INS1000 Documentation

Aceinna Engineering

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INS1000 Developer Manual

Welcome to the INS1000 Manual. This manual provides information on how to set up INS1000 RTK system including both Rover and Basestation. The manual also documents output message and protocol of the INS1000 system.

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CHAPTER 1

Set Up & Software Guide

1.1 1. Introduction

This guide shows how to set up and install the INS1000 rover, and use the GUI. Please read it carefully.

AceinnaNav Control Software (ACS) is a graphical user interface for the AceinnaNav integrated navigation system. It displays continuous position, velocity, attitude, and trajectory information from the system. Additionally, it also provides tools to configure the system and log output data from the system. AceinnaNav version 0.19.4.8, https://www.aceinna.com/userfiles/files/Software/Inertial-System/ACS.zip

1.2 2. Installation Guide

AceinnaNav Control Software runs on Java Runtime Environment (JRE) 9. For JRE 9 download and setup, please refer to Oracle official website. To run the software, double-click the AceinnaNav.jar file.

Some PCs may not recognize the USB of the AceinnaNav system. The user needs to install the usb driver according to the system of the PC. The drivers are provided in the For Linux/For Mac/For Windows folders with the control software.

1.3 3. Connection

Before connecting to the AceinnaNav system, make sure the system's power is on. There will be a light indicating power. Check that the USB is plugged into the computer and the control software is installed in the computer.

To connect to the system, use the "Com Port Setting" dialog, shown in Figure 1. The user can reopen the dialog by choosing "System > Connect" menu if it is closed.

To choose a port, first click the [Refresh] button to get the list of available ports and then select a port from the drop-down list (shown in Figure 2). The baud rate is fixed as 230400 now. After all are set, click the [Connect] button. Please try another port if the message "Cannot open the port" shows up.

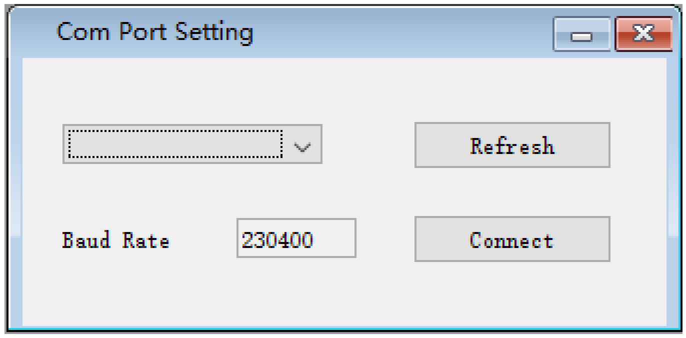


Fig. 1: Figure 1: Connection dialog

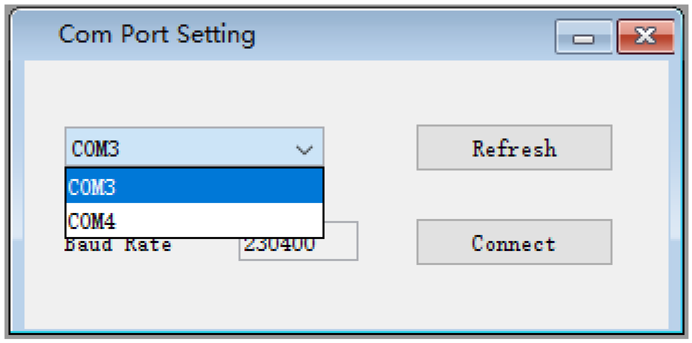


Fig. 2: Figure 2: Port selection

1.4 4. View

1.4.1 4.1. Subsystems Status

At the bottom-right corner of the interface, there are four indicators for the status of IMU, GNSS, PPS and NTRIP subsystems shown in Figure 3. A flashing green circle means the subsystem is on. Normally, IMU and GNSS turn on right after the power is supplied, and PPS turns on after the time is resolved with GNSS measurements. Users may be able to see the navigation data output with enough satellite data. NTRIP indicator will be on whenever the system receives information from the base station. The user can use these four indicators to see if the system is working properly or not.

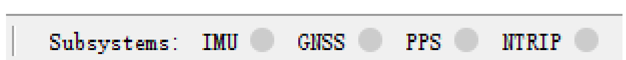


Fig. 3: Figure 3: Subsystems status indicators

1.4.2 4.2. Product ID, Engine and Firmware Version

At the bottom-left corner of the interface, the user can see the product ID and the engine version of the system as shown in Figure 4.

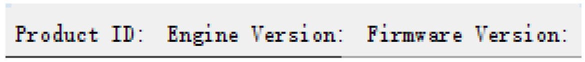


Fig. 4: Figure 4: Product ID and engine version

1.4.3 4.3. Navigation Information

Navigation information dialog (shown in Figure 5) displays the Kalman Filter navigation message from the system, including time, position, velocity and attitude information. This message comes in 1 Hz synchronized with the GNSS measurements. For more details about the message, please refer to AceinnaNav Reference Manual. The user can reopen the dialog in “View > Navigation Info” menu if it is closed.

1.4.4 4.4. Satellites Signal Status

GNSS signal status dialog (shown in Figure 6) displays the satellite signal strength information obtained from the GNSS observables. For each satellite it shows the satellite system, unique satellite number, and the L1/L2 signal strength. For more details about the message, please refer to AceinnaNav Reference Manual. The user can reopen the dialog in “System -> SV Signal” menu if it’s closed.

1.4.5 4.5. IMU data

IMU data dialog (show in Figure 7) displays the current acceleration and rotation rate in polyline graphs. If the IMU data doesn’t show up, the user can click the [Turn on IMU data] button to enable the output of the raw IMU data.

The direction of the axes of an IMU can be identified using the accelerometer signal. When an accelerometer is placed in upward direction on a level surface, its output should be approximately 9.8 m/s2. On the other hand, if it is place in downward direction, the output should be -9.8m/s2. Hence, for the plot in Figure 7, the positive z-axis is positing downward. The positive direction of all three axes of an IMU can be identified this way.

1.4.6 4.6. Trajectory

Trajectory view dialog (shown in Figure 8) displays the current trajectory. The software starts recording the trajectory when the dialog is open. When the dialog is closed, the trajectory will be cleared.

1.5 5. User Configuration

To get accurate navigation data, the user needs to configure several parameters in the navigation system. The control software provides a basic interface for necessary setup, and also an advanced interface for more detailed configuration.

1.5.1 5.1. Basic User Configuration

Basic user configuration dialog is used to set up the orientation of the navigation system relative to the vehicle and the position of the antennas. Once these are set up, the system can output correct position, velocity and attitude information of the vehicle.

Basic user configuration can be opened by choosing “System > Basic User Configuration”. The interface is shown in Figure 9.

The first step is to set up the orientation of the sensor relative to the vehicle. The user first chooses the direction of the IMU X-axis relative to the user body frame. And then choose the direction of the IMU Y and Z.

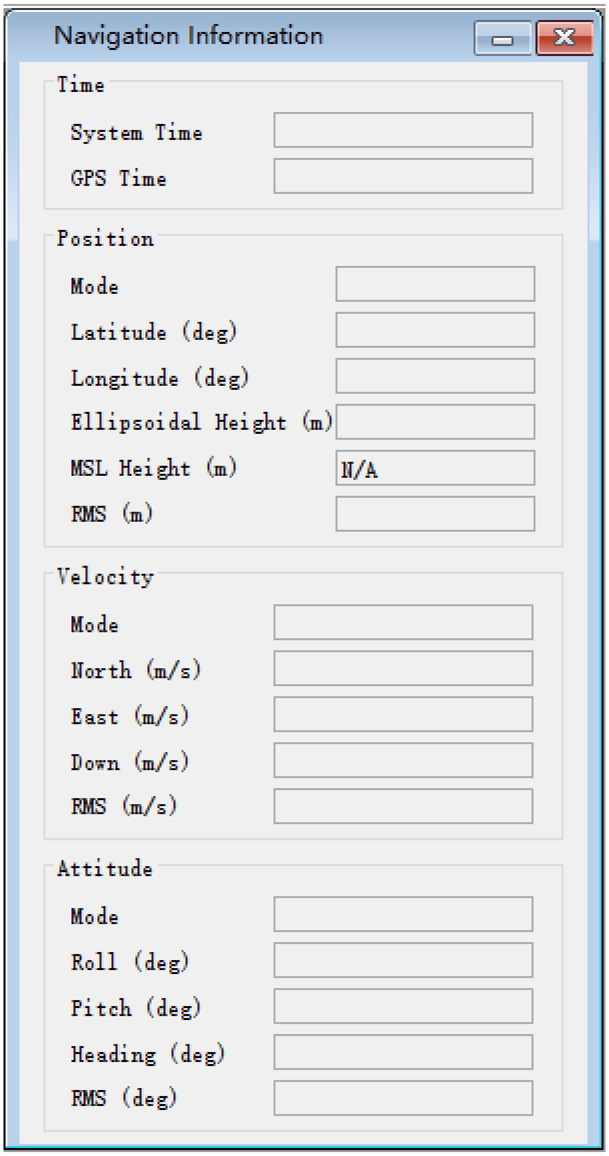


Fig. 5: Figure 5: Navigation information dialog

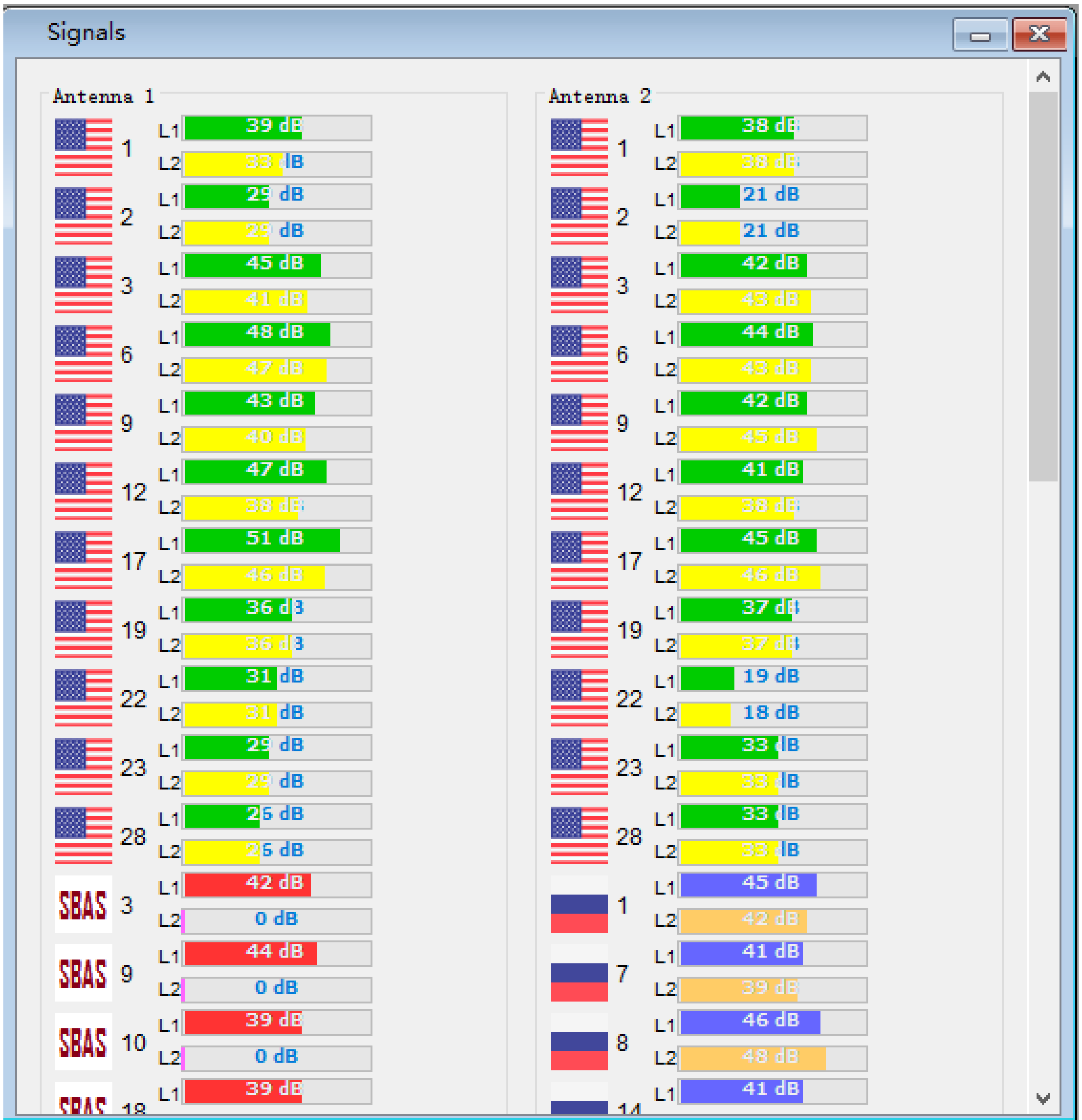


Fig. 6: Figure 6: GNSS signal status

Fig. 7: Figure 7: IMU data graphs

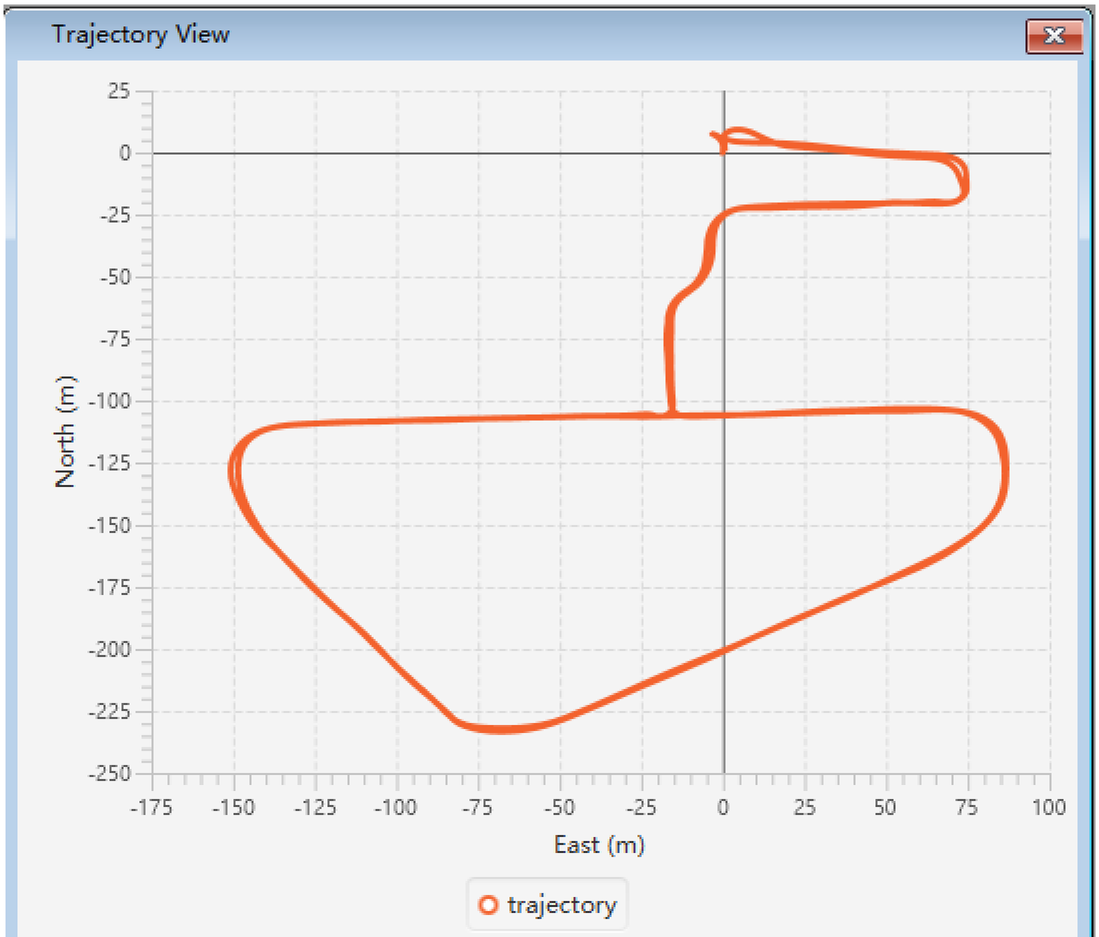


Fig. 8: Figure 8: Trajectory view dialog

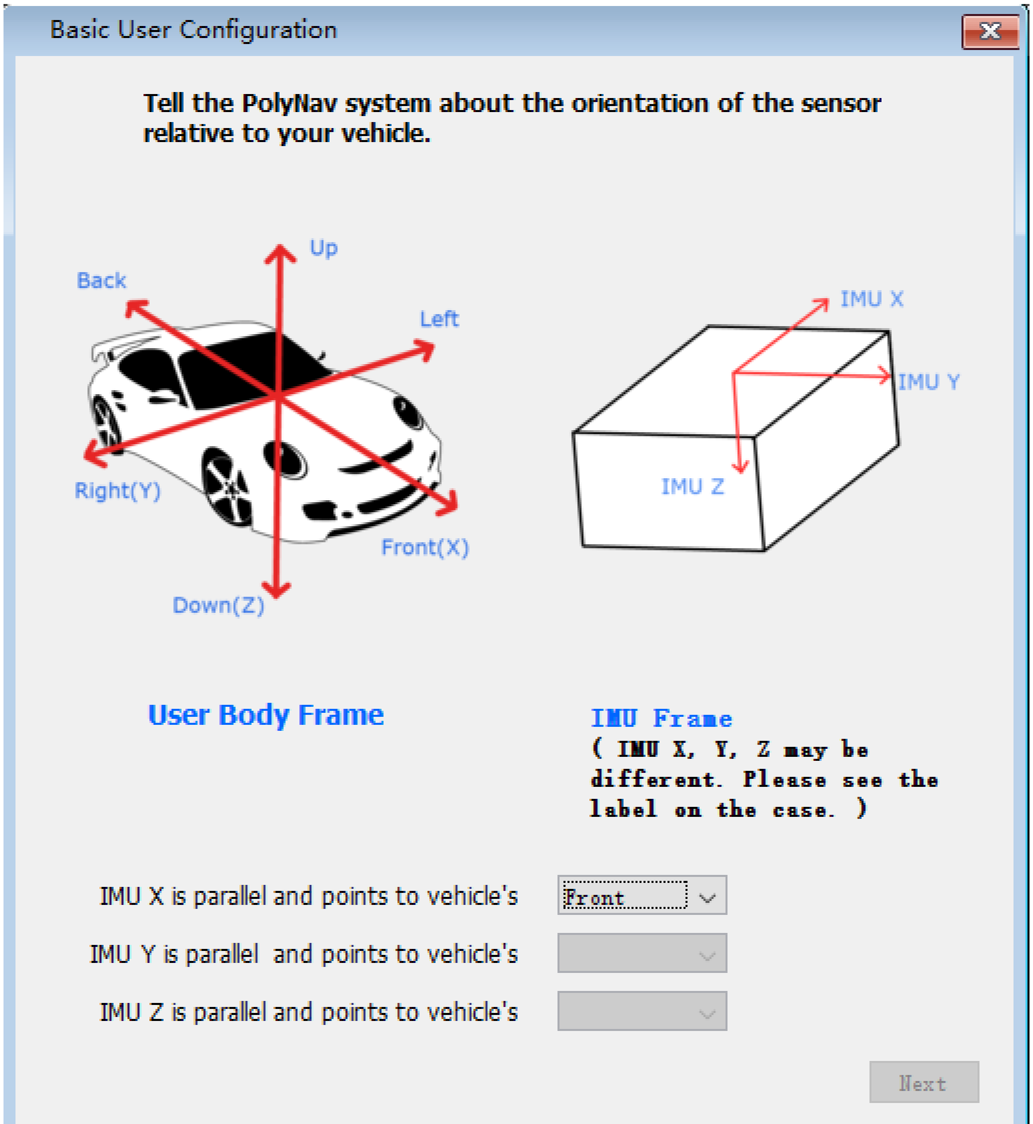


Fig. 9: Figure 9: Set up the orientation of the navigation system

For a vehicle, the user body frame is defined in Figure 10. And IMU frame is marked on the case.

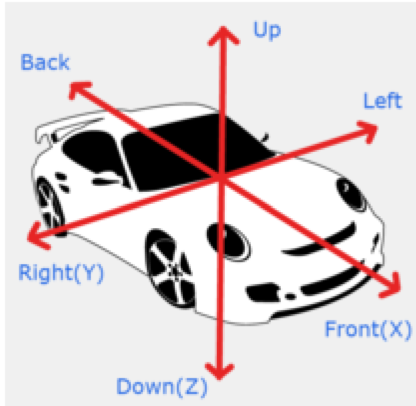


Fig. 10: Figure 10: User body frame definition

Next step is to setup the position of the antennas (shown in Figure 11). The user needs to measure the coordinates of the two antennas in the user body frame with the origin at the case top center. And then input the coordinates into the dialog. The user also needs to measure the distance between two antenna centers and input the measurement into the dialog.

The final step is to choose the max output rate and turn on/off output messages (shown in Figure 12). Max output rate is the output rate of the compact navigation message (message 13). The user can adjust the data rate of this message. The detailed definition and rate of all messages can be found in Aceinna Reference Manual.

1.5.2 5.2. Advanced User Configuration

Advanced user configuration dialog contains more detailed configurations of the system. To open the dialog, the user chooses "System > User Configure" from the menu (shown in Figure 13). The available configurations are shown below.

5.2.1. Output Control

The user can do the followings in the navigation output control tab shown in Figure 14:

- Specify the navigation output position. The user can choose from the center of the IMU or the cross-mark on top of the IMU housing.
- If the static position pinning is enabled, the system will output a fixed position during a static period detected by the GNSS. Note that there is a chance that the system can miss the detection if the signal quality becomes weak.
- Specify the smooth transition interval to RTK_FIXED.
- Choose ICD messages for output. Pay specific attention when choosing high-rate outputs as outputting multiple high-rate messages can saturate the communication port.
- Check the current output position offset and whether the static position pinning is enabled in the system with the [Query] button.

5.2.2. Navigation Control

The user can control the behavior of the navigation in the tab shown in Figure 15.

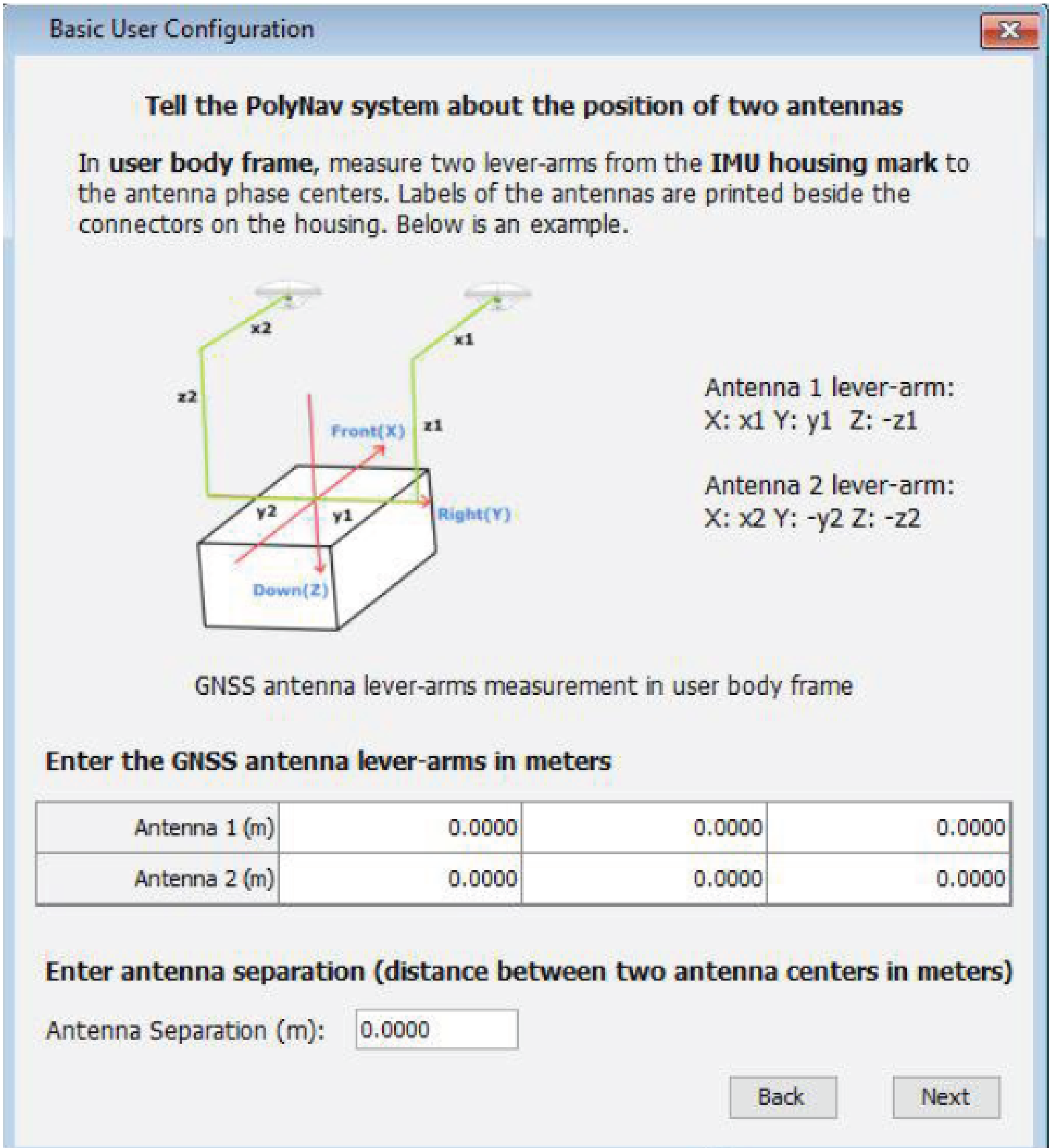


Fig. 11: Figure 11: Set up the position of the two antennas

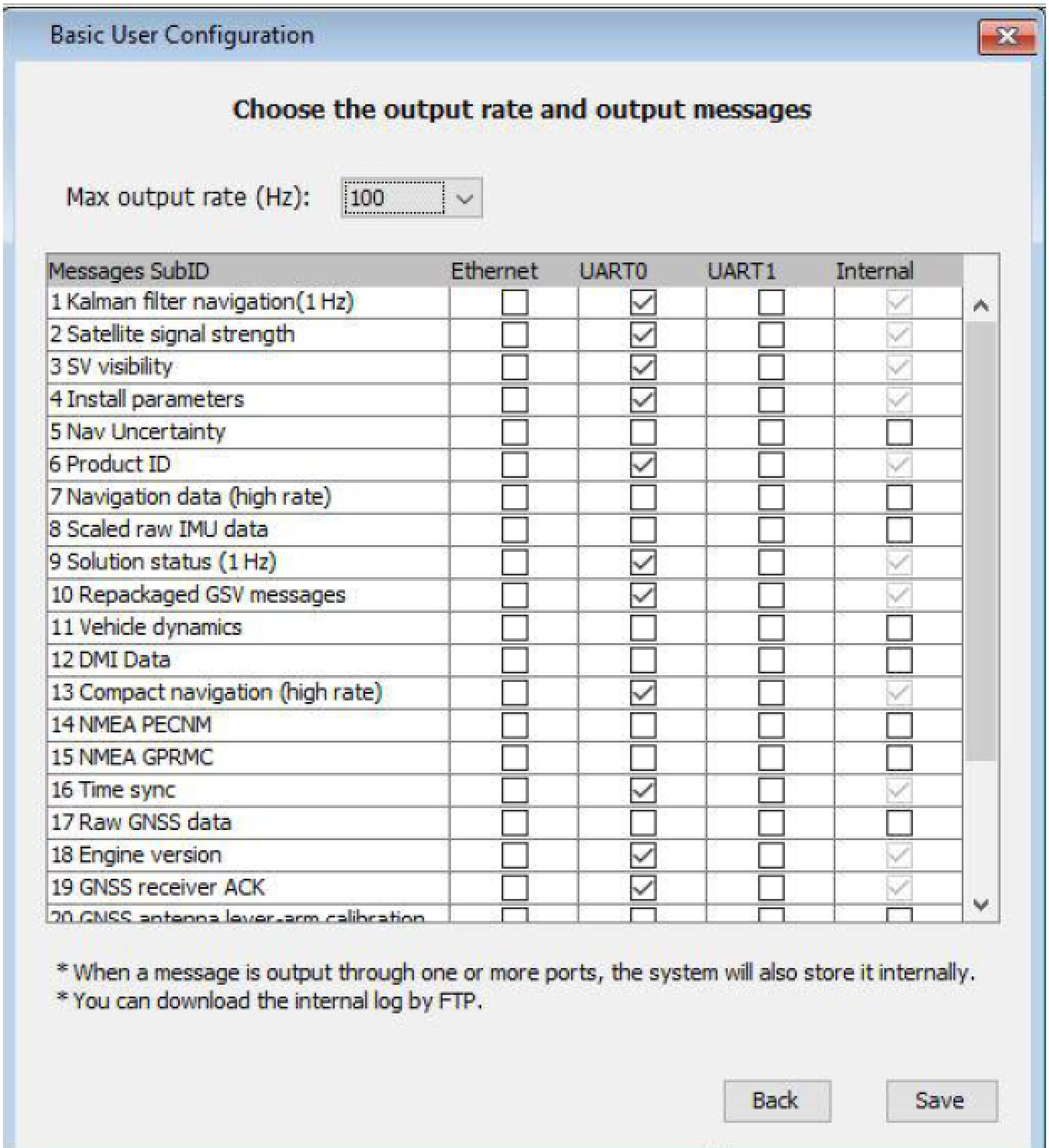


Fig. 12: Figure 12: Choose output rate and output messages

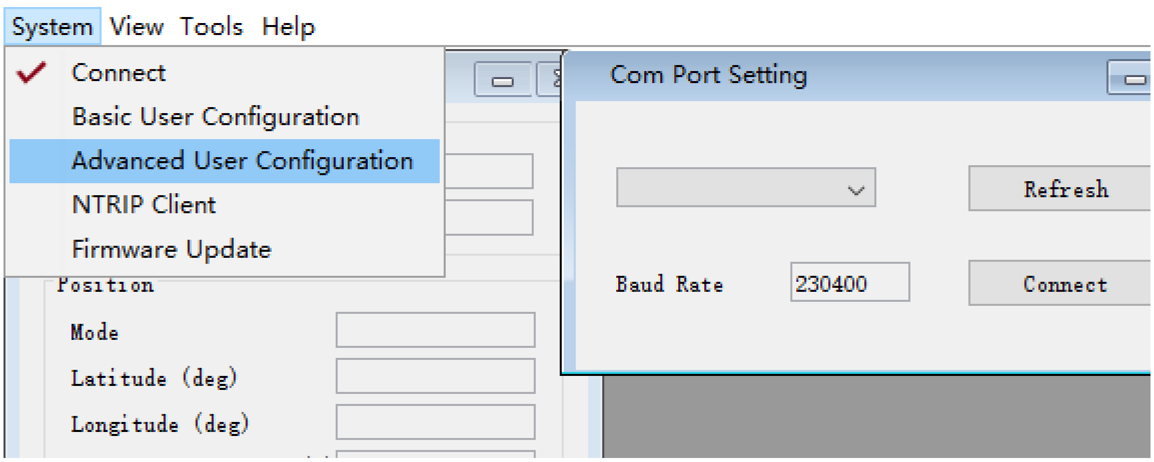


Fig. 13: Figure 13: User configuration menu

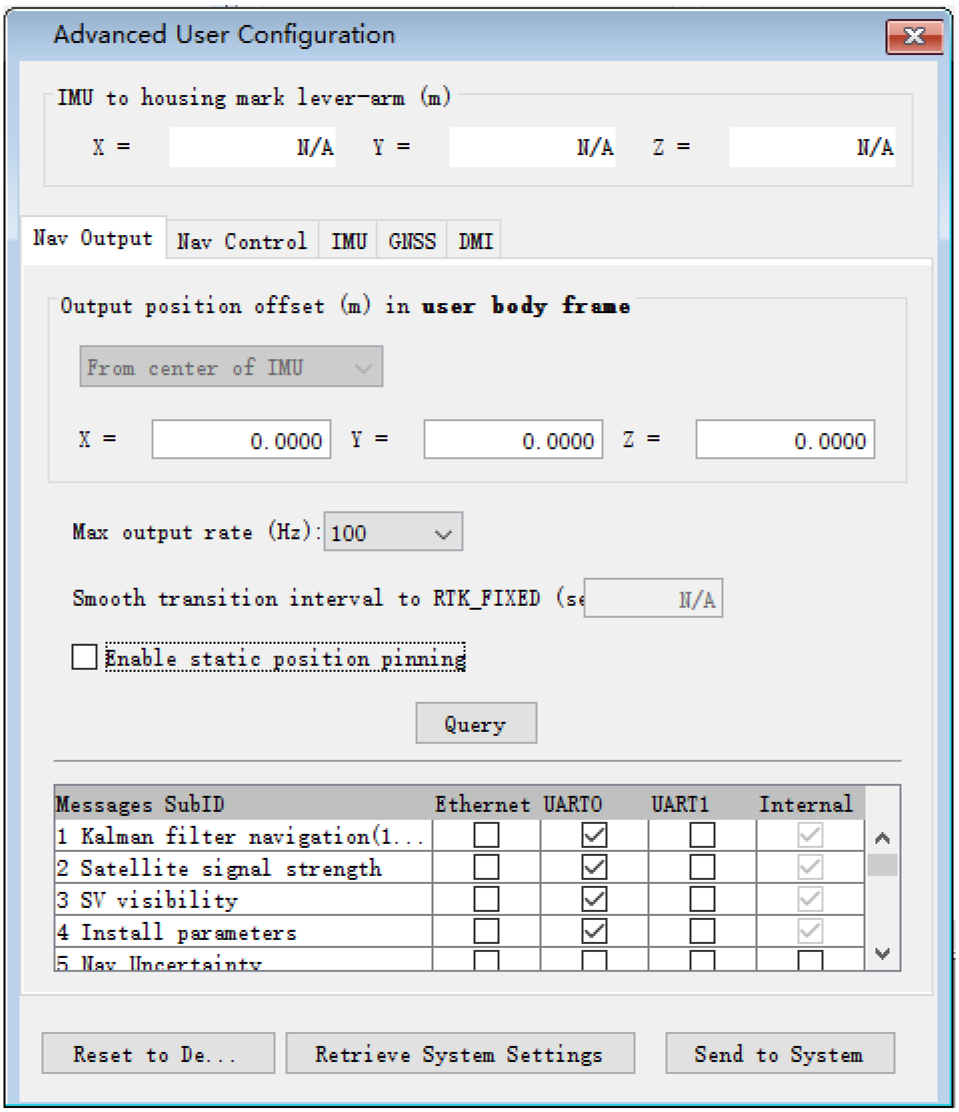


Fig. 14: Figure 14: Navigation output control tab

The user can enable initialization of heading from the GNSS velocity. To activate this option, the x-axis of the user body frame must be aligned with the forward direction of the vehicle. See "Install Parameters" tab to set the transformation from the IMU frame to the user body frame. Also, the minimum speed for the heading initialization can be specified.

The navigation error keeps growing if no aiding source is available. The system will stop outputting the navigation results if the dead-reckoning time exceeds the maximum that the user specifies.

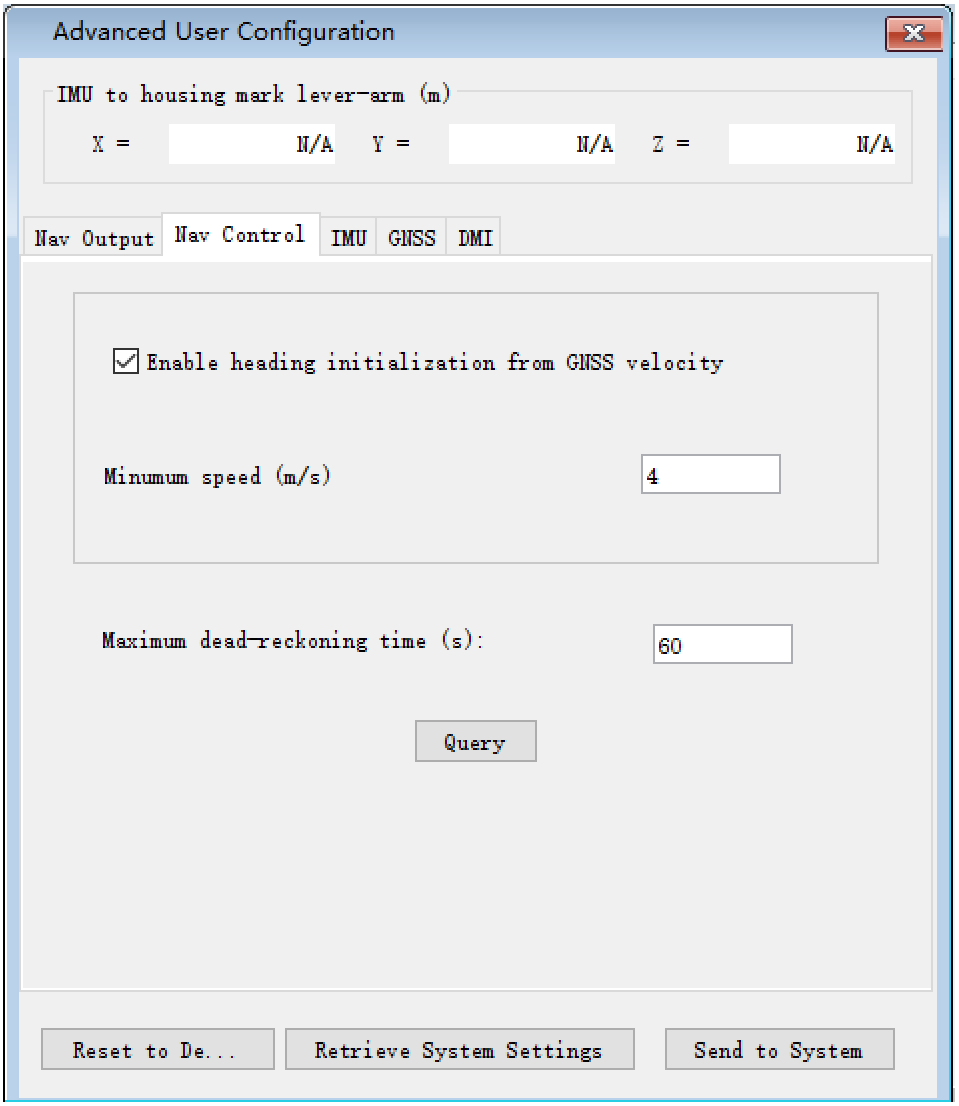


Fig. 15: Figure 15: Navigation control tab

5.2.3. IMU Setup

In the "IMU" tab (shown in Figure 16), the user can do the followings :

- Specify the matrix for the transformation from the IMU frame to the user body frame. Please refer to the detailed Transformation Matrix in reference manual.
- Check the current transformation matrix of the system with the [Query IMU matrix] button.

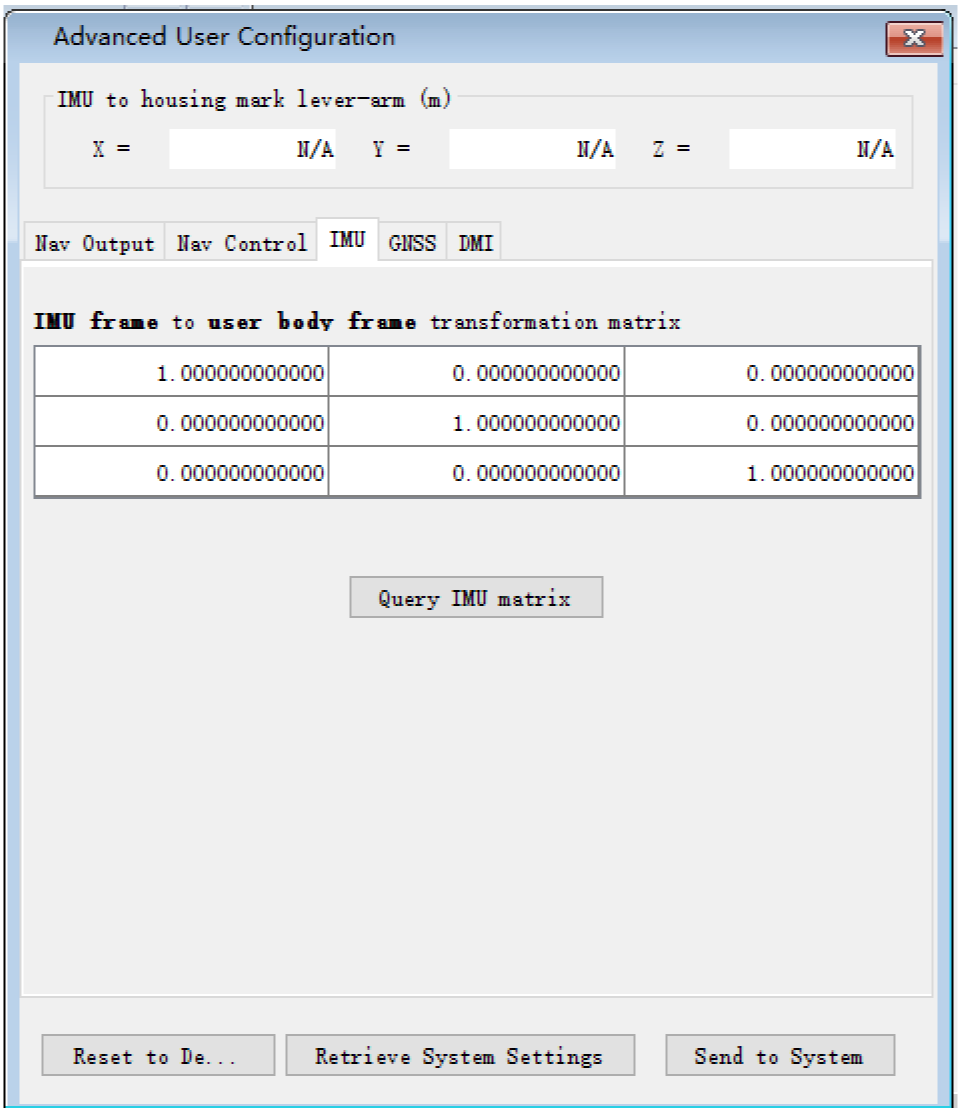


Fig. 16: Figure 16: IMU configuration tab

5.2.4. GNSS Setup

In the "GNSS" tab (shown in Figure 17), the user can do the followings :

- Set the lever-arms of the GNSS antennas. Note that the lever-arms to be entered shall be in meters from the cross-mark on top of the IMU housing to the antennas phase center in the user body frame.
- Set the separation between two GNSS antennas, which will aid the carrier-phase ambiguity resolution for the attitude determination.
- Check the current antenna lever-arms of the system with the [Query lever-arm] button.
- Check the antenna separation of the system with the [Query] button.

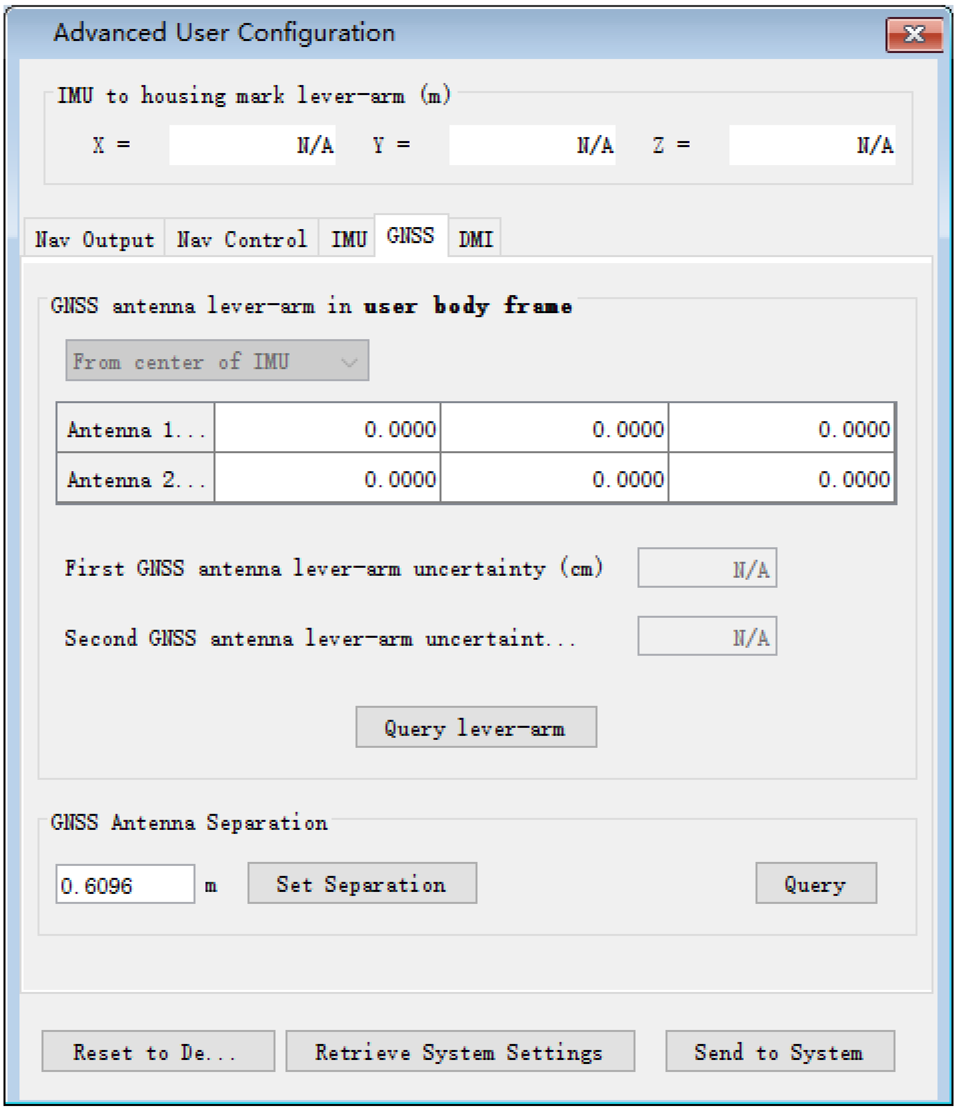


Fig. 17: Figure 17: GNSS configuration tab

1.6 6. NTRIP Client

The user can configure the NTRIP client settings using the NTRIP Client settings dialog (shown in Figure 18). To open the dialog, choose "System > NTRIP Client" from the menu shown in Figure 19. After all information is entered, press the [Set] button to configure the NTRIP client information. After seeing a message box with "Configuration finished", restart the system to use the new NTRIP client settings. The user can also [Query] the current NTRIP client settings of the system. To get the settings, click the [Query] button in the NTRIP Client dialog and the information will show up.

If user use "rtk2go.com" as server, the default password is "BETATEST".

Previous NTRIP settings will be stored in the table below. The user can reuse previous settings by double-clicking that particular setting.

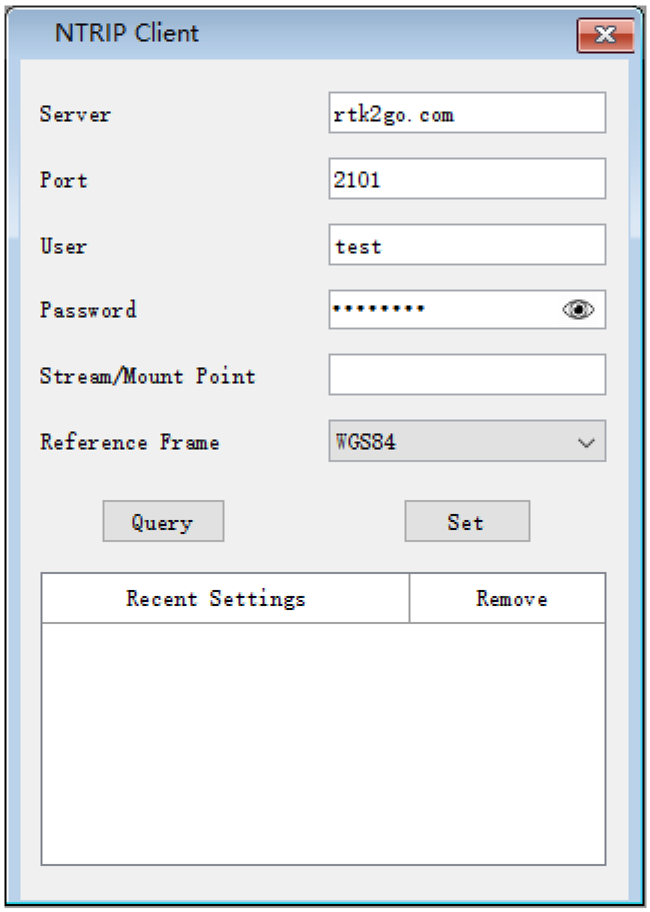


Fig. 18: Figure 18: NTRIP client settings dialog

1.7 7. Firmware Update

1.8 8. Tools

The control software provides tools to log and decode output data from the system.

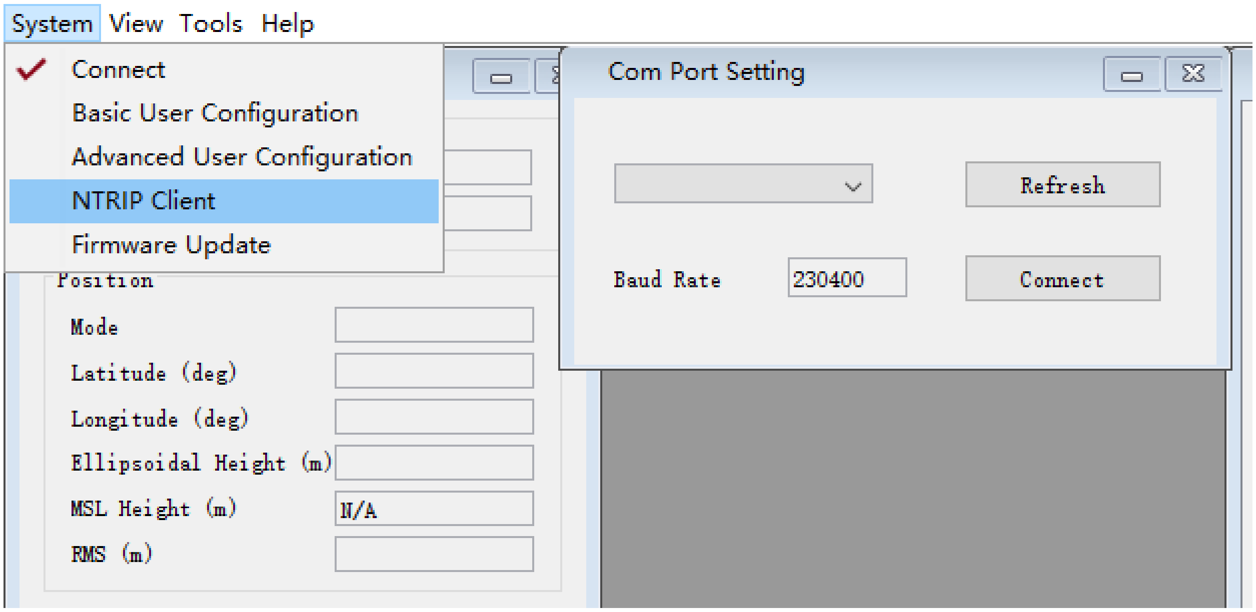


Fig. 19: Figure 19: NTRIP Client menu

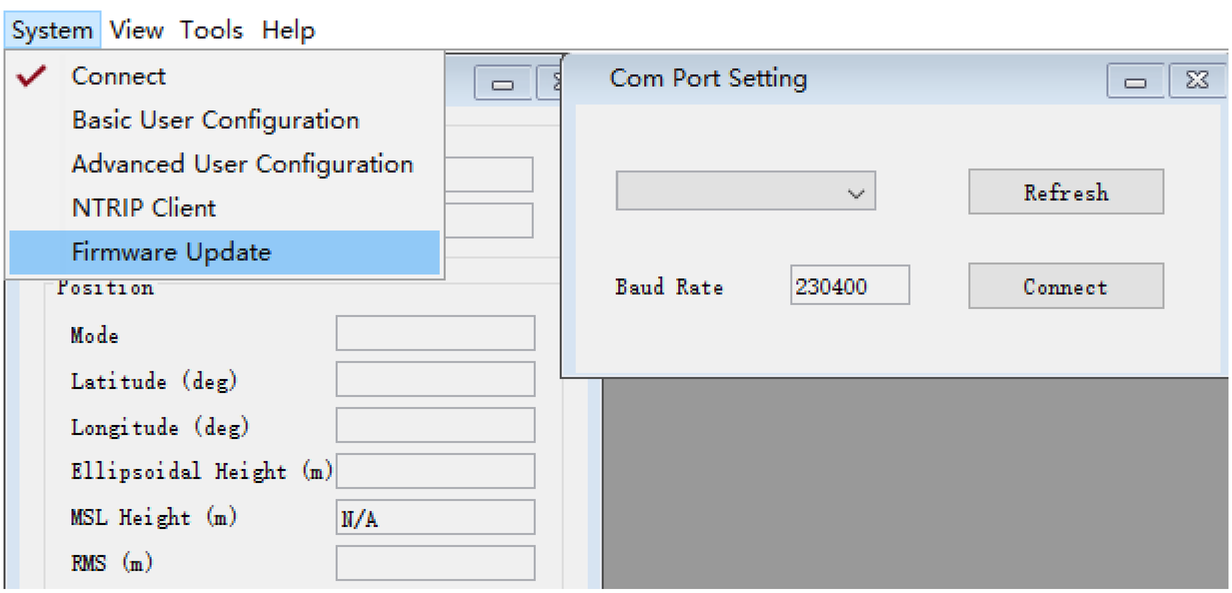


Fig. 20: Figure 20: Firmware update menu

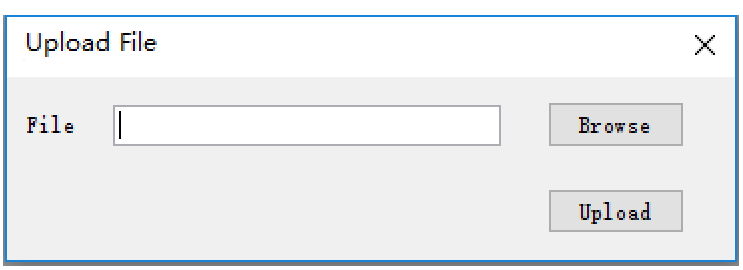


Fig. 21: Figure 21: Firmware file selection

1.8.1 8.1. Log Data

The user can log binary data from the system using the Export dialog by choosing the "Tools > Export" menu.

Before logging, make sure that the software has opened the right port and the status of the subsystems IMU, GNSS, and PPS are on at the bottom-right hand corner.

To choose a folder to save the data, click the [Browse] button. To log the data, click [Start Export] button in Figure 22. To finish logging, click the [Stop Export] button then a message about the saved data file name will show up. The file name convention is yyyy_mm_dd_HH_MM_SS.dat, e.g. 2018_02_09_02_36_34.dat.

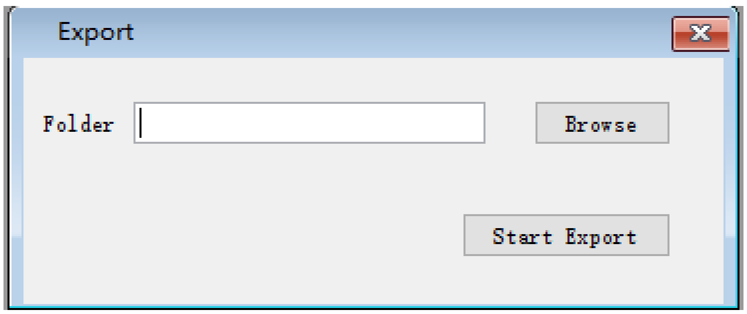


Fig. 22: Figure 22: Data export dialog

1.8.2 8.2. Decode Data

The user can decode the logged data using the decoder provided by the control software. The decoder (shown in Figure 23) is available by choosing "Tools > Decode" menu. To decode a file, use the [Browse] button to find the file for decoding and then press the [Decode] button. Usually, the decode takes a few seconds to finish. For a large file, it may take up to a minute. Please wait until it is finished.

The decoded results will be stored in the same folder as the data files and consist of three files: *kf.txt, *nav.txt and *.kml. The *kf.txt file stores Kalman Filter message. The *nav.txt file stores the high-rate compact navigation messages. Lastly,*.kml file stores the trajectory that can be viewed in Google Earth software.

The user can choose to convert the attitude quaternion to roll, pitch, and heading using the "Attitude in roll, pitch, heading" check box. For more details about the conversion, please refer to the AceinnaNav Refence Manual.

The user can also set the output decimation rate to adjust the density of the points in the KML trajectory file. For example, entering "30" makes the decoder output to the KML file at every 30 points.

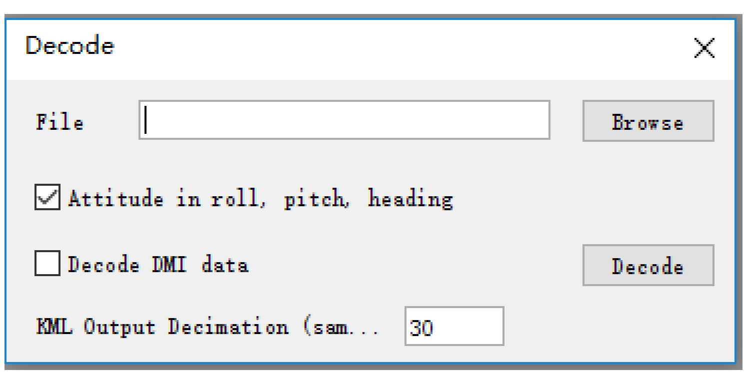


Fig. 23: Figure 23: Data decode dialog

1.8.3 8.3. Zero Velocity Update

The user can send Zero Velocity Update (ZUPT) messages when the vehicle is not moving. Specifically, this will improve the navigation system where the GNSS signal is degraded. The user can set and send this message using the Zero Velocity Update dialog at the “Tools > Zero Velocity Update” menu (shown in Figure 24). After setting the horizontal and vertical standard deviation, click [Activate] button to keep sending the message containing these two values. Click [Deactivate] button to stop sending. If both values are set to zero, the message cannot be sent.

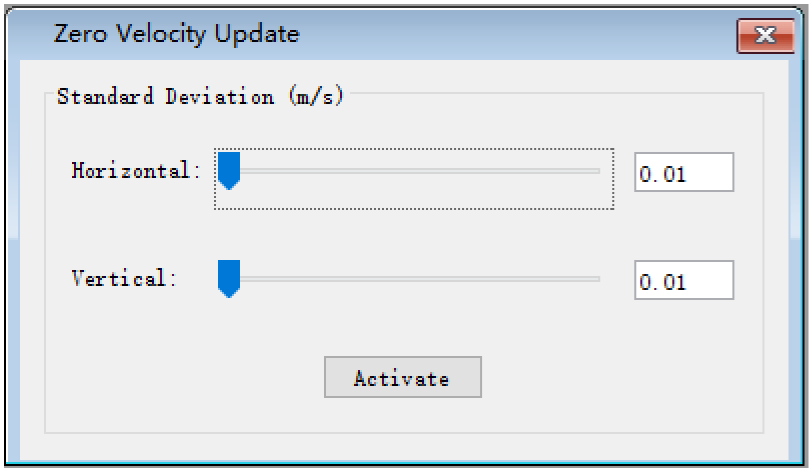


Fig. 24: Figure 24: Zero Velocity Update dialog

1.8.4 8.4. Static Heading Event

The user can send a static heading event message to initialize the inertial navigator when the position is available from the GNSS receivers but the heading initialization has difficulties due to degraded GNSS signals. To send the message, the user can use the Static Heading Event dialog at the “Tools > Static Heading Event” menu (shown in Figure 25). After setting the heading, ZUPT RMS, and heading RMS, click [Activate] button to keep sending the message containing these values. Click [Deactivate] button to stop sending. If both of the ZUPT RMS, and heading RMS are set to zero, the message cannot be sent.

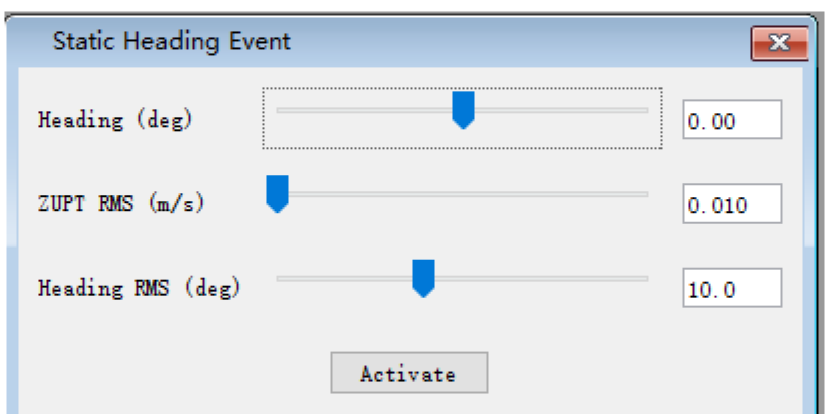


Fig. 25: Figure 25: Static Heading Event dialog

1.8.5 8.5. Static Geo-Pose Event

The user can send a static geo-pose event message to initialize or aid the inertial navigation system when GNSS signals are not available. The static geo-pose event can be opened by choosing "Tools > Static Geo-Pose Event" menu (shown in Figure 26).

The user needs to input the known position and attitude information. And then click [Activate] button to keep sending these values to aid the navigation system. Click [Deactivate] button to stop sending.

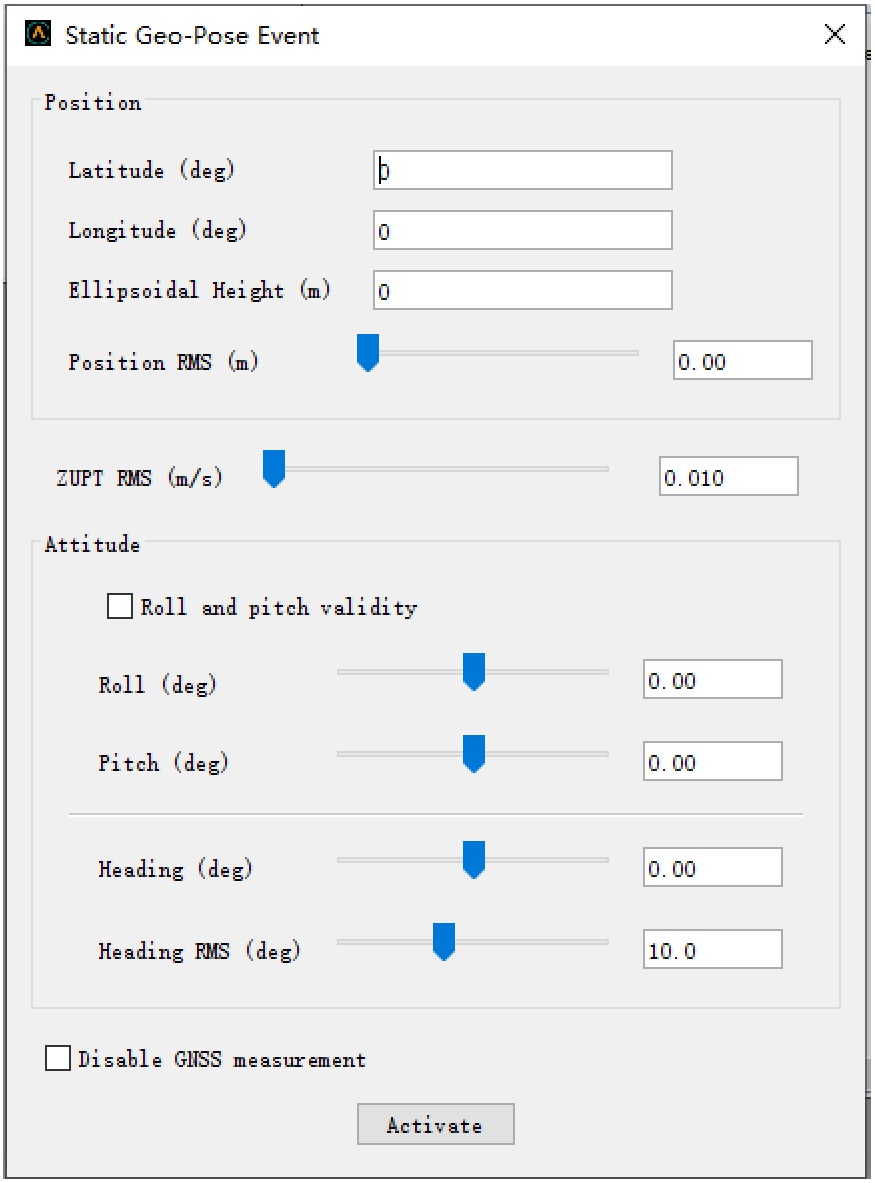


Fig. 26: Figure 26 Static Geo-Pose Event Dialog

1.8.6 8.6. Heading Initialization using an External Sensor

The heading can be initialized using the NMEA message "$HEHDT" which could be generated by other sensors in the user's vehicle. To use this initialization method, the output port of the user's sensor needs to be connected to one of the input ports of the Aceinna-Nav system; either UART0 or Ethernet. To enforce this initialization method, please make sure to turn off the option initializing the heading from the GNSS velocity; see Figure 15.

1.9 9. Internal Data Download

The system internally stores the raw sensor data and navigation data, of which the naming convention is as follows:

- Raw sensor data: raw_wwww_ssssss.dat
- Navigation data: nav_wwww_ssssss.dat

Where "wwww" and "ssssss" corresponding to the GPS week number and seconds of the week at the start of the mission.

User can download the internal data using any FTP client, following the next steps:

- **Set the computer Ethernet IP address as 192.168.100.xxx where xxx could be any number from 2 to 254, except 97, becaus**

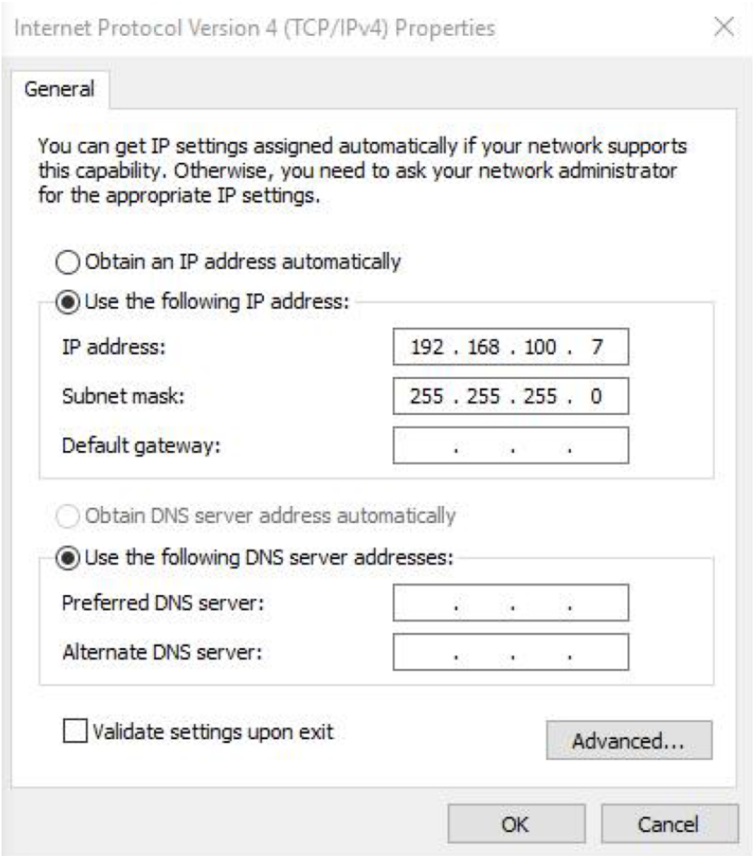


Fig. 27: Figure 27: IP address setting

- Power on the rover station system, then use a FTP client in PC side to connect the system following the configurations, Host name: 192.168.100.97,Port number: 2100,User name: ftp,Password: ftppw. After connection setup successfully, user could see the raw data and navigation data in the FTP client.

1.10 10. web application

The web application is composed of two parts, one part is python driver that log the data from serial port and upload to web application user interface, another part is the web application user interface. For the python driver,user could download it from github. https://github.com/Aceinna/python-ins1000

Flag	Description
KFN	Kalman Filter Navigation Message
CNM	Compact Navigation Message (High Rate)
SSS	Satellite Signal Strength
GSVM	Repackaged GSV Message

The table above is data format of python drive, and could be found in json file(rover.json) located in the path python-ins1000-master->setting.

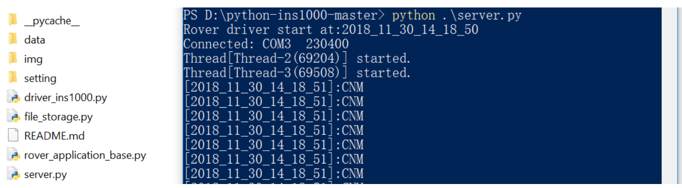


Fig. 28: Figure 28: python serial tool usage

User could run the python script and then upload data to web application user interface, for the web application ui, https://developers.aceinna.com/maps

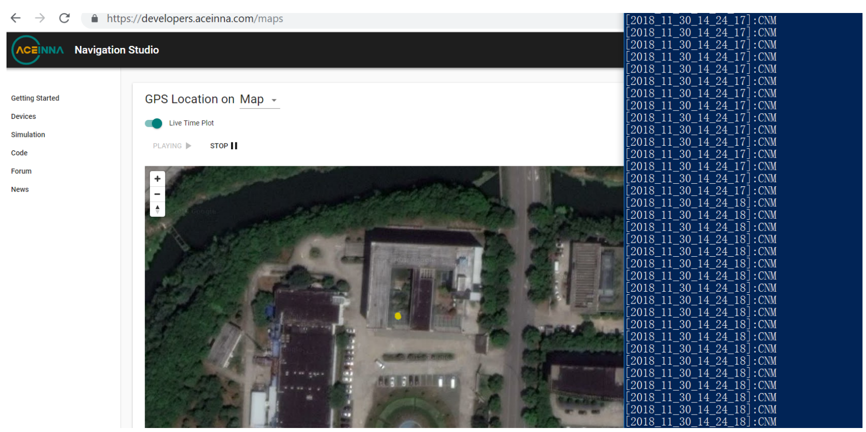


Fig. 29: Figure 29: web application usage

Press the button(Live Time Plot) on the web application ui, the image of live path of the rover station is shown on the screen. Meanwhile, the data will be logged synchronously in folder: python-ins1000-master->data.

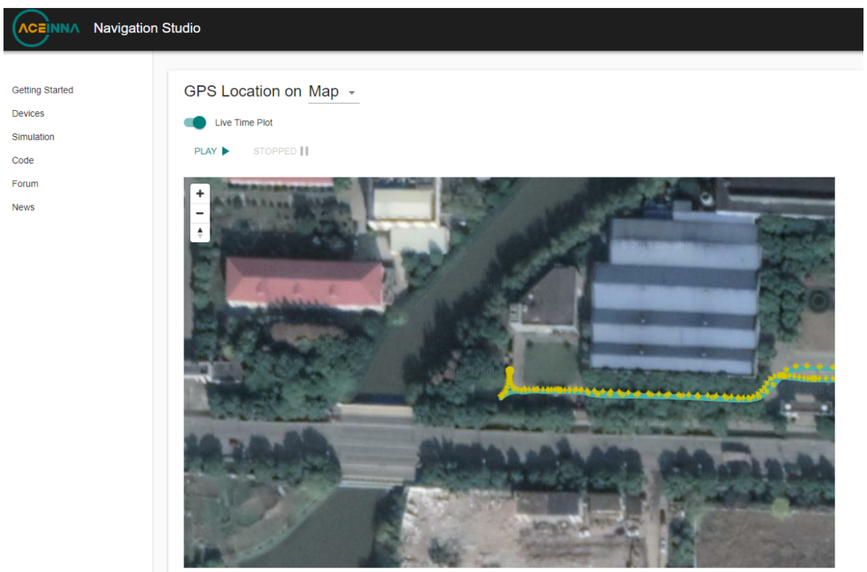


Fig. 30: Figure 30: real time path demo

CHAPTER 2

Basestation Guide

2.1 1. Introduction

The INS1000 GNSS Base Station is a ruggedized dual-frequency (L1/L2) multi-constellation GNSS (GPS, QZSS, GLONASS, Beidou, Galileo) reference station which can be easily configured as a local base station to broadcast real-time RTCM corrections for any RTK-capable rover systems. User-friendly GUI is available to setup a base station quickly by either connecting to the rover through local radio link or NTRIP caster/client (network RTK). The system can also record all tracked dual frequency multi-constellation measurements for post- processing.

2.2 2. Setting Up the Base Station

To properly operate the Base Station the following ports must be connected in the correct locations. See the picture above.

- Antenna to antenna port
- COM-PORT1 Cable to PC
- Power/Ethernet Cable to Power.

The antenna should be mounted to an outdoor location such as roof with clear sky view.

Note: The Power/Ethernet cable connector has a red mark on it. Match the red dot to the red mark on the mating connector shell. To remove the cable just pull back lightly on the connector shell.

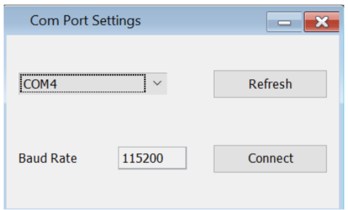
2.3 3. Configuration

This section give you insight on configuring the INS1000 Base Station Software. The first steps provide calibration information, real-time calculations, and different viewing options. It will go over all the settings, viewing options, and tools in the software. It also includes exporting information for further data analysis. For the Set Up to run smoothly, please read carefully and follow along the User Guide.

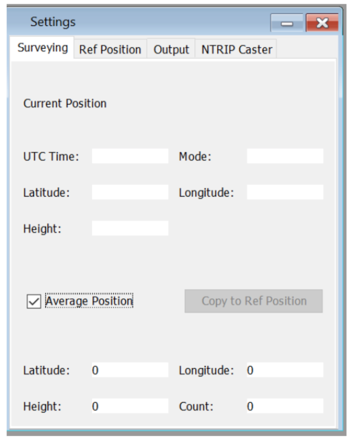
2.3.1 3.1 Configure

Locate the GNSS basestation software. Application pGnssBase, https://www.aceinna.com/userfiles/files/Software/Inertial-System/ACS.zip

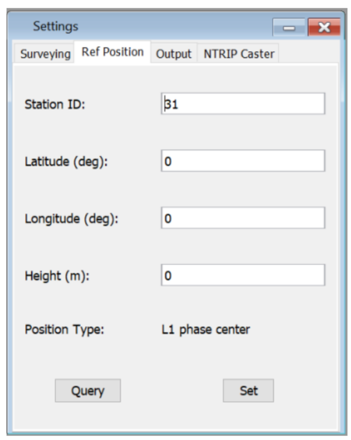
- Run "pGnssBase.jar" software.
- Open "Com Port Settings" Window.
  - Click [Refresh] button
  - Select the corresponding COMPORT from the drop-down tab.
  - Click [Connect] button.



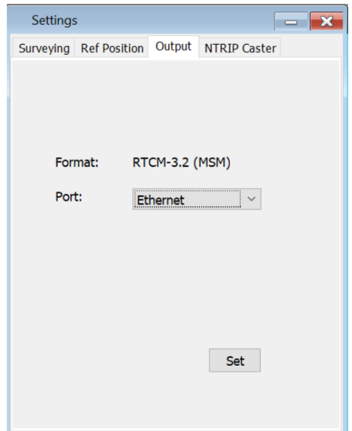
- Click [Surveying] Tab
- Check/Click [Average Position]
- Wait until the count reaches the desired Avg. time (recommend at least 300 counts ~= 5min)
- Unclick/Uncheck [Average Position]
- Click [Copy to ref Position] Button



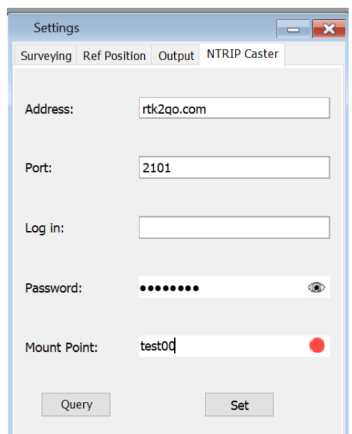
- On Settings window, switch to [Ref Position] tab, previous surveying position will show up here.
- Click [Set] button to send the position to base station receiver.
- Click [Query] button to double check or check the current position stored inside the base station receiver.



- On Settings window, switch to [Output] tab,
- Click [Set] once to setup broadcast correct message format for RTK rover.
  - This step only need to be done once when the base station is first setup or the format has to be changed



- On Settings window, switch to "NTRIP Caster" tab.
- After filling in the server host information, Click [Set] button.
- You can also Click [Query] button to check the currentserver host information stored inside the base station receiver through the Ethernet/Modem



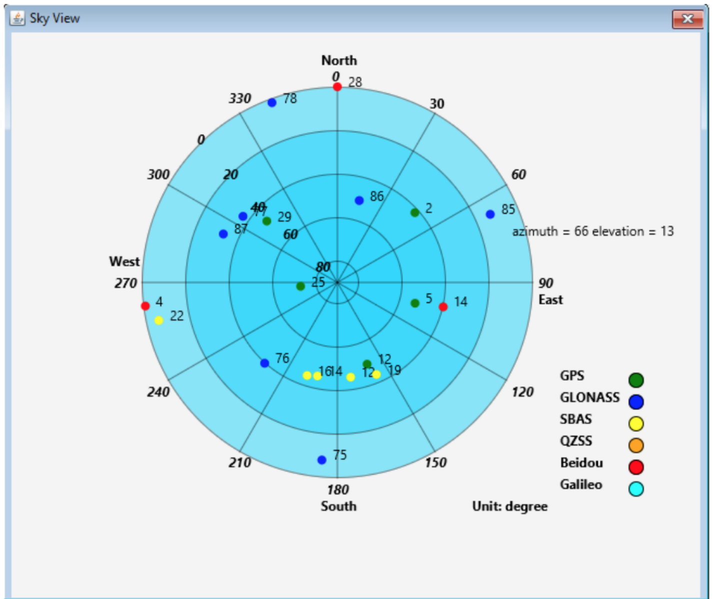
Note: When the base station has successfully connected to the server and started to stream the correction message, the red spot next to the "Mount Point" will turn into green color.

2.3.2 3.2 Sky View

Sky View shows the distribution of satellites in real time based on the elevation and azimuth.

To view Satellite details:

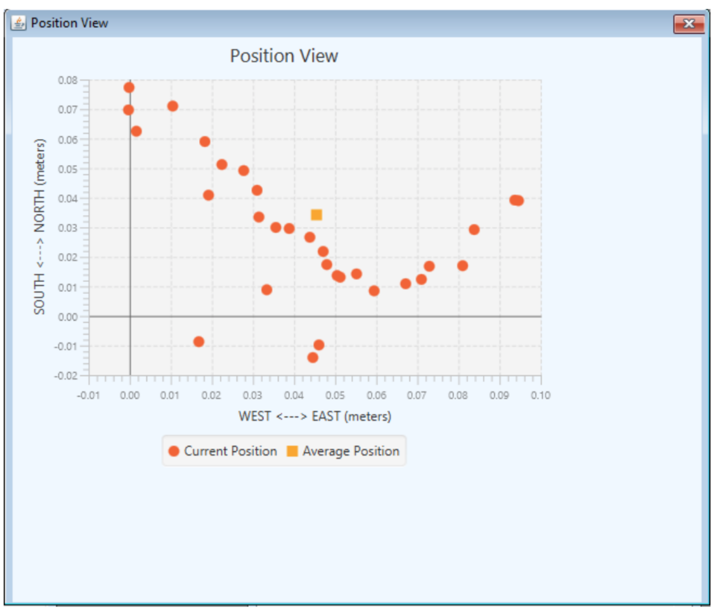
1. Double Click one satellite and it shows the elevation and azimuth information.
2. Click that satellite and it the elevation and azimuth information will disappear.



2.3.3 3.3 Position View

Shows the current position after opening the Position View.

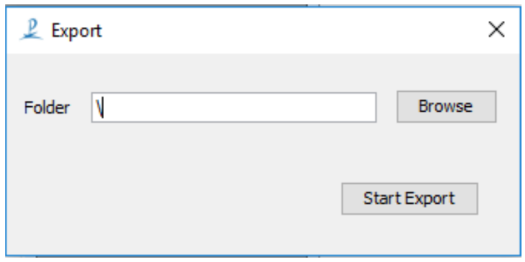
1. After clicking the [Average Position] checkbox in [Settings] -> [Surveying] Position View also shows the average position in real time.
2. Average Position is represented with a yellow square within the graph.



2.3.4 3.4 Export data

Export data allows you to save a log file of the Base Station.

1. Choose a directory to save the log file of Base Station and then click [Start Export].
2. Then Click [Stop Export] to finish the completed Export.



CHAPTER 3

Reference Manual

3.1 1. Introduction

INS1000 is an integrated navigation system consisting of an inertial measurement unit (IMU) and other sensors. Thus it can output continuously the position, velocity and attitude information of the vehicle. A dual-antenna GNSS receiver is used as the primary aiding sensor. Also supported is a distance measurement indicator (DMI) which can be attached to a wheel of the vehicle/robot to measure the rotation rate of the wheel. Integration of a DMI would give an improved solution in challenging environments: urban canyons, tunnels or indoor. This document explains how to use the system.

3.2 2. The IMU Frame and the Body Frame

The IMU frame is the frame in which the IMU's measurement output is generated. The direction of the axes of an IMU can be identified using the accelerometer signal. When an accelerometer is placed in upward direction on a level surface, its output should be approximately 9.8 m/s^2.On the other hand, if it is place in downward direction, the output should be -9.8 m/s^2. The positive direction of all three axes of an IMU can be identified this way.

The body frame is the frame in which the inertial navigation solution is generated. The center of the IMU frame coincides with that of the body frame. However, there can be differences in the attitude between the two frames due to physical limitations in the installation of the IMU. For a vehicle, the forward-right-down is typically the body frame of choice. Thus, there will be a rotation matrix C^b_{IMU} to transform the IMU measurements to the body frame and, for the example below, it is written as

$$C^b_{IMU} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

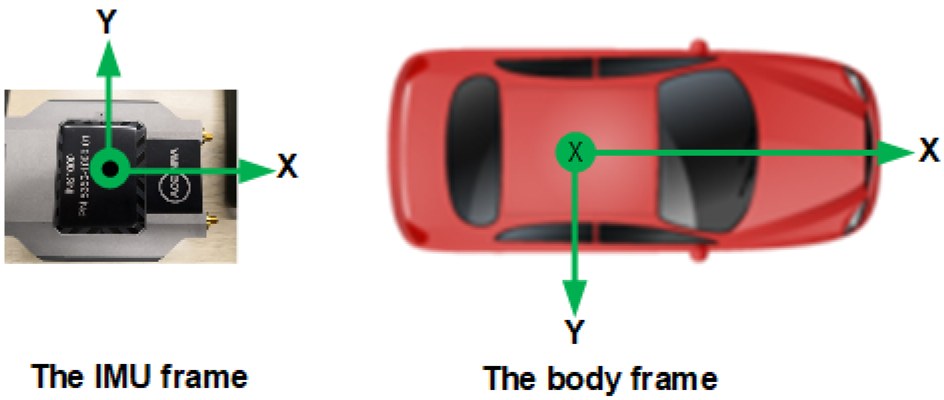


Fig. 1: Figure 1: The IMU frame and the body frame

IMU X	IMU Y	IMU Z	Transformation Matrix
Forward	Right	Down	[1,0,0; 0,1,0; 0,0,1]
Forward	Left	Up	[1,0,0; 0,-1,0; 0,0,-1]
Forward	Down	Left	[1,0,0; 0,0,-1; 0,1,0]
Forward	Up	Right	[1,0,0; 0,0,1; 0,-1,0]
Backward	Left	Down	[-1,0,0; 0,-1,0; 0,0,1]
Backward	Right	Up	[-1,0,0; 0,1,0; 0,0,-1]
Backward	Up	Left	[-1,0,0; 0,0,-1; 0,-1,0]
Backward	Down	Right	[-1,0,0; 0,0,1; 0,1,0]
Right	Backward	Down	[0,-1,0; 1,0,0; 0,0,1]
Right	Forward	Up	[0,1,0; 1,0,0; 0,0,-1]
Right	Up	Backward	[0,0,-1; 1,0,0; 0,-1,0]
Right	Down	Forward	[0,0,1; 1,0,0; 0,1,0]
Left	Forward	Down	[0,1,0; -1,0,0; 0,0,1]
Left	Backward	Up	[0,-1,0; -1,0,0; 0,0,-1]
Left	Up	Forward	[0,0,1; -1,0,0; 0,-1,0]
Left	Down	Backward	[0,0,-1; -1,0,0; 0,1,0]
Up	Forward	Left	[0,1,0; 0,0,-1; -1,0,0]
Up	Backward	Right	[0,-1,0; 0,0,1; -1,0,0]
Up	Right	Forward	[0,0,1; 0,1,0; -1,0,0]
Up	Left	Backward	[0,0,-1; 0,-1,0; -1,0,0]
Down	Forward	Right	[0,1,0; 0,0,1; 1,0,0]
Down	Backward	Left	[0,-1,0; 0,0,-1; 1,0,0]
Down	Left	Forward	[0,0,1; 0,-1,0; 1,0,0]
Down	Right	Backward	[0,0,-1; 0,1,0; 1,0,0]

Table 1: List of IMU to body frame transformation matrices

3.3 3. Measuring Lever Arm

The lever-arm is the relative position of other sensors from the center of the IMU. To make the measurement process easier, we make a cross-mark on top of the IMU housing and publishes the vector from the center of the IMU to the mark, l_I^{IMU}, which is called the internal lever-arm. Thus users can measure the relative position from the cross-mark to other sensors which is referred to as the external lever-arm in the body frame, l_E^b. Therefore, the total lever-arm vector is computed as follows:

$$C^b_{IMU} l^{IMU}_I + l^b_E$$

The following methods can be used to precisely measure the lever-arms:

- Computer Aided Design (CAD) Software
- Close-range Photogrammetry
- Precision Surveying using total stations or theodolites together with GNSS

3.4 4. NTRIP Client

A base station can send out RTCM messages to support the RTK, which enables cm-level positioning accuracy. Networked Transport of RTCM via Internet Protocol (NTRIP) is a protocol to stream the RTCM data over the internet. The user can configure the NTRIP client settings using the control software.

3.5 5. User ICD Messages

As shown in Figure 2, all ICD messages are composed of header, payload and checksum parts. The header's size is 6 bytes containing 2 sync bytes, message ID, message sub-ID and payload length.

Header (6 bytes)	Payload	CheckSum (2 bytes)

Figure 2: Message structure

The checksum shall be computed over the payload part using the Fletcher-16 algorithm as below sample code. Note that all multi-byte entries are written in little-endian format.

```
checksum_A = checksum_B = 0;
for (i = 0; i < payload_length; ++i)
{
    checksum_A += payload[i];
    checksum_B += checksum_A;
}
```

3.5.1 5.1. Kalman Filter Navigation Message (1 Hz)

This message is an output of the navigation message at the center of the IMU in 1 Hz synchronized with the GNSS measurements. If the inertial navigator is not running, however, this message contains GNSS-only solutions of the primary GNSS antenna.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x01
5	uint16_t	Payload length	91
6	double	System time	seconds
7	double	GPS time; see Note 1	seconds
8	double	Latitude	radians
9	double	Longitude	radians
10	double	Ellipsoidal height	m
11	double	Velocity in north	m/s
12	double	Velocity in east	m/s
13	double	Velocity in down	m/s
14	double	Roll, rotation about the x-axis	radians
15	double	Pitch, rotation about the y-axis	radians
16	double	Heading, rotation about the z-axis	radians
17	uint8_t	Position mode	See Note 2
18	uint8_t	Velocity mode	See Note 2
19	uint8_t	Attitude status	0: Invalid, 1: Coarse, 2: Fine
20	uint8_t	Checksum A	
21	uint8_t	Checksum B	

Note:

1. GPS seconds since starting week; thus this will not rollover after 604800.
2. **Position and velocity mode are defined as follows:**
    - 0: Invalid,
    - 1: Dead-reckoning (navigating with inertial measurements only),
    - 2: Stand-alone (autonomous or single point positioning),
    - 3: Precise point positioning (using precise ephemeris data)
    - 4: Code differential (using code-corrections from base stations or SBAS)
    - 5: RTK float
    - 6: RTK fixed
    - 7: User aiding (aiding by the user input)

3.5.2 5.2. Satellite Signal Strength

This message delivers the satellite signal strength information obtained from the GNSS observable.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x02
5	uint16_t	Payload length	19 + N_SV * 10
6	double	System time	seconds
7	double	GPS time	
8	uint8_t	Receiver ID	
9	uint8_t	Antenna ID	
10	uint8_t	Number of satellites (N_SV)	
11	uint8_t	SV system; see Note 1	First satellite data
12	uint8_t	SVID; see Note 2	
13	float	L1 C/N0 (dB-Hz)	
14	float	L2 C/N0 (dB-Hz)	
15	uint8_t	SV system	Second satellite data
16	uint8_t	SVID	
17	float	L1 C/N0 (dB-Hz)	
18	float	L2 C/N0 (dB-Hz)	
…			
	uint8_t	Checksum A	
	uint8_t	Checksum B	

Note:

1. 0: GPS, 1: GLONASS, 2: Galileo, 3: QZSS, 4: Beidou, 5: SBAS
2. SVID is the unique satellite number used in each satellite system; for GPS it is the PRN number and for GLONASS it is the SLOT number.

3.5.3 5.3. SV Visibility

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x03
5	uint16_t	Payload length	18 + N_SV * 10
6	double	System time	seconds
7	double	GPS time	seconds
8	uint8_t	Receiver number	
9	uint8_t	N_SV	Number of SV data
10	uint8_t	SV system	First satellite data
11	uint8_t	SVID	
12	float	Azimuth (deg)	
13	float	Elevation (deg)	
14	uint8_t	SV system	Second satellite data
15	uint8_t	SVID	
16	float	Azimuth (deg)	
17	float	Elevation (deg)	
…			
	uint8_t	Checksum A	
	uint8_t	Checksum B	

3.5.4 5.4. Install Parameters

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x04
5	uint16_t	Payload length	72+N_ANT*32
6	double[3][3]	IMU axes transformation matrix	
7	uint8_t	N_ANT	Number of antennas
8	double[3]	Lever-arm vector of 1st antenna	m
9	double	Lever-arm variance of 1st antenna	m^2
10	double[3]	Lever-arm vector of 2nd antenna	m
11	double	Lever-arm variance of 2nd antenna	m^2
…			
	uint8_t	Checksum A	
	uint8_t	Checksum B	

3.5.5 5.5. Nav Uncertainty Message

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x05
5	uint16_t	Payload length	32
6	double	System time	seconds
7	double	Position RMS	m
8	double	Velocity RMS	m/s
9	double	Attitude RMS	deg
10	uint8_t	Checksum A	
11	uint8_t	Checksum B	

3.5.6 5.6. Product ID Message

This message contains the identification number of the product. To receive this message send the message defined in Section 8.1.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x06
5	uint16_t	Payload length	2
6	uint16_t	Product ID	
7	uint8_t	Checksum A	
8	uint8_t	Checksum B	

3.5.7 5.7. Navigation Data Message (High Rate)

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x07
5	uint16_t	Payload length	99
6	double	System time	seconds
7	double	GPS time of week	seconds
8	double	Latitude	deg
9	double	Longitude	deg
10	double	Ellipsoidal height	m
11	double[3]	Velocity in NED	m/s
12	double[4]	Body to NED attitude quaternion	See Note 1 in Section 6.13
13	uint8_t	Alignment mode	
14	uint16_t	GPS week number	
15	uint8_t	Checksum A	
16	uint8_t	Checksum B	

3.5.8 5.8. Scaled Raw IMU Data

This message contains scaled raw IMU data. The reference frame of this data is the IMU frame.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x08
5	uint16_t	Payload length	56
6	double	System time	seconds
7	double[3]	Acceleration	m/s^2
8	double[3]	Rotation rate	degrees/s
9	uint8_t	Checksum A	
10	uint8_t	Checksum B	

3.5.9 5.9. Solution Status (1 Hz)

This message shows the Kalman filter solution status. The RMS of the position, velocity and attitude is the squre-root of the diagonal elements of the covariance matrix of the Kalman filter.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x09
5	uint16_t	Payload length	92
6	double	System time	seconds
7	uint8_t	Number of SVs used	
8	uint8_t	Processing mode	
9	uint16_t	GPS week number; if 0 time is not synced to GPS	
10	double	GPS time of week	seconds
11	double[3]	Position RMS (NED)	m
12	double[3]	Velocity RMS (NED)	m/s
13	double[3]	Attitude RMS (NED)	deg
14	uint8_t	Checksum A	
15	uint8_t	Checksum B	

3.5.10 5.10. Repackaged GSV Message

This is a repackaged NMEA GSV message generated by the receiver.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x0A
5	uint16_t	Payload length	length 12 + N_SV * 5
6	double	System time	seconds
7	uint8_t	Receiver number	
8	uint8_t	Antenna ID	
9	uint8_t	SV system	
10	uint8_t	N_SV	
11	uint8_t	SVID	SVID of 1st SV
12	uint8_t	Elevation	deg
13	uint16_t	Azimuth	deg
14	uint8_t	SNR	db-Hz
15	uint8_t	SVID	SVID of 2nd SV
16	uint8_t	Elevation	deg
17	uint16_t	Azimuth	deg
18	uint8_t	SNR	db-Hz
…			
	uint8_t	Checksum A	
	uint8_t	Checksum B	

3.5.11 5.11. Vehicle Dynamics Message

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x0B
5	uint16_t	Payload length	67
6	double	System time	seconds
7	double	GPS time of week	seconds
8	double[3]	Acceleration in body frame. See Note 2 in Section 5.13	
9	double[3]	Rotation rate in body frame. See Note 3 in Section 5.13	
10	uint16_t	GPS week number	
11	uint8_t	Alignment mode	
12	uint8_t	Checksum A	
13	uint8_t	Checksum B	

3.5.12 5.12. Distance Measurement Indicator Data12

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x0C
5	uint16_t	Payload length	13
6	double	System time	seconds
7	int32_t	Pulse count	
8	uint8_t	DMI ID	
9	uint8_t	Checksum A	
10	uint8_t	Checksum B	

3.5.13 5.13. Compact Navigation Message (High Rate)

This message is a high-rate real-time navigation output at the position defined by the user.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x0D
5	uint16_t	Payload length	119
6	double	System time if week = 0, otherwise GPS timeof week	seconds
7	double	Latitude	degrees
8	double	Longitude	degrees
9	float	Ellipsoidal height	m
10	float[3]	Velocity in North, East, Down	m/s
11	float[4]	Attitude quaternion; see Note 1	Scalar, X, Y, Z
12	float[3]	Acceleration in body frame; see Note 2	m/s2
13	float[3]	Rotation rate in body frame; see Note 3	degrees/s
14	float[3]	Position RMS in NED	m
15	float[3]	Velocity RMS in NED	m/s
16	float[3]	Attitude RMS in NED	degrees
17	uint16_t	GPS week number	If 0 time is not synced to GPS
18	uint8_t	Alignment status	0: Invalid, 1: Coarse, 2: Fine
19	uint8_t	Checksum A	
20	uint8_t	Checksum B	

Note:

1. Attitude quaternion for the transformation from the body frame to the NED frame, q_b^n. Note that the quaternion in ROS is defined as (X, Y, Z, scalar). The DCM corresponding to q_b^n can be computed as follows:

$$C_b^n = \begin{bmatrix} q_0^2 + q_1^2 - q_2^2 - q_3^2 & 2(q_1 q_2 - q_0 q_3) & 2(q_1 q_3 + q_0 q_2) \\ 2(q_1 q_2 + q_0 q_3) & q_0^2 - q_1^2 + q_2^2 - q_3^2 & 2(q_2 q_3 - q_0 q_1) \\ 2(q_1 q_3 - q_0 q_2) & 2(q_2 q_3 + q_0 q_1) & q_0^2 - q_1^2 - q_2^2 + q_3^2 \end{bmatrix}$$

where q_i are elements of q_b^n. Let $C_b^n = \{c_{ij}\}$ then if $|c_{31}| < 0.9999$ the Euler angles can be computed as follows:

$$\phi = atan2(c_{32}, c_{33})$$

$$\Theta = atan\left(-c_{31}/\sqrt{c_{32}^2 + c_{33}^2}\right)$$

$$\psi = atan2(c_{21}, c_{11})$$

where ϕ, Θ and ψ are the roll, pitch and heading, respectively.

2. Acceleration output is corrected for the gravity, Coriolis force and the estimated accelerometer biases: $f^b - b_a + C_e^b(g^e - 2w_{ie}^e \times v^e)$ where f^b is the specific force measurement from the IMU, b_a estimated accelerometer bias, C_e^b the DCM for the transformation from the ECEF to the body frame, g^e the gravity vector computed from the model, w_{ie}^e the earth's rotation rate vector, and v^e the velocity vector.
3. Rotation rate output is corrected for the earth rotation rate and the estimated gyro biases, i.e., w_{ie}^e.

3.5.14 5.14. NMEA PECNM Message

This message is NMEA style text message corresponding to the message in Section 5.13.

3.5.15 5.15. NMEA GPRMC Message

This is the NMEA GPRMC message generated by the primary GNSS receiver.

3.5.16 5.16. Time Sync Message

This message contains the time sync message between the system time and GPS time. It gets generated at every PPS event. The GPS time corresponding to the system time can be obtained by

GPS time = System computer time - Bias

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x10
5	uint16_t	Payload length	16
6	double	System computer time	seconds
7	double	Bias with respect to GPS time	seconds
8	uint8_t	Checksum A	
9	uint8_t	Checksum B	

3.5.17 5.17. Raw GNSS Data Message

This message contains raw data generated by the GNSS receivers.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x11
5	uint16_t	Payload length	10+N
6	double	System computer time	seconds
7	uint8_t	Receiver number	
8	uint8_t	Receiver type	
9	uint8_t[N]	Raw GNSS data	
10	uint8_t	Checksum A	
11	uint8_t	Checksum B	

3.5.18 5.18. Engine Version Message

This message shows the engine version of the system. To receive this message the user needs to send an 8-byte binary message “0xAF 0x02 0x06 0x0B 0x01 0x02 0x02 0x02” to the system.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x12
5	uint16_t	Payload length	N
6	char[N]	Engine version string	
7	uint8_t	Checksum A	
8	uint8_t	Checksum B	

3.5.19 5.19. GNSS Receiver Acknowledge Message

This message shows the acknowledge response from a GNSS receiver.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x13
5	uint16_t	Payload length	2
6	uint8_t	Receiver number	
7	uint8_t	Receiver type	
8	uint8_t	Checksum A	
9	uint8_t	Checksum B	

3.5.20 5.20. GNSS Antenna Lever-Arm Calibration Data

Although it is recommended to accurately measure the lever-arms, sometimes it is very difficult to measure them. In this case the user can let the system calibrate the lever-arm vector. The calibration, however, must be done in an open-sky area with RTK enabled. For the primary antenna, the trajectory must include frequent turns, up-hill or down-hill driving for a considerably long time (one hour or more). Thus it would be the best to measure precisely with other instruments. Also the dual-antenna solution cannot be used in the solution during the calibration mode. So the INS initialization must be done with GNSS velocity.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x14
5	uint16_t	Payload length	57
6	double	Internal computer time	seconds
7	double[3]	Lever arm vector in body frame	
8	double[3]	Variance	m2
9	uint8_t	Antenna indicator; see Note 1	0: pri, 1: sec-pri
10	uint8_t	Checksum A	
11	uint8_t	Checksum B	

Note:

1. When antenna indicator is '1' the message outputs the vector from the primary to the secondary antenna in the body frame. To get the lever-arm of the secondary antenna, the primary lever-arm vector must be added. Shown in Figure is a plot of this message for a lever-arm of the secondary antenna with respect to the primary antenna. It is recommended to take the mean values after the convergence.

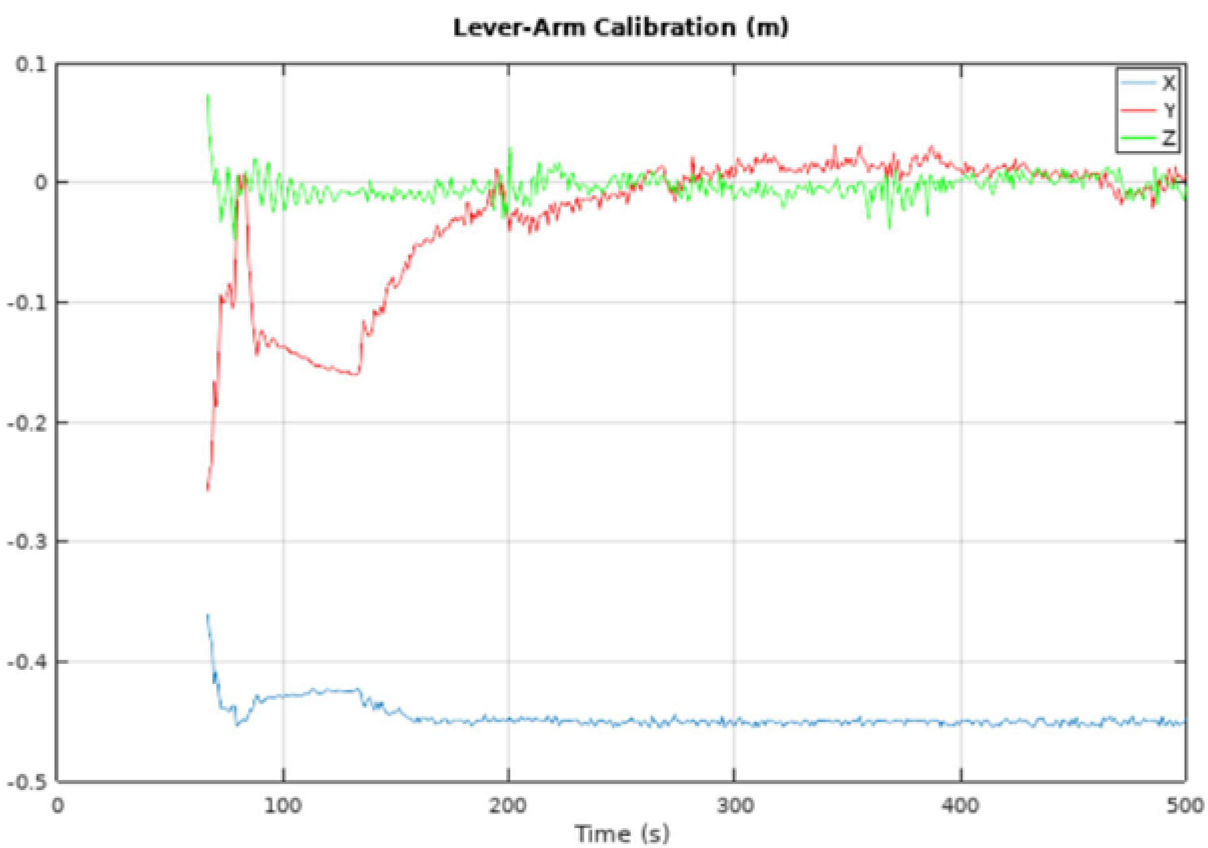


Fig. 2: Figure 4: The IMU frame and the body frame

3.5.21 5.21. DMI Lever-Arm Calibration Data

TBD.

3.5.22 5.22. Geoid Height

This message outputs the Geoid height, which is the height of Geoid above the ellipsoid. The height above Geoid, treated normally as the height above mean sea level (MSL), can be computed as follows:

Height above MSL = Height above ellipsoid - Geoid height

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x16
5	uint16_t	Payload length	12
6	double	GPS time	seconds
7	float	Geoid height	m
8	uint8_t	Checksum A	
9	uint8_t	Checksum B	

3.5.23 5.23. Corrected IMU Data

This message contains IMU data corrected for the sensor biases estimated by the fusion algorithm. Note that the effect of the gravity and the Earth's rotation rate is still included in the sensor data. The reference frame of this data is the user body frame and thus the rotation from the IMU frame to the user body frame is applied.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x17
5	uint16_t	Payload length	58
6	double	GPS time of week	seconds
7	double[3]	Acceleration	m/s2
8	double[3]	Rotation rate	degrees/s
9	uint16_t	GPS week number	
10	uint8_t	Checksum A	
11	uint8_t	Checksum B	

3.5.24 5.24. GPS-UTC Time Offset

This message contains the offset between the GPS time and the UTC. Note that GPS time is ahead of the UTC, which is called the leap seconds.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x05
4	uint8_t	Message sub-ID	0x18
5	uint16_t	Payload length	1
6	uint8_t	GPS - UTC time offset	seconds
7	uint8_t	Checksum A	
8	uint8_t	Checksum B	

3.5.25 5.25. NMEA GGA Message

This is the NMEA GGA message generated by the primary GNSS receiver.

3.6 6. System Diagnostic Messages

3.6.1 6.1. Text Message

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x07
4	uint8_t	Message sub-ID	0x00
5	uint16_t	Payload length	N
6	char[N]	Text	
7	uint8_t	Checksum A	
8	uint8_t	Checksum B	

3.6.2 6.2. Sensor Message Count

This message indicates the activity of each sub-system thus it can be used to monitor the system.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x07
4	uint8_t	Message sub-ID	0x01
5	uint16_t	Payload length	16
6	uint16_t	IMU message count	
7	uint16_t	GNSS message count	
8	uint16_t	PPS count	
9	uint16_t[5]	Reserved	
10	uint8_t	Checksum A	
11	uint8_t	Checksum B	

3.7 7. External Event Messages

This section defines messages that users can send to the system to improve the navigation performance.

3.7.1 7.1. Zero Velocity Update Event

The user can send zero velocity update (ZUPT) messages when the vehicle is not moving. Especially, this will improve the navigation system where the GNSS signal is degraded. For the ZUPT message to be effective, it shall be sent at a rate higher than 2 Hz (recommended rate is 3 Hz).

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x09
4	uint8_t	Message sub-ID	0x01
5	uint16_t	Payload length	4
6	uint16_t	Horizontal Standard Deviation	mm/s (0: Invalid)
7	uint16_t	Vertical Standard Deviation	mm/s (0: Invalid)
8	uint8_t	Checksum A	
9	uint8_t	Checksum B	

3.7.2 7.2. Static Heading Event

This message can be used to initialize the inertial navigator when the position is available from the GNSS receivers but the heading initialization has difficulties due to degraded GNSS signals. For this message to be effective, it shall be sent at a rate higher than 2 Hz (recommended rate is 3 Hz).

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x09
4	uint8_t	Message sub-ID	0x02
5	uint16_t	Payload length	5
6	int16_t	Heading	0.01 degrees
7	uint16_t	ZUPT RMS	mm/s (0: Invalid)
8	uint8_t	Heading RMS	0.1 deg (0: Invalid)
9	uint8_t	Checksum A	
10	uint8_t	Checksum B	

3.7.3 7.3. Static Geo-Pose Event

This message can be used to initialize or aid the inertial navigation system when GNSS signals are not available. For this message to be effective, it shall be sent at a rate higher than 2 Hz (recommended rate is 3 Hz).

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x09
4	uint8_t	Message sub-ID	0x03
5	uint16_t	Payload length	32
6	double	Latitude	deg
7	double	Longitude	deg
8	float	Ellipsoidal height	m
9	int16_t	Roll	0.01 degrees
10	int16_t	Pitch	0.01 degrees
11	int16_t	Heading	0.01 degrees
12	uint16_t	Position RMS	cm (0: Invalid position)
13	uint16_t	ZUPT RMS	mm/s (0: Invalid)
14	uint8_t	Heading RMS	0.1 deg (0: Invalid)
15	uint8_t	Flags	See Note 1
16	uint8_t	Checksum A	
17	uint8_t	Checksum B	

Note:

1. The first LSB (0x01) is used to denote the validity of the roll and pitch; the second LSB (0x02) is used to disable GNSS measurements.

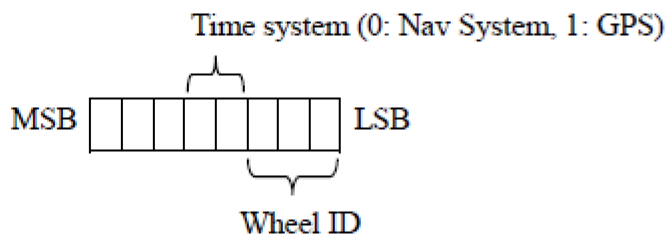
3.7.4 7.4. Wheel Speed Event

Users can input a wheel speed of their vehicle to improve the navigation performance. For this message to be effective, it shall be sent at a rate higher than 2 Hz.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x09
4	uint8_t	Message sub-ID	0x04
5	uint16_t	Payload length	15
6	double	Time	seconds
7	float	Speed	m/s
8	uint16_t	Speed RMS	mm/s (0: Invalid speed)
9	uint8_t	Flags	See Note 1
10	uint8_t	Checksum A	
11	uint8_t	Checksum B	

Note:

1. Usage of flags.



3.8 8. System Configuration Messages

This chapter describes the messages to get the information about the system or to configure the system without using the control software.

3.8.1 8.1. Antenna Separation

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x06
4	uint8_t	Message sub-ID	0x06
5	uint16_t	Payload length	04
6	uint8_t	Message type of the request	
7	uint8_t	Message sub-ID of the request	
8	uint8_t	Response	1: ACK, 2: NACK
9	uint8_t	Reserved	
10	uint8_t	Checksum A	
11	uint8_t	Checksum B	

3.8.2 8.2. User Configuration Setup

Send the following message to request the product ID.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x06
4	uint8_t	Message sub-ID	0x0B
5	uint16_t	Payload length	0x01
6	uint8_t	Topic	0x01
7	uint8_t	Checksum A	
8	uint8_t	Checksum B	

3.8.3 8.3. Antenna Separation

This message sets the separation between two antennas, which will aid the ambiguity resolution for the attitude determination.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x06
4	uint8_t	Message sub-ID	0x0D
5	uint16_t	Payload length	8
6	uint8_t	Topic	0x07
7	uint8_t	Antenna ID 1	0x00
8	uint8_t	Antenna ID 2	0x01
9	uint8_t	Reserved	
10	float	Separation	m
11	uint8_t	Checksum A	
12	uint8_t	Checksum B	

3.8.4 8.4. User Configuration Setup

This message is used to setup the user configuration which controls the behavior of the navigator. The system will respond with the message in Section 8.1. For this to take effect, the user needs to restart the system after sending this message.

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x06
4	uint8_t	Message sub-ID	0x0D
5	uint16_t	Payload length	$93 + 12n_A + 2n_M or 114 + 12n_A + 2n_M$
6	uint8_t	Topic	0x0A
7	uint8_t	Aiding sensor indicators	See Note 1
8	uint8_t	Flags	See Note 2
9	uint8_t	Number of User ICD messages to configure (n_M)	
10	uint8_t	Minimum GNSS velocity for heading initialization	m/s
11	uint16_t	Maximum dead-reckon time; the system will stop outputting the navigation solution if the dead-reckoning time exceeds this limit.	seconds
12	uint16_t	Maximum Nav Output Rate	0.1 Hz
13	double[3][3]	IMU to user-frame rotation matrix (C^b_{IMU})	In row-major order
14	int32_t[3]	Output position offset	1.0e-4 m
15	int32_t[n_A][3]	GNSS antenna lever arm in the user body frame	1.0e-4 m
16	User ICD message configuration block; exists only if $n_M > 0$.		See Note 3
17	DMI configuration block; exists only if the DMI bit is set in the aiding sensor indicators.		See Note 4
18	uint8_t	Checksum A	
19	uint8_t	Checksum B	

Note:

1. Aiding sensor indicators:

Bits	Usage
1-2	Number of GNSS antennas (nA)
3	DMI exists
4-8	Reserved

2. Usage of flags:

Bits	Usage
1	Initialize heading from GNSS velocity; to activate this option the x-axis of the user body frame must be aligned with the forward direction of the vehicle.
2	Enable static position pinning; the system will output a fixed position during a static period detected by the GNSS. Note that there is a chance that the system can miss the detection if the signal quality becomes bad.
3	If set the entered GNSS antenna lever-arm is w.r.t. the IMU housing mark; otherwise it is w.r.t. the center of the IMU.
4	If set the entered output position lever-arm is w.r.t. the IMU housing mark; otherwise it is w.r.t. the center of the IMU.
5	If set the entered DMI antenna lever-arm is w.r.t. the IMU housing mark; otherwise it is w.r.t. the center of the IMU.
6-8	Reserved

3. User ICD message configuration block; care needs to be taken when choosing high-rate outputs as outputting multiple high-rate messages can saturate the communication port.

Field	Type	Description	Content
1	uint8_t	Sub-ID for message 1	See Section 5
2	uint8_t	Port ID for message 1	See below for port ID definition
3	…		
4	uint8_t	Sub-ID for message nM	See Section 5
5	uint8_t	Port ID for message nM	See below for port ID definition

Port ID	Definition
0x00	Invalid, the output is turned off
0x01	Ethernet
0x02	UART0
0x04	UART1
0x80	Internal Log

4. DMI configuration block:

Field	Type	Description	Content
1	uint8_t	DMI ID	0: Invalid, otherwise valid
2	double	DMI scale factor	pulse/m
3	int32_t[3]	DMI lever-arm	1.0e-4 m

3.8.5 8.5. User Configuration Query

The system will send the current configuration if it receives the following message:

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x06
4	uint8_t	Message sub-ID	0x0B
5	uint16_t	Payload length	0x01
6	uint8_t	Checksum A	
7	uint8_t	Checksum B	

The format of the response will be the same as the one in Section 8.4 except that the message sub-ID is 0x0C. If it fails to read the stored configuration, it will respond with the message in Section 8.1 with NACK.

3.8.6 8.6. IP Address of the System

Users can query the IP address of the system by sending the following message:

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x06
4	uint8_t	Message sub-ID	0x0B
5	uint16_t	Payload length	0x01
6	uint8_t	Topic	0x0B
7	uint8_t	Checksum A	
8	uint8_t	Checksum B	

If the Ethernet port is connected, the system will respond with the following message:

Field	Type	Description	Content
1	uint8_t	Sync 1	0xAF
2	uint8_t	Sync 2	0x20
3	uint8_t	Message type	0x06
4	uint8_t	Message sub-ID	0x0C
5	uint16_t	Payload length	0x05
6	uint8_t	Topic	0x0B
7	uint8_t[4]	IP Address	
8	uint8_t	Checksum A	
9	uint8_t	Checksum B	

If the port is not connected the system will send out an NACK message in Section 8.1 with the 'Reserved' field 0x0B.

3.9 9. CANBUS Messages

Defined in this section are the messages to be sent through the CANBUS.

3.9.1 9.1 Message ID 0x001

This message contains the system time of the navigation data.

Field	Type	Description	Content
1	uint32_t	Seconds	
2	uint32_t	Nano seconds	

3.9.2 9.2 Message ID 0x002

This message contains the GPS seconds of the week of the navigation message.

Field	Type	Description	Content
1	uint32_t	Seconds	
2	uint32_t	Nano seconds	

3.9.3 9.3 Message ID 0x003

This message contains the horizontal position of the vehicle.

Field	Type	Description	Content
1	int32_t	Latitude	10^{-7} deg/bit
2	int32_t	Longitude	10^{-7} deg/bit

3.9.4 9.4 Message ID 0x004

This message contains the horizontal velocity.

Field	Type	Description	Content
1	int32_t	Velocity in North	10^{-4} m/s
2	int32_t	Velocity in East	10^{-4} m/s

3.9.5 9.5 Message ID 0x005

This message contains the vertical position and velocity.

Field	Type	Description	Content
1	int32_t	Ellipsoidal height	10^{-4} m
2	int32_t	Velocity in Down	10^{-4} m/s

3.9.6 9.6 Message ID 0x006

This message contains the roll and pith of the vehicle.

Field	Type	Description	Content
1	int32_t	Roll	10^{-6} deg
2	int32_t	Pitch	10^{-6} deg

3.9.7 9.7 Message ID 0x007

Field	Type	Description	Content
1	int32_t	Heading	10^{-6} deg
2	uint16_t	GPS week number	
3	uint8_t	Alignment status	0: Invalid, 1: Coarse, 2: Fine
4	uint8_t	Roll, pitch heading status	0: Invalid, 1: Valid

3.9.8 9.8 Message ID 0x008

This message contains x-components of the corrected IMU data.

Field	Type	Description	Content
1	int32_t	Acceleration X-axis	10^{-6} m/s2/bit
2	int32_t	Rotation rate in X-axis	1/360000 deg/bit

3.9.9 9.9 Message ID 0x009

This message contains y-components of the corrected IMU data.

Field	Type	Description	Content
1	int32_t	Acceleration Y-axis	10^{-6} m/s2/bit
2	int32_t	Rotation rate in Y-axis	1/360000 deg/bit

3.9.10 9.10 Message ID 0x00A

This message contains z-components of the corrected IMU data.

Field	Type	Description	Content
1	int32_t	Acceleration Z-axis	10^{-6} m/s2/bit
2	int32_t	Rotation rate in Z-axis	1/360000 deg/bit

3.9.11 9.11 Message ID 0x101

This message contains the system time of the raw IMU data.

Field	Type	Description	Content
1	uint32_t	seconds	seconds
2	uint32_t	Nano seconds	

3.9.12 9.12 Message ID 0x101

This message contains x-axis components of the raw IMU data.

Field	Type	Description	Content
1	int32_t	Acceleration X-axis	10^{-6} m/s2/bit
2	int32_t	Rotation rate in X-axis	1/360000 deg/bit

3.9.13 9.13 Message ID 0x0103

This message contains y-axis components of the raw IMU data.

Field	Type	Description	Content
1	int32_t	Acceleration Y-axis	10^{-6} m/s2/bit
2	int32_t	Rotation rate in Y-axis	1/360000 deg/bit

3.9.14 9.14 Message ID 0x0104

This message contains z-axis components of the raw IMU data.

Field	Type	Description	Content
1	int32_t	Acceleration Z-axis	10^{-6} m/s2/bit
2	int32_t	Rotation rate in Z-axis	1/360000 deg/bit

3.10 10. Tips for System Usage

If a laptop computer's display is too close to a GNSS antenna, it can cause adverse effects on the navigation system due to jamming/interference.

Fig. 3: Figure 5: Laptop computer jamming the GNSS

CHAPTER 4

System Setup Guide

4.1 1. Introduction

INS1000 is an integrated navigation system consisting of an inertial measurement unit (IMU) and other sensors. Thus, it can continuously output the position, velocity and attitude information of the vehicle. This document explains how to connect the hardware, install, and configure the system.

4.2 2. Power

To power on the system, connect the power cable (shown in Figure 1) to a DC power. The voltage of the power should be between 12 to 24 V. When the system is up, the power light on the box (shown in 2) will be turned on.

4.3 3. Connection

4.3.1 3.1 Serial Connection

The INS1000 system supports serial communication: both the base station and rover station could connect with PC tool with serial cable respectively, however, a null modem adaper for Male-Famale head of serial line transfer is a requirement. To establish serial communication, use one Serial to USB cable to connect the COM-PORT of the data cable (shown in Figure 3) to computer.

To find the serial port, for Windows computer, users can use the steps below. For linux or Mac computers, use the equivalent steps.

- Disconnect the blue USB from your computer.
- Open the **Device Manager page** on your computer
- Connect the blue USB to your computer and check the **Ports** section to see which port is added.

Fig. 1: Figure 1: Power connector

Fig. 2: Figure 2: Power light

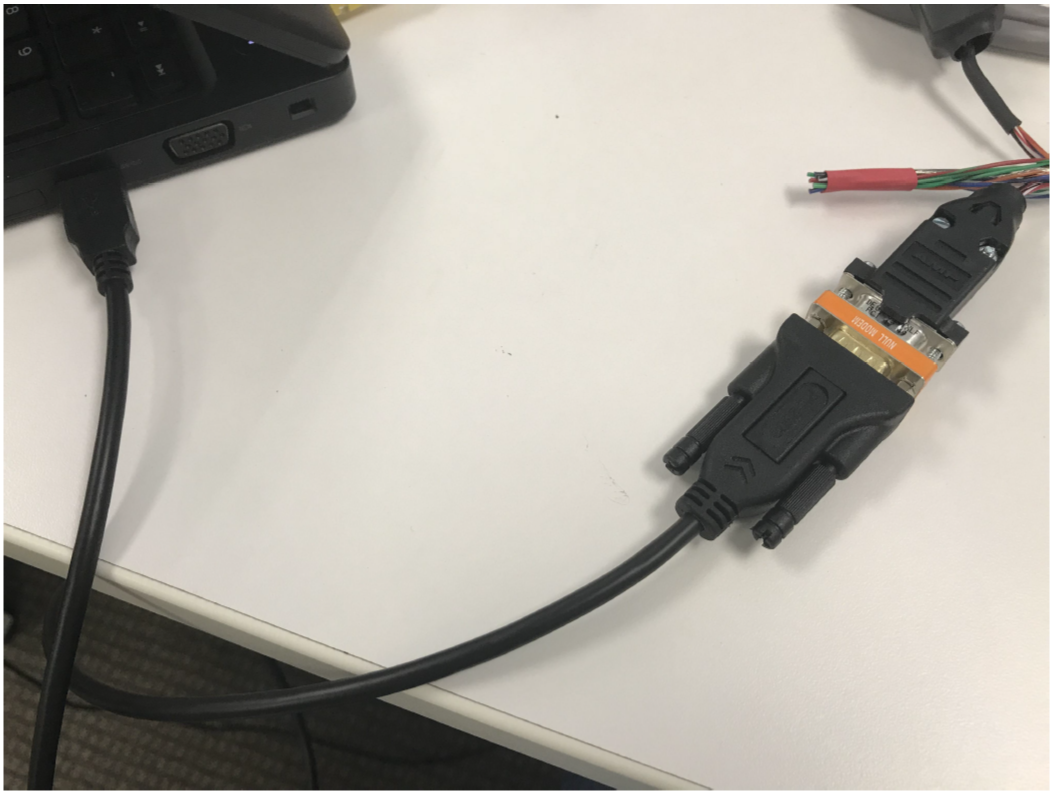


Fig. 3: Figure 3: Connect the serial usb to computer

The INS1000 system outputs multiple data messages. To control which messages are sent through serial connection, use the AceinnaNav Control Software (see section 5.1 in AceinnaNav Control Software User Manual), or send User Configuration Setup message to the system (see section 8.4 in INS1000 Reference Manual).

4.3.2 3.2 Ethernet Connection

The INS1000 system supports ethernet communication,the RTK signal of rover station is synchronized via the ethernet cable on the left side. To establish ethernet communication, there are two kinds of connection:

First, there is

- Direct connection: Connect an ethernet cable between the white connector of the data cable (shown in Figure 4) and a computer or other data receiver.

Users need to set the IP address of the computer or data receiver to 192.168.100.XXX. XXX can be any number from 2 to 254, except 97. The system's IP address is 192.168.100.97. Data port is 8888.

- Connection with router: Connect an ethernet cable between the white connector of the data cable (shown in Figure 5) and a router, another cable between the router, and your computer (shown in Figure 6) or other data receiver.

To set up ethernet communication, users need to turn on DHCP of the ethenet interface on the computer. Users also need to retrieve the IP address from the INS1000 system using System IP Address Query message. The system will send back a System IP address response (see section 8.6 in INS1000 Reference Manual for query and response format). The data port is 8888.

To control which messages are sent through ethernet cable, use the AceinnaNav Control Software (see section 5.1 in AceinnaNav Control Software User Manual), or send User Configuration Setup message to the system (see section 8.4

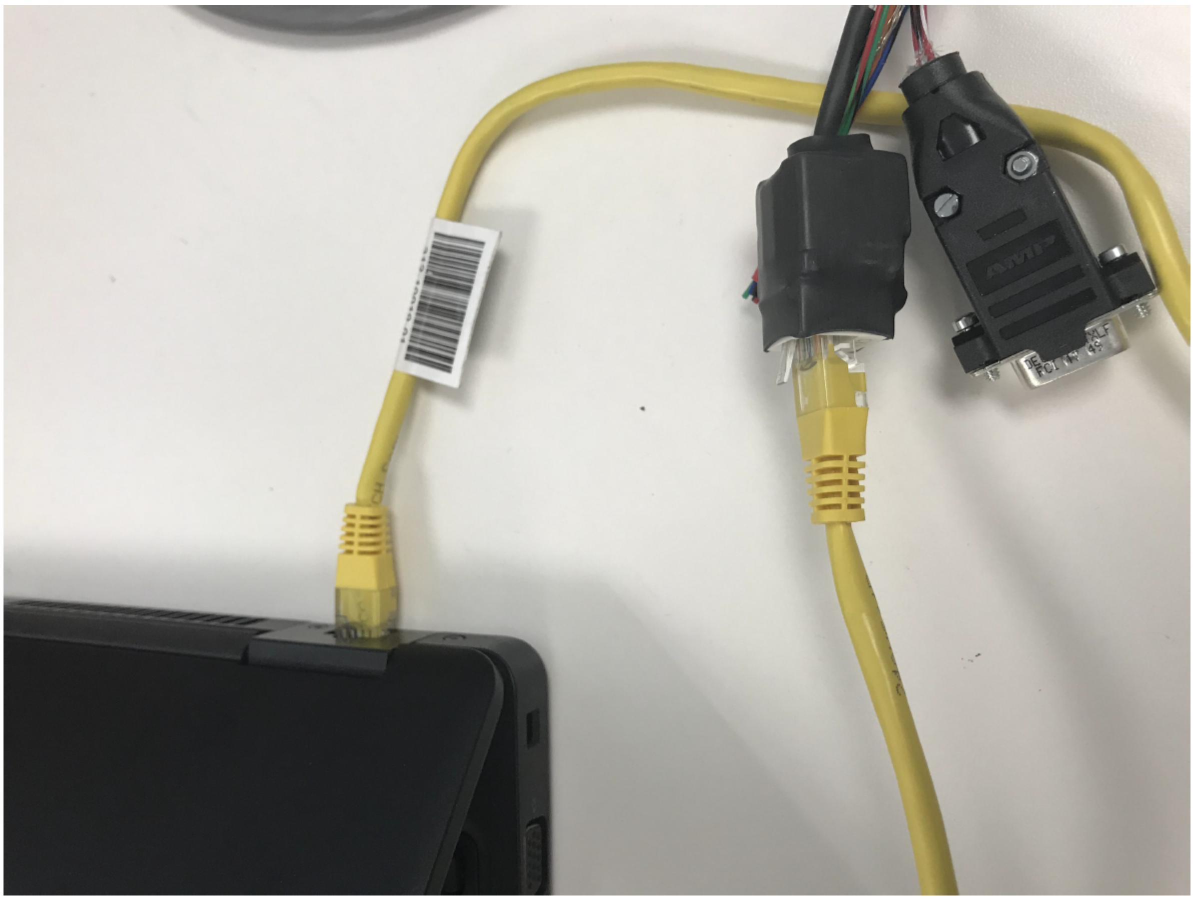


Fig. 4: Figure 4: Connect an ethernet cable between the ethernet connector and a computer

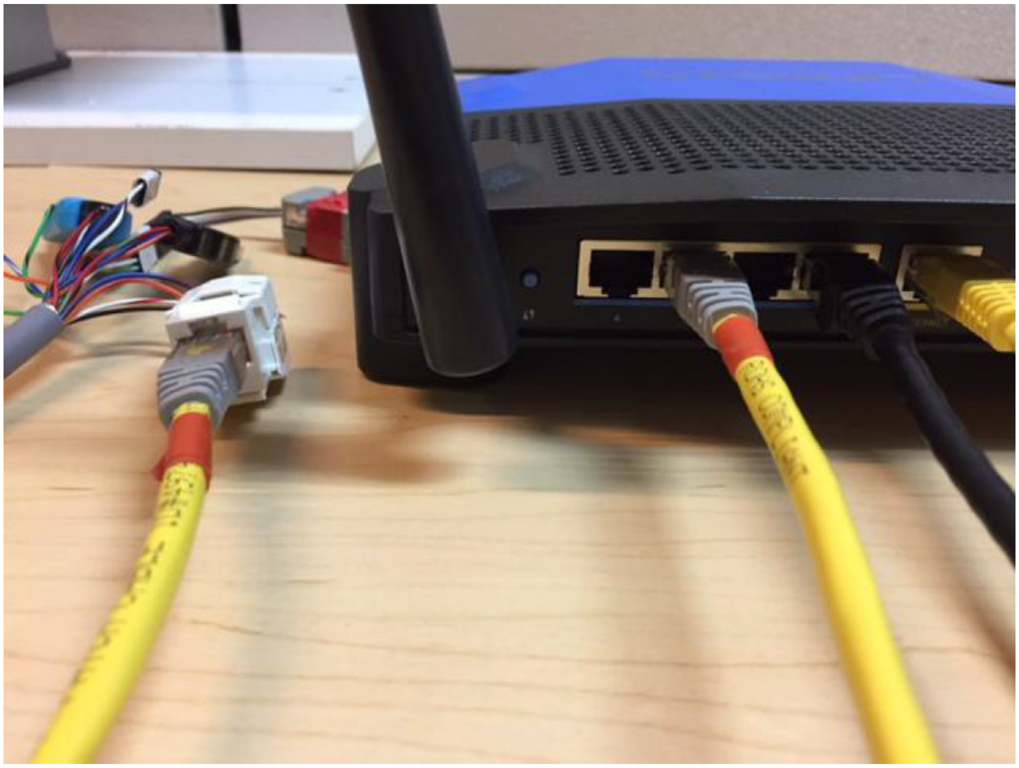


Fig. 5: Figure 5 Connect an ethernet cable between the ethernet connector and a router

Fig. 6: Figure 6 Connect an ethernet cable between the router and a computer

in INS1000 Reference Manual).

4.3.3 3.3 The Null Modem Adapter

Both base station and rover station have serial port, please pay special attention to the DB9 serial wire sequece: Make sure that the transmitting device's Transmit (TX) signal is routed to the receiving device's Receive (RX) line. Similarly, the receiving device's transmission line is routed to the communicating device's receiving line. That is, a null modem adapter should be a wire sequence converter between DB9 female to DB9 female or DB9 male to male connection. note: user should choose the null modem adapter below in the left, not the mini gender changer in the right. After finished the serial port connection(base/rover station), user should verify the connection work normally with a serial tool(serial tool could receive data from rover/base station),then change to GUI.

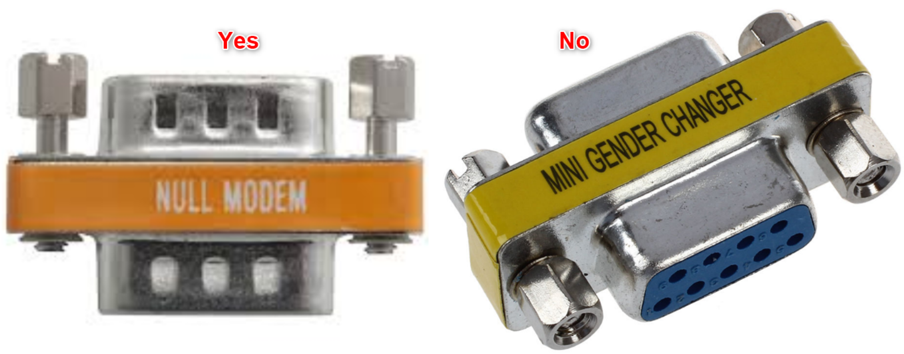


Fig. 7: Figure 7: DB9 wire conventer

4.4 4. Data Format

All output data format are described in INS1000 Reference Manual.

The INS1000 system accepts input message through serial connection and Ethernet connection. All input data format can be found in section 7 and 8 in INS1000 Reference Manual.

4.5 5. RTK

The INS1000 system supports Real-Time Kinematic (RTK) positioning. To turn on RTK mode, users need to do the followings:

- Connect the system to the Internet: Connect an ethernet cable between a router which can access the Internet, and the white connector of the data cable (shown in Figure 7).
- Configure NTRIP client of the system: Use NTRIP client setting dialog of the AceinnaNav Control Software to set the system to use an available RTK base station. See section 6 in AceinnaNav Control Software User Manual about how to use NTRIP client setting dialog.

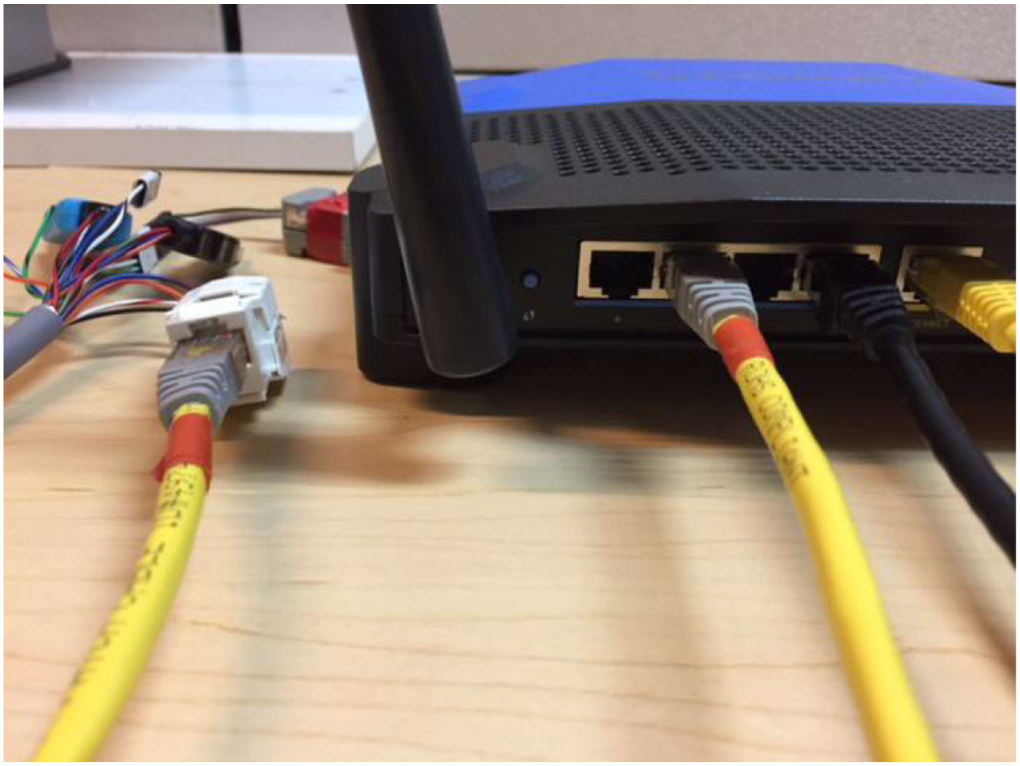


Fig. 8: Figure 8 Connect the system to a router

4.6 6. System Status

Users can check the following to see if your system is working properly. The procedures below may need to use AceinnaNav Control Software to check the status of the system. To see system status in the software, users need to connect the blue USB to a computer, and then open the software and establish a serial connection. See section 2 and 3 in AceinnaNav Control Software User Manual about software installation and connection establishment.

- Check if the system is powered: Check if the light on the box is turned on. If it isn't turned on, the system isn't powered.
- Further check if subsystem is working: In the AceinnaNav Control Software, check if the IMU, GNSS, and PPS indicators blink green at the bottom-right corner (shown in Figure 8).
- Check if attitude is coming: In the AceinnaNav Control Software, check if the Attitude Mode is fine in the Navigation Information dialog (shown in Figure 9).

If the Attitude Mode is invalid, place the system under open sky and check if satellite signal is enough with the signal panel of the software. Under open sky, there is usually 10 to 20 satellites for each antenna in the signal panel.

- If you are using RTK, check if the system is on RTK mode: In the AceinnaNav Control Software, check if the Postion Mode is RTK_FLOAT or RTK_FIXED (shown in Figure 10). Check if NTRIP indicator blink at the bottom-right corner (shown in Figure 11).

4.7 7. Interface Cable Pin Definition

The table below is the cable pin definition. Figure 12 is the sectional view of 19 position wiring cable.

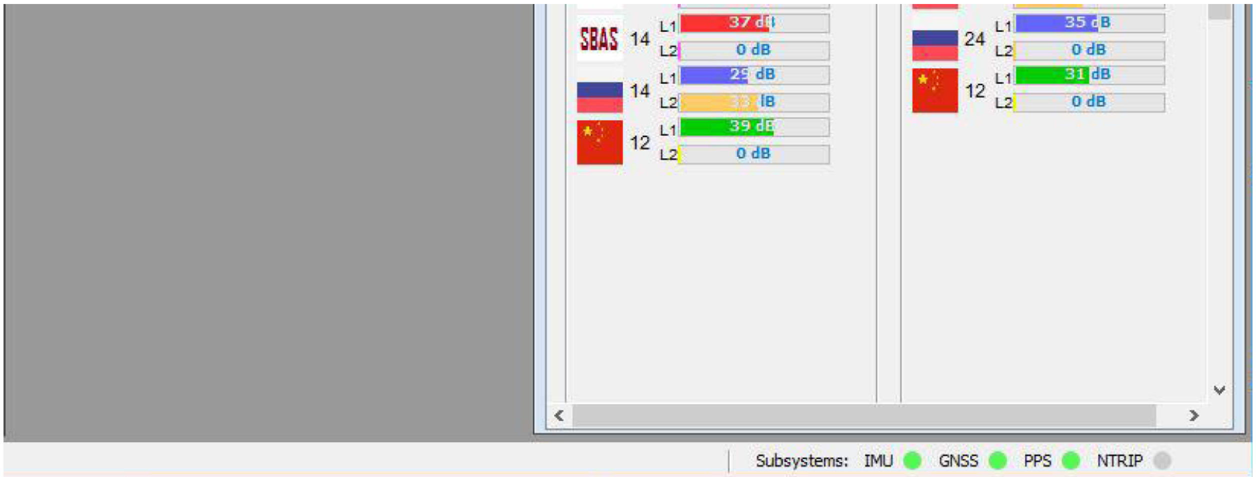


Fig. 9: Figure 9 Subsystem status indicators

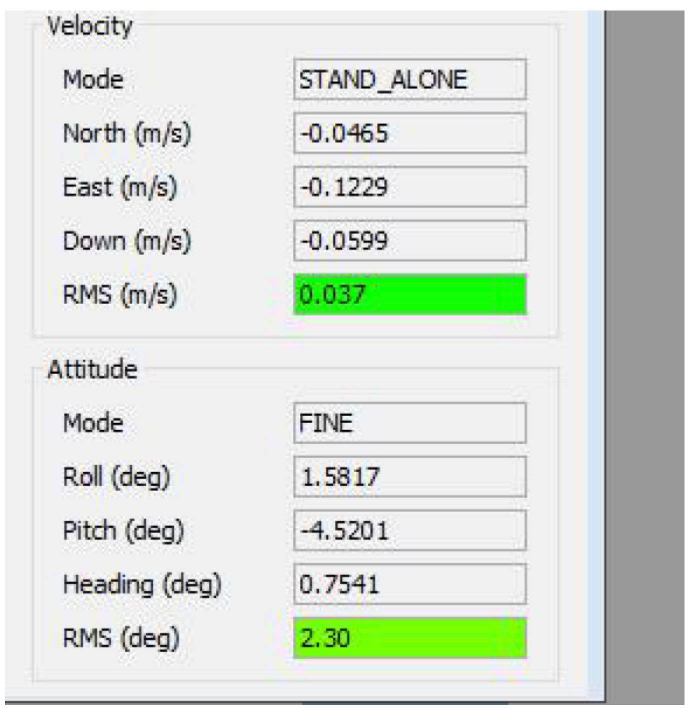


Fig. 10: Figure 10 Attitude Mode

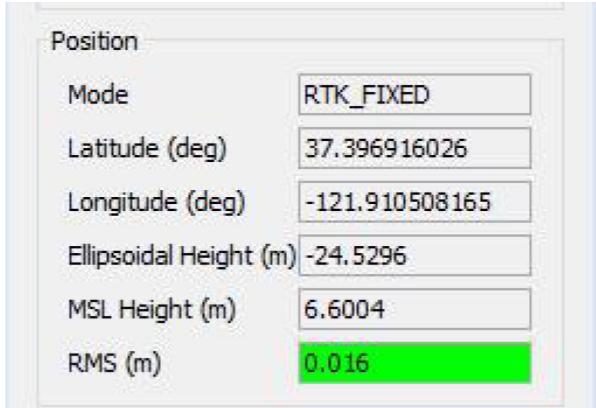


Fig. 11: Figure 11 RTK Mode

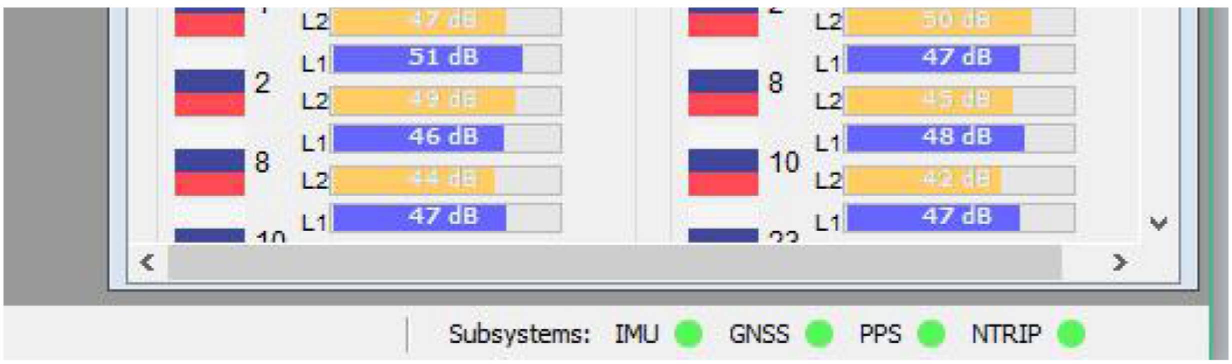


Fig. 12: Figure 11 NTRIP indicator

INS1000 Rover using LEMO coaxial connetcors										
6 position wiring				16 position wiring (15C wire)				19 position wiring (20C wire,blue-white not used)		
pin number	name	wire color code		pin number	name	wire color code		pin number	name	wire color code
1	GND	white-blue		1	GND			1	Rx_N	white-red
2	USB1_DM	white-green		2	EQEP_0B	geen-white		2	Rx_P	black-red
3	USB1_DP	green-white		3	EQEP_0A	orange		3	CAN_50Hz	green-white
4	VDD 5V	blue-white		4	TIMER4	blue		4	UAR4_TxD	red-white
5	VCC 12V	orange(dark)-wl		5	GPIO2_3	white-black		5	UAR4_RxD	black-white
6	GND	white-orange		6	I2C1_SCA	red-black		6	USB0_DP	blue-black
				7	I2C1_SDA	green-black		7	USB0_DM	orange-black
				8	RX1_N	orange-black		8	UART5_RxD	green-black
				9	RX1_P	blue-black		9	GND	red-black
				10	TX1_N	black-white		10	GND	red-green
				11	TX1_P	red-white		11	Tx_N	blue-red
				12	GND	blue-white		12	Tx_R	orange-red
				13	TIMER5	black		13	DCAN0_Tx	red
				14	GPIO0_27	green		14	DCAN0_Rx	white
				15	GPIO1_13	red		15	EQEP_1A	white-black
				16	GPIO1_12	white		16	EQEP_1B	blue
								17	PPS_LD	orange
								18	UART5_TxD	green
								19	GND	black

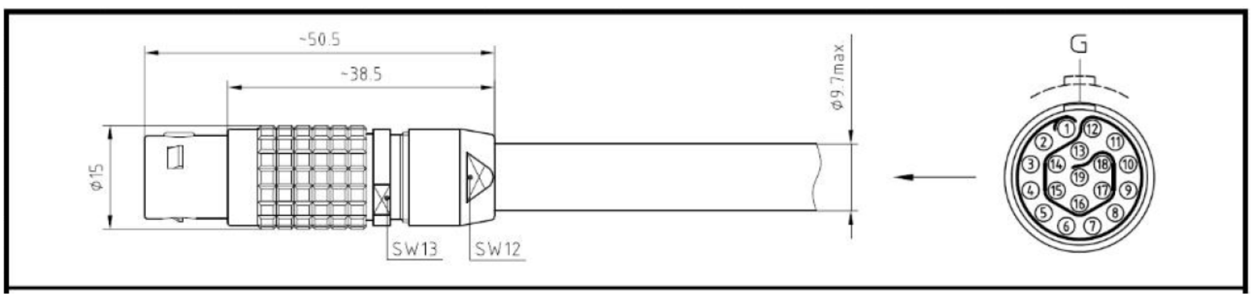


Fig. 13: Figure 12 Sectional View of 19 Position Wiring Cable