



User Guide

M20X High-precision integrated navigation receiver



Rev 1.0

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Technical Assistance

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Safety Information

Before using the receiver, please make sure that you have read and understood this User Guide, as well as the safety requirements.

- Connect your devices strictly based on this User Guide
- Install the GNSS receiver in a location that minimizes vibration and moisture
- Avoid falling to ground, or colliding with other items
- Keep a sound ventilation environment
- Change the cable if damaged

Related Regulations

The receiver contains integral Bluetooth® wireless technology. Regulations regarding the use of the datalink vary greatly from country to country. In some countries, the unit can be used without obtaining an end-user license. But in some countries administrative permissions are required.

Use and Care

The receiver can withstand the rough treatment that typically occurs in the field. However, the receiver is high-precision electronic equipment and should be treated with reasonable care.

Warning and Caution

An absence of specific alerts does not mean that there are no safety risks involved. A Warning or Caution information is intended to minimize the risk of personal injury and/or damage to the equipment.

WARNING- A Warning alerts you to a potential risk of serious injury to your person and/or damage to the equipment, because of improper operations or wrong settings of the equipment.

CAUTION- A Caution alerts you to a possible risk of damage to the equipment and/or data loss.

Warranty Notice

Qtalis does not warranty devices damage because of force majeure (lighting, high voltage or collision).

Qtalis does not warranty the disassembled devices.

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1. Product Overview

1.1 Product Introduction

The M20 X is a high-performance dual-antenna integrated navigation and positioning product that complies with automotive-grade design and manufacturing standards. It is based on MEMS inertial navigation technology and integrates satellite navigation (with RTK support) and vehicle information (such as wheel speed and gear signals).

By leveraging GNSS/INS/DR fusion algorithms, the M20 X delivers continuous high-precision position, velocity, and attitude data even in challenging environments such as urban canyons, overpasses, tree-lined roads, highways, and industrial parks where satellite signals may be blocked or affected by multipath.

It provides a reliable and stable high-precision positioning solution for applications such as autonomous driving, low-speed unmanned vehicles, smart ports, digital mines, trunk logistics, industrial park cleaning, ROBOTAXI, and ROBOBUS.

1.2 Product Features

Automotive-Grade Design

The entire device is designed to meet automotive-grade standards, complying with IATF 16949 and PPAP manufacturing processes. It integrates qtalis's self-developed all-constellation, all-frequency GNSS baseband processor SoC chip, certified to AEC-Q100 standards, and is equipped with a high-precision IMU that meets ASIL B functional safety requirements.

High-Precision Fusion Algorithm Engine

The high-precision RTK/IMU fusion algorithm engine incorporates GNSS anti-interference and anti-multipath technologies, significantly improving positioning accuracy in tree-covered and partially obstructed environments. The IMU raw data is

fully temperature-calibrated and compensated, and with years of accumulated DR algorithm expertise, the system maintains excellent positioning performance even in fully blocked environments like tunnels.

Rich Communication Interfaces

Equipped with automotive Ethernet, dual CAN/CAN FD, dual RS232 serial ports, and PPS output, it also supports external wheel speed sensor input.

Multiple Data Outputs

Supports real-time data output at 100 Hz (optional 200 Hz), including GNSS raw data, IMU raw data, RTK positioning results, and integrated navigation outputs.

1.3 Product Appearance and Connector Pinout Description

Product Appearance



Figure 1-1: Appearance diagram of M20 X GNSS/INS receiver

Main Connector Pinout Description

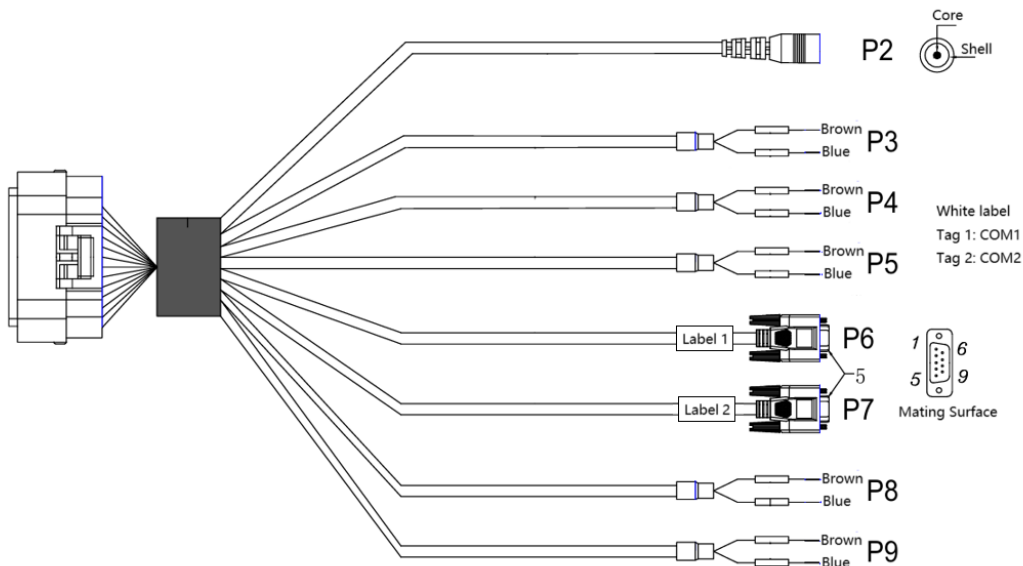


Figure 1-2 Wire Harness and Connector Description

The following table provides the definitions and descriptions for each interface shown in the diagram.

Table 1-1 Main Connector Pinout Description

Pin	Definition		Description
1	P2		Power Supply
2	P3	CAN1H	CAN1 High
		CAN1L	CAN1 Low
3	P4	CAN2H	CAN2 High
		CAN2L	CAN2 Low
4	P5	PPS	PPS 5V Signal
		GND	Power Ground

5	P6	COM1	Serial Port 1
6	P7	COM2	Serial Port 2
7	P8	ENET_P	Vehicle Ethernet Positive Data Line (P)
		ENET_N	Vehicle Ethernet Negative Data Line (N)
8	P9	RESERVED	Reserved
		GND	Power Ground

2. Installation

This chapter introduces how to install the M20 X GNSS/INS Receiver.

2.1 Packing List

Table 2-1 Packing List

Cable Name	Quantity	Description
M20 X GNSS/INS Receiver Main Unit	1 piece	Included, used to provide high-precision positioning and navigation information.
Data Power Connection Cable	1 piece	Included, used to connect the M20 X to external power supply and communication equipment
High-Precision GNSS Antenna	2 pieces	Optional, used to receive satellite signals
RF Coaxial Cable	2 pieces	Optional, used to connect the device to GNSS antennas. The main antenna is connected via FAKRA-A, and the secondary antenna is connected via FAKRA-C
DC Power Supply	1 set	User-supplied, used to output voltage of +5~32V, with a minimum power output of 10W

2.2 Installing the Main Unit

The main unit should be securely and reliably mounted, with a rigid connection to the carrier, ensuring that the relative positions of the main unit, antenna, and carrier remain fixed. The following requirements apply to the installation area for the main unit:

1. The main unit should be installed on a rigid structure, with the surface flatness requirement of less than 1° (flatness refers to the pitch and roll angles between the rigid structure surface and the horizontal plane).

2. The temperature of interference units around the main unit should be kept below 85°C.

3. No vibration-interfering units should be within a 50 cm radius of the main unit. The unit should be placed away from vibration sources such as engines, subwoofers, and other areas prone to strong vibrations. The IMU should avoid the following frequency bands: **15.8kHz-17.8kHz, 28-35.6kHz, 44kHz, 18.3-20.3kHz, 1.9-2.1kHz.**

4. The main unit should be placed away from areas with complex electromagnetic environments, such as near LiDAR, instrument panels, and other equipment.

The recommended installation method is as follows, as shown in Figure 2-2:

1. Horizontal installation, with a horizontal angle of less than 5°, the smaller the better.

2. The X-axis of the main unit should point in the direction of the carrier's forward motion, the Y-axis should be perpendicular to the forward direction and point to the right, and the Z-axis should point downward.

3. The X-axis of the main unit should be parallel to the vehicle's longitudinal centerline, with a distance of less than 70 cm.

4. The main unit should be installed at or near the center of the rear axle of the vehicle.

If the orientation of the main unit does not meet the above requirements, a horizontal deflection arrangement can be used with deflection angles in multiples of 90°.



Figure 2-1 Complete Device Installation Instructions

2.3 Installing the Antenna

When installing the GNSS antenna, please pay attention to the following:

- 1. Clear, Unobstructed View Above the GNSS Antenna:** Ensure there are no obstacles above the GNSS antenna to avoid signal interference.
- 2. Horizontal Placement of the GNSS Antenna:** The GNSS antenna should be placed horizontally. If tilting is necessary, the angle should not exceed 15°.
- 3. Rigid Connection Between the GNSS Antenna and the Carrier:** The GNSS antenna should be rigidly connected to the carrier to ensure it does not shift or shake during the carrier's movement.
- 4. Antenna Connection Ports:** The main antenna connected to the device uses a FAKRA-A interface, while the secondary antenna uses a FAKRA-C interface. The specific locations are shown in Figure 1-2.

2.4 Antenna Parameters and Rotation Parameters

After the initial installation of the main unit, it is necessary to accurately measure the GNSS antenna's rod arm. It is recommended to use professional surveying equipment such as a total station or laser rangefinder to measure the rod arm, and set the rod arm value using commands (for definition and configuration, see [section 3.6](#)).

If the main unit is a dual-antenna model, after completing the dual-antenna installation, the installation angle for the dual antennas should be set using commands (for definition and configuration, see [section 3.7](#)).

If the main unit is installed using a horizontal deflection arrangement, the main unit's coordinate system will not coincide with the vehicle's coordinate system. In this case, additional rotation parameters (RBV) need to be set (for definition and configuration, see [section 3.8](#)).

Manually measured RBV is often not sufficiently accurate, and the rod arm effect may influence results. After setting the initial RBV manually, an online calibration process can be performed to refine the RBV. The online calibration can automatically estimate a more accurate RBV in a short period, improving the overall system performance (for the online calibration process, see [section 4.7](#)).

2.5 Vehicle Model Parameters

After completing the installation of the main unit, it is necessary to measure the rod arm from the main unit to the center of the rear axle and set the rod arm value using commands (for definition and configuration, see [section 3.9](#)).

2.6 Connecting Communication Equipment

The M20 X can communicate with external devices using serial ports, vehicle Ethernet, or CAN/CAN FD bus.

2.6.1 Serial Ports

The M20 X is equipped with two serial ports, COM20 and COM2, as shown in Table 2-3. The baud rate, parity, and other settings for the serial ports can be configured using the SETCOM command. For more details, refer to the serial protocol in [section 3.2](#).

Table 2-2 COM Port Configuration

Port	RS232	Flow Control
COM20	support	none
COM2	support	none

Steps to Connect the Serial Port:

1. Insert one end of the data and power connection cable into the data interface of the main unit;
2. Connect the other end of the data and power connection cable to a computer or other communication device.

2.6.2 Vehicle Ethernet

The M20 X is equipped with a vehicle Ethernet interface, supporting the 100Base-T1 vehicle Ethernet standard, and can be used to communicate with external in-vehicle Ethernet devices. The Ethernet port supports IPv4 network layer and TCP/IP transmission, allowing users to remotely debug, receive differential data output for position and attitude information, or upgrade firmware.

Steps to Connect Ethernet:

1. Insert one end of the data and power connection cable into the data interface of the main unit.
2. Connect the other end of the data and power connection cable (vehicle Ethernet

bare wire) to another in-vehicle Ethernet communication device. If you need to connect to a computer or other industrial Ethernet device, use a vehicle Ethernet to industrial Ethernet converter.

For Ethernet configuration details, refer to [section 3.3](#).

2.6.3 CAN/CAN FD

The M20 X is equipped with two CAN/CAN FD bus interfaces, with a maximum data rate of 5 Mbps. The interface CAN FD1 is used for wheel speed input.

Steps to Connect the CAN/CAN FD Bus::

1. Insert one end of the data and power connection cable into the data interface of the main unit.
2. Connect the other end of the data and power connection cable's bare wire to the external CAN/CAN FD bus using an adapter.

For CAN/CAN FD bus configuration details, refer to [section 3.4](#).

2.7 Connecting Synchronized Devices

The M20 X provides PPS as a time synchronization signal, which can be selected according to actual requirements. The steps to connect the synchronization signal are as follows:

1. Insert one end of the data and power connection cable into the data interface of the main unit.
2. Connect the bare wire of the other end of the data and power connection cable to the user's synchronization device. The GND signal must be connected to the ground of the user's device.

2.8 Connecting the Odometer

The M20 X can be connected to an odometer. Wheel speed information can be forwarded to the M20 X via the DBC protocol, helping to improve the accuracy of combined navigation positioning when satellite signals are lost. Please choose according to your actual needs.

2.9 Connecting the Power Supply

Please confirm the positive (+) and negative (-) terminals of the power cable to avoid incorrect connections.

Steps to Connect the Power Supply:

1. Insert one end of the data and power connection cable into the data interface of the main unit.
2. Connect the bare power wires at the other end of the data and power connection cable to the power supply.

3. Configuration Instructions

3.1 System Wiring Workflow

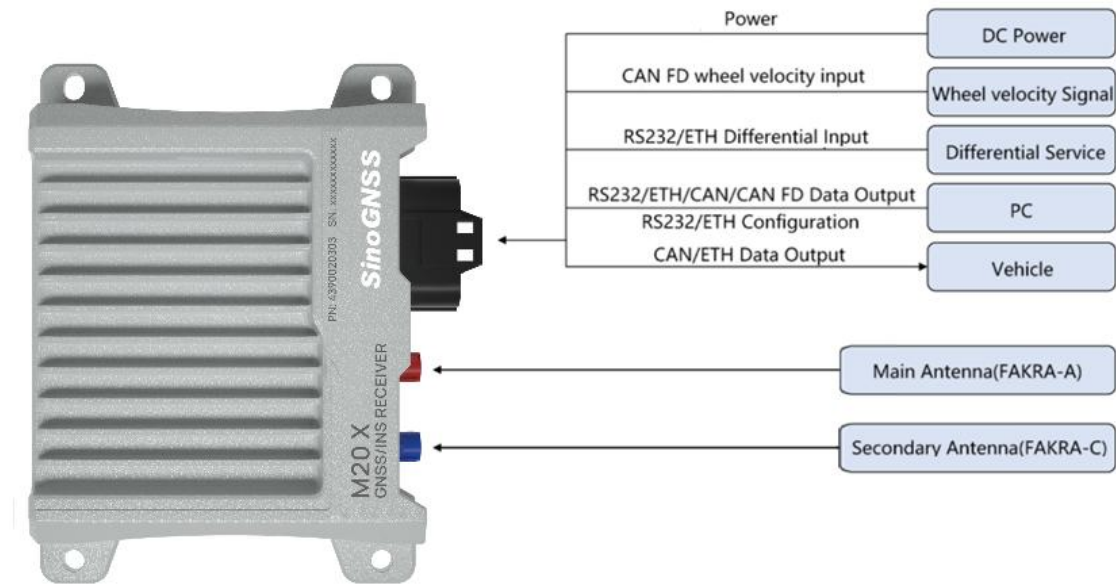


Figure 3-1 System Architecture Diagram

3.2 Serial Port Configuration

The M20 X can communicate with a computer or other devices via the serial port. Before establishing communication, both sides need to properly configure the serial port parameters. The default serial port settings are shown in Table 3-1.

Table 3-1 Default Serial Port Configuration

Parameter	Value
Baud Rate	COM20: 115200, COM2: 115200 (default)
Parity	None
Data Bits	8 bit

Stop Bits	1 bit
-----------	-------

Use the following command to change the serial port configuration:

To change the baud rate of COM20 to 115200, enter the following command:

COM COM20 115200

To change the baud rate of COM20 to 921600, enter the following command:

COM COM20 921600

The M20 X supports communication with a remote terminal via the serial port, meaning it can establish communication with the unit using a virtual terminal software. Before establishing communication, please ensure that the serial port settings of both the terminal and the M20 X are consistent. A computer can be used as a remote terminal for purposes such as navigation data storage.

3.3 In-Vehicle Ethernet

Before using the in-vehicle Ethernet to connect the M20 X, the vehicle Ethernet port of the main unit needs to be configured via the serial port. For serial communication details, refer to section 3.2.

Additionally, since a computer cannot directly recognize the in-vehicle Ethernet, after completing the M20 X in-vehicle Ethernet configuration via the serial port, you will need to use the appropriate interface converter to enable communication between the computer and the main unit.

3.3.1 Static IP

Both the main unit and the computer need to be assigned unique IP addresses, with static IP addresses typically used in testing environments.

To configure the main unit's IP address, a USB-to-serial cable is generally required.

For the detailed commands involved, please refer to the M20 X Message Manual.

The main unit's IP address is **192.168.1.104**, and the subnet mask is **255.255.255.0**.

3.3.2 ICOM

ICOM is a virtual serial port used for in-vehicle Ethernet connections and can be understood as an application layer protocol in the TCP/IP protocol suite. The transport control layer protocol for ICOM can use either TCP or UDP.

Currently, the main unit uses the TCP protocol and acts as the server. The connection port is 8089.

3.4 CAN/CAN FD

This chapter introduces the configuration of the CAN/CAN FD bus. The M20 X supports communication with a computer or other devices in the system via the CAN/CAN FD bus. For device connection, refer to [section 2.6.3](#).

Before connecting the main unit via the CAN/CAN FD bus, you need to configure the CAN/CAN FD port through the serial port or in-vehicle Ethernet. For serial communication, please refer to [section 3.2](#). For in-vehicle Ethernet communication, please refer to [section 3.3](#).

3.5 CAN Bus

Once the device connection is completed, the following configurations can be made:

1. To configure CANFD1 with a baud rate of 500K (the exact value should match the vehicle's CAN bus), use the following command:

SETCAN CAN1 ON 500K

2. To configure CANFD1 to connect to the J1939 node NODE1, use the following command:

SETJ1939 NODE1 CAN1 AA

3. Save configuration:

SAVECONFIG

Note: The user can specify other standard protocol stacks.

3.6 Antenna Arm Length

The integrated navigation system combines GNSS and INS. In GNSS, the reference point for position information is the phase center of the GNSS antenna. In INS, the reference point for position, velocity, and attitude information is the navigation center of the main unit. Therefore, in the integrated navigation system, to provide accurate position, velocity, and attitude information, it is necessary to obtain the positional relationship of the GNSS main antenna phase center relative to the navigation center of the main unit in the vehicle coordinate system. This parameter is critical for the proper functioning of the integrated navigation system.

The three-dimensional distance between the GNSS main antenna phase center and the navigation center of the main unit is referred to as the antenna arm length. The navigation center of the main unit is considered the origin, with the X, Y, and Z axes aligned with the vehicle coordinate system.

**Antenna arm length configuration : setleverarm ANT1 <param1> <param2>
<param3>**

<param1>/<param2>/<param3> : Represents the X/Y/Z coordinate values of the antenna arm length, in meters.



Figure 3-2 Antenna Arm Length from the Main Unit to the GNSS Antenna

The following is an example of the GNSS antenna arm length:

As shown in Figure 3-1, the measured antenna arm lengths are as follows:

X Offset=0.620m, Y offset=-0.310m, Z offset=-0.620m

Use the command 'setleverarm' to set the antenna arm length:

```
setleverarm ANT1 0.620 -0.310 -0.610
```

Note: The antenna arm length error will directly affect the position error in the integrated navigation system output. It is essential to ensure high precision.

3.7 Dual Antenna Installation Angle

M20 X can use dual antennas for orientation, assisting the main unit in static initialization and improving attitude angle accuracy during operation. The dual antenna installation angle refers to the rotation angle of the two antennas relative to the vehicle coordinate system and needs to be configured before using the device. The calculation method for the dual antenna installation angle is as follows:

Looking down at the vehicle, the main antenna serves as the center of rotation, and the vehicle's forward direction (X-axis) is the reference starting direction for rotation. A clockwise rotation is positive, and a counterclockwise rotation is negative. If the main

antenna is on the left and the secondary antenna is on the right, with the line connecting them perpendicular to the vehicle's forward direction (X-axis), the dual antenna installation angle is 90 degrees.

Dual antenna installation angle configuration: `setinsheadingdiff <param>`

<param>: Dual antenna installation angle, unit: deg

3.8 Rotation Parameters

The attitude deviation between the system coordinate frame and the vehicle coordinate frame is referred to as the rotation parameters, i.e., RBV. Essentially, RBV is the set of Euler angles representing the rotation from the system coordinate frame to the vehicle coordinate frame. Figure 3-3 shows the RBV from the system coordinate frame to the vehicle coordinate frame.

Rotation Parameter Configuration : `setrotationangle <param1> <param2> <param3>`

<param1>/<param2>/<param3>: Rotation angles around the X/Y/Z axes, in degrees.

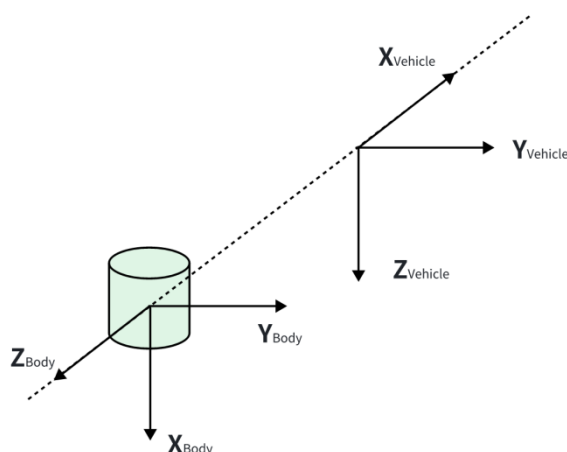


Figure 3-3 Rotation Parameters from Device Coordinate System to Vehicle Coordinate System

The Euler angles for the rotation from the device coordinate system to the vehicle

coordinate system are: X: 0°, Y: -90°, Z: 0°, the rules are as follows:

You must rotate the vehicle coordinate system to align with the device coordinate system;

The rotation must follow the Z→Y→X sequence;

The rotation direction of the coordinate axes follows the right-hand rule.

Use the `setrotationangle` command to set the RBV.:

setrotationangle 0 -90 0

Note: The RBV from the device coordinate system to the vehicle coordinate system should be measured as accurately as possible; otherwise, it will introduce additional errors in attitude, velocity, and position.

3.9 Rear Axle Lever Arm

In normal driving conditions, the lateral speed and vertical speed at the center of the rear axle are both 0. To correctly use the constraint information and improve the vehicle's DR (dead reckoning) performance, it is necessary to manually measure the lever arm value from the machine to the rear axle center point after the installation. The measurement method can refer to [section 3.6](#), which discusses the antenna lever arm measurement.

The configuration of the rear axle lever arm: **setleverarm NHC** <param1> <param2> <param3>

<param1>/<param2>/<param3>: Represents the X/Y/Z coordinate values of the rear axle center lever arm, in meters.

Note: When the vehicle is connected to wheel speed data, this configuration must be set correctly; otherwise, it may lead to abnormal results.

3.10 PPS

M20 X provides PPS as a time synchronization signal. The method for connecting the synchronization device is described in [section 2.7](#).

The device by default outputs a second pulse PPS signal, with the rising edge synchronized to GPS time. When the GNSS signal is received well, the synchronization accuracy is 20ns.

4. Usage Workflow

Before starting to use the M20 X, please ensure that the installation and configuration of the device have been completed as described in Chapter 2 and Chapter 3, and that the device has been powered on. The following is the operational flowchart for the M20 X GNSS/INS receiver.

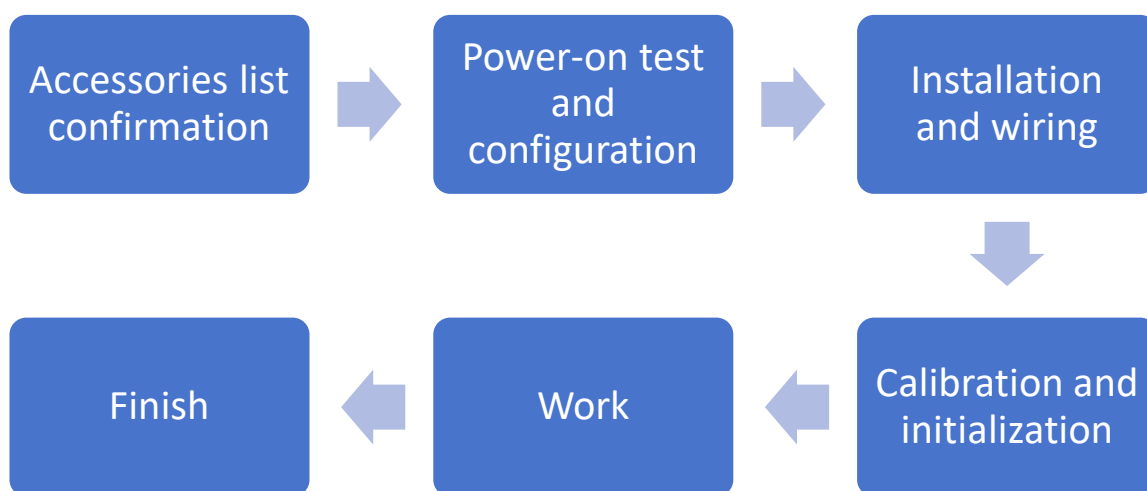


Figure 4-1 Usage Flowchart

4.1 Start Communication

Upon the first startup, M20 X will print part of the configuration and initialization information, such as firmware version and inertial navigation configuration.

For example, when using serial communication on COM2, send the command `LOG VERSION`. If the device responds with the following similar content, it indicates that the device has started working and the communication via the current port is functioning properly:

Receive command

Command accepted! Port: COM2

VERSION: x.xxx

If the command is sent incorrectly, the device will return an error message similar to the following:

Error!

4.2 First-time Use Configuration

Before the first use, you need to complete some system configurations using the commands listed in Table 4-1. For detailed command definitions, please refer to the "M20 X Command Manual."

Table 4-1 First Use Configuration Content

User Settings	Applicable Commands	Remarks
Antenna to Navigation Center Lever Arm	See Section 3.6	
Vehicle Installation Angle	See Section 3.7	
Dual Antenna Installation Angle	See Section 3.7	
Minimum Alignment Speed	setdrconfigv	Optional, default is 3m/s, lower limit is 1m/s
Rear Axle Lever Arm	See Section 3.9	
Online Calibration for Whole Machine	See Section 4.7	Only required for initial installation, without moving the device

Note:

1. After configuration, the saveconfig command must be sent to save the parameters;

otherwise, the parameters will be lost after the machine is powered off and will need to be reconfigured.

2. After saving the configuration parameters, the reset command must be sent or the system must be manually rebooted for the changes to take effect.

3. After reinstalling the machine, the antenna/rear axle lever arm and RBV must be measured and configured again.

4. After moving the antenna, it is necessary to remeasure and reconfigure the antenna lever arm.

4.3 Differential Data

Differential data is transmitted from a reference station to a rover station to improve the positioning accuracy of the rover. The data format is generally in RTCM protocol (RTCM 3.x version).

The reference station is a GNSS receiver with a fixed and known location, which broadcasts differential data via some means. The rover station needs to continuously receive differential data from the reference station to calculate its current accurate position.

Users can set up their own reference station or rent a commercial reference station. Regardless of the method, a communication link is required between the reference station and the rover station to transmit the differential data.

During testing, differential data transmission can be completed using a computer and data forwarding software such as STRSVR. In a working environment, devices like radio stations or DTUs can be used to establish the data link. As a rover station, M20 X generally receives differential data through serial port COM20 or Ethernet.

4.3.1 Serial Port Access

1. Configure the baud rate, parity, and other settings for COM20: **COM COM20 115200**
2. Configure the input and output data format for COM20: **INTERFACEMODE AUTO AUTO ON**
3. Save configuration: **SAVECONFIG**
4. Connect COM20 to the differential data source interface.

4.3.2 Vehicle Ethernet Access

After completing the IP and ICOM configuration in Section 3.2, use an Ethernet cable and converter to connect the device to the computer. Establish a network connection in the network debugging tool and directly transmit differential data.

4.3.3 RTK Status

After completing the differential data connection, you can use other ICOM ports to monitor the positioning status.

Keep the network connection in section 4.3.2 unchanged. Establish a new ICOM connection (e.g., ICOM2) in the network debugging assistant, and send the command `LOG ICOM2 BESTPOSA ONTIME 1`. Find the field in the BESTPOSA message that indicates the positioning status. When the field shows `NARROW INT`, it indicates that valid differential data has been successfully received and used.

4.4 Wheel speed access

After the integrated navigation receiver accesses the vehicle's wheel speed data, it can effectively assist the system in dead reckoning when satellite signals are severely blocked or unavailable, improving the precision of the integrated navigation in environments with poor satellite signals. The integrated navigation generally uses

CAN/CAN FD to access the vehicle's wheel speed signal. Before accessing the wheel speed, please ensure that the CAN/CAN FD bus and the rear axle lever arm configuration have been completed as per [sections 3.4](#) and [3.9](#).

The wheel speed update frequency is typically required to be no less than 20Hz (recommended to be no less than 50Hz), with accuracy better than 0.1m/s (recommended better than 0.01m/s), resolution lower than 0.02m/s, and delay no greater than 10ms. The device does not have a built-in terminal matching resistor, so a matching resistor must be used at the connection end.

After the wheel speed is connected, you can use the RAWDMI command to verify if the device has received the wheel speed information. The specific method is to send the command `LOG RAWDMIA ONNEW` via serial or Ethernet. If the RAWDMIA message is continuously received, it indicates that the device has successfully received the wheel speed information.

4.5 Real-Time Operation

At this point, you can use commands to configure the device to output position, attitude, and other information. During real-time operation, please note the following points:

1. Please ensure that the device is in an environment where satellite signals can be properly received. When satellite signals cannot be received, raw IMU data will not be output by default. If the signal quality is poor, the corresponding position and attitude information may not meet operational requirements;
2. INS navigation information and GNSS navigation information can be obtained independently. Integrated navigation information is typically output via INS-related messages.

4.6 System Alignment

The process by which the integrated navigation system obtains estimates of position,

velocity, and attitude to complete system initialization is called system alignment. After the M20 X is powered on, the system will perform alignment internally according to the following procedure:

1. After the device is powered on, it enters the inactive state, i.e., INS INACTIVE state;
2. When satellite signal reception is good, from the moment the first satellite is acquired and tracked until a sufficient number of satellites are tracked to calculate the position, the device will be in the WAITING INITIALPOS state, until a reliable position solution is obtained;
3. If an accurate position solution is already available, the device will enter the WAITING AZIMUTH state, waiting for the external determination of the vehicle's azimuth;
4. Before official navigation begins, the device must travel in a straight line with a sufficiently high speed for a period of time to complete coarse alignment. During this process, the device will be in the INS ALIGNING state. Once coarse alignment is complete, it will enter the INS ALIGNMENT COMPLETE state;
5. When dual antennas are connected and the dual antenna installation angle is correctly configured, the device supports static initialization, allowing coarse alignment for integrated navigation to be completed without meeting dynamic movement requirements;
6. The RTK results are used to continuously refine the alignment. Once the vehicle has completed several sharp turns and the accuracy successfully converges, the alignment is completed, and the system enters the fine alignment mode, namely the INS SOLUTION GOOD state;
7. When the estimated variance of accuracy is large, the system will enter the INS HIGH VARIANCE state. When GNSS navigation results are unavailable, it will enter the INS SOLUTION FREE state. Table 4-2 summarizes and describes the above

navigation states, which can be monitored through INS-related messages such as INSPVAX.

Table 4-2 Inertial Navigation States

State Identifier	Description
INACTIVE	IMU logs exist, but the alignment procedure has not started; INS is in an inactive state.
ALIGNING	INS is in alignment mode.
HIGH_VARIANCE	INS is in an abnormal state due to high variance.
SOLUTION_GOOD	INS is in navigation mode with good solution.
SOLUTION_FREE	INS filter is in navigation mode, but GNSS contains errors.
ALIGNMENT_COMPLETE	INS filter is in navigation mode, but vehicle dynamics are insufficient to keep the system within specification.
DETERMINING_ORIENTATION	INS is determining the IMU axes aligned with the direction of gravity.
WAITING_INITIAL_POS	INS filter has determined the IMU orientation and is waiting for initial position estimation to begin the alignment process.
WAITING_AZIMUTH	INS filter has determined orientation, initial biases, initial position, and valid roll and pitch estimates. It will not proceed without azimuth.
INITIALIZING_BIASES	During the first 10 seconds of static data, the INS filter is estimating initial biases.

The pure GNSS solution results are provided only through GNSS-related messages, such as BESTGNSSPOS and BESTGNSSVEL. When the integrated navigation algorithm is operating normally, non-INS messages support a maximum output rate of 5 Hz, while INS-related messages support a maximum output rate of 100 Hz (or 200 Hz if optional configuration is enabled).

When outputting high-frequency INS-related messages, the data volume is large. To ensure data integrity, it is recommended to use the Ethernet port to transmit messages in binary format. If using a serial port for transmission, it is recommended to set the serial port baud rate to 921600.

The commonly used integrated navigation messages are shown in Table 4-3:

Table 4-3 Integrated Navigation Related Messages

Category	Related Information
Position	INSPOS, INSPVAX
Speed	INSVEL, INSSPD, INSPVA
Attitude	INSATT, INSPVAX
Solution Confidence	INSSTDEV

4.7 Online Calibration

After the device completes the initial installation and configuration of parameters such as RBV, antenna lever arm, and dual antenna installation angle, the online calibration function can be used to estimate more accurate parameters, thereby improving the accuracy of the integrated navigation results.

The online calibration parameters are as follows: 1. RBV parameters; 2. Antenna lever arm parameters; 3. Dual antenna installation angle parameters (optional); 4. Wheel speed error parameters (optional). Among these, the dual antenna installation angle

parameters and wheel speed parameters require input of corresponding observation values.

The online calibration process is as follows:

1. Power on the device, send the calibration parameter reset command, and clear the existing parameters:

ClearDrClbParam

2. Send the device reboot command and wait for the device to complete the reboot;
3. Refer to the alignment procedure in Section 4.6 to complete the device alignment;
4. Keep the vehicle moving at a steady speed (recommended above 5 m/s, not lower than 1 m/s) for 5 to 10 minutes. The recommended route is shown in Figure 4-1. If it is not possible to follow a figure-eight path, ensure that during the online calibration process, the vehicle's movement includes both straight-line driving and turning;
5. The online calibration status can be queried using a command:

Set Calib State on/off

6. After the command is sent, the serial port will continuously output the online calibration status of each parameter:

\$CALIB,454230.210,RBV,1,LeverArm,0,HeadingDiff,1,Odom,0

Among them, RBV/LeverArm/HeadingDiff/Odom corresponds to the RBV parameter, antenna lever arm parameter, dual antenna installation angle parameter, and wheel speed error parameter, respectively. A status of 0 indicates that calibration is in progress, while a status of 1 indicates that calibration is complete.

7. Each time the device is powered on, it will read the calibration status and parameters. If the corresponding parameters have been calibrated, it will automatically configure the parameters after calibration.

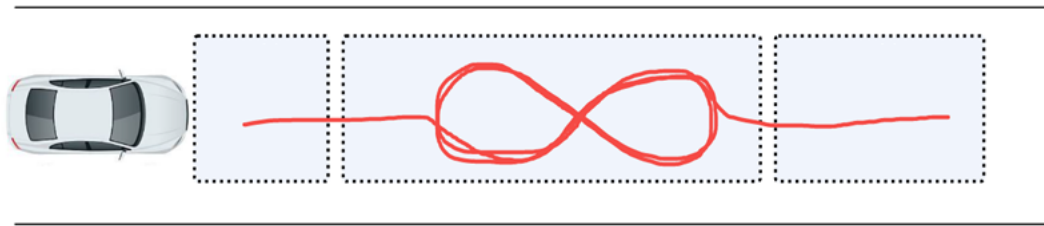


Figure 4-2 Recommended Route for Online Calibration

4.8 Data Post-Processing

The raw data output by the M20 X can be processed using professional software. The post-processing software, through bidirectional calculation and smoothing, can provide more accurate positioning results afterward, which can serve as the test benchmark. For the M20 X performance parameters, please refer to Appendix B.

4.9 Firmware Upgrade

Due to continuous product iteration and optimization, firmware upgrades may be required. The firmware upgrade package can be downloaded from our company's official website. For the firmware upgrade method, please refer to the "Firmware Upgrade Instructions."

Appendix A: Product Dimensions Diagram

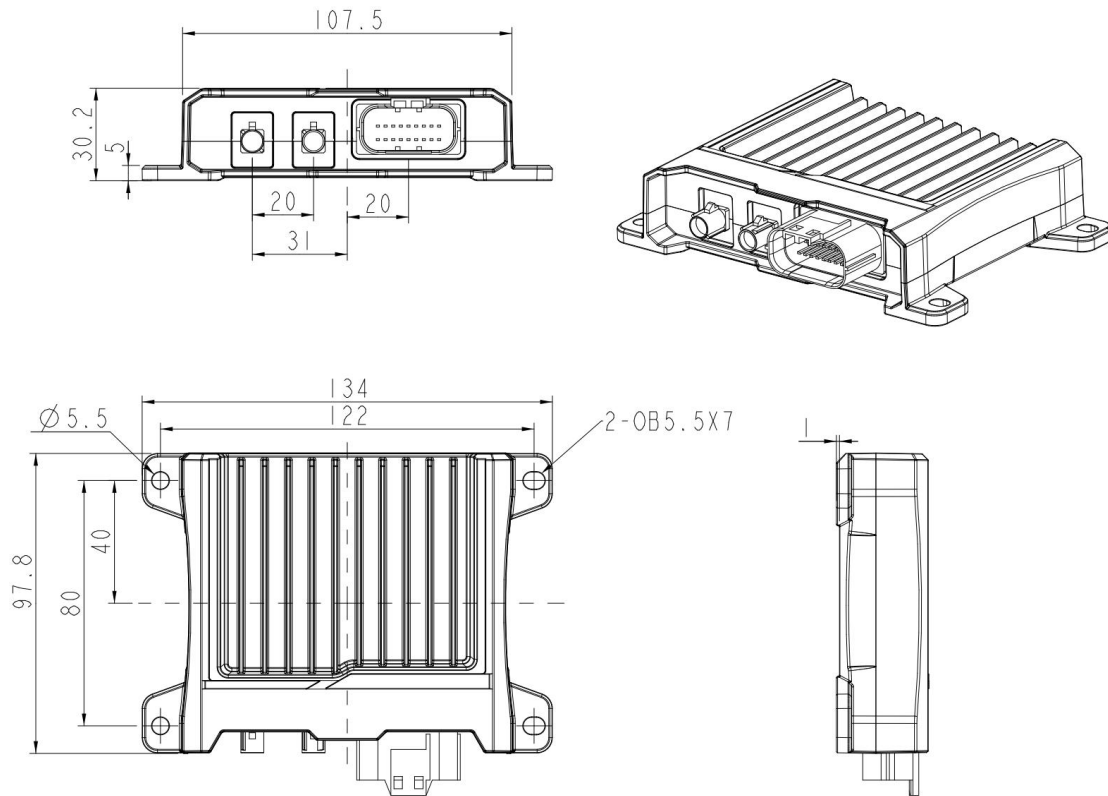


Figure A-1 Product Dimensions Diagram

Appendix B: Parameter Description

B.1 Parameter Description for M20 X GNSS/INS Receiver

Signal Tracking	
GPS	L1C/A, L2P, L2C, L5, L1C*
BDS	B1I, B1C*, B2I, B2a, B2b*, B3I
GLO	G1, G2, G3*
GAL	E1, E5b, E5a, E5 AltBoC*, E6C*
QZSS*	L1C/A, L2C, L5, L1C*
SBAS*	L1C/A, L5
IRNSS*	L5

Performance Specifications	
Cold Start	< 20s
Hot Start	< 10s
Signal Reacquisition	< 1s
RTK Initialization Time	5s
Initialization Reliability	99.90%
PPP Convergence Time	20min
Time Accuracy	20ns
Velocity Accuracy	0.02 m/s
Heading Accuracy	0.15°/R

Positioning Specifications	
Standalone	1.5m Horizontal 3m Vertical
Single Baseline RTK	8 mm + 1 ppm Horizontal 15 mm + 1 ppm Vertical
PPP	0.1m Horizontal 0.2m Vertical

IMU	
Gyro ⁴	
Range	±300°/s
Zero Bias	0.1°/s
Repeatability	
Zero Bias Over	0.3°/s
Temperature	
Zero Bias Stability	1.8°/h (XY) 1.4°/h (Z)
Angular Random Walk	0.09°/√h(XY) 0.10°/√h(Z)
Accelerometer ⁴	
Range	±300°/s
Zero Bias	0.1°/s
Repeatability	
Zero Bias Over	0.3°/s
Temperature	
Zero Bias Stability	1.8°/h (XY) 1.4°/h (Z)
Angular Random Walk	0.09°/√h(XY) 0.10°/√h(Z)

Integrated Navigation	
Loss of Lock Horizontal Position Drift	±1% @1km/60s ²
Loss of Lock Heading Drift	0.15°@60s
Fix Recovery Time	≤5s
Data Rate	GNSS Raw Observation: 5Hz RTK Positioning: 5Hz GNSS+INS Positioning: 100Hz (200Hz Optional) IMU Raw Data Rate: 100Hz(200Hz Optional)

Data Format	
NMEA-0183	GPGGA, GPGSV, GPGLL, GPGSA, GPGST, GPHDT, GPRMC, GPVTG, GPZDA
Custom ASCII Format	INSPVA, INSPVAX, BESTPOS
RTCM3.X	1004-1008, 1012, 1019, 1020, 1033, 1042, 1045/1046, 1230
MSM3-MSM7	1073-1077, 1083-1087, 1123-1127, 1093-1097

Communication	
External Interface	On-board Ethernet*1, CAN/CAN FD*2, RS232 serial port*2, PPS*1
Antenna Interface	2*GNSS antenna interface (Fakra-A, Fakra-C)

Electrical	
Input Voltage	5V-32V
Power Consumption	3W

Environmental	
Working Temperature	40 °C to + 85 °C
Storage Temperature	-55 °C to + 95 °C
Humidity	100% non-condensing
Waterproof	IEC 60529 IPX2
Dustproof	IEC 60529 IP5X
Vibration	JESD22-B103

Physical	
Size (L × W × H)	134mm×98mm×30.2mm
Weight	374±20g

Antenna Interface	
Impedance Matching	50Ω
LNA Power: External	+3.3V@(0-100) mA
LNA Gain	20 - 35dB

Figure B-1 M20 X performance parameters

B.2 GNSS Antenna Specifications

M20 X should use an active antenna. The M20 X can provide 5V DC antenna power, supporting a maximum current of 100mA. The following parameters are for reference:

1. Frequency Range: Should cover all frequency bands: GPS (L1/L2/L5), GLONASS (G1/G2), BDS (B1/B2/B3), Galileo (E1/E5a/E5b).
2. Gain: 20 ~ 35 dB.
3. Noise Figure (NF): Less than 1.5.
4. Phase Center Deviation: Less than ± 2 mm.

B.3 RF Coaxial Cable Specifications

The antenna RF coaxial cable should match the impedance of the antenna and receiver, with a characteristic impedance of 50 Ω . It is recommended that the cable attenuation be less than 10dB.

Appendix C: Description of Commonly Used Coordinate Systems

C.1 Definition of Commonly Used Coordinate Systems in a Combined Navigation System

In a combined navigation system, the commonly used coordinate systems include the local navigation coordinate system, the vehicle coordinate system, the body coordinate system, and the user-defined coordinate system.

C.1.1 Local Navigation Coordinate System:

The Local Navigation Coordinate System, also known as the NED (North-East-Down) coordinate system, is defined as follows:

N-axis: Points towards the North (in the plane perpendicular to the D-axis, from the user's direction pointing towards the North Pole).

E-axis: Points towards the East (the right-hand orthogonal axis derived from the N-axis and D-axis).

D-axis: Points downward (in the direction of the reference ellipsoid's normal).

The origin of the local navigation coordinate system is the navigation center marked on the overall body casing of the system.

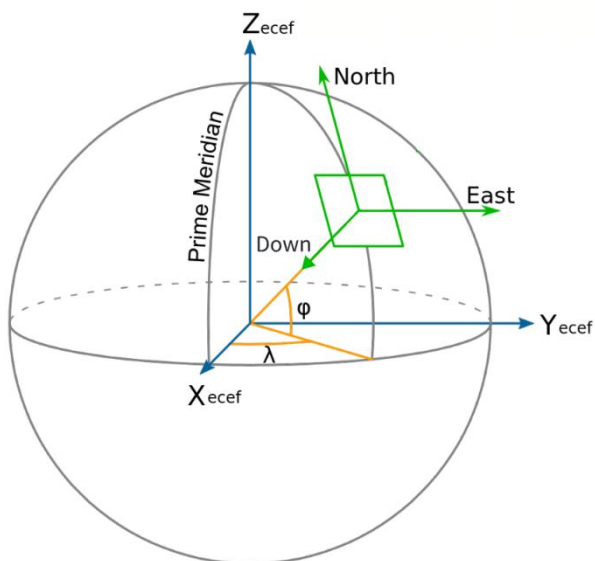


Figure C-1 Local Navigation Coordinate System

C.1.2 Device Coordinate System

The origin and axis directions of the device coordinate system are marked on the device casing, with the navigation center serving as the origin of the coordinate system.

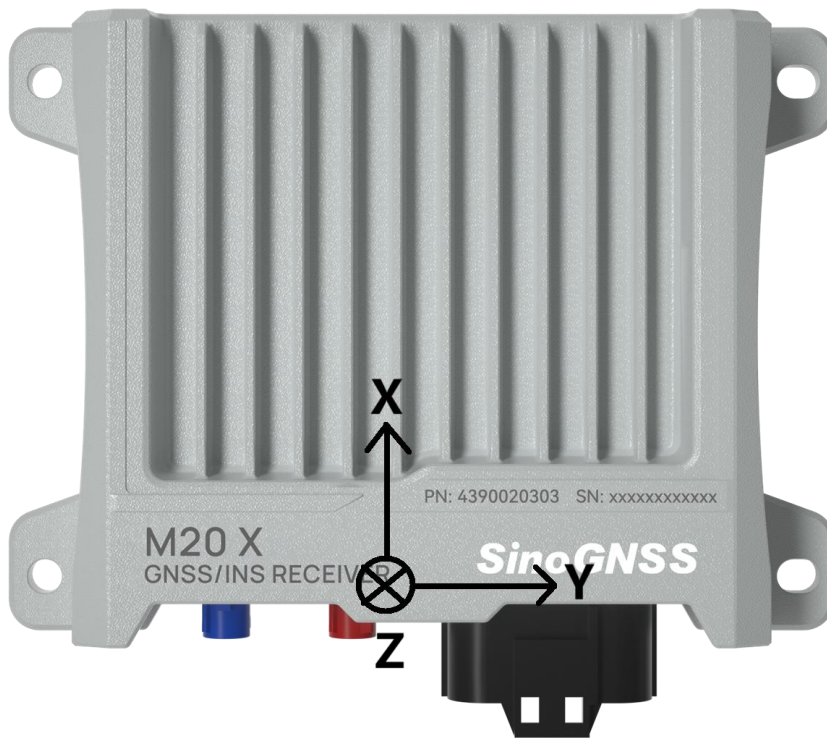


Figure C-2 Device Coordinate System

C.1.3 Vehicle Coordinate System

The origin of the vehicle coordinate system is the navigation center marked on the main device housing.

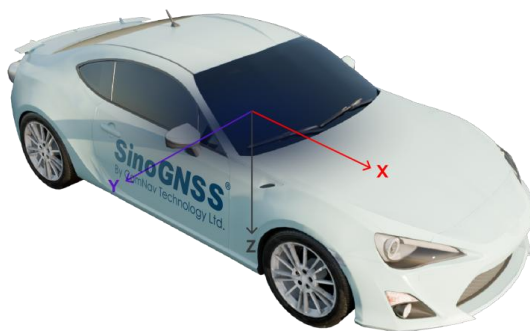


Figure C-3 Vehicle Coordinate System

The axis definitions of the vehicle coordinate system are as follows:

Z-axis: Perpendicular to the vehicle floor, pointing downward toward the bottom of the vehicle

X-axis: Pointing in the forward driving direction of the vehicle

Y-axis: An orthogonal axis derived from the X and Z axes, forming a right-handed coordinate system

If using a land vehicle model, please strictly configure the antenna lever arm and rotation parameters according to this vehicle coordinate system.

C.1.4 User-Defined Coordinate System

A coordinate system whose origin is specified by the user is called a user-defined coordinate system. By default, the device outputs the position and velocity information of the navigation center (i.e., the origin of the device coordinate system). You can use the `setleverarm user` command with a specified coordinate offset to set the origin of the coordinate system to any desired point.

By default, the device outputs the attitude as the rotation angles from the local navigation coordinate system (NED) to the device coordinate system. You can use the `SETINSROTATION` command with a specified RBV to set the attitude information as the rotation angles from the local navigation coordinate system to another coordinate system.