receiver rear panel diagram without the mentioned connector is presented in figure 4. The other indications provided in table 1 are still valid for this figure.

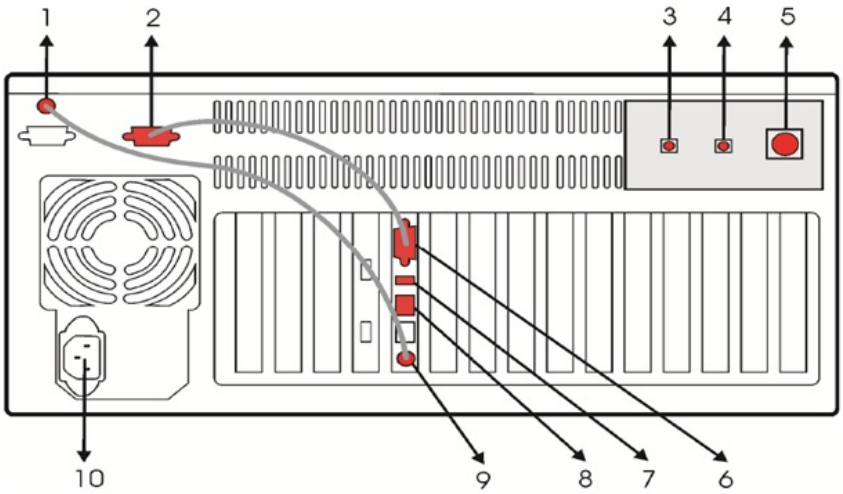


Figure 4: TTS-4 receiver rear panel diagram (no PPS out connector version)

4.2 Antenna installation

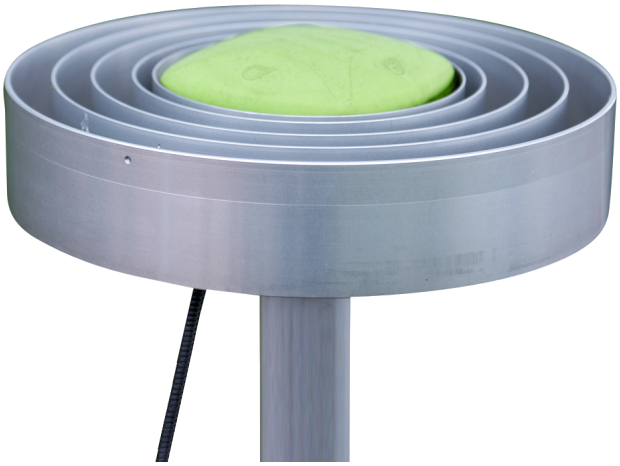
To optimize the signal reception, the antenna should have the unobstructed view of the sky. The coordinates of the electrical phase centre of the antenna should be defined to within a centimetre accuracy, which can be achieved, for example, using a GPS geodetic receiver, or using RINEX data from the TTS-4 receiver. The required coordinates are: latitude, longitude and height over the reference ellipsoid in the ITRF[2] (or X, Y, Z also in ITRF). The procedure of obtaining these coordinates, and inserting them into the receiver is presented in sec. *Antenna Coordinates* (p.19).

The antenna (e.g. fig.6) should be connected to the TTS-4 receiver antenna connector (connector 5 in fig. 3) using special coaxial cable.
Please notice that the antenna should be as far from other metal elements as possible in order to avoid any interference. Also, the antenna location should provide an unobstructed view of the sky. While locating multiple antennas, separating them from each other is advised. An example of properly located multiple antennas is presented in picture 5.

[2]ITRF: International Terrestrial Reference Frame. For more info please see: `http://itrf.ensg.ign.fr/ITRF` web site, or *Glossary: ITRF* (p.47)

Figure 5: Multiple antennas location example

(a) Standard antenna



(b) Choke ring antenna

(c) TSA - temperature stabilized antenna

Figure 6: Examples of satellite-system antennas

4.3 Internal keyboard and LCD screen

It is necessary to connect the inbuilt keyboard to the receiver, i.e. to join connectors 1 and 9 in fig. 3) using a PS-2 cable (fig. 7b), and to connect the LCD screen, i.e. to join connectors 2 and 6 in fig. 3) using a VGA cable (fig. 7a).

An additional external keyboard can be connected using any of the USB connectors in the rear panel or in front of the receiver.

(a) VGA cable (b) PS-2 cable

Figure 7: PS-2 and VGA cables

4.4 Connecting reference frequency signal and 1 PPS signal

It is necessary to connect reference frequency signal to the receiver SMA connector 3, and reference 1PPS signal to the TTS-4 receiver SMA connector 4 (both connectors marked in fig. 3). Both signals must be coherent (in phase), i.e. they should be generated by the same source (clock). TTS-4 accepts reference frequency signal in range 3-20 MHz.

4.5 Power connection

The power supply should be connected to the connector 10 (fig. 3), using the attached cable. The power requirements:
AC 230 V $\pm$ 10%, 45 to 60 Hz or AC 110 V $\pm$ 10%, 55 to 65 Hz.

5 Receiver configuration and interfaces

This section describes the user-available interfaces (*Main screen* (p.12), *Main menu* (p.14), *WEB interface* (p.15)), and tools (*Receiver configuration tool* (p.17), *Network configuration tool* (p.39), *Bug report tool* (p.38) and *Software Update manual* (p.44))

5.1 User interfaces

The receiver parameters may be configured using a touch screen, a console interface, a *WEB interface* (p.15), or by manual editing of the configuration file.
PikTime Systems recommends to use the console or *WEB interface* (p.15).

5.1.1 Main screen

After booting Time Transfer System-4 (TTS-4) receiver, an observation interface should be displayed. You can select options using:

- Keyboard (by pressing function keys specified in brackets, or by using arrows and an Enter button while scrolling the menu)
- Mouse
- TTS-4 touch screen

While the Main screen is displayed, (fig. 8) you can select following items (also using keyboard shortcuts):

- F1 - Change satellite system list order (GPS, GLONASS, Galileo, WAAS/Egnos).
- F2 - Enter the Main Menu.
- F3 - Switch between delays and position info.

The parameters that appear on the Main screen are described below:

- Satellites data section:
  - PRN - satellite number
  - Az - satellite azimuth
  - Elev - satellite elevation
  - SN-Lxx - signal to noise ratio (for the signal at a given frequency)
  - Slot - satellite orbit slot number (GLONASS only)
- Time Transfer System-4:
  - SN - Serial number of the receiver
  - HW - The hardware version and the firmware version
  - SW - Software version
  - GPS/GLONASS dt(ns) - an approximate time offset between local time and reference time
  - Temperature - an internal temperature of the receiver [^{o}C]
  - Freq. Sync. - synchronization to the reference frequency status indicator:

    - Wait - The receiver is waiting for the external frequency lock. This state will be displayed each time when the external frequency oscillator is disconnected, its amplitude is too low, or the actual external frequency is different from the specified in the TTS-4 configuration (please see section 5.2.7).
    - Locked - the external frequency source is being used.
  - Freq. Level - the reference frequency signal level
    - Low - the external frequency signal amplitude is lower than required, or the signal is not connected
    - Ok - the external frequency signal amplitude meets the required specifications.
  - Sync. Status - the TTS-4 synchronization status indicator
    - Waiting - the receiver is synchronizing,
    - Ok - the synchronization status OK
  - 1 PPS status - 1PPS reference signal status
    - No PPS - the reference 1PPS signal is not correct, or 1PPS is not connected
    - Ok - the reference 1PPS signal is correct
  - Antenna DC - the status of antenna power supply
    - Off - the antenna does not draw any DC. This state will be displayed if the antenna is not connected, or the antenna/antenna cable is broken.[3]
    - Overload - the antenna draws too high DC. This state will be displayed if the antenna is short circuited or broken.
    - Normal - the antenna power consumption is correct
- Delays Info / Position Info section[4]:
  - x,y,z - a user configured Cartesian antenna coordinates
  - lat, log, hgt - a user configured Ellipsoidal antenna coordinates

[3]The receiver with TSA antenna use additional power supply. In this case the antenna power is provided by additional unit, so the antenna current reported by the TTS-4 software is 0 (off).

[4]A known bug is present in this section, in software versions <2.20: the time displayed at the bottom of this section is only approximately synchronized by GNSS (as standard to GPS).

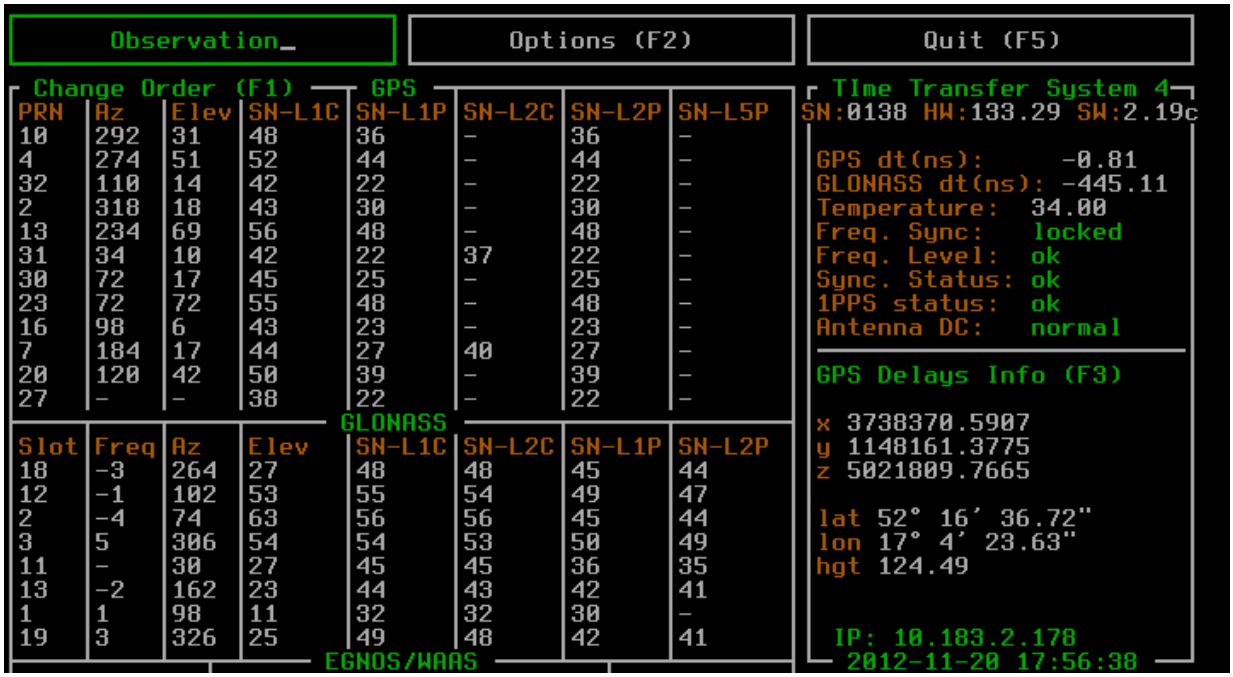


Figure 8: Main screen

Due to the limited number of rows on the main screen not all tracked satellites can be displayed at a time. Please use F1 key to switch the order of the displayed satellites systems. If you would like to display all satellites of a specific satellite system, press F1 key until the requested satellite system is displayed at the top of the list.

5.1.2 Main menu

While the Main screen is displayed, pressing the F2 key will activate the Main Menu and enable a selection of the following options (fig. 9):

- F1 - *Receiver Configuration Tool* (p.17)
- F2 - *Network Configuration Tool* (p.39)
- F3 - Copy Files - a tool to copy CGGTTS and RINEX files to USB pendrive.
- F4 - Return to the Main screen.
- F6 - *Bug Report* (p.38) - Create Bug Report and copy it on a USB pendrive
- F7 - Version Report - Create Version Report and copy it on a USB pendrive
- F8 - Receiver Shut Down - Enter Shut down sub-menu

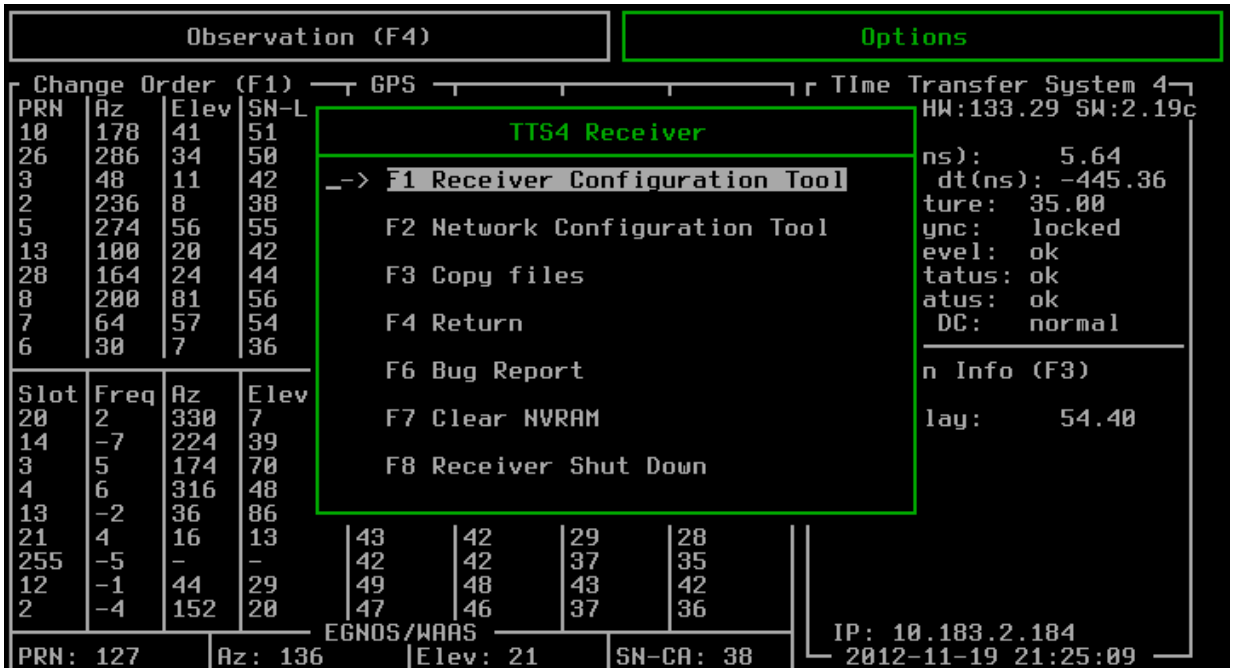


Figure 9: Main Menu

5.1.3 Web Interface

The Web Interface allows for the remote access to both: the measurement results and the TTS-4 receiver configuration.
In order to connect to the receiver via Web interface, please:

1. Access the receiver using an IP address and a web browser[5]
2. Enter login and password (default login: tts3, default password: tts3) and enter the web interface menu (fig. 10)

While on web interface main menu, the following options are available:

- Common View Files (fig. 11)
- RINEX Files (fig. 12)
- Online observation
- Configuration (requires an additional login and password, default login: admin, default password: tts3)
- Show Receiver Logs

[5]Please note that some web browsers may not work properly with TTS-4 web interface, please try accessing this feature using other web browser

Figure 10: Web interface main menu

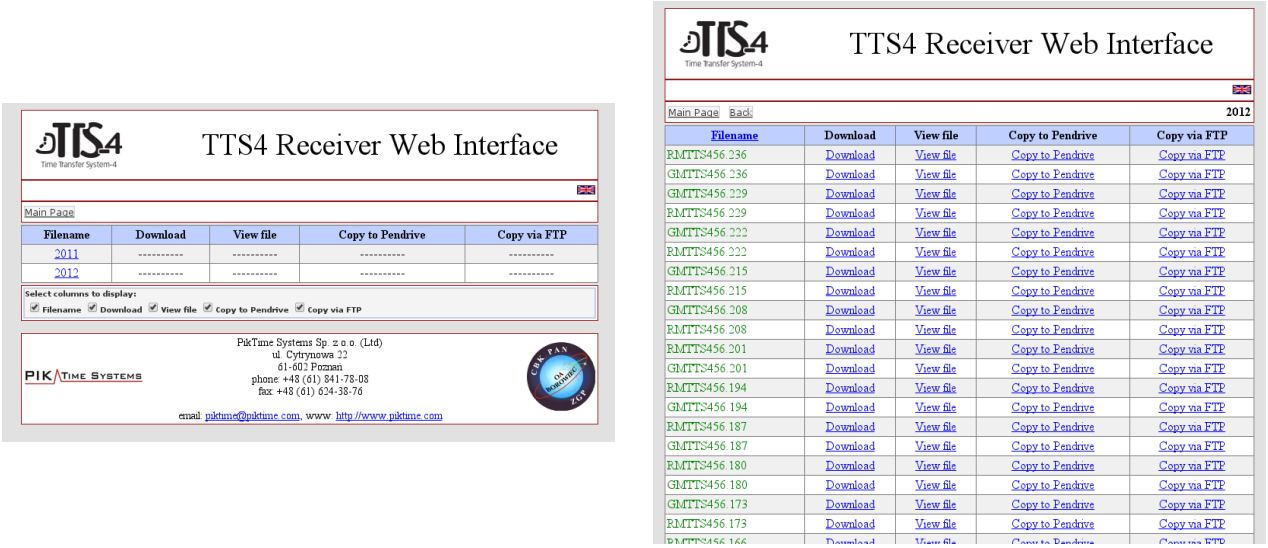


Figure 11: Common View files access using Web Interface

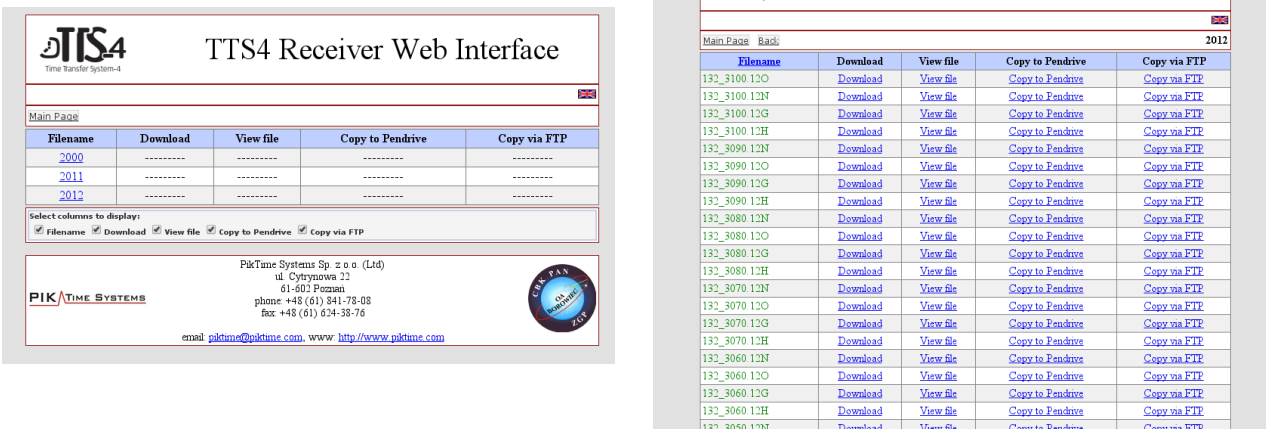


Figure 12: RINEX files access using Web Interface

Please note, that files displayed at the console and at the web interface are ordered alphabetically. If the file prefix name was changed, the newly created files may be placed at the end of the list. Please check if the displayed files are sorted starting from the most recent ones. If not, please change sort order by pressing `filename`, and verify if the latest files are on the list. There is also a possibility, that there are multiple pages of files - you can switch pages using page numbers located in the right lower corner of the page.

5.2 Receiver configuration tool

In order to start Receiver Configuration Tool, please:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver configuration tool

The following options are available (fig. 13):

1. *Header Section* (p.18) - Configures CGGTTS[6] file Header Section.
2. *Position* (p.19) - Enters the antenna coordinates.
3. *Delays* (p.21) - Sets the receiver delays.
4. *RINEX* (p.27)[7] - Configures RINEX Section.
5. *Automatic Data Upload* (p.29) - Configures a receiver automatic data upload.
6. *Other Options* (p.34) - Additional Options.
7. *Save Setup* (p.36) - Saves configuration on a hard disk.
8. *Save Setup to Pendrive* (p.37) - Saves current configuration on a USB pendrive.
9. *Restore Setup from Pendrive* (p.37) - Restores previous configuration from USB pendrive,
10. Exit - Returns to Observation Screen.

[6] CGGTTS: CCTF Group on GNSS Time Transfer Standards. For more info, please see `http://tycho.usno.navy.mil/cggtts.html`"About the CGGTTS data format", or *Glossary: CGGTTS* (p.47)

[7] RINEX: The Receiver Independent Exchange Format. For more info, please see `http://igscb.jpl.nasa.gov/igscb/data/format/rinex210.txt`"RINEX: The receiver Independent Exchange Format" by Werner Gurtner, or *Glossary: RINEX* (p.47)

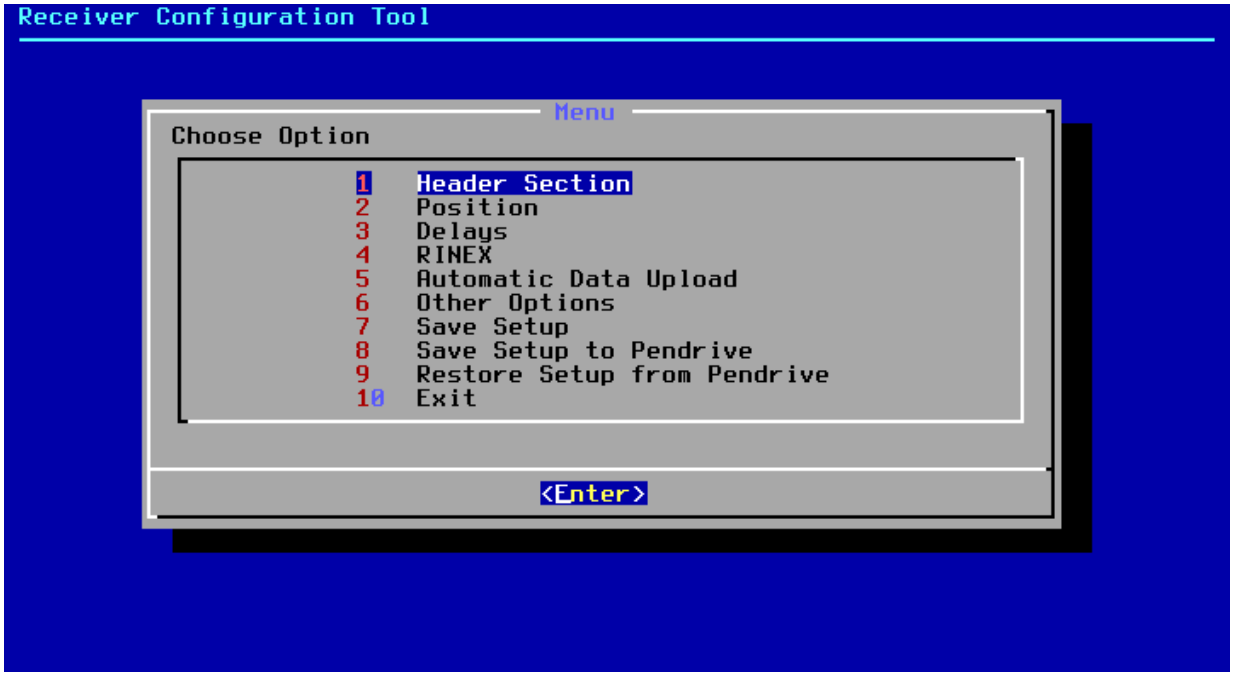


Figure 13: Receiver configuration tool.

5.2.1 CGGTTS header section

Also see: *Glossary: CGGTTS* (p.47)
In order to change CGGTTS parameters, please:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 -Receiver Configuration Tool
3. select Header Section and enter the following parameters (fig. 14)
    - Laboratory - Acronym of the laboratory, where observations are performed
    - Ref Clock - Identifier of the reference time. For laboratories contributing to TAI, it can be a 7-digit code of a clock or a 5-digit code of a local UTC, as attributed by the BIPM
    - CGGTTS file id - the two alphabetical character code for the laboratory and two receiver identification characters (please see the description of CGGTTS file name convention)
    - Day of creation of CGGTTS file - a day of the week, when the new CGGTTS file will be created

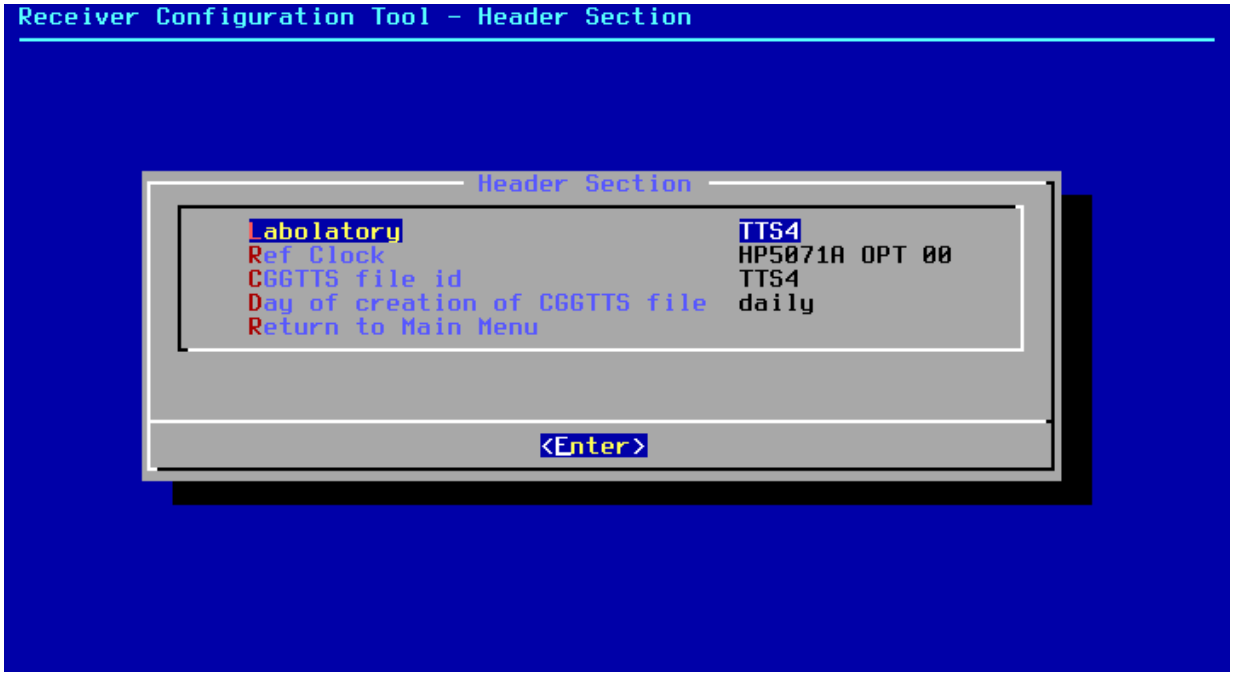


Figure 14: CGGTTS header section.

After changes, please:

1. Select Return,
2. Select Exit,
3. Confirm saving changes and observation process restart.

5.2.2 Antenna coordinates

The coordinates of the electrical phase centre of the antenna should be defined with a centimetre accuracy, as it it crucial for the receiver operation. In order to insert the coordinates into the receiver, please use the following procedure:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver Configuration Tool,
3. select Position using a menu bar,
4. Enter Latitude and Longitude of the receiver (fig. 15) using one of the following methods (16 and 17):
   - Degrees - in degrees and decimal fraction of degrees
   - Deg/Min/Sec - in Degrees, Minutes and Seconds and decimal fraction of seconds
5. Enter altitude
6. select Return to Main Menu
7. select Exit
8. answer Yes to “Do you want to save the configuration before exit”,
9. answer Yes to prompt “Do you really want to save this configuration”

10. answer Yes to prompt “Restart the observation process”

Please remember to perform a *Clear NVRAM procedure* (p.37) after each antenna coordinates or receiver delays modification.

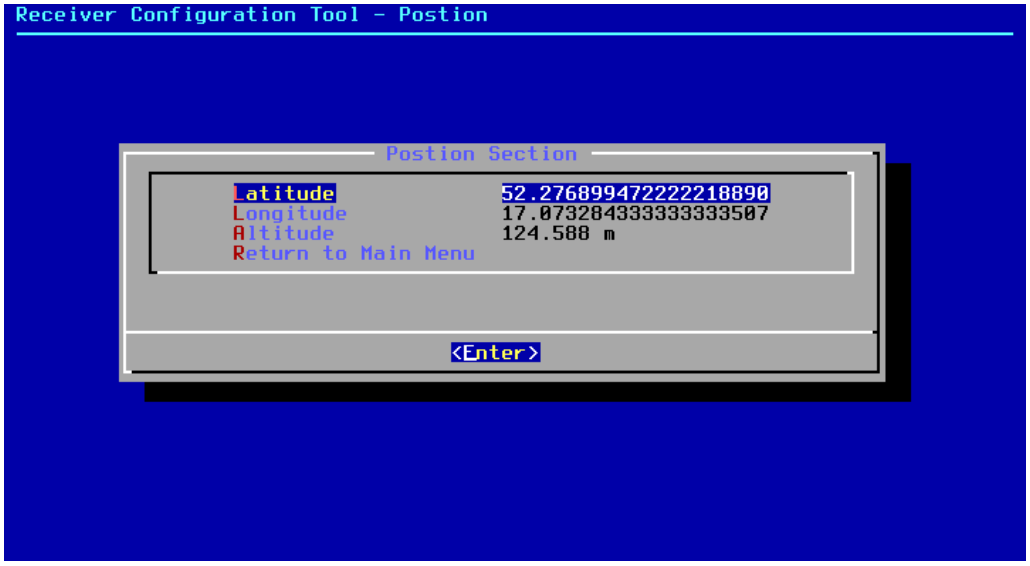


Figure 15: Antenna coordinates input.

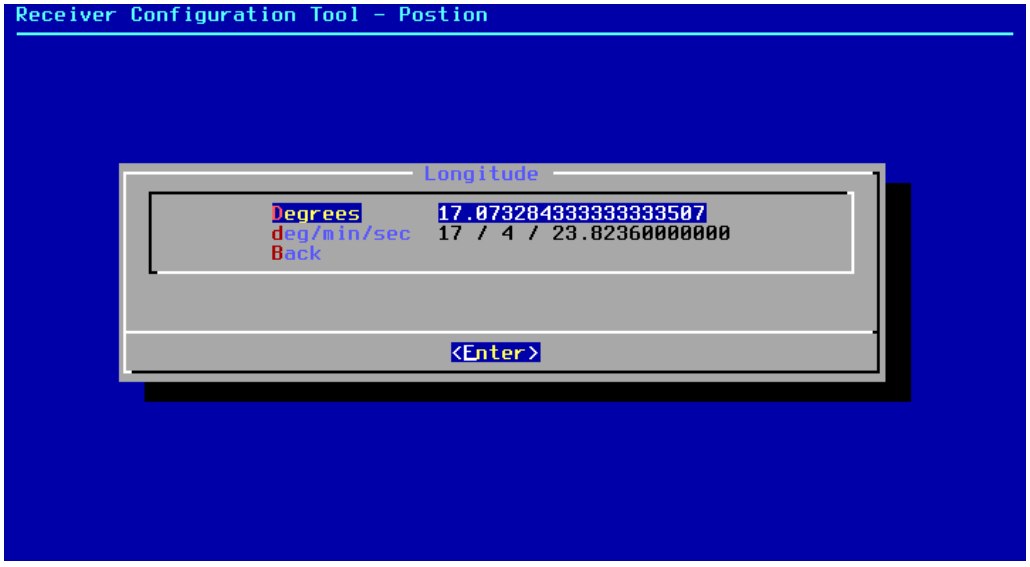


Figure 16: Antenna coordinates input(2).

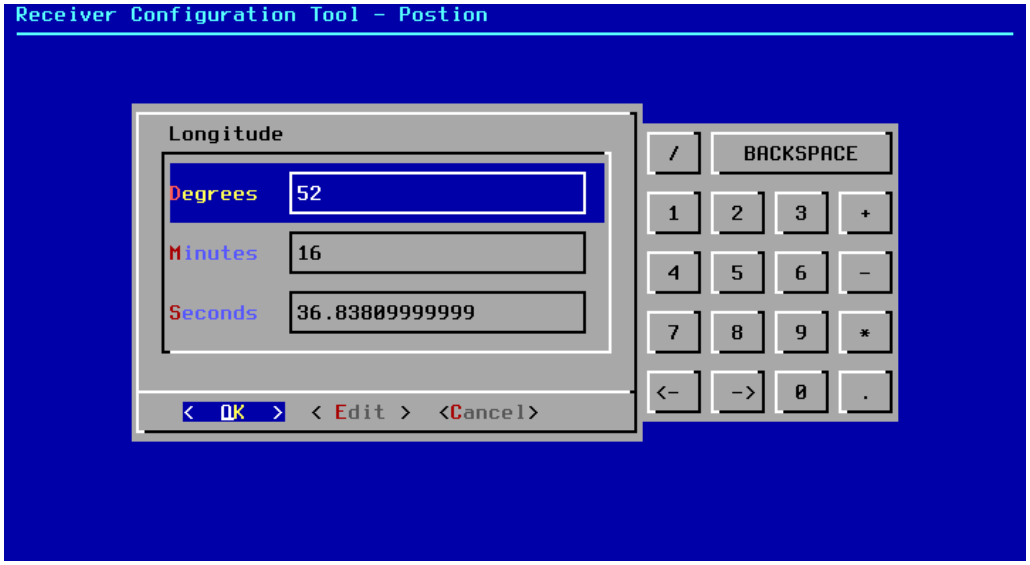


Figure 17: Antenna coordinates input(3).

The TTS-4 receiver operates in a fixed-position mode. In order to obtain accurate antenna position, please:

1. Enter the approximate antenna position (even ± 100 meters is acceptable) (sec. *Antenna Coordinates* (p.19)).
2. Carry one full day of observations.
3. Compute the precise antenna position using RINEX data and correct the previously entered antenna coordinates.

Presenting imprecise coordinates to the receiver will result in the high noise of daily measurements (RMS above 5ns, provided no other factors influence). In order to determine the coordinate shift, PikTime Systems recommend using Bernese GNSS Software, or a free online tool for PPP computation provided by NRCAN[8] (also used by the BIPM for timing computations) for RINEX data computations. PikTime, at customers request, may assist in setting up the antennas accurate position, as this may be quite complicated procedure. Sending data to PikTime for verification before submitting them to BIPM for the first time is also recommended.

5.2.3 TTS-4 receiver delays

TTS-4 uses 4 types of delays (described below):

- GPS delays
- GLONASS delays
- Reference delay
- User reference frequency to 1PPS offset (Please see section *TTS-4 reference frequency to 1PPS offset* (p.24))

[8]PPP positioning tool is available at: `http://www.geod.nrcan.gc.ca/products-produits/ppp_e.php`
PPP positioning manual is available at: `http://www.geod.nrcan.gc.ca/userguide/pdf/howtouse.pdf`

GPS and GLONASS internal delays were measured during a calibration process and users do not need to change them.
TTS-4 utilizes separate internal delays for each satellite system, frequency and code. The internal delays were measured in the calibration process, and users should not change them until the new calibration will be performed.
The antenna cable delay was measured by the PikTime, and users do not need to change it until the antenna cable is changed.
The reference delay is a sum of the delays of the 1PPS cables, distributors, and other devices connected between the laboratory main 1PPS reference point, and 1PPS input to the TTS-4. This value must be measured by the TTS-4 users, using the time interval counter, and introduced to the receiver. The reference delay should be measured very precisely, as it affects the TTS-4 accuracy (type B uncertainty).

In order to change TTS-4 receiver delays, please use the following procedure:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver Configuration Tool,
3. select Delays using the menu bar,
4. select the specified delay (fig. 18)
5. enter the delay value (e.g. Reference delay - fig. 19)
6. select Return to Main Menu
7. select Exit
8. answer Yes to “Do you want to save the configuration before exit”,
9. answer Yes to prompt “Do you really want to save this configuration”
10. answer Yes to prompt “Restart the observation process”

Please remember to perform a *Clear NVRAM procedure* (p.37) after each antenna coordinates or receiver delays modification.

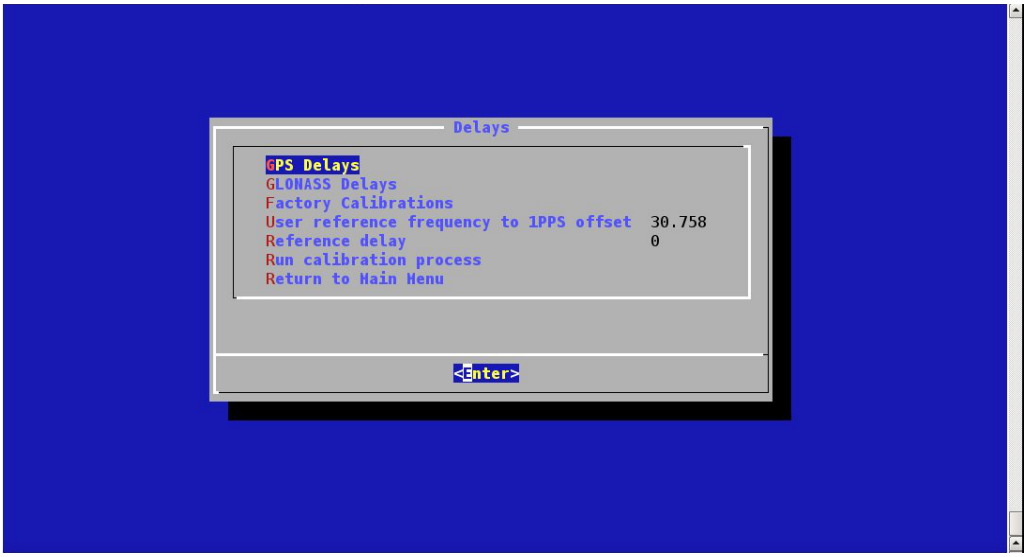


Figure 18: Delay selection

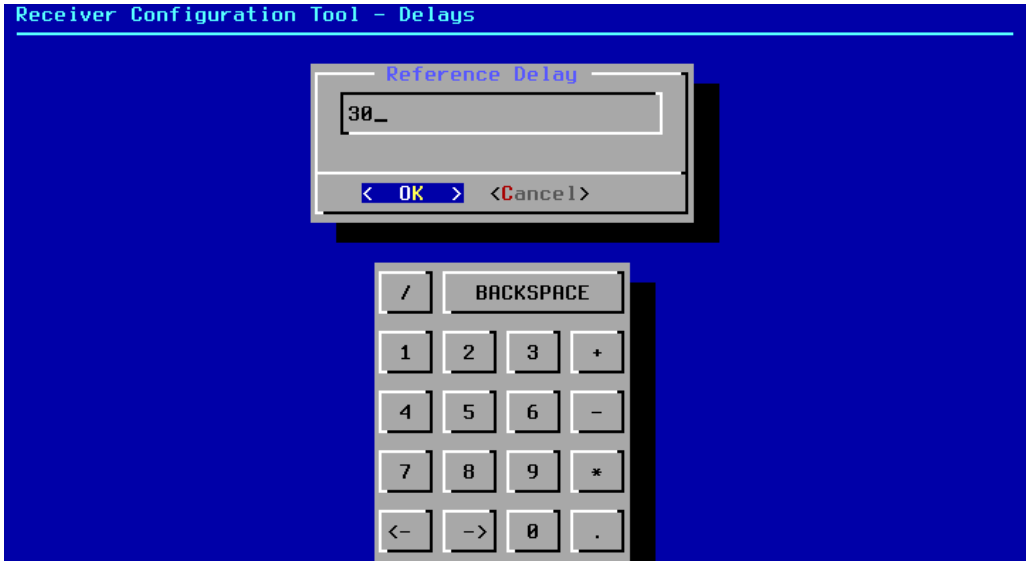


Figure 19: Delay value entering (reference delay)

Cable delay measurement

Piktime systems attaches to each of the receivers an antenna cable required for receiver connection, along with the information about cable's delay. When necessary, and when no counter is available, in order to calculate new cable delay, please follow the equation:

$$dt = \frac{l}{k * c} \tag{1}$$

where: dt - cable delay in seconds, l - lenght of the cable in meters, k - cable propagation factor (no unit), c - the light speed in vacuum in m/s. For example:

```
-The length of the cable l=2m,
-The lightspeed in vacum c=299 792 458 m/s
-The velocity of propagation in cable k=0.83
The cable delay may be then obtained as:
dt = 2/(0.83*299 792 458) = ~8.04 ns
```

Piktime Systems recommends to measure the delay using universal time interval counter and a source of two 1pps signals:

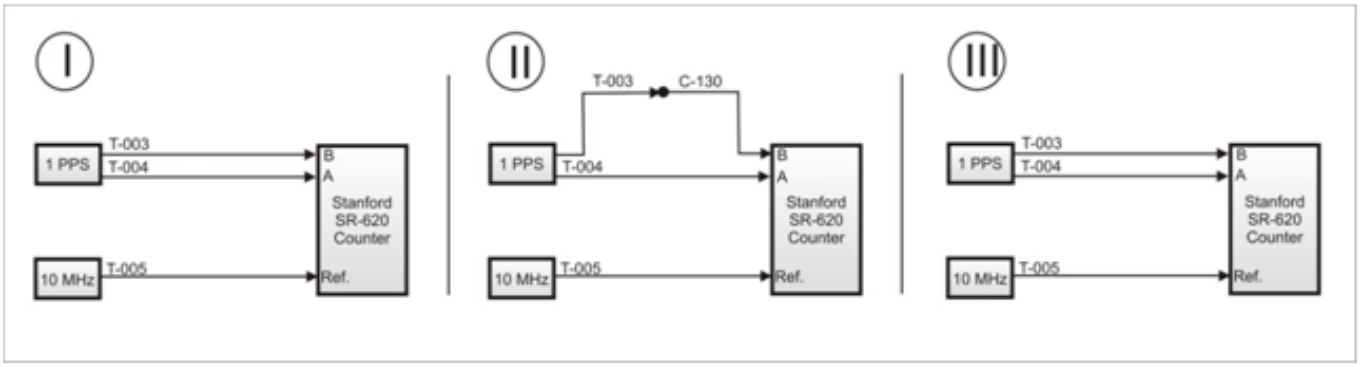


Figure 20: Local method of cable delay measurement diagram

In fig. 20, the measured cable in denoted as C-130, and other symbols are:
A - Start input of the counter
B - Stop input of the counter
Ref. - reference frequency for the counter, usually 5/10 MHz depending on the counter

The counter should be working in time interval mode, with trigger level for both inputs set at 0.5V, at 50Ω. Standard adapters or connectors used to connect calibrated cable (at the diagram II, the connector between T-003 and C-130) are estimated to be 0.1ns. User should subtract this value from the final result of the following equation:

$$\mathrm{dt} = \mathrm{Meas_{II}} - \frac{(\mathrm{Meas_I} + \mathrm{Meas_{III}})}{2}, \qquad (\mathrm{trig.level} = 0.5\mathrm{V}) \tag{2}$$

where dt - test cable delay, $\mathrm{Meas_{I,II,III}}$ - subsequent time interval counter measurement result, using configurations presented in fig. 20.
The counter accuracy should be at the level of 0.1ns or better.

5.2.4 TTS-4 reference frequency to 1PPS offset

TTS-4 receiver internal time scale is synchronized to external reference clock, using reference frequency and 1PPS signals, which must be coherent.
TTS-4 internal reference time is synchronized to the first zero-crossing of reference frequency cycle arriving after 1PPS pulse.
There is a constant offset between 1PPS reference signal connected to the TTS-4 receiver and TTS-4 reference time.
As time laboratory usually uses 1PPS signal as the reference, before starting the operation of the TTS-4, it is necessary to input into the receiver the phase difference between laboratory 1PPS and reference frequency at the receiver's input.

This offset can be measured using oscilloscope, or time & frequency counter with sub-nanosecond precision.
The procedure is as follows:

1. Switch on the counter

2. Set-up the counter inputs:
    - start (input A), trigger level 0.5 V, DC, 50 Ω,
    - stop (input B), trigger level 0.0 V, AC, 50 Ω,
    - time interval measurement mode.
3. Connect:
    - 1pps cable to start input of the counter
    - Reference frequency cable to stop input of the counter
4. Measure the delay between the 1pps and 10 MHz signals

The obtained results should be introduced to the receiver as "User reference frequency to 1PPS offset"

In order to change TTS-4 receiver user reference frequency to 1PPS offset, please use the following procedure:

- While in Main screen, press F2 - Main Menu,
- Press F1 - Receiver Configuration Tool,
- Using menu bar select Delays,
- Select "User reference frequency to 1PPS offset" (fig. 18)
- Enter delay value (fig. 21)
- Select Return to Main Menu
- Select Exit
- Answer Yes to "Do you want to save configuration before exit",
- Answer Yes to prompt "Do you really want to save this configuration"
- Answer Yes to prompt "Restart the observation process"

In order to correctly compute the internal offset between 1PPS signal, and internal time scale the results of factory calibrations for selected reference frequency must be introduced to TTS-4 configuration in the "Factory calibrations" subsection of the delays configuration section (fig. 22).
TTS-4 is factory calibrated for 5MHz and 10MHz.
If the used reference frequency is different, than 5MHz or 10MHz, or receiver has not been factory calibrated, the special calibration procedure described in separate technical note must be performed.

NOTE: TTS-4 receiver's delivered before 2014th has not been calibrated at factory.

Warning: It may happen, that 1PPS signal comes very close to corresponding zero-crossing of the input reference frequency, in such a situation, data accuracy can be reduced.
In such case the value of the "1PPS-frq offset corr" on the main receiver screen will be blinking red, or will be displayed in yellow color.

You can check the value of the "1PPS-frq offset corr" by taping F3 key on main TTS-4 screen, until the parameter is displayed (fig. 23)

If the "1PPS-frq offset corr" is blinking red the 1PPS reference signal cable should be extended by 5 ns (120 cm).
If the value is displayed in yellow color, we recommend to extend the 1PPS, but it is not mandatory. Please remember to measure and enter to the receiver configuration the new values of "reference delay", and "TTS-4 reference frequency to 1PPS offset" when the 1PPS reference signal cable is extended.

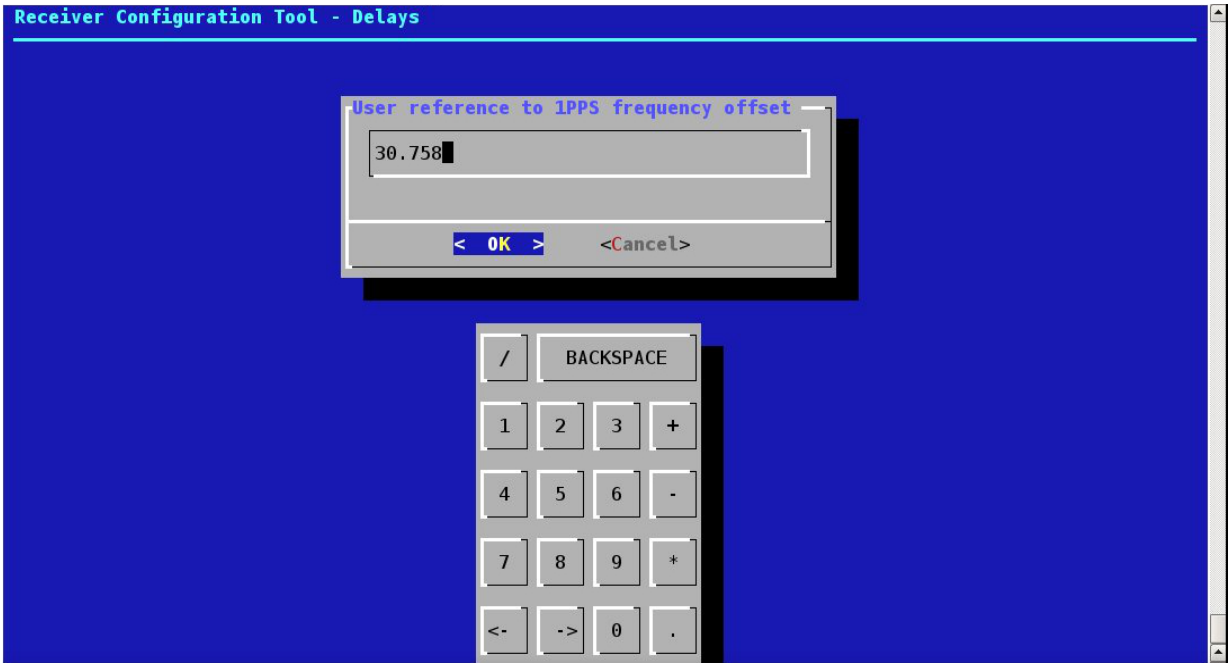


Figure 21: Presenting the value of 1PPS - freq offset to the receiver.

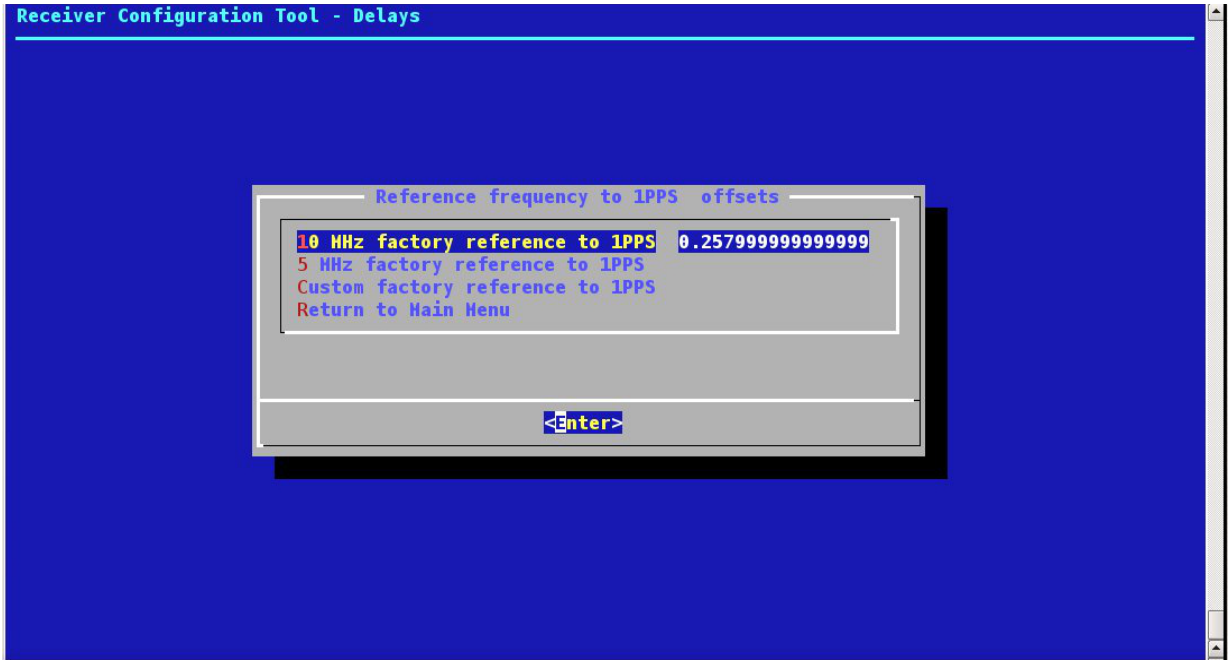


Figure 22: Reference frequency to 1PPS offset menu

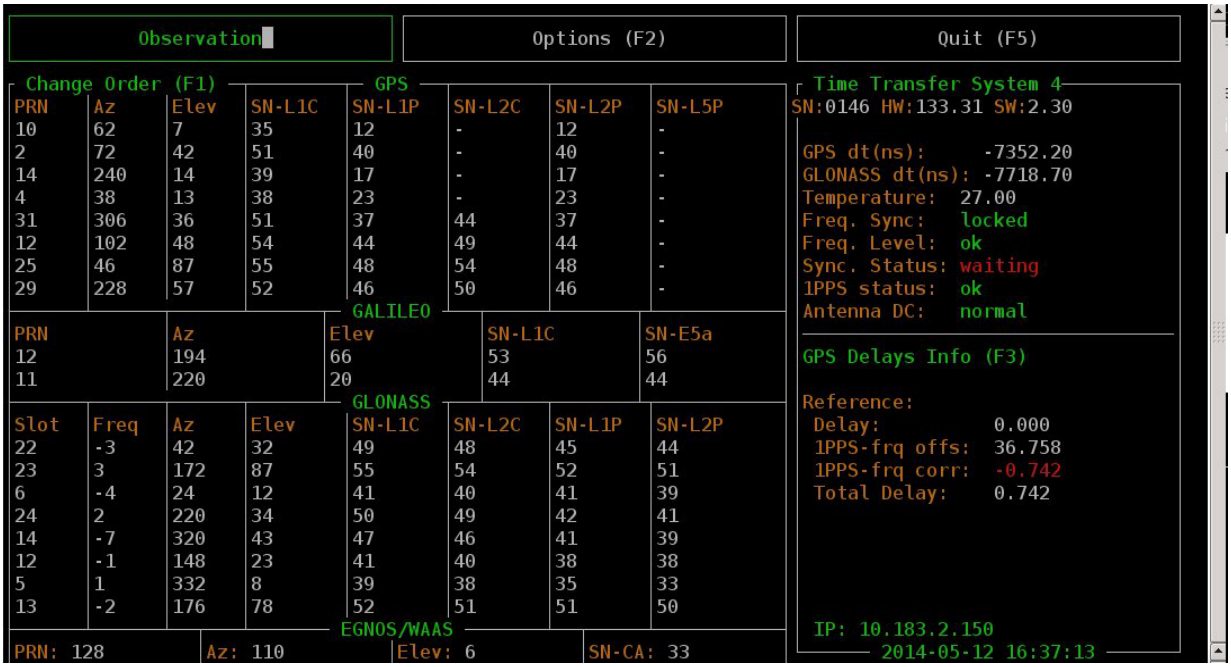


Figure 23: The main menu presenting values of delays and 1PPS - reference freq offset

5.2.5 RINEX section

Also see: *Glossary: RINEX* (p.47)
In order to change RINEX file parameters, please:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver Configuration Tool,
3. select RINEX Section, end enter the following parameters (fig. 24):
    - Name of the Agency (Run by) - the name of the agency where observations are performed
    - Name of Antenna Marker
    - Number of Antenna Marker
    - Name of Observer - the name of the person responsible for the observations
    - Name of Agency - the name of the agency where the observation are performed
    - Antenna Type - the IGS antenna type
    - Antenna Number
    - Observations Interval - the observation interval in seconds (default: 30 sec)
    - Antenna Height - the distance to the bottom surface of the antenna above marker in meters
    - Eccentricity of Antenna (East) - the eccentricity of the antenna center to marker related to the East [in meters].
    - Eccentricity of Antenna (North) - the eccentricity of the antenna center to marker related to the North [in meters]
    - RINEX file id - the prefix of the name of the RINEX created files
    - Applying of delays - Enables/disables utilization of the cable and receiver internal delays (default: disable)

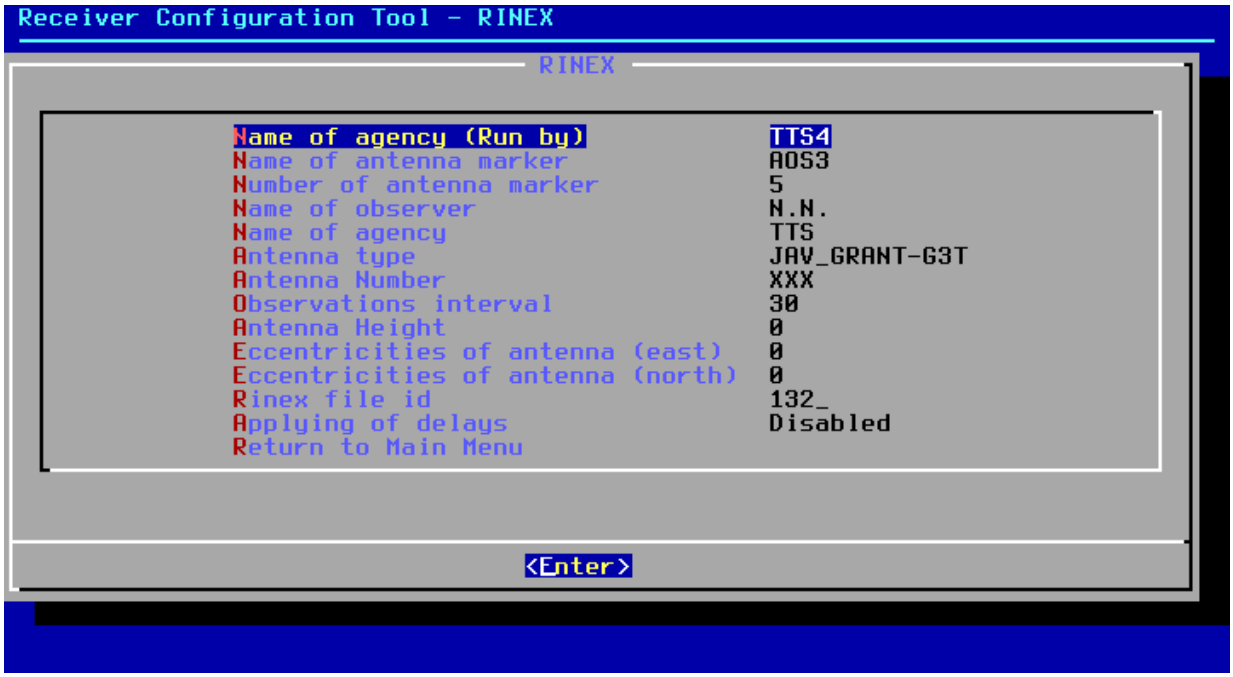


Figure 24: RINEX section.

After changes, please:

1. Select Return,
2. Select Exit,
3. Confirm saving changes and observation process restart.

5.2.6 Automatic Data Upload

An automatic data upload tool configures the receiver CGGTTS and RINEX data upload to FTP servers. The procedure varies slightly depending on the type of data uploaded. The parts of the procedure common for all the data types are placed between markers. The parts of the procedure that require user attention are marked red. After presenting each configuration to the receiver, please test it using the `Test Configuration` option from the menu. Test's desired results are presented below, between markers `CONFIGURATION TEST`. In order to configure the receiver automatic data upload, please:

COMMON PART - INSTALLATION START

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver Configuration Tool
3. select Automatic Data Upload

END OF COMMON PART - INSTALLATION START

CGGTTS/UTC DATA

- Select CGGTTS (fig. 25)
- Select the old pre-defined BIPM-CGGTTS entry (fig. 26)
- Change status to disabled (fig. 27)
- Select "Add New FTP host"
- Enter Configuration Name (for example NBIPM-CGGTTS) (fig. 28)
- Set status to "enable"
- Enter Host name: a.b.c.d, where a.b.c.d is IP address you have obtained form BIPM
- Enter name and password you have obtained from BIPM
- Change remote path to: `/data/UTC/XXXX/links/cggtts`, where XXXX should be replaced by your laboratory BIPM acronym
- Change "Passive mode" to enable
- Change "Compression" to none
- Test the configuration using the `Test Configuration` option. The results should be consistent with those presented in `CONFIGURATION TEST` below.

END OF CGGTTS/UTC DATA

CGGTTS/UTCr DATA

- Select CGGTTS (fig. 25)
- Select "Add New FTP host" (fig. 26)
- Enter Configuration Name (for example NBIPM-CGGTTS_UTCr) (28)
- Set status to "enable"

- Enter Host name: a.b.c.d, where a.b.c.d is IP address you have obtained form BIPM
- Enter name and password you have obtained from BIPM
- Change remote path to: `/data/UTC/XXXX/links/cggtts`, where XXXX should be replaced by your laboratory BIPM acronym
- Change "Passive mode" to enable
- Change "Compression" to none
- Test the configuration using the `Test Configuration` option. The results should be consistent with those presented in `CONFIGURATION TEST` below.

END OF RINEX/UTC DATA

RINEX/UTC DATA

- Select RINEX (fig. 25)
- Select the old pre-defined BIPM-RINEX entry (fig. 26)
- Change status to disabled (fig. 27)
- Select "Add New FTP host"
- Enter Configuration Name (for example NBIPM-RINEX) (28)
- Set status to "enable"
- Enter Host name: a.b.c.d, where a.b.c.d is IP address you have obtained form BIPM
- Enter name and password you have obtained from BIPM
- Change remote path to: `/data/UTC/XXXX/links/cggtts`, where XXXX should be replaced by your laboratory BIPM acronym
- Change "Passive mode" to enable
- Change "Compression" to gzip
- Test the configuration using the `Test Configuration` option. The results should be consistent with those presented in `CONFIGURATION TEST` below.

END OF RINEX/UTC DATA

RINEX/UTCr DATA

- Select RINEX (fig. 25)
- Select "Add New FTP host" (fig. 26)
- Enter Configuration Name (for example NBIPM-RINEX_UTCr) (fig. 28)
- Set status to "enable"
- Enter Host name: a.b.c.d, where a.b.c.d is IP address you have obtained form BIPM
- Enter name and password you have obtained from BIPM
- Change remote path to: `/data/UTC/XXXX/links/cggtts`, where XXXX should be replaced by your laboratory BIPM acronym
- Change "Passive mode" to enable
- Change "Compression" to gzip
- Test the configuration using the `Test Configuration` option. The results should be consistent with those presented in `CONFIGURATION TEST` below.

END OF RINEX/UTCr DATA

COMMON PART - CONFIGURATION TEST

4. After filling each configuration, please select `Test Configuration` in order to verify settings. The correct result of each test should be:

```
Trying to connect to FTP Server
=> Connection Successful.
Trying to login.
=> Login Successful.
Trying to enter destination directory.
=> Warning:  Can't enter destination directory at
/usr/local/share/recconf//backup.pl line 312.
Trying to create destination directory.
=> Directory Created.
Trying to enter created directory.
=> Successfully entered destination directory.
Do you want to upload test file?  (y/n)
#y
Trying to PUT file "test" to destination directory
=> File has been uploaded successfully
Trying to DELETE file:  "test"
=> File has been deleted successfully.
Closing connection...
=> Connection closed.
Test completed successfully.  Press any key to continue.
```

COMMON PART - CONFIGURATION TEST

COMMON PART - INSTALLATION END

5. Select "Return"
6. Select "Return to main menu"
7. Select "Save Upload Configuration" (fig. 25 and fig. 29)
8. Select "Return to main menu"
9. Select "Exit"
10. Confirm saving configuration before exit
11. Do not confirm restarting of observation process (it is not necessary)

END OF COMMON PART - INSTALLATION END

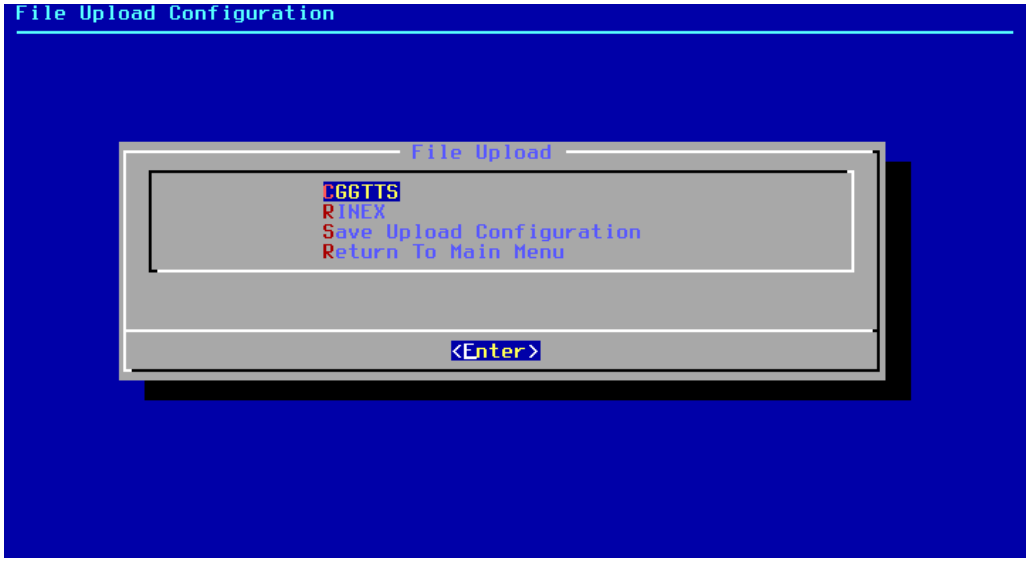


Figure 25: Automatic data upload menu

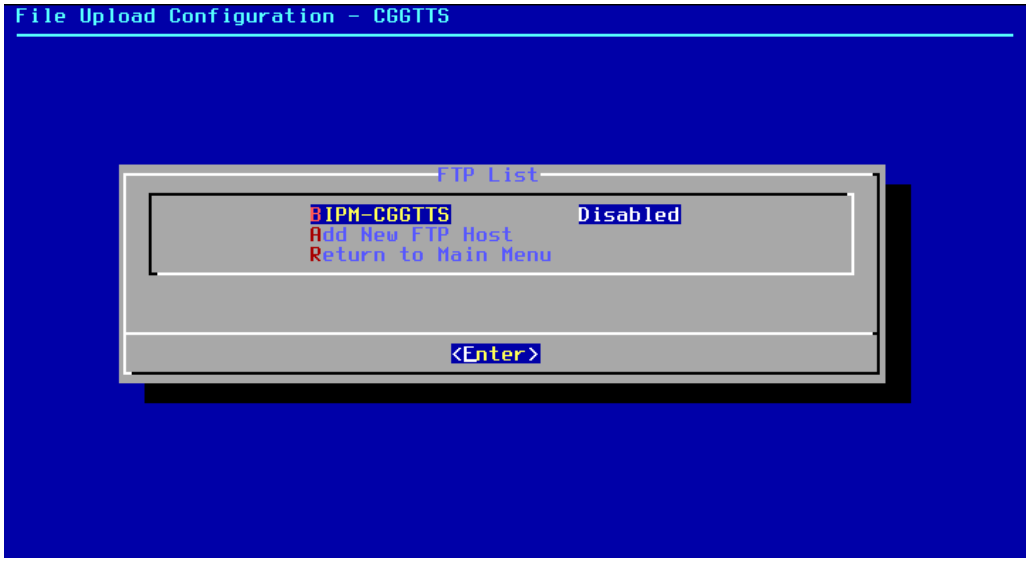


Figure 26: Automatic data upload FTP list

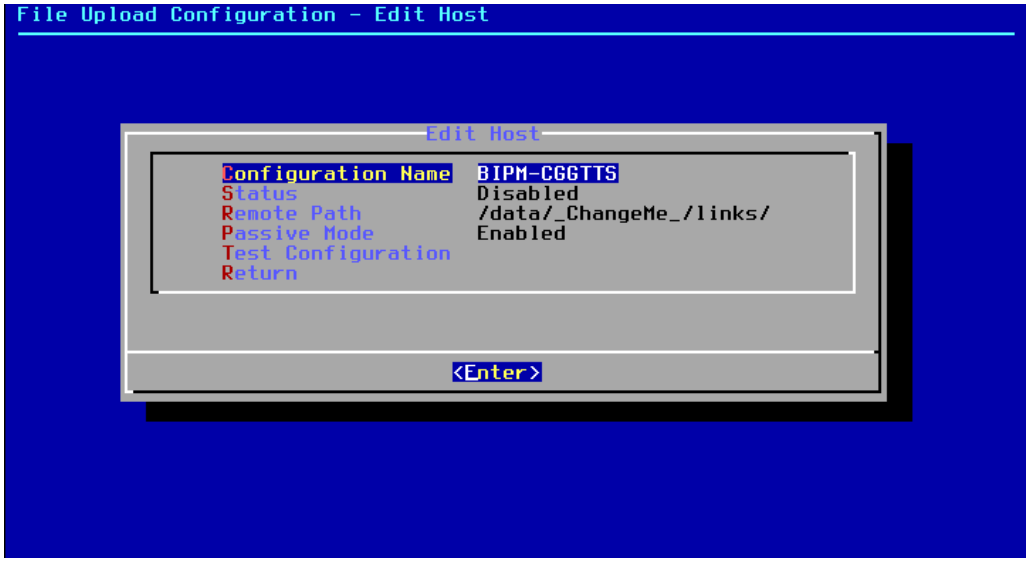


Figure 27: Automatic data upload BIPM server configuration

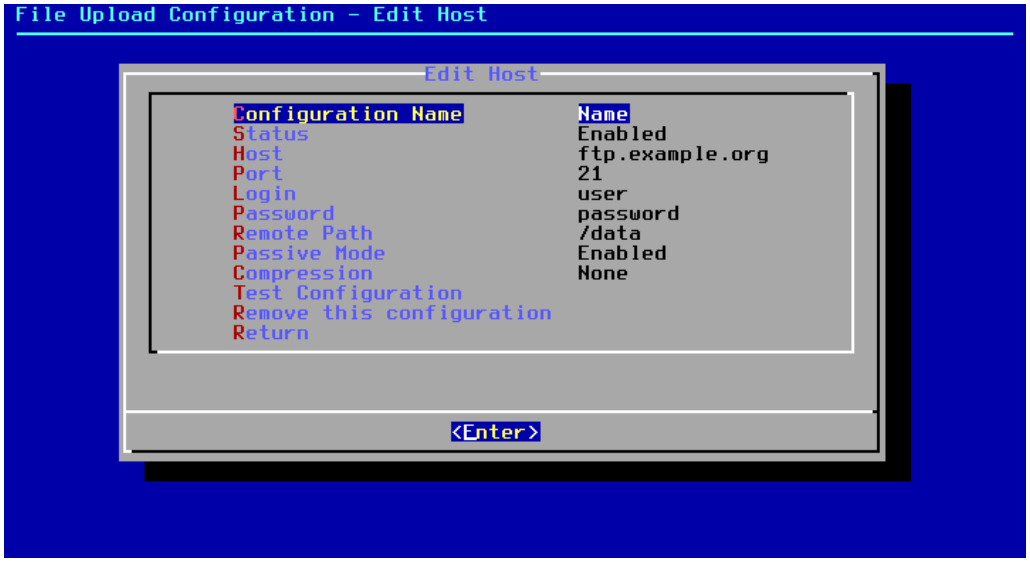


Figure 28: Automatic data upload new FTP server configuration

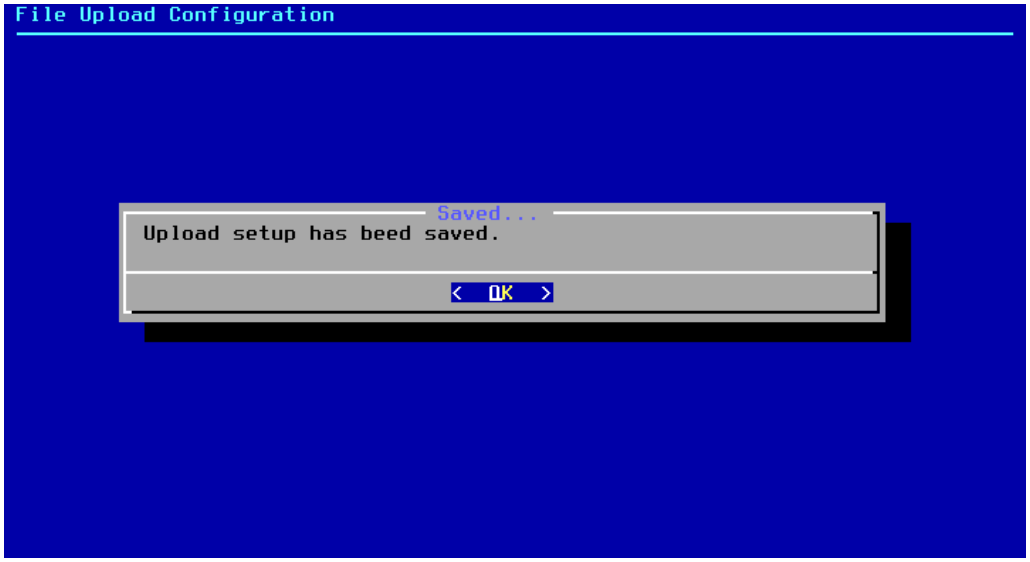


Figure 29: Automatic data upload configuration saving

5.2.7 Other options

In order to enter Other options menu, please follow the following procedure:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver Configuration Tool,
3. select Other options (fig. 30), and enter parameters:
   - Debug - Enables/disables creating debug files. The debug file contains raw observation data, not usable for users. The debug files consumes a lot of the disk space, please enable it only in case of problems, at PikTime request.
   - Elevation Mask - cut-off angle (satellites with the elevation below the elevation mask will not be observed). Observing the low elevation satellites may increase noise of the data - this value should be set to 5 - 10 deg.
   - Synchronization to external frequency (described in *section Reference frequency selection procedure* (p.35)).

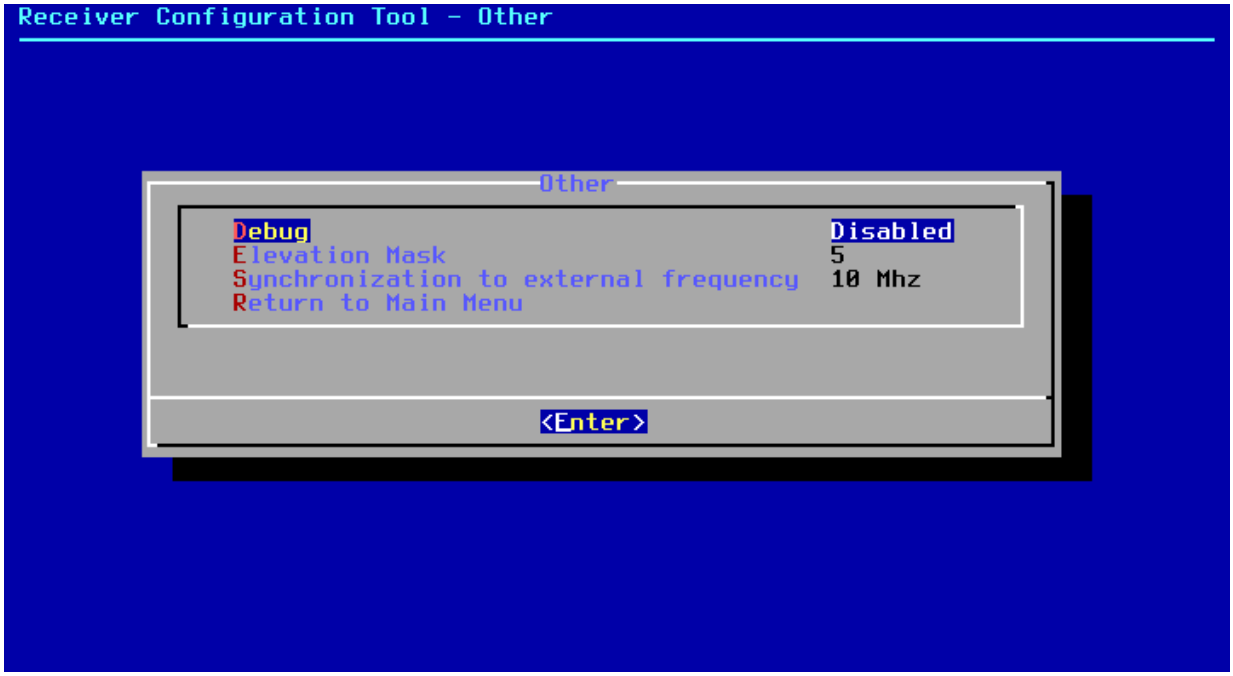


Figure 30: Other options menu.

After changes, please:

1. Select Return,
2. Select Exit,
3. Confirm saving changes and observation process restart.

Reference frequency selection procedure
The frequency of 3-20MHz reference signal should be configured using the following procedure:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver Configuration Tool,
3. select Other options using menu bar,
4. select Synchronization to external frequency (fig. 30),
5. select the value of the frequency of connected signal: 3-20MHz (fig. 31),
6. select Return to Main Menu,
7. select Exit,
8. answer Yes to “Do you want to save the configuration before exit”,
9. answer Yes to prompt “Do you really want to save this configuration”,
10. answer Yes to prompt “Restart the observation process”

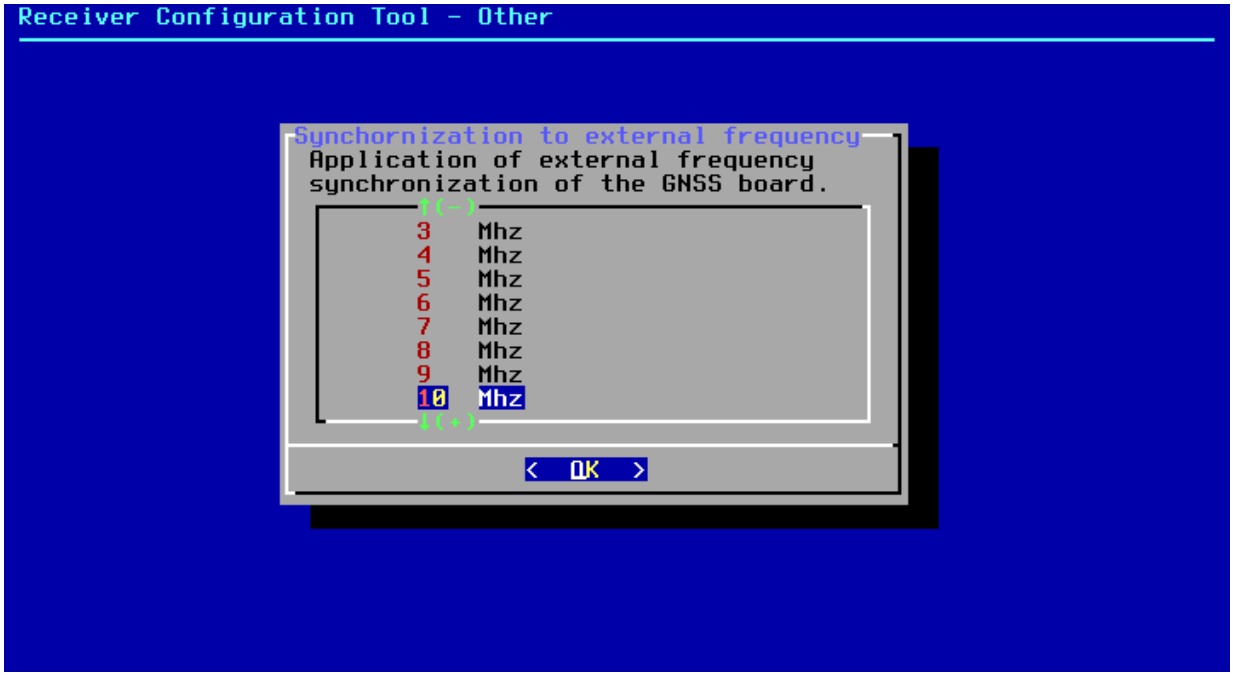


Figure 31: Reference frequency selection.

5.2.8 Save receiver configuration

After setting the receiver configuration, it should be saved.
In order to save TTS-4 receiver configuration, please:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver Configuration Tool
3. select Save Setup (fig. 32)

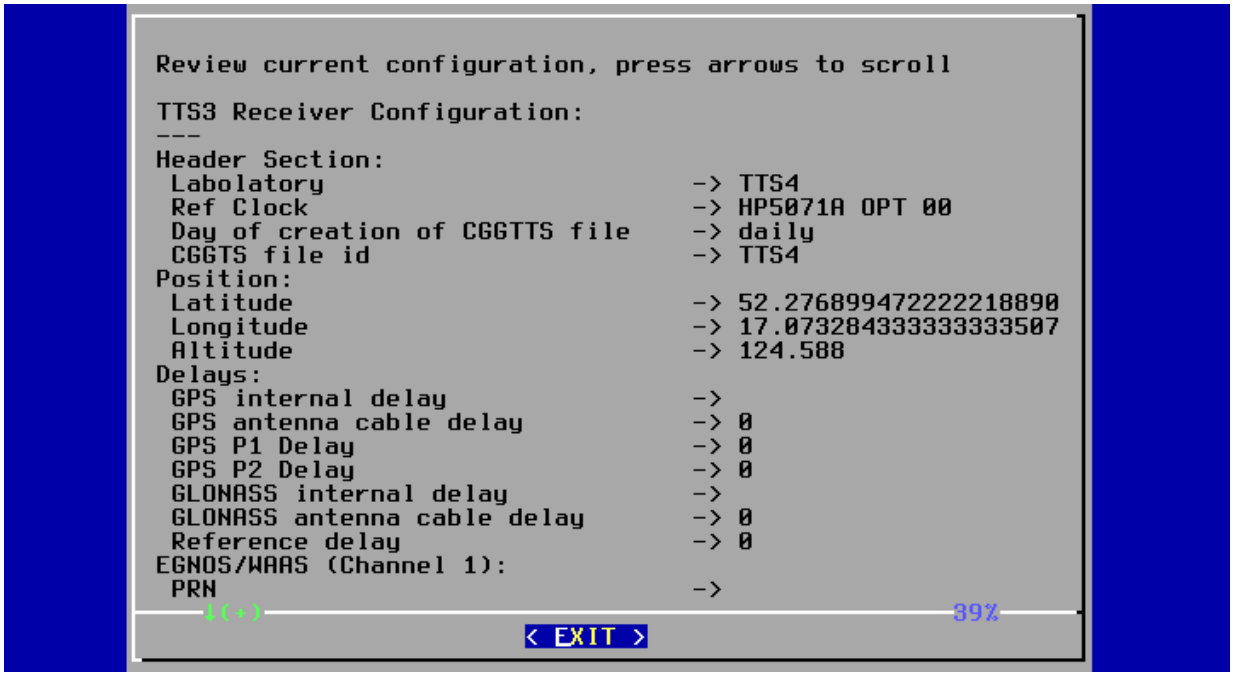


Figure 32: Receiver configuration saving.

5.2.9 Clearing TTS-4 GNSS module NVRAM procedure

TTS-4 is designed especially for time comparison. It is working in the improved timing mode, therefore the antenna position should be very accurate. It may sometimes cause some problems, if the antenna position is wrong, or the receiver has been moved to a different location (after relocating, the data stored in NVRAM may be wrong).

PikTime Systems recommends to clear NVRAM every time when:

- the antenna position has been changed or the new antenna coordinates were introduced,
- the antenna or the antenna cable was changed or temporarily disconnected,
- 1PPS or the reference frequency cable or the source was changed.

If the NVRAM has not been cleared it may take some time, until the receiver starts to produce good quality data on P-code.
In order to clear GNSS please:

1. While the Main screen is displayed, press F2 - Main Menu,
2. Press F7 key - Clear NVRAM
3. Confirm the clearing of NVRAM by pressing “Y” key

After approximately 1 min. a confirmation message “NVRAM cleared.” should appear.

5.2.10 Save and restore TTS-4 configuration, USB pendrive procedure

In order to save the current TTS-4 configuration to a USB pendrive please follow the following procedure:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver Configuration Tool,
3. select Save setup to a pendrive

In order to restore TTS-4 configuration from the USB pendrive please follow the following procedure:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F1 - Receiver Configuration Tool,
3. select Restore setup from pendrive

Please note, that TTS-4 will use the first partition on a pendrive, and that the partition should be VFAT formatted. Some USB pendrives may however not work correctly with TTS-4. In order to verify it, please execute command: `mdir c:` .

5.2.11 Bug Report

The bug report tool should be used only if necessary, as it stops the observation process. This tool was implemented in order to generate the debug file which contains information about the current TTS-4 configuration and the outputs of test procedures. Before generating a bug report you may try to identify the problem on your own by switching to Virtual terminal 6 (press ALT+F6), and checking for error messages. The output bug report file should be sent to PikTime.
In order to generate a bug report, please:

1. plug in a pendrive to TTS-4 receiver USB connector[9]
2. While the Main screen is displayed, select F2 - Main Menu
3. select F6 - Bug report, and press any key (the bug report generation should take about 2 min.) (fig. 33)
4. please send AOS.output.tar.bz2 generated at your USB pendrive to PikTime
5. press ALT+F5 to return to VT5

The bug report may also be generated using an alternative procedure:

1. Switch to Virtual Console 1 (press ALT+F1)
2. Log in as root (login: root , default password: tts3receiver)
3. Plug in the pendrive to the TTS-4 receiver USB connector
4. execute command: bugreport (bug report generation should take about 2 min.) (fig. 33)
5. please send AOS.output.tar.bz2 generated at your USB pendrive to PikTime.

[9] Please note, that TTS-4 will use first partition on pendrive, and that the partition should be VFAT formatted. Some USB pendrives may however not work correctly with TTS-4. In order to verify it, please execute command: `mdir c:` .

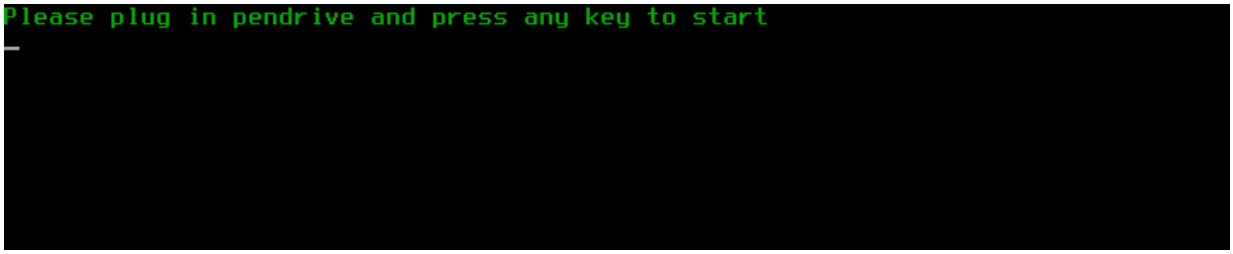


Figure 33: Bug report generation

5.2.12 Validation of receivers accuracy

The simplest way to verify the accuracy of a receiver is to compare its results with other receiver (working at any timing laboratory). The most common problems with TTS-4 receiver accuracy are the following:

- Input of the imprecise coordinates to the receiver will result in the decrease of the precision of the measurements. In order to avoid this kind of behaviour, please recalculate antennas position as described in sec. *Antenna Coordinates* (p.19).

PikTime systems may also perform the computations for you (if provided with a few days CGGTS and RINEX data). The accuracy verification procedure is recommend before starting to send data to the BIPM.

5.3 Network Configuration Tool

In order to start receiver network configuration tool, please:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F2 - Network Configuration Tool

While in this menu, the following options are available (fig. 34):

1. *Interface Configuration* (p.40) - Configures the receiver network configuration file.
2. *Edit Internet Access File* (p.42) - Configures the internet access file.
3. *FTP Server* (p.42) - Sets the FTP server on or off.
4. *Save Setup* (p.43)- Displays and saves the receiver current network configuration.
5. *Save Setup to Pendrive* (p.43) - Saves the current configuration to the USB pendrive.
6. *Restore Setup from Pendrive* (p.43) - Restores the previous configuration from the USB pendrive,
7. Exit - Returns to Observation Screen.

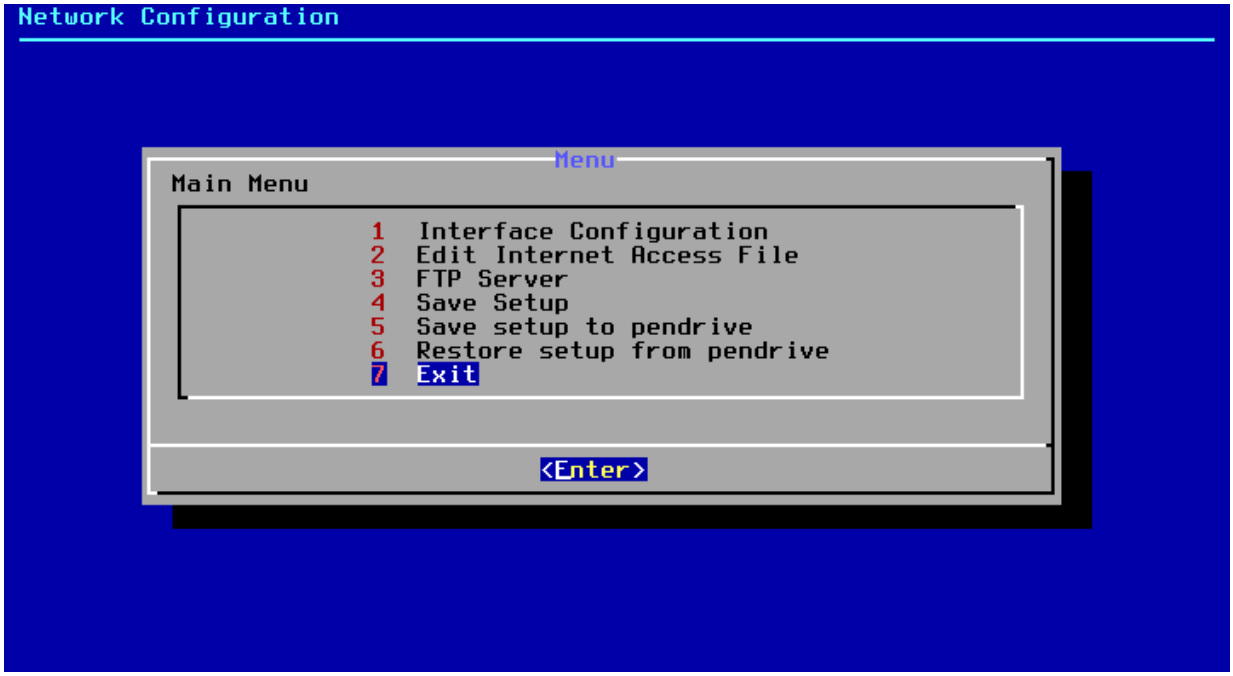


Figure 34: Network Configuration Tool.

5.3.1 Interface Configuration

In order to change TTS-4 receiver network configuration, please:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F2 - Network Configuration Tool
3. select Interface Configuration

The following parameters can be set(fig. 35):

- Get settings from DHCP:
  - on - The receiver will get network settings from the DHCP server (fig. 34a)
  - off - The network settings will be defined manually, as follows:
- IP Adres- Sets the receiver IP Address (fig.36b)
- Network Prefix - Netmask selection (fig. 36c)
- Gateway - Sets the gateway address
- DNS Servers - Configures DNS Servers
- Domain - Sets the network domain
- Host name - Configures the receiver network host name (fig.36d)

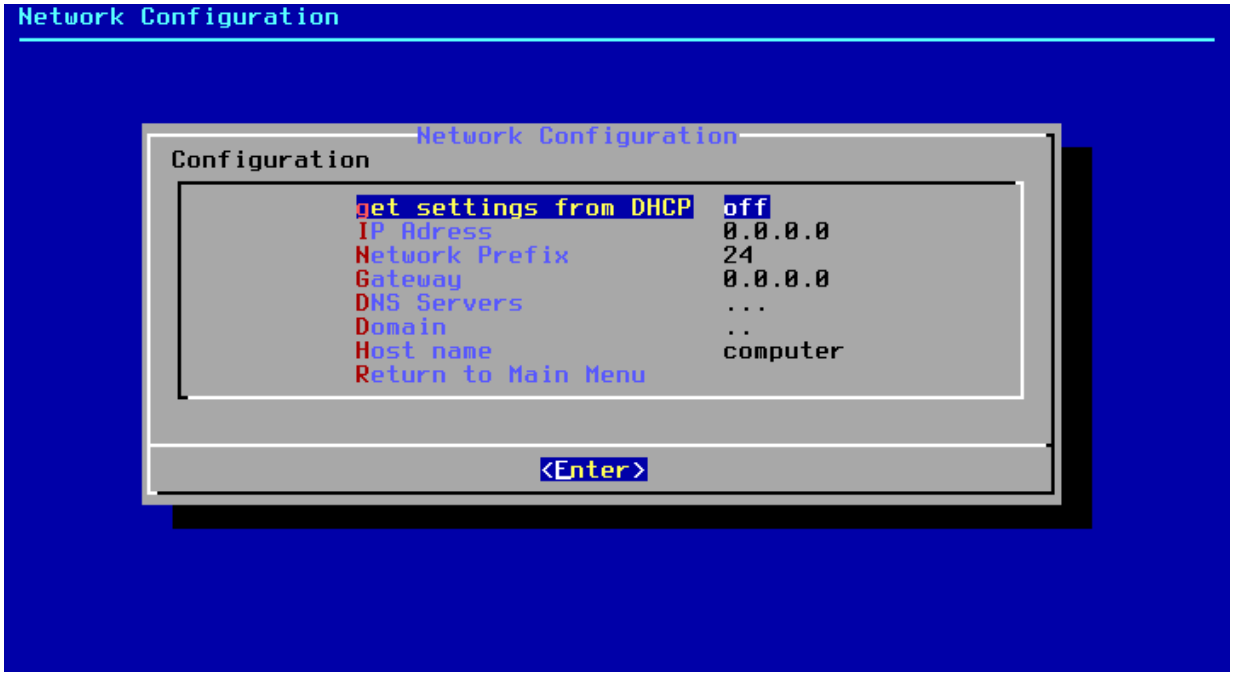
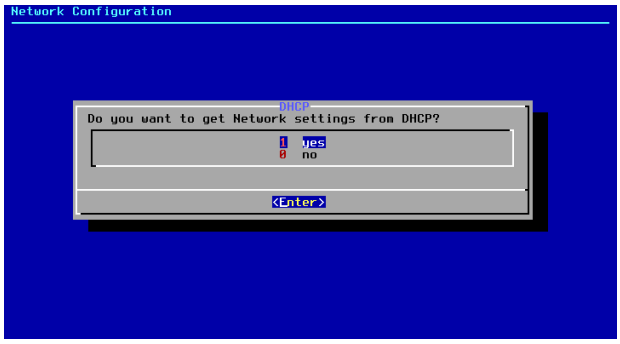
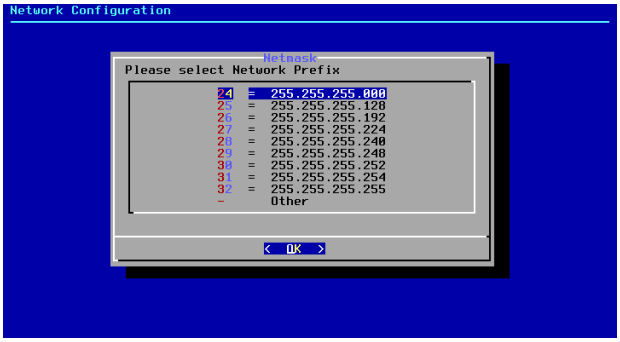


Figure 35: Network Configuration Tool menu.



(a) Choice of using a DHCP server by TTS-4 receiver

(b) IP address setting



(c) Netmask configuration

(d) Network hostname configuration

After changes, please:

1. Select Return,
2. Select Exit,
3. Confirm saving changes and restarting observation process.

5.3.2 Edit Internet Access File Procedure

The file contains the list of workstations' IP addresses, which are allowed to connect to TTS-4 receiver. TTS-4 will accept WWW, FTP and ssh connections only from hosts specified in this file.
Notation IP/network prefix is allowed , for example:
192.168.0.0/24 = 192.168.0.0-192.168.0.255
10.0.0.0/8 = 10.0.0.0 - 10.255.255.255

5.3.3 FTP Server

In order to enable/disable TTS-4 receiver FTP server, please:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F2 - Network Configuration Tool
3. select FTP Server (fig. 36)

You can specify whether the FTP server should be on of off.

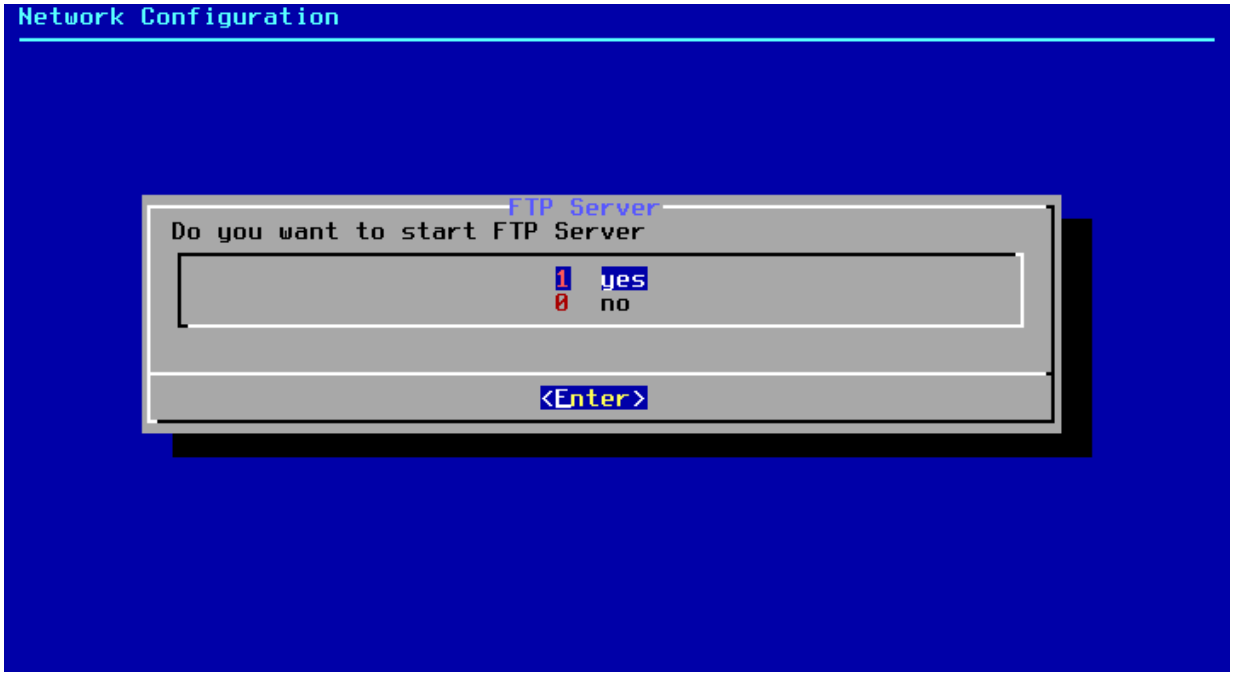


Figure 36: FTP server setting

5.3.4 Save network configuration

After setting the receiver network configuration, it should be saved.
In order to save TTS-4 receiver network configuration, please:

1. While the Main screen is displayed, press F2 - Main Menu,
2. press F2 - Network Configuration Tool
3. select Save Setup (fig. 37)

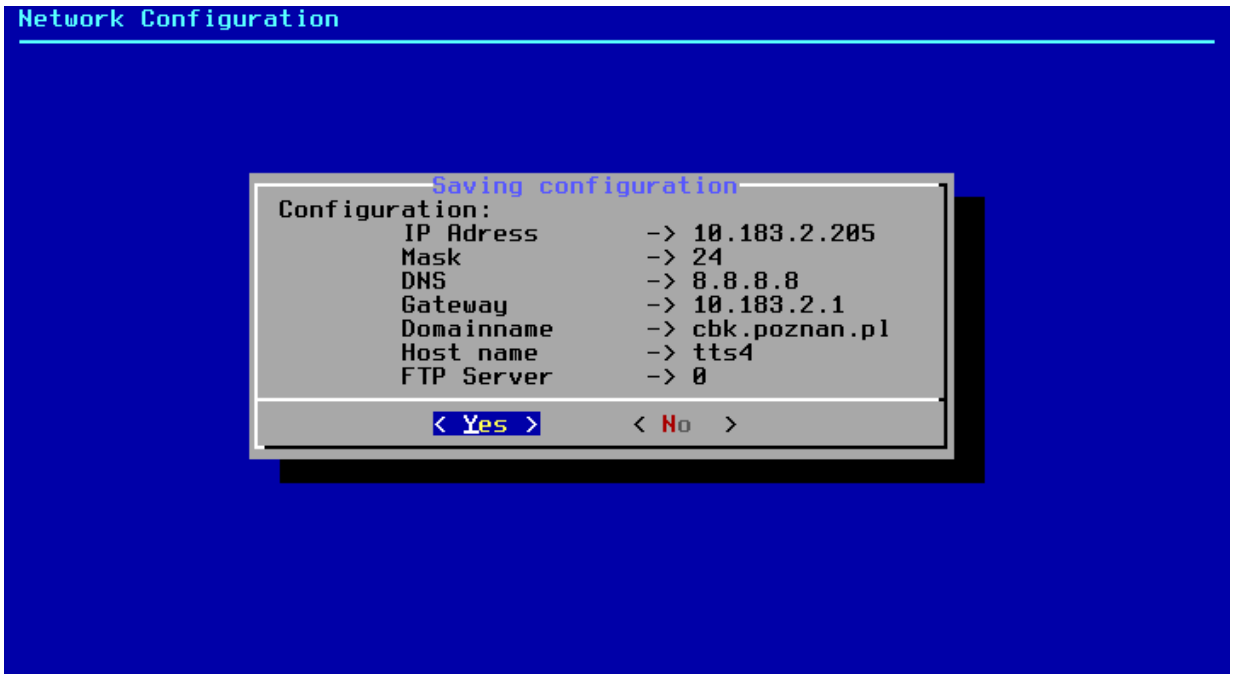


Figure 37: Network configuration saving.

5.3.5 Save and restore TTS-4 network configuration, USB pendrive procedure

In order to save the current TTS-4 network configuration to the USB pendrive please follow the following procedure:

1. While the Main screen is displayed, press F2 key - Main Menu,
2. press F2 key - Network Configuration Tool,
3. select Save setup to the pendrive

In order to restore TTS-4 network configuration from the USB pendrive please follow the following procedure:

1. While the Main screen is displayed, press F2 key - Main Menu,
2. press F2 key - Network Configuration Tool,
3. select Restore setup from the pendrive

5.4 Software upgrade

In order to provide the best possible measurement results, PikTime Systems keeps developing TTS-4 receiver software. Every software version fixes bugs and inconveniences reported by users, or spotted by PikTime Systems team, so it is recommended to always have the latest software version.

At PikTime Systems website: `http://www.piktime.com`, at “TTS-4” -> “TTS-4 Upgrades” section, a link to the latest TTS-4 receiver software version disc image is provided. In order to verify, that the downloaded ISO image is complete, additional MD5 code and file size will is provided for each file. After downloading the disc image, please burn it to a CD as a bootable CD (the ISO image should be burned to the CD using "burn ISO image to disc" option. Copying the ISO file, or the files extracted from the ISO file, to the CD will not produce a usable disc.).

In order to upgrade the software version of the TTS-4 receiver, please use the following procedure:

1. please insert upgrade disc (the burned ISO image CD) into the CD drive,
2. please restart the receiver,
3. After the "TTS4 Upgrade Disk" message appears on the screen, please enter: u
   (this step will take approx. 5-20 min. to complete),
4. please remove the disc from the CD drive,
5. please reboot the receiver by pressing Enter key,
6. please boot the receiver using the main partition (select "tts4" from booting menu),
7. please upgrade the GNSS module firmware (only if necessary)
   (a) please confirm upgrade of the GNSS module firmware
   WARNING: DO NOT TURN THE RECEIVER OFF DURING THIS PROCESS
   firmware upgrade will take approx. 5-10 min.
   (b) after the firmware upgrade, the message “GNSS module firmware successfully upgraded” will appear on the screen.

If the receiver doesn’t work after the upgrade, please check the diagnostic messages at console 6 (please press ALT+F6). It is also possible to boot the receiver from the backup partition (please select "backup" from booting menu).
Please always remember to perform a *Clear NVRAM* (p.37) procedure after upgrading the software (or presenting new antenna position or receiver delay values) to the receiver, as it it crucial to the quality of measurement results.

Additional options:
FTP SERVER ACTIVATION: (user login for ftp server is tts3ftp)

1. please switch to console 1 (please press ALT+F1),
2. please log in as root,

3. please execute the following command: `ftpon`
   and set the password for tts3ftp user.

FTP SERVER DEACTIVATION:

1. please switch to console 1 (please press ALT+F1),
2. please log in as root,
3. please execute the following command: `ftpoff`

These instructions, together with the current software changelog, are also available at PikTime Systems website: `http://www.piktime.com`, at "TTS-4 Receiver" -> "TTS-4 Upgrades" section[10].

5.5 Troubleshooting

This section contains problems submitted by TTS-4 users, which didn't fit into previous sections.

1. *Question: The receiver works, observes satellites, measures time differences between local and internal time scales but doesn't write the result into output files. Files only have headers but not measurement results.*

   Answer: There may be not enough free space on hard disk drive, some old data may need to be removed. In order to check the amount of free disk space, please log in to the receiver:

   - switch to VT1 (press ALT+F1)
   - log in as root (login: `root`, default password `tts3receiver`)
   - execute command: `df -h`.

   The output should look similar to the following:

Filesystem	Size	Used	Avail	Use%	Mounted on
/dev/sda1	9.4G	733M	8.2G	9%	/
/dev/sda5	210G	203G	0	100%	/data

Table 2: Exemplary `df -h` command output

   Please check if any of the partitions is full (100% means, that the partition is full). If there is no free disc space left, please use `mc` tool to erase old files.Please execute the following commands:

   - `cd /data`

[10] Please note, that only registered, and confirmed by PikTime Systems users are allowed to access most of TTS-4 related website sections

- `mc`

Now using arrow keys, please go into `/debug` subdirectory, and if there are any files, please delete them all. You can also delete old data from subdirectories: `/data/rinex/YYYY` and `/data/cggtts/YYYY` where YYYY represents the year number. Please leave only the current year and the previous year. After that, please restart the receiver.

6 Glossary

6.1 ITRF

From `http://itrf.ensg.ign.fr/general.php`:
A Terrestrial Reference frame provides a set of coordinates of some points located on the Earth's surface. It can be used to measure plate tectonics, regional subsidence or loading and/or used to represent the Earth when measuring its rotation in space. This rotation is measured with respect to a frame tied to stellar objects, called a celestial reference frame. The International Earth Rotation and Reference Systems Service (IERS) was created in 1988 to establish and maintain a Celestial Reference Frame, the ICRF, and a Terrestrial Reference Frame, the ITRF. The Earth Orientation Parameters (EOPs) connect these two frames together.

6.2 CGGTTS

From `ftp://62.161.69.5/pub/tai/data/cggtts_format_v1.pdf,ftp://62.161.69.5/pub/tai/data/cggtts_format_v2.pdf`:
The Consultative Committee for Time and Frequency (CCTF) advocated in its Recommendation S 5 (2001) that the manufacturers of receivers used for timing with global navigation satellite systems (GNSS) implement the technical guidelines for receiver hardware which are compiled by the CCTF Group on GNSS Time Transfer Standards (CGGTTS). These guidelines have been compiled with the aim of achieving a system that can transfer time with an accuracy of 1ns or better. They can be applied to all available global navigation satellite systems, such as GPS, GLONASS, WAAS, EGNOS, MSAS, and Galileo.

6.3 RINEX

From `http://igscb.jpl.nasa.gov/igscb/data/format/rinex210.txt`
The first proposal for the "Receiver Independent Exchange Format" RINEX has been developed by the Astronomical Institute of the University of Berne for the easy exchange of the GPS data to be collected during the large European GPS campaign EUREF 89, which involved more than 60 GPS receivers of 4 different manufacturers. (...). Currently the format consists of six ASCII file types:

1. *Observation Data File*
2. *Navigation Message File*
3. *Meteorological Data File*
4. *GLONASS Navigation Message File*
5. *GEO Navigation Message File*
6. *Satellite and Receiver Clock Date File*

TTS-4 is following the standard naming convention for RINEX files:

`ssssdddf.yyt`

`ssss`: 4-character station name designator
`ddd`: day of the year of first record
`f`: file sequence number/character within day:

- daily f=0 - file contains all the existing data of the current day
- hourly f=a - 1st hour (00h-01h), b = 2nd hour (01h-02h), ..., x = 24 hour (23h-24h)

yy: two-digit year
t: file type:

- 0: Observation file
- N: Navigation file
- M: Meteorological data file
- G: GLONASS navigation file
- L: Galileo navigation file
- P: Mixed GNSS navigation file

A DS4W© application

This section describes the DS4W© application by Dariusz Lemański, Astrogeodynamical Observatory.
DS4W© is a simple application for CV data computations. The software calculates the clock\time scale differences using GPS or GLONASS CV CGGTTS data. The program works in a command prompt window. It requires two CGGTTS formatted data files, and produces three output files: `differences.*` , `report.*` and `result.*` (where * is either `gps` or `glo` extension).

Running the application

In order to run the application, while in prompt window, please call:

```
ds4w <file1> <file2> <interval for linear fitting> <data type>
```

where:

- `<file1>`,`<file2>` are CGGTTS formatted data files,
- `<interval for linear fitting>` is the time interval for linear fit,
- `<data type>` is one of the following strings: `l1c, l1p,l2c,l2p,l3c,l3p`.

Examples:

- `ds4w lab1.gps lab2.gps 24 l1c` (interval 1 day = 24h; L1C data)
- `ds4w lab1.gps lab2.gps 12 l1c` (interval $^1/_2$ day = 12h; L2C data)
- `ds4w lab1.gps lab2.gps 8 l1c` (interval $^1/_3$ day = 8h; L3C data)
- `ds4w lab1.gps lab2.gps 6 l1p` (interval $^1/_4$ day = 6h; L1P data)
- `ds4w lab1.gps lab2.gps 4 l2p` (interval $^1/_6$ day = 4h; L2P data)
- `ds4w lab1.gps lab2.gps 3 l3p` (interval $^1/_8$ day = 3h; L3P data)

Output files: differences.*

This file contains raw differences of provided files.
The file header contains the names of computed files, and determines, which one of them is the reference file.
The file body contains seven columns:

- RMJD: MJD date + time of observation as the fraction of the day [days]
- LAB1: REFGPS / REFSYS value [ns]
- LAB2: REFGPS / REFSYS value [ns]
- DELTA: difference between LAB1 and LAB2 values [ns]

- PRN: satellite vehicle PRN number [no unit]
- MJD: Modified Julian Day [days]
- TIME: start time of the track [HHMMSS, UTC hours, minutes and seconds]

Example:

LAB1 - LAB2

RMJD	LAB1	LAB2	DELTA	PRN	MJD	TIME
54850.00417	-4.4	8.8	-13.2	9	54850	000600
54850.00417	-3.2	8.3	-11.5	26	54850	000600
54850.00417	-4.9	7.5	-12.4	15	54850	000600
54850.00417	-5.0	7.6	-12.6	28	54850	000600
54850.00417	-5.9	5.9	-11.8	27	54850	000600

Output files: report.*

This file contains fit results for given interval of estimation.
he file header contains the names of computed files, and determines, which one of them is the reference file.
The file body contains six columns:

- MJD: Modified Julian Day [days], when the fit interval is less than one day (24h), the value of MJD is RMJD
- AVE: fit result for given interval [ns]
- RMS: root mean square [ns]
- TOTAL: total number of common view measurements [no unit]
- ACCEPT: number of accepted common view measurements [no unit]
- %: percent of the accepted common view measurements [no unit]

Example:

LAB1 - LAB2

MJD	AVE	RMS	TOTAL	ACCEPT	%
54850	-11.47	0.91	623	612	98
54851	-13.29	0.97	610	595	97

Output files: result.*

This file contains filtered differences of provided files using 3σ criterion.
The file header contains the names of computed files, and determines, which one of them is the reference file.
The file body contains seven columns:

- RMJD: MJD date + time of observation as the fraction of the day
- LAB1: REFGPS / REFSYS value [ns]
- LAB2: REFGPS / REFSYS value [ns]
- DELTA: difference between LAB1 and LAB2 values [ns]
- PRN: satellite vehicle PRN number [no unit]
- MJD: Modified Julian Day [days]
- TIME: start time of the track [UTC hours, minutes and seconds]

Example:

LAB1 - LAB2

RMJD	LAB1	LAB2	DELTA	PRN	MJD	TIME
54850.00417	-4.4	8.8	-13.2	9	54850	000600
54850.00417	-3.2	8.3	-11.5	26	54850	000600
54850.00417	-4.9	7.5	-12.4	15	54850	000600
54850.00417	-5.0	7.6	-12.6	28	54850	000600
54850.00417	-5.9	5.9	-11.8	27	54850	000600
54850.00417	-7.2	5.6	-12.8	18	54850	000600