X1 Combined Navigation System

USER MANUAL

Description

This document is applicable to the X1 high precision receiver.

No: UG015	Ver.: V1.0	Date: 2024.12.2

CONTENTS

1 X1 OVERVIEW

X1 is a highly integrated and rugged IMU-enhanced GNSS receiver with the following technical features:

- Deeply coupled GNSS+INS navigation engine
- Built-in Bynav GNSS high precision positioning and heading board
- Built-in tactical grade IMU module
- Enhanced connection options including serial, CAN and Ethernet
- Multi-vector RTK positioning engine
- Support full-constellation, multi-frequency RTK positioning and heading
- Support modern signal systems such as BDS-3 and Galileo
- Support GNSS/IMU raw data output and post processing
- Low latency

Besides, X1 also has the following features:

DEEPLY COUPLED NAVIGATION ENGINE

Empowered with deeply coupled GNSS/INS navigation engine, X1 fuses deeply the IMU and RTK solution and observation pre-processing, providing real-time high-precision navigation results such as position, velocity and 3D attitude.

DUAL ANTENNA POSITIONING AND HEADING

The GNSS signals received by dual antennas can independently provide accurate position and attitude, further improving the robustness and availability of the GNSS/INS system.

SCALABILITY

Software scalability: customers can upgrade software firmware for free within three years; Hardware scalability: provide multiple interfaces, including Ethernet, serial, etc., also provide EVENT I/O synchronization and can work with other sensors (such as LIDAR, SLAM, etc.).

HIGH RELIABILITY

X1 can work well in demanding environments and maintain reliable and stable positioning performance for a period when satellite signals are lost or interfered.

SCENE OPTIMIZATION

Optimized for in-vehicle applications: based on vehicle characteristics modeling, it can tackle with the most challenging environments such as urban road canyon and satellite signal interference, providing continuous, stable and reliable real-time high-precision positioning services for intelligent vehicle application.

Figure 1-1 IMU-enhanced GNSS receiver X1

1.1 X1 Connectors

X1 has the following connectors:

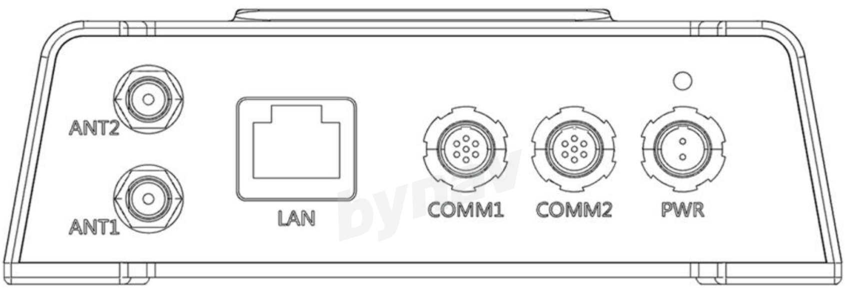
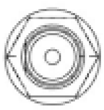
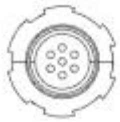


Figure 1-2 X1 Connectors

Table 1-1 X1 Connector List

Connectors	Label	Type	Description
	ANT1	SMA-K	Connect X1 to the GNSS antenna 1 (primary)
	ANT2	SMA-K	Connects X1 to the GNSS antenna 2 (secondary)

	LAN	RJ45	Connect X1 to the Ethernet, communicating with X1 by network
	COMM1	Push-pull self-locking connector	Provide access to communication signals for X1, including: Serial port COM1 (RS-232) 1 EVENT IN (3.3 V LVTTL) 1 PPS (shared pin with EVENT OUT) (3.3 V LVTTL)
	COMM2	Push-pull self-locking connector	Provide access to communication signals for X1, including: Serial port COM2 (RS-232) CAN Bus
	PWR	Push-pull self-locking connector	Connect X1 to power supply

1.2 X1 LEDs

The X1 has the listed LED to indicate status.

Table 1-2 PWR LED Status Indicator

Label	Status	Description
PWR	Green	Normal
	Green Blink	Power supply voltage is above superior limit
	Off	Power supply is off, abnormal or below inferior limit

2 X1 Installation

This chapter provides instructions regarding how to install the X1.

2.1 Preparation

2.1.1 Shipping Box

The below mentioned accessories will be provided along with the X1:

- ·Power cable (PWR)--Push-pull self-locking connector to bare wire.
- ·Communication Cable 1 (COMM1)--Push-pull self-locking connector (single location pin, COMM1) to DB9 connectors and two bare wires (EVENT I/O signal).
- ·Communication Cable 2 (COMM2)--Push-pull self-locking connector (double location pin, COMM2) to DB9 connectors and two bare wires (CAN Bus).
- Four M5 screws (for mounting X1)

Table 2-1 XI Cables included in Shipping Box

Cable	Quantity(pc)	Description
Power Cab (PWR)	1	Connect X1 to an external power supply, with push-pull self-locking connector to bare wires
Communication Cable 1 (COMM1)	1	Correspond to COMM1 interface, providing COM1 port, PPS and EVENT signal, with push-pull self-locking connector to DB9 and bare wires
Communication Cable 2 (COMM2)	1	Correspond to COMM2 interface, providing COM2 port and CAN Bus, with push-pull self-locking connector to DB9 and bare wires

2.1.2 Additional Equipment

You may need the following additional equipment to have X1 to start working (available from Bynav):

- ·A +9V ~ +32VDC, direct current power supply capable of at least 10W
- ·Two high-precision GNSS antennas, and matched RF coaxial cables (with SMA-J connecting to X1 and the other end connecting to GNSS antenna, dual-antenna work mode is recommended.)
- Ethernet cable (above CAT5e, only in case that network communication is required)

Table 2-2 X1 Optional Cables

Cable	Quantity(pc)	Description
Ethernet Cable	1	Connect to X1 Ethernet port, with RJ45 connector, above CAT5e
RF Coaxial Cable	2	Connect X1 to GNSS antenna, with SMA-J to TNC generally

2.1.3 GNSS Antenna

It is recommended to use an active antenna with typical gain 40±2 dB, and the operation frequency supporting GPS(L1/L2/L5), GLONASS(G1/G2), BDS(B1/B2), Galileo(E1/E5b), the noise coefficient is ≤2dB and output impedance is 50Ω. X1 provides 5VDC feed to antenna, which maximum supports 200mA current.

2.1.4 Coaxial Cables

You need to choose an appropriate RF coaxial cable which matches the impedance of the antenna and receiver (50Ω) and has a line loss not exceeding 10dB. The coaxial cable connects to GNSS antenna with the other end SMA-J connecting to X1.

2.1.5 Power Supply

The X1 power supply is required to be able to provide:

- A voltage in the range of +9V~+32VDC
- At least 10W of stable output power

2.2 X1 Installation

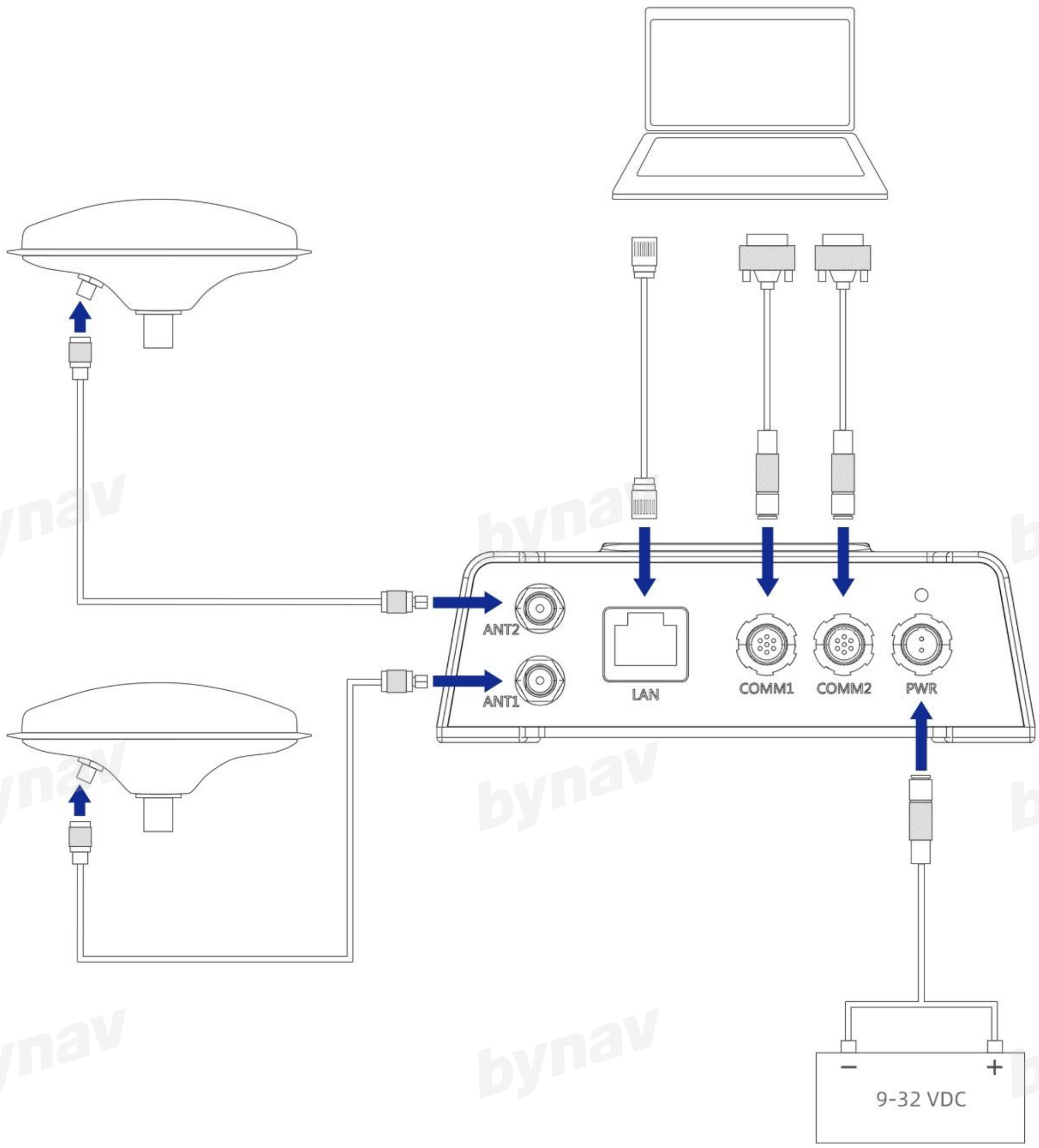


Figure 2-1 X1 Installation Overview

1. Mount the GNSS antenna (dual antennas are recommended, in case of single antenna, connect to ANT1 interface)
2. Mount X1 enclosure
3. Connect X1 to GNSS antenna using RF coaxial cable
4. Connect X1 to a computer using Ethernet cable or Serial Communication cable (on demand)
5. Connect X1 to other devices using Communication cable I/O signals (on demand)
6. Connect X1 to external power supply using Power cable

2.2.1 Mount GNSS Antenna

The X1 supports single-antenna and dual-antenna mode. Dual-antenna mode is recommended, in which the GNSS heading data can greatly increases system reliability.

When mounting the antenna, pay attention to the following:

- ·Choose a location with open sky and unobstructed view
- ·Mount the antenna on a secure and stable structure rigidly to avoid any movement due to dynamics
- ·It's recommended that the distance between the primary and secondary antennas be at least 1 meter (the longer the better)

It is recommended that the baseline (connecting line) of the GNSS dual antennas be parallel or perpendicular to the carrier travelling direction, as shown in the below.

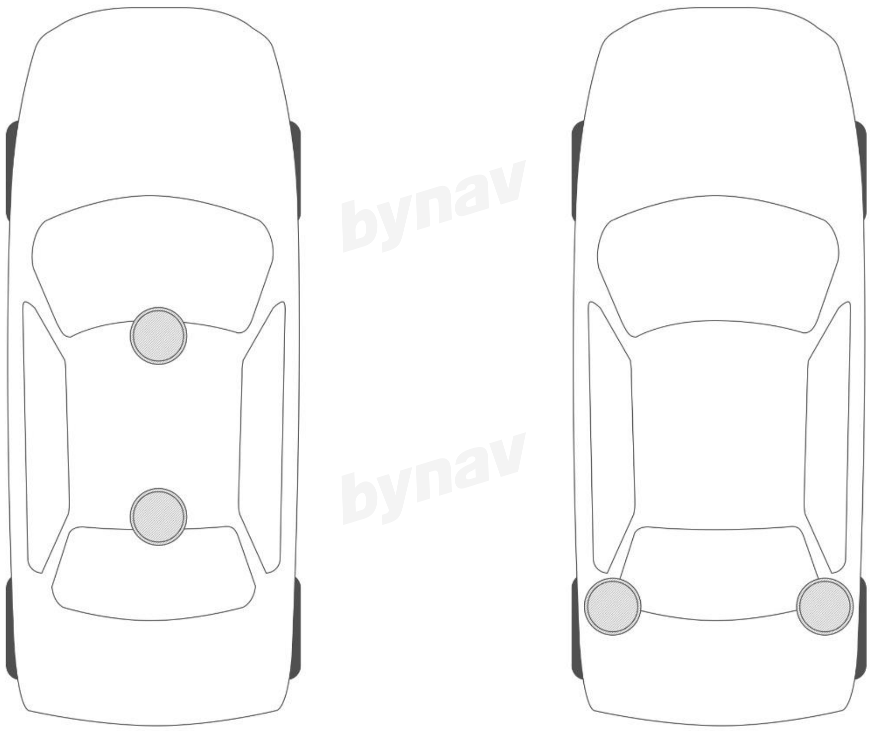


Figure 2-2 Two Recommended GNSS Antenna Installation Mode

2.2.2 Mount X1 Enlosure

The X1 must be mounted rigidly on the carrier to ensure the relative position between X1 and the antennas be fixed. Moreover, please ensure the X1 is mounted on a stable and secure surface to avoid any movement or waggle in dynamic environment. Generally it's recommended to use M5 screws to rigidly fix the X1 on the carrier.

To simplify the system configuration, it's recommended that X1 be installed close to the rear axle of the carrier and maintain a level attitude (the Z axis should point up perpendicularly from the ground), and the Y axis on the housing of X1 should point to the carrier travelling direction (as illustrated below). If it's not mounted in this way, you need to measure and configure the rotation parameter (RBV) additionally.

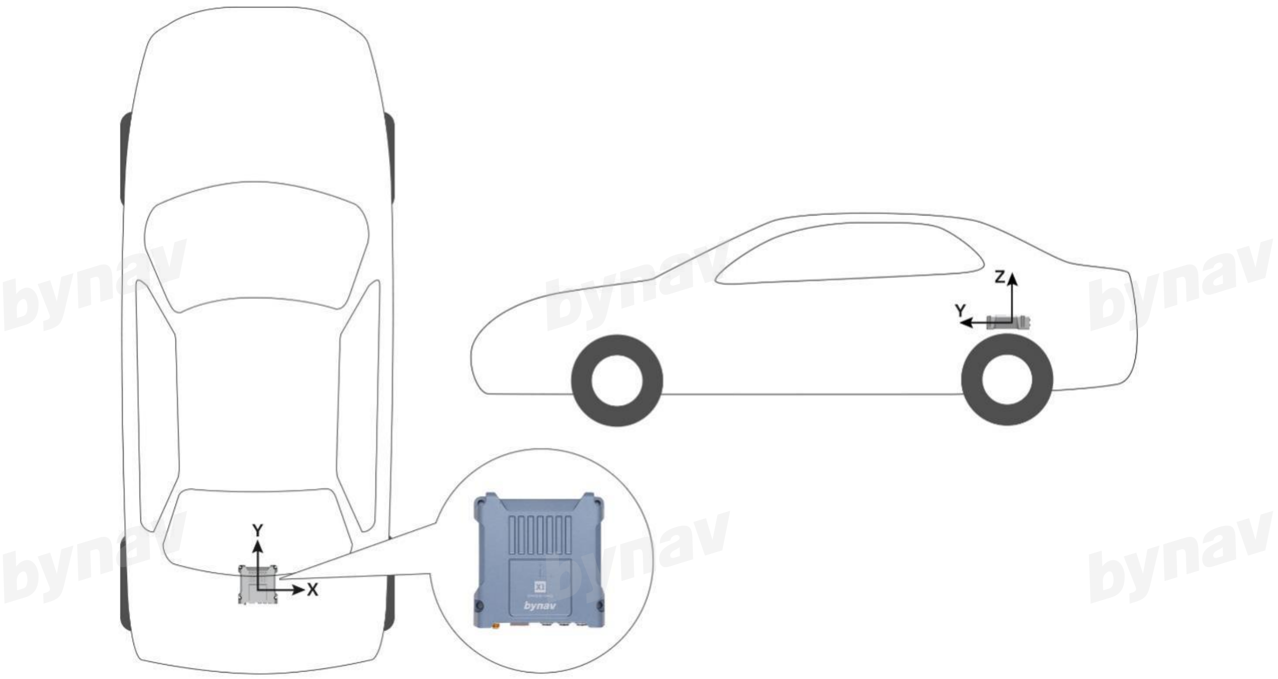


Figure 2-3 Recommended X1 Installation Mode

2.2.3 Measure the Lever Arm and Rotation Parameter (RBV)

After the X1 is mounted for the first time, you need to measure the lever arm of two GNSS antennas. It's recommended to measure it using professional survey equipment, for example, a total station or laser range finder, and later set the lever arm value into X1. To simplify the calculation of lever arm, Bynav provides a software BYOFFSET which can be downloaded for free from the official website.

If the IMU Body frame does not coincide with the Vehicle frame, accurate measurement of the rotation parameter (**RBV**- **R**otation parameter from the IMU **B**ody Frame to **V**ehicle Frame) is required. Therefore, it is strongly recommended to ensure that IMU Body frame coincides with Vehicle frame (or with a fixed angle of 90, 180, 270 degrees) to simplify RBV configuration.

Once the RBV value is set into system, a fine calibration on RBV is recommended (see the command **错误!未找到引用源。**) because manually measured RBV is often not accurate enough, and fine RBV calibration can automatically and accurately estimate rotation parameters. An accurate RBV value can improve overall system performance.

**NOTE*:*

See Appendix B, Lever Arm and RBV *for more information about frames, lever arm and RBV.*

2.2.4 Connect X1 to Data Communication Equipment

The X1 can communicate with external communication equipment using serial, Ethernet or CAN Bus.

2.2.4.1 Serial Port

The X1 provides two serial ports: COM1 and COM2. COM1 port is provided by COMM1 interface and COM2 port, by COM2 interface.

Table 2-3 X1 Serial Port Protocol

Port	RS-232	RS-422	Flow Control
COM1	Supported	Not supported	No
COM2	Supported	Not supported	No

COM1 and COM2 ports communicate under RS-232 protocol. To configure serial port, you can enter the SERIALCONFIG command.

Please Refer to 3.1.1 to understand how to configure the baud rate and parity, etc.

To connect to a serial port:

- ·You can connect the push-pull self-locking connector of the Communication Cable 1 included in the shipping box to COMM1 interface or Communication cable 2 to COMM2 interface of X1
- ·You can connect the other end DB9 connector of the cable to the computer or other communication devices
- You can see A.7 and A.8 for cable definition in details

2.2.4.2 Ethernet Port

The X1 is equipped with a RJ45 port and supports 10Base-T/100Base-Tx adaptive Ethernet, which can be used to communicate with external devices, such as computers. The Ethernet port supports IPv4 network layer and TCP/IP transmission. The user can use it to remote debug, receive correction data, output position and attitude, or upgrade firmware, etc.

Steps to connect to Ethernet network:

- You can·connect the Ethernet port of X1 to external communication devices, such as computers using Ethernet cable

Please refer to Chapter 4 for detailed Ethernet configuration.

2.2.4.3 CAN Bus

The X1 is equipped with CAN Bus port available on the COMM2 interface.

To connect to the CAN Bus:

- You can·connect push-pull self-locking connector of Communication cable 2 included in the shipping box to COMM2 interface of X1
- You can·connect the other end Bare Wire of Communication cable 2 to the external CAN Bus

2.2.5 Connect I/O Signals to X1 (Optional)

X1 provides EVENT IN, EVENT OUT and PPS as synchronization signals, in which the PPS signal and EVENT OUT signal share the same pin provided by COMM1.

To access the I/O signals:

- You can·connect push-pull self-locking connector of Communication cable 1 included in shipping box to COMM1 interface of X1
- You can·connect the other end EVENT_IN or PPS of the Communication cable 1 to user's I/O device, as well as connect the GND signal to user's device ground wire

See 6 for the I/O signals configuration.

2.2.6 Connect Odometer to X1 (Optional)

The X1 can be connected to an odometer to improve the positioning accuracy when the satellite signal is lost.

The X1 supports odometer inputs in two ways. The first is to transmit the vehicle speed data (usually read from OBD) directly to X1 through the communication port. Refer to the *UG017_ Interface Protocol* for more details. The second is to connect to a pulse odometer, which needs to connect the pulse signal to the EVENT_IN pin of X1.

2.2.7 Connect Power to X1

To connect power to the X1:

- You can·connect push-pull self-locking connector of power cable included in shipping box to the PWR interface of X1
- You can·connect the other end Bare Wire of power cable to a +9V~+32VDC power supply

*WARNING:

You should connect the +VIN marked bare wire to the positive pole of the power supply, and the -VIN marked bare wire to the negative pole. Do not reverse.

2.2.8 Check X1 Status

After the X1 is installed, power it on. At this moment you need to confirm X1 system is operating correctly:

- ·You can check that the PWR LED is solid green
- ·You can send the command **LOG VERSION**, and X1 will return the following message:

$BDVER, 19082190, 19091214, 19092628, 19091022,, *45

The bolded text demonstrates X1 firmware version, and the version number you received from the message may not be the same. This message indicates that X1 has successfully started working.

2.2.9 X1 Self-check (Optional)

Under standard installation mode, X1 can self-check the correctness of the parameter configuration and prompt the parameters that may be wrong. Please refer to the *UG017_ Interface Protocol* for more details.

3 Configuration

Before starting X1 configuration, make sure you have installed X1 as described in Chapter 2 and powered it on.

3.1 X1 Communication Methods

X1 can establish communication with external devices by the following methods:

- Serial Port Communications refer to 3.1.1
- Ethernet Port Communications refer to 3.1.2
- CAN Bus Communications, refer to UG008_CAN_Protocol

When the communication is established, you can send commands to configure X1 system.

To maximize the application of X1 capabilities, please refer to *UG017_Interface Protocol* and Appendix C for more commands decription.

3.1.1 Serial Port Communication

The X1 can communicate with a computer or other devices via serial port. Before establishing the communication, both the X1 and computer must be configured properly. The X1's default port settings are:

·115200 bps

·no parity

·8 data bits

·1 stop bit

Both COM1 and COM2 ports support to be configured using the commands. Refer to UG016_X1_A1_C1_Interface Protocol for more commands.

Table 3-1 X1 Supported Serial Ports

Receiver	Supported Ports	Configuration Command
X1	COM1，COM2	SERIALCONFIG

3.1.1.1 Change Serial Configuration

You can enter **SERIALCONFIG** command to change the configuration of a certain serial port:

·To change the data rate of COM2 to 115200, you can enter:

SERIALCONFIG COM2 115200

·To change the data rate of COM1 to 921600 and enable even parity, you can enter:

SERIALCONFIG COM1 921600 E

3.1.1.2 Communicate using a Remote Terminal

X1 supports communicating with a remote terminal via serial port. Use any standard communications software that emulates a terminal to establish bidirectional communications with the X1 serial ports. Before establishing the communications, ensure the serial configuration of the terminal matches with the X1. A computer can emulate a remote terminal to store data logging files.

3.1.2 Ethernet Port Communication

The Ethernet port must be configured before using, refer to the Chapter 4 for detailed configuration.

3.1.3 ICOM Communication

ICOM port is a virtual port used for Ethernet connection. It can be understood as an application layer protocol of the TCP/IP protocol suite. ICOM's transmission control layer protocol can use TCP or UDP.

You can enter **DNSCONFIG** command to configure Ethernet DNS. If using DHCP, DNS will be automatically configured.

Default ICOM configurations are as below（Output ICOM configuration by entering **LOG ICOMCONFIG**）:

·ICOMCONFIG ICOM1 TCP :1111

·ICOMCONFIG ICOM2 TCP :2222

·ICOMCONFIG ICOM3 TCP :3333

·ICOMCONFIG ICOM4 TCP :4444

Each ICOM port can be used as a server (waiting to be connected by external device) or as a client (actively connecting to a certain port of the server).

For more ICOM configuration commands, such as **IPCONFIG, ICOMCONFIG** etc. refer to Appendix C.

3.1.4 CAN Bus Communication

X1 is equipped with one CAN Bus, which supports maximum data rate up to 1 Mbps. For CAN Bus protocol refer to *UG009 CAN Protocol*.

3.2 Starting Communication

None of the ports have data transmission when powered on for the first time, they are all in a status that wait for commands.

In case of communicating with X1 through COM1, you can enter:

LOG COMCONFIG

The X1 returns the messages:

<OK

[COM1]

COM1 115200 N 8 1 IN: AUTO OUT: AUTO

COM2 115200 N 8 1 IN: AUTO OUT: AUTO

The returned messages show the serial port configuration that you queried by commands. The first line shows the command is recognized and executed correctly; the second line shows that the communication port you are using is COM1; the third line shows the COM1 port output data in AUTO format; the fourth line shows the COM2 port output data in AUTO format.

If the command is not recognized or executed correctly, it will return:

<ERROR

3.3 System Configuration

When you **use X1 for the first time,** you need to input some commands to configure the system. The following command is required to be sent (refer to Appendix A-2 for navigation center definition, and refer to Appendix C for detailed command description):

Table 3-2 X1 Configuration for First Use

Configuration	Command	Comments
Lever arm from X1 navigation center to antenna1	SETINSTRANSLATION ANT1	The Vehicle frame (unit:m)
Lever arm from X1 navigation center to antenna2	SETINSTRANSLATION ANT2	The Vehicle frame (unit:m)
Rotational offset from IMU **B**ody Frame to **V**ehicle Frame	SETINSROTATION RBV	Unit: degree
Offset from X1 navigation center to user-defined output point	SETINSRANSLATION USER	Optional, by default output position of X1 navigation center
Minimum alignment velocity	SETALIGNMENTVEL	Optional, default 2 m/s, inferior limit 1 m/s

Please see Appendix B for details of lever arm and RBV, which must be measured accurately before use. The measurement accuracy of the antenna lever arm should be better than 3cm and for RBV it should be better than 5 degrees, after the first installation it will run automatic RBV calibration to have the accuracy within 0.1 degrees.

*Note:

- After the configuration, you must send the SAVECONFIG command to save the parameters. Otherwise, you'll need to re-configure as the parameters will be lost when X1 is powered off.
- When you reinstall the X1 or move the antenna, you need to re-measure the lever arm and RBV, and then re-configure X1 system.

3.4 Receiving Correction Data

The correction data is transmitted from base station to rover station to improve positioning accuracy under RTCM protocol (RTCM 3.X). The base station is a GNSS receiver with a fixed position that is already known and is configured to transmit correction data to the rover.

In this case X1 is the rover station whose position is unknown yet, so it needs to acquire the correction data continuously from the base station to calculate the current position.

You can build your own base station or rent a commercial one. Either way, a data link is needed to transmit correction data from the base station to the rover, usually by radio, mobile communication network, etc. Refer to the *AN087_RTCM via Network for Base and Rover Configuration Guide_Bynav* to see how to build a base station and establish a data link.

3.4.1 X1 Rover Station Configuration

The following three commands are used to configure the rover:

SERIALCONFIG [port] baud [parity [databits [stopbits]]

// configure serial port parameter

INTERFACEMODE port rx_type tx_type

// configure input and output data type

SAVECONFIG

// save configuration

For example, configure COM1 to receive correction data:

SERIALCONFIG COM1 115200 N 8 1

// configure COM1 with data rate 115200, no parity, 8 data bits, 1 stop bit

INTERFACEMODE COM1 AUTO AUTO

// configure COM1 input in AUTO format, no output

SAVECONFIG

// save configuration

*Note:

·If you use the INTERFACEMODE command to change the input format from the default AUTO format to other formats (such as RTCM), then the commands in BYNAV format will not be recognized or executed. You need to use the INTERFACEMODE command again to change the input data into AUTO or BYNAV format.

3.5 Real Time Operation

Once X1 is configured in accordance with section 3.3 and 3.4, you can then enter commands to configure the X1 position and attitude message output.

Keep the following items in mind:

- ·By default, raw data will be output as soon as the IMU is powered on, but the IMU data cannot be used until the error is accurately estimated, which is usually completed with GNSS data. Therefore, please ensure that X1 is in an open and unobstructed location when it is powered on.

- ·The IMU data and GNSS data are calculated separately. X1 can output GNSS data even when the GNSS+INS algorithm is not working, and the GNSS+INS integrated data is generally output through INS related messages, refer to Appendix C for details.

The INS related messages can monitor INS status. See the status in the following table:

Table 3-3 INS Status

Status Marking	Description
INS_INACTIVE	Alignment not activated
WAITING_INITIALPOS	Waiting for position
WAITING_AZIMUTH	Waiting for Azimuth
INS_ALIGNING	In coarse alignment
INS_ALIGNMENT_COMPLETE	Coarse alignment completed
INS_HIGH_VARIANCE	High covariance Attitude estimation not converged
INS_SOLUTION_GOOD	Alignment completed with good results
INS_SOLUTION_FREE	Poor satellite signals not available

3.5.1 System Alignment

An initial position, velocity and attitude estimated values are required to activate the navigation system. This process is called system alignment. When X1 is powered on, the system will be aligned in the following stages:

- ·X1 enters the inactive status after powered-on, i.e. the INS_INACTIVE status;
- ·Ensure that the satellite signal is good, X1 will remain in the WAITING_INITIALPOS status from capturing the first satellite until receiving enough satellites signals to get good position solution;
- ·Once getting the precise position, X1 switches to the WAITING_AZIMUTH status waiting for carrier's azimuth, at that moment, a rough estimation of the attitude can be achieved by carrier movement, dual antenna heading, etc.
- ·Then before starting navigation, XI is in the INS_ALIGNING status during the period in which the carrier must first go straight with sufficient speed to complete the coarse alignment or get stable dual antenna heading. Once the coarse alignment is completed, the X1 then enters

INS_ALIGNMENT_COMPLETE status.

- ·After that. X1 enters the fine alignment stage. The alignment result is continuously corrected by the RTK result. When the carrier performs several large turns, the accuracy is successfully converged to complete the alignment, and finally X1 enters the navigation mode, i.e. the INS_SOLUTION_GOOD status;
- ·When the variance of the accuracy estimation is large, it will enter the INS_HIGH_VARIANCE status; when the satellite signals are poor and unavailable, it will enter the INS_SOLUTION_FREE status.

*Note:
The above INS status is shown in the INS related messages.

3.5.2 Data Collection

Once X1 enters the navigation mode, you can configure the output messages to get navigation data. The GNSS/INS data is generally output by the INS related messages, below shows the commonly used messages:

Table 3-4 GNSS/INS -Related Messages

Classification	Related Messages
Position	INSPOS INSPVA
Velocity	INSVEL INSSPD INSPVA
Attitude	INSATT INSPVA
Solution Reliability	INSSTDEV

Comment: INSPVA message includes position, velocity and attitude at the same time.

GNSS data is only provided by GNSS related messages, such as RTKPOS and RTKVEL. When the GNSS/INS integrated navigation algorithm is working normally, the non-INS related messages only support maximum 5Hz output, while the maximum data rate of the INS related messages is the same as the IMU data rate.

*Note:
When outputting INS related messages at high rate, as the data is large, it is better to output in binary format and use the Ethernet Port for data transmission to ensure the data integrity. If using serial port, you need to configure the serial baudrate as 921600 using SERIALCONFIG. Refer to *UG017_Interface Protocol* for more details.

3.6 Post Processing

X1 supports raw data post processing using professional software such as Waypoint Inertial Explorer, through the software's bi-directional solution and smoothing, you will get more accurate positioning results which can be used as a test benchmark. (See the specification in A.1).

bynav bynav bynav bynav bynav bynav bynav bynav bynav

4 Ethernet Configuration

This chapter describes how to configure the Ethernet port. Before connecting to X1 by Ethernet, you'll need to configure the Ethernet port of X1 through serial ports. Refer to the section 3.1.1 for serial ports communication.

4.1 Static IP Address Configuration

Both X1 and the computer need to be assigned a unique IP address, which is typically used in a test environment. After IP address is configured, connect X1 and computer using the Ethernet cable as illustrated below. You can test the Ethernet port by turning on the Network Test Tool on the computer.

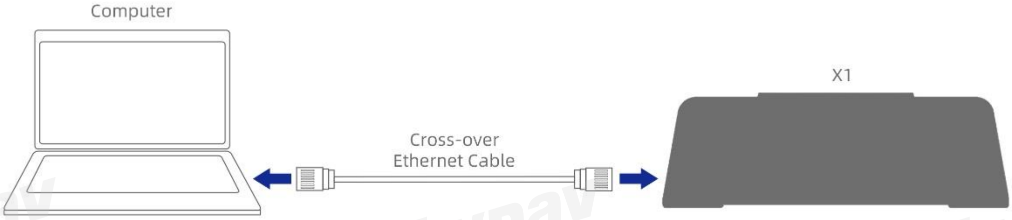


Figure 4-1 Connect X1 to a Computer Using Ethernet Cable

4.1.1 Configure Static IP Address -Computer (Windows 7)

Follow the below steps to set up computer static IP Address:

- ·Click Start->Control Panel
- ·Click Network and Sharing Center
- ·Click Change Adapter Settings, and the Local Connection window appears
- ·Right Click Properties button, and the Local Connection Properties window appears
- ·Choose Internet Protocol Version 4 (TCP/IPv4), and then click Properties button, and the Properties window appears
- Click Use the Following IP Address, then enter IP address, Subnet mask and default Gateway.

*Reminder:

- Ensure the Ethernet settings of your computer matches those of X1, for example, configure:

IP address = 192.168.1.11

Subnet mask = 255.255.255.0

Gateway = 192.168.1.1

- Click the OK button, and the Local Connection Properties window appears.
- Click the Close button, and the Local Connection window appears
- Click the Close button
- Confirm the Setup is completed

4.1.2 Configure Static IP Address -X1

By default, the IP configuration of X1 is:

IP: 192.168.8.151

Subnet mask: 255.255.0.0

Gateway: 192.168.8.1

The configuration steps are the following:

- ·Connect X1 to the computer using the Communication cable 1 or 2 included in the shipping box
- · Establish a connection with X1 using Serial Port Debugging Software in order to send commands to X1
- ·Assign the TCP/IP port number needed for connection by entering:
- ICOMCONFIG ICOM1 TCP :2000（*A space is required after 'TCP'）
- ·Assign the IP address, Subnet mask and Gateway by entering:
- IPCONFIG ETHA STATIC 192.168.1.10 255.255.255.0 192.168.1.1
- *Reminder:
- This command configures the following value to X1:
- IP address = 192.168.1.10
- Subnet mask = 255.255.255.0
- Gateway = 192.168.1.1
- ·Save Ethernet configuration:
- SAVECONFIG
- ·Output TCP/IP configuration:
- LOG IPCONFIG
- Configure the static IP address of your computer, refer to the section 4.1.2

4.1.3 Complete Ethernet Setup

- Connect the X1 to the computer using Ethernet Cable
- Connect to X1 using any third-party terminal program that supports TCP/IP

4.2 Dynamic IP Address Configuration

The dynamic IP address is generally used in formal environment, connect X1 to the computer through DHCP server, as illustrated in following Figure:

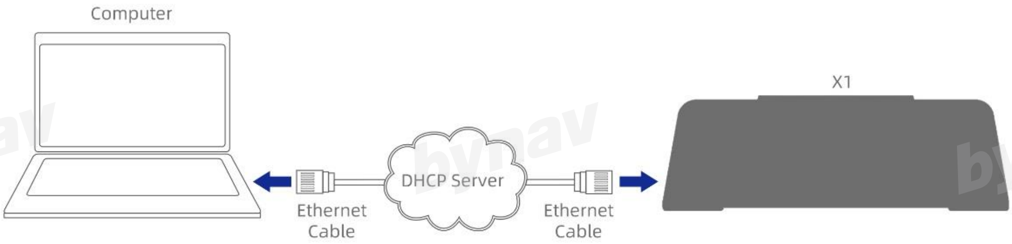


Figure 4-2 Connect a Computer to X1 by DHCP server

To set up a dynamic IP address:

- ·Connect X1 to a computer using the Communication Cable 1 or 2 included in the shipping box
- ·Establish a connection with X1 using Serial Port Debugging Software in order to send commands to X1
- ·Get the dynamic IP address from DHCP server by entering

IPCONFIG ETHA DHCP

- ·Assign the TCP/IP port number by entering:

ICOMCONFIG ICOM1 TCP :2000（*A space is required after ‘TCP’）

- ·Output TCP/IP configuration:

LOG IPCONFIG

- ·Save configuration:

SAVECONFIG

- ·Output ICOM configuration

LOG ICOMCONFIG

4.3 Accessing Correction Data by Ethernet port

X1 can access correction data using an Ethernet connection.

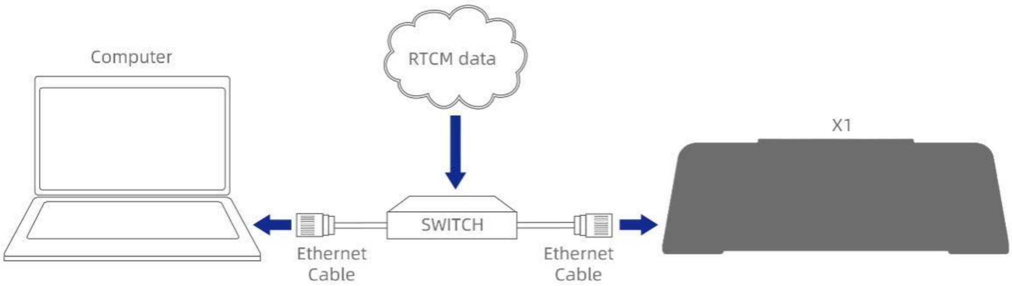


Figure 4-3 Accessing Correction Data from Ethernet Port

- ·Connect X1 to the computer with the Communication Cable 1 or 2 included in the shipping box
- ·Establish a connection with X1 using Serial Port Debugging Software in order to send commands to X1
- ·Connect X1 to a power supply using the Power cable
- ·Connect X1 to a server using Ethernet cable
- ·Establish Ethernet connection using static or dynamic IP address
- Enter the following commands through serial port:

ICOMCONFIG ICOM1 TCP < base station IP address> : <base station port number>

// Request IP address of correction data, and map the virtual serial port ICOM1 to this address

INTERFACEMODE ICOM1 AUTO AUTO

// Configure ICOM1 input data in AUTO format, no output

LOG ICOM1 BESTPOSA ONTIME 1

// Enable BESTPOSA message output, frequency 1Hz (optional)

SAVECONFIG

// Save configuration

**Reminder:*

· Output BESTPOSA message is to confirm that X1 is in RTK mode.

5 CAN Bus Configuration

The Bynav X1 receiver also supports communicate with other devices in the system, such as computers and data loggers using CAN Bus, which is available on the COMM2 interface of X1. First connect to the CAN Bus as described in section 2.2.4.3.

Then before CAN communication is available, it is recommended to use serial port to configure the CAN port. The below configurations are needed:

- ·You should use the J1939CONFIG command to specify J1939 NAME and desired address.
- ·You can use the CANCONFIG command to place the receiver on bus
- ·You can configure CAN Port to receive GNSS Corrections

Please refer to the *UG009 CAN Protocol* for explanation of CAN Bus commands and logs.

J1939CONFIG NODE1 CAN1 AA

CANCONFIG CAN1 ON 250K

CCOMCONFIG CCOM2 NODE1 J1939 61184 6 FF

INTERFACEMODE CCOM2 RTCM NONE OFF

CCOMCONFIG CCOM1 NODE1 J1939 126720 7 FE

INTERFACEMODE CCOM1 BYNAV BYNAV OFF

LOG CCOM1 INSPVAA ONTIME 0.05

SAVECONFIG

These commands configure 2 virtual CAN Communication ports (CCOM) on physical CAN interface 1. CCOM2 is used to receive RTCM corrections (PGN 61184=0x0EF00), CCOM1 is used to send position, velocity and attitude information (PGN 126720=0x1EF00).

6 EVENT Configuration

X1 provides an EVENT_IN and an EVENT_OUT/PPS as synchronization signals, in which the EVENT_OUT signal and the PPS signal share the same pin provided by COMM1.

The signal connection is described in section 2.2.5.

6.1 EVENT_IN Configuration

The external device can use the EVENT_IN signal to synchronize X1, which is generally used to connect the pulse signal of the odometer or the Data Ready signal of an external sensor such as Camera, Lidar, etc. to achieve synchronization between sensors. This pin can apply an accurate GPS time stamps to the external signal with an accuracy better than 50ns.

If you want to test the sync signal, connect the sync signal to the EVENT_IN pin and enable the output of the following message:

LOG MARK2TIMEA ONNEW

Please refer to **错误!未找到引用源。** for more details of the message.

6.2 EVENT_OUT Configuration

X1 can also synchronize the external device by outputting synchronization signal. By default, the EVENT_OUT outputs the second pulse PPS signal, whose leading edge is synchronized with the GPS time. When the GNSS signal is received well, the synchronization accuracy is better than 20ns. You can also enter commands to configure the frequency, pulse width and trigger edge. Configure the EVENT OUT by entering:

FREQUENCYOUT [switch] [plusewidth] [period] [edge] [instance]

For example, enable EVENT OUT, frequency 1Hz, pulse width 20%, positive trigger edge:

FREQUENCYOUT ENABLE 20000000 100000000 POSITIVE 1

Please refer to **错误!未找到引用源。** for more details of the message.

7 Firmware Upgrade

The firmware upgrade steps are the following:

- ·Open the software BY_CONNECT, select correct port number and baud rate and then click OPEN.

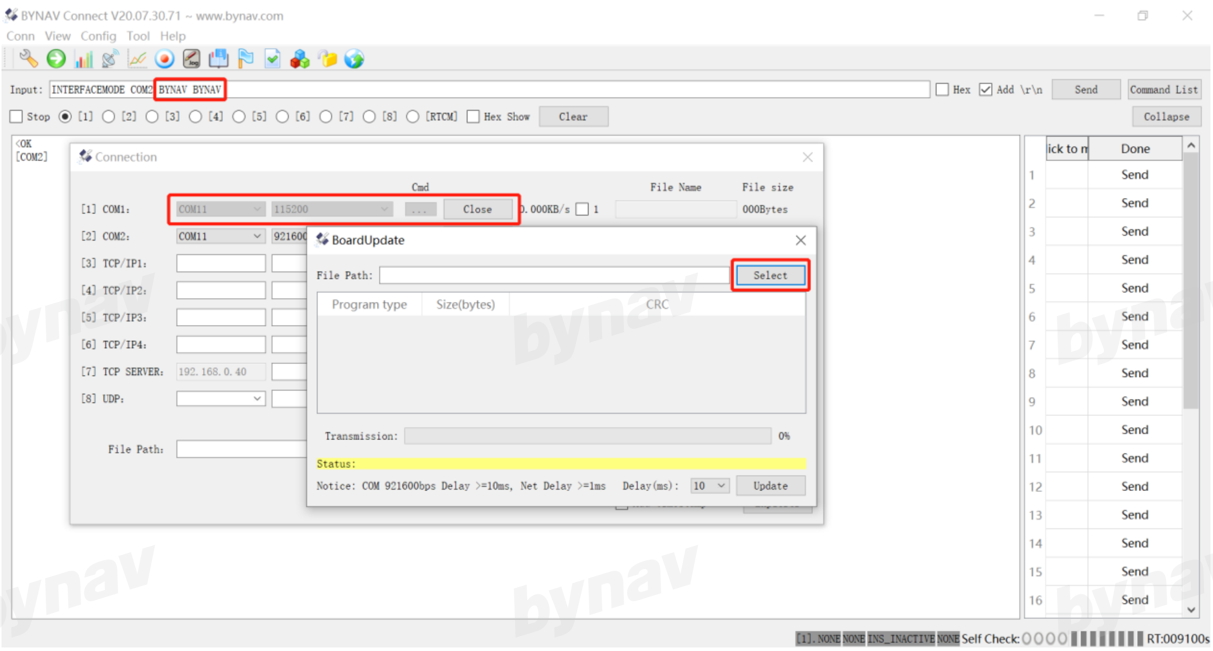


Figure 7-1 BY_connect Interface

- ·Click BoardUpdate->select to open the upgrade file and select “****.dat”.

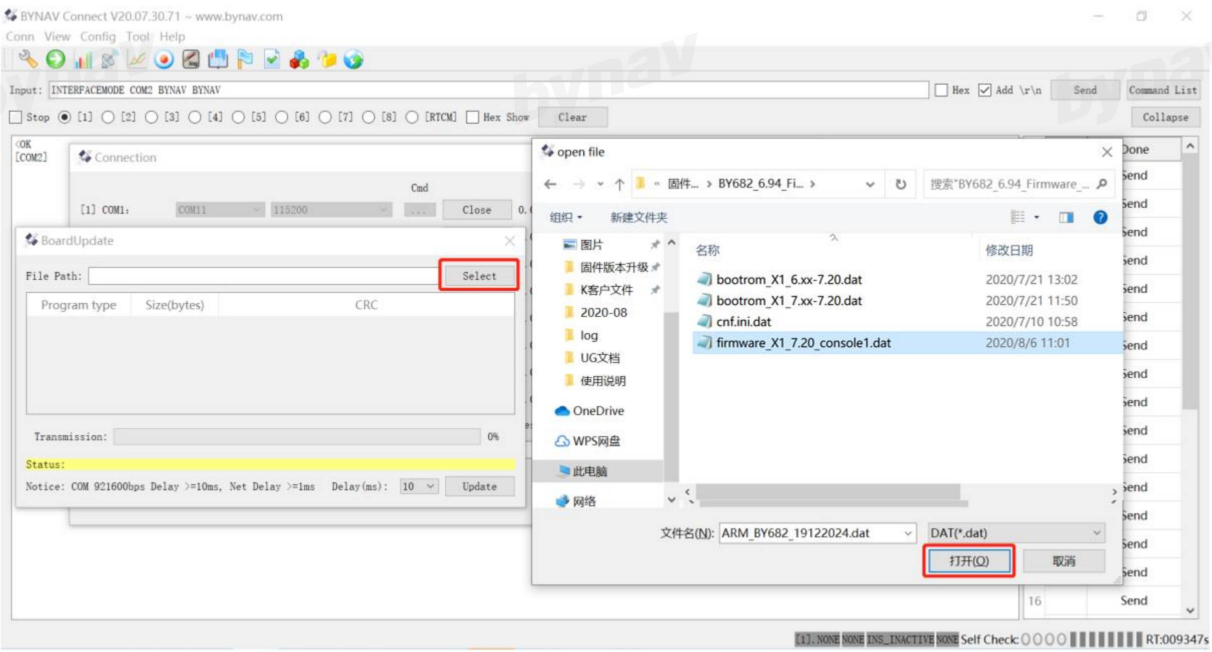


Figure 7-2 Firmware Update

- Confirm the upgrade file is correct and click the "Upgrade" button.

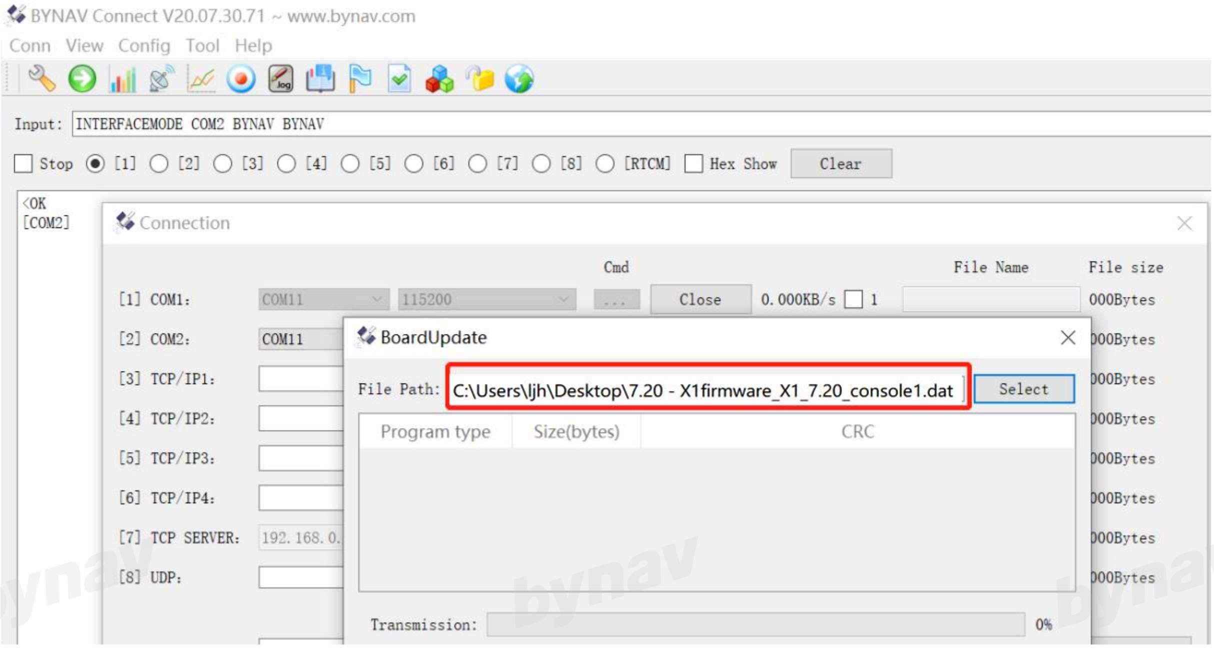


Figure 7-3 Firmware Selection

*Note:

After clicking the "Upgrade" button, the PC interface will prompt you to wait for 3s to confirm whether the communication link is normal. If the communication fails, the following window will pop up. You need to try again after checking that the communication link is normal.

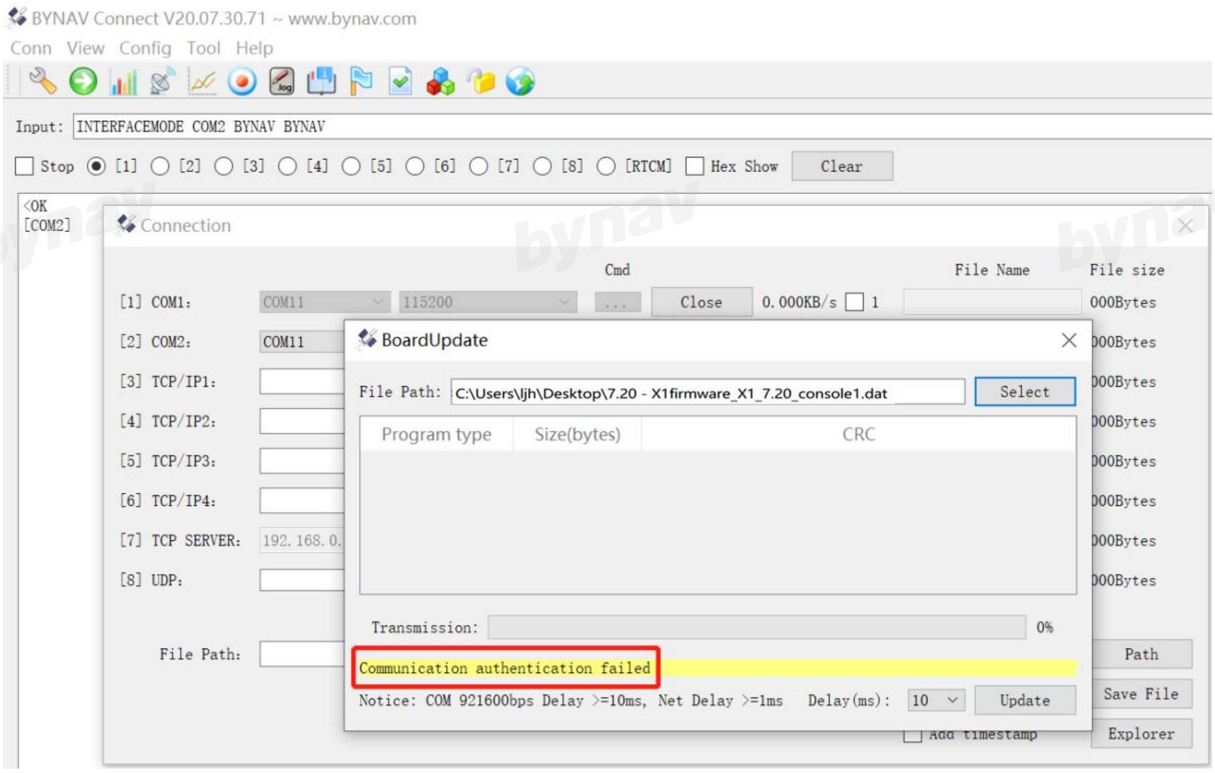


Figure 7-4 Communication Failed

- If the communication is normal, you'll enter the upgrade interface as shown below:

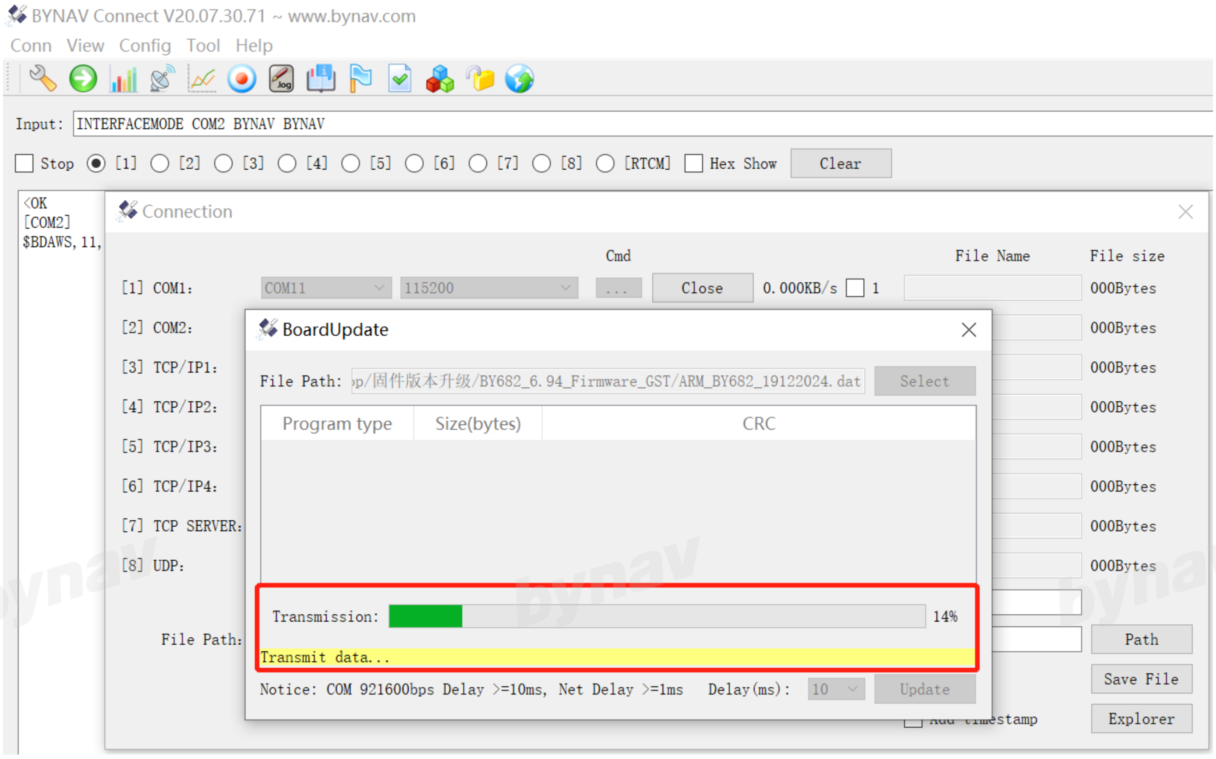


Figure 7-5 Updating

- When reaching 100%, the software starts to count down. At that moment, the upgrade is not completed yet. Do not power it off. If failed, you need to reopen the BoardUpdate.
- If the upgrade successfully completed, the following pop-up window will appear. Finally, close the serial port and reboot.

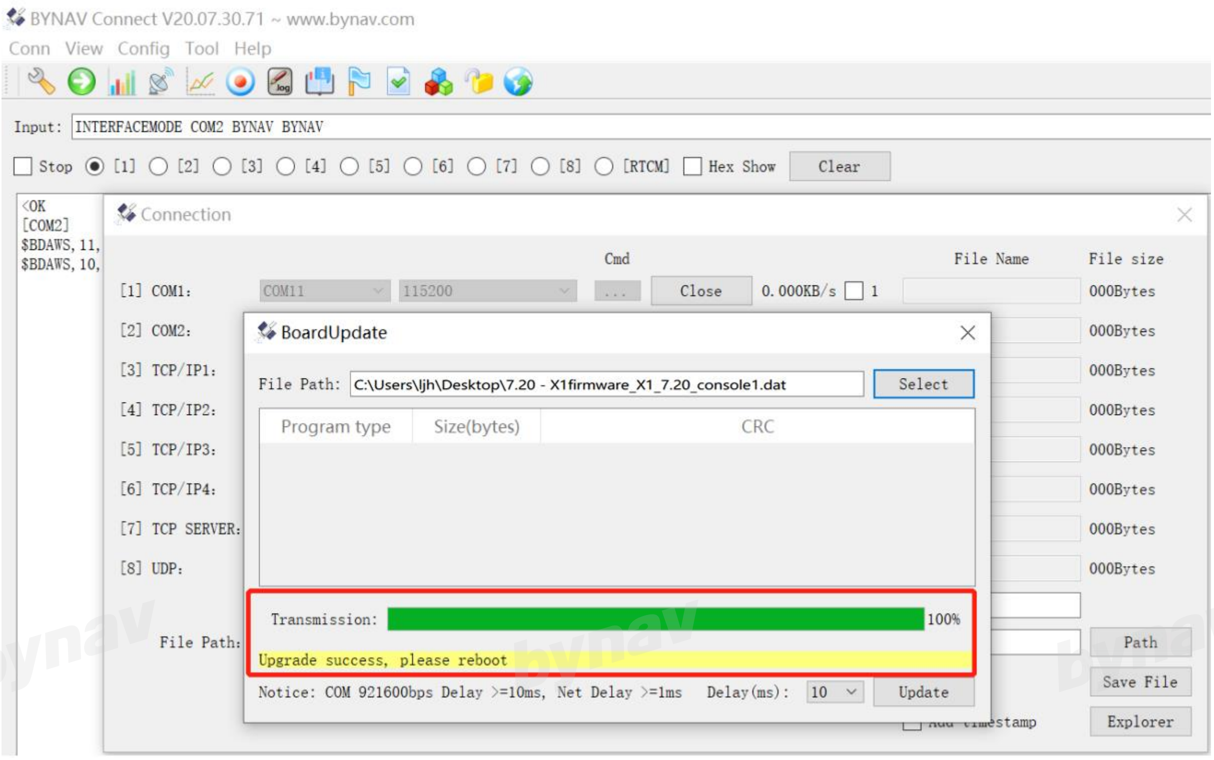


Figure 7-6 Update Success

- When choosing upgrade via Ethernet port, you just need to switch the connection way, configure the correct IP address, port number.

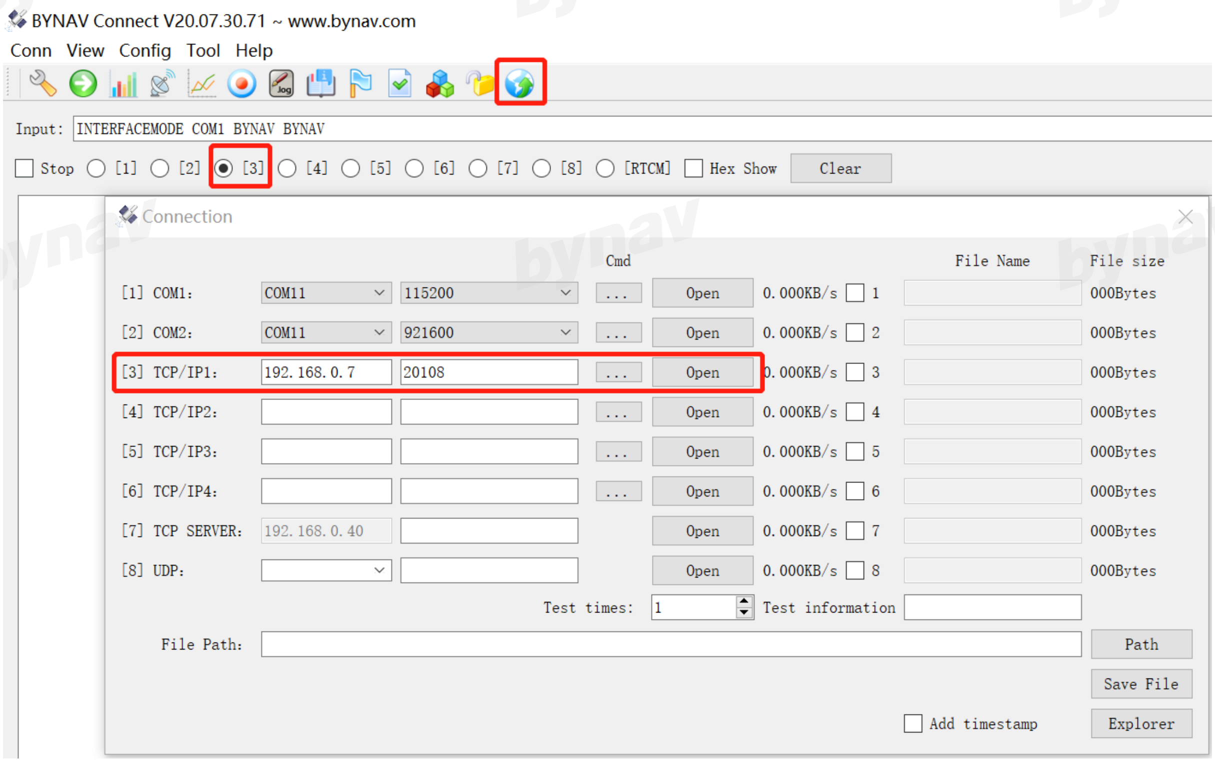


Figure 7-7 Ethernet Connection

Appendix A X1 Technical Specifications

Table 7-1 X1 Physical Specifications

Size	116mm * 114.2mm * 38.6mm
Weight	432g

Appendix A mainly describes the X1 technical specifications and the cables included in shipping box.

A.1 X1 Performance

Table 7-2 X1 Performance

Horizontal Accuracy[3,4]	Single Point		1.5m
	RTK		1cm + 1ppm
Vertical Accuracy[3,4]	Single Point		2.5m
	RTK		1.5cm + 1ppm
Signal Tracking	GPS		L1 C/A, L2, L5
	GLONASS		G1,G2
	BDS		B1I,B2I
	BDS-3		B1C, B2a
	Galileo		E1,E5b
	QZSS		L1 C/A, L2, L5
	NavIC(IRNSS)		L5
Measurement Accuracy	Carrier Phase		≤1mm（RMS）
	Pseudorange	L1CA, L2, G1, G2	≤ 0.12m（RMS）
		Other signals	≤ 0.06m（RMS）
Time to First Fix	Cold start		≤ 60s
	Hot start		≤ 40s
Maximum Data Rate	GNSS measurement		5Hz
	RTK position		5Hz
	INS position/attitude		125Hz
	IMU raw data rate		125Hz
Time Accuracy[5]	20ns RMS		
Velocity Accuracy[6]	0.03m/s RMS		
Heading Accuracy	baseline = 2m		0.08°
	baseline = 4m		0.05°
Velocity Limit	300m/s		
Acceleration Limit	4g		

Note 3: Typical value. Performance will be affected by GNSS status, satellites' location, baseline length, multipath and other interference.

Note 4: Using 1 km baseline and the receiver with good antenna performance, without considering possible errors due to antenna phase center offset.

Note 5: -130dBm and more than 12 satellites are available.

Note 6: Open sky without any obstruction,99%@static.

Table 7-3 Performance during GNSS Outage

Model	**Outage Duration**	**Positioning Mode**	**Position Accuracy(m) RMS**		**Velocity Accuracy(m/s) RMS**		**Attitude Accuracy (Degree) RMS**		
			Horizontal	Vertical	Horizontal	Vertical	Roll	Pitch	Azimuth
X1-5	0s	RTK	0.015	0.020	0.019	0.014	0.018	0.018	0.084
		PP	0.010	0.020	0.016	0.012	0.008	0.008	0.030
	10s	RTK	0.235	0.140	0.058	0.024	0.035	0.035	0.110
		PP	0.015	0.020	0.020	0.017	0.010	0.010	0.034
X1-6	0s	RTK	0.010	0.020	0.016	0.012	0.015	0.015	0.076
		PP	0.010	0.020	0.013	0.011	0.006	0.006	0.020
	10s	RTK	0.180	0.125	0.047	0.023	0.028	0.028	0.095
		PP	0.010	0.020	0.016	0.015	0.007	0.007	0.022

Table 7-4 Built-in IMU Performance

Module	Parameter	Unit	X1-5	X1-6
Gyroscope	Range	deg/s	± 450	± 450
	Rate Bias Repeatability	deg/s	0.1	0.1

	Rate Bias Stability	deg/hr	3	1.2
	Angular Random Walk	deg/Öhr	0.2	0.08
Accelerometer	Range	g	± 5	± 10
	Rate Bias Repeatability	mg	5	3
	Rate Bias Stability	mg	70	16
	Velocity Random Walk	m/s/Öhr	0.03	0.033
IMU Ouput	Raw Data Output Frequency	Hz	125	125

A.2 X1 Mechanical Specification and Navigation Center

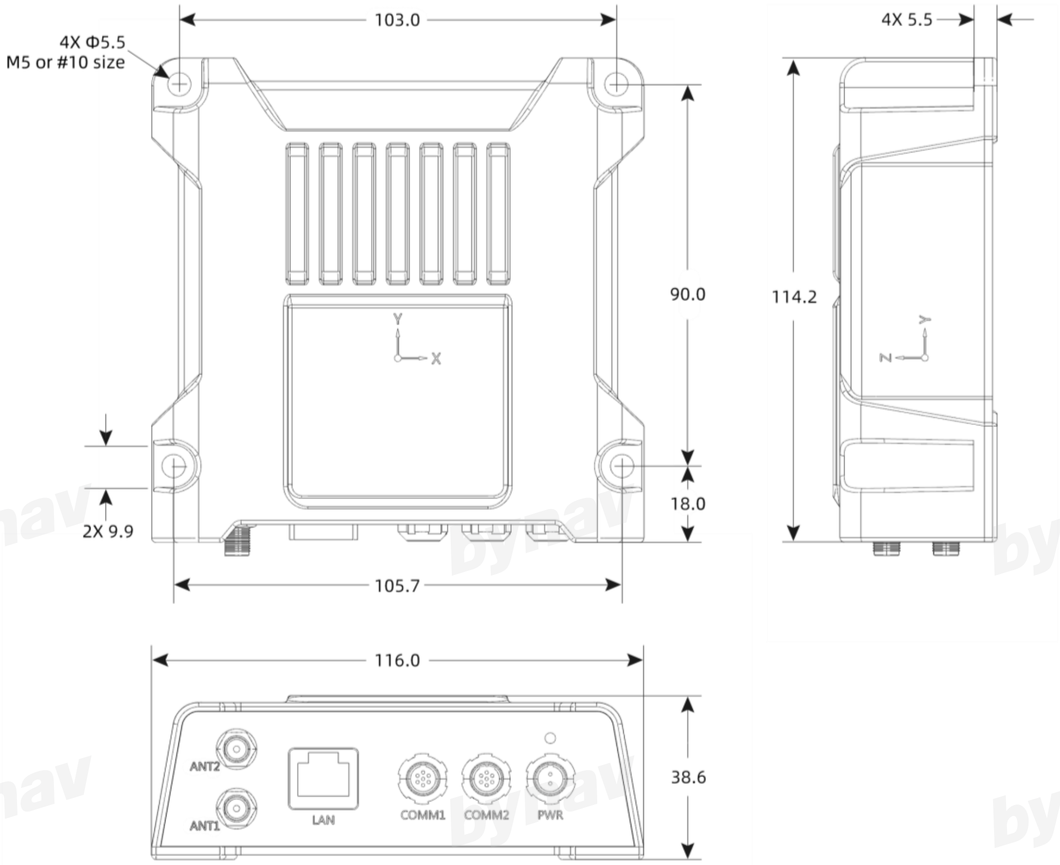


Figure 7-8 X1 Mechanical Parameters

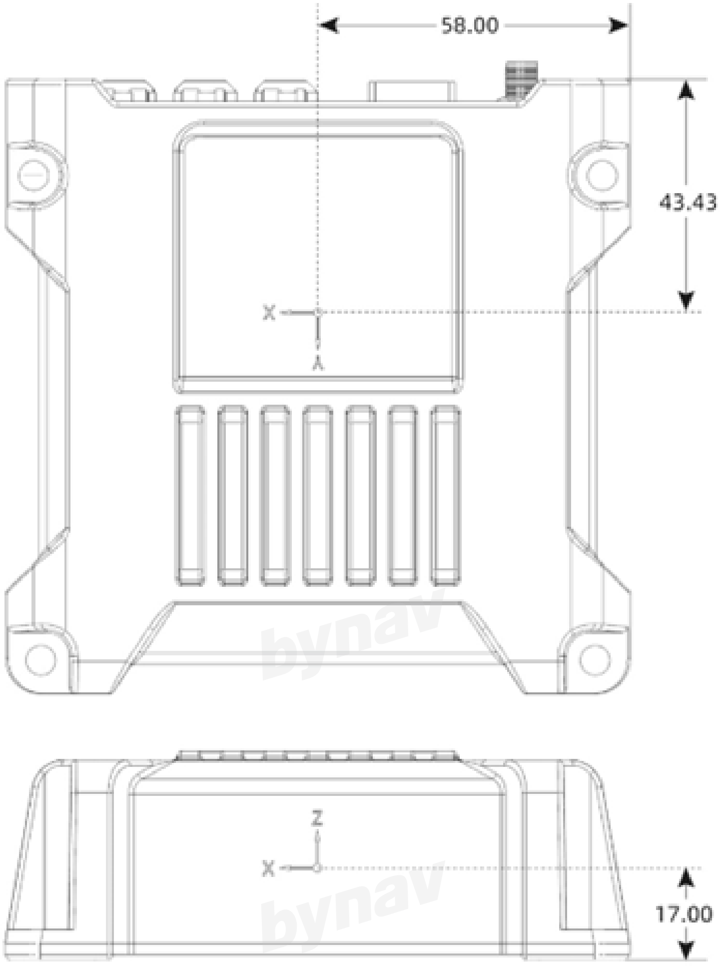


Figure 7-9 X1 Navigation Center

A.3 X1 Electrical and Environmental Specifications

Table 7-5 X1 Environmental Specifications

Parameter	Value
Operating Temperature	-40℃ ~ +85℃
Storage Temperature	-55℃ ~ +85℃
Humidity	95% non-condensing
Vibration	JESD22-B103

Table 7-6 X1 Power Parameters

Parameter	Value
Power Consumption	4.8W typical value (full constellation, full frequency)
Inrush Current	0.37A for less than 1.3ms (@12V;typical value)

Table 7-7 X1 RF Input/LNA Power Output

Antenna Connector	SMA-K female, 50Ω impedance			
RF Input Frequency	GPS L1: GPS L2: GPS L5: BDS B1I: BDS B1C: BDS B2I: BDS B2a: BDS B3I:	1575.42MHz 1227.60MHz 1176.45MHz 1561.098MHz 1575.42MHz 1207.14MHz 1176.45MHz 1268.52MHz	GLONASS L1: GLONASS L2: GLONASS L3: Galileo E1: Galileo E5a: Galileo E5b: Galileo E5: Galileo E6:	1593-1610MHz 1237-1254MHz 1202.025MHz 1575.42MHz 1176.45MHz 1207.14MHz 1191.795MHz 1278.75MHz
LNA power	+5VDC, 0mA~200mA			

A.4 X1 I/O Signal

Table 7-8 X1 I/O Signal

Signal	I/O	Default	Comments
EVENT_IN	I	Active high	
EVENT_OUT /PPS	O		Programmable variable output pulse, frequency range from 1Hz to 10MHz (see **错误!未找到引用源。** command for details), shared pin

Table 7-9 X1 I/O Signal Electrical Parameters

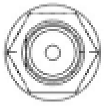
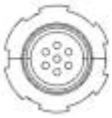
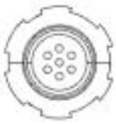
Signal	Mark	V_{IL}(V)			V_{IH}(V)		
		Min	Typ	Max	Min	Typ	Max
EVENT_IN	EVENT	-0.3	-	0.8	2	3.3	3.45

Signal	Mark	V_{OL} (V)			V_{OH}(V)			Current (mA)
		Min	Typ	Max	Min	Typ	Max	
EVENT_OUT	PPS	-	-	0.4	2.4	-	-	12

A.5 X1 Connectors

Table 7-10 X1 Connectors

Connectors	Label	Type	Description

	ANT1	SMA-K	Connect X1 to the GNSS antenna 1 (primary)
	ANT2	SMA-K	Connects X1 to the GNSS antenna 2 (secondary)
	LAN	RJ45	Connect X1 to the Ethernet, communicating with X1 by network
	COMM1	Push-pull self-locking connector	Provide access to communication signals for X1, including: Serial port COM1 (RS-232) 1 EVENT IN (3.3 V LVTTL) 1 PPS (shared pin with EVENT OUT) (3.3 V LVTTL)
	COMM2	Push-pull self-locking connector	Provide access to communication signals for X1, including: Serial port COM2 (RS-232) CAN Bus
	PWR	Push-pull self-locking connector	Connect X1 to power supply

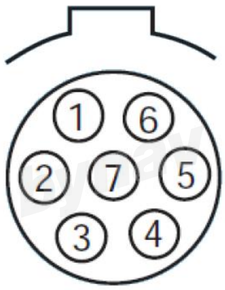


Figure 7-10 COMM1/COMM2 Pin

Table 7-11 COMM1 Pin Definition

Pin	Signal	Direction	Description
1	——	——	Unconnected
2	GND		
3	RS232_TXD1	Output	X1 COM1 RS232
4	RS232_RXD1	Input	
5	GND		
6	PPS	Output	3.3V LVTTL
7	EVENT_IN	Input	3.3V LVTTL

Note: the signal direction is defined for X1

Table 7-12 COMM2 Pin Definition

Pin	Signal	Direction	Description
1	Reserved	-	Reserved

2	GND	-	-
3	RS232_TXD2	Output	X1 COM2 RS232
4	RS232_RXD2	Input	
5	GND	-	-
6	CAN_H	Input / Output	CAN Bus
7	CAN_L	Input / Output	

*Note: The direction of signal is defined for X1

A.6 X1 Power Cable (PWR)

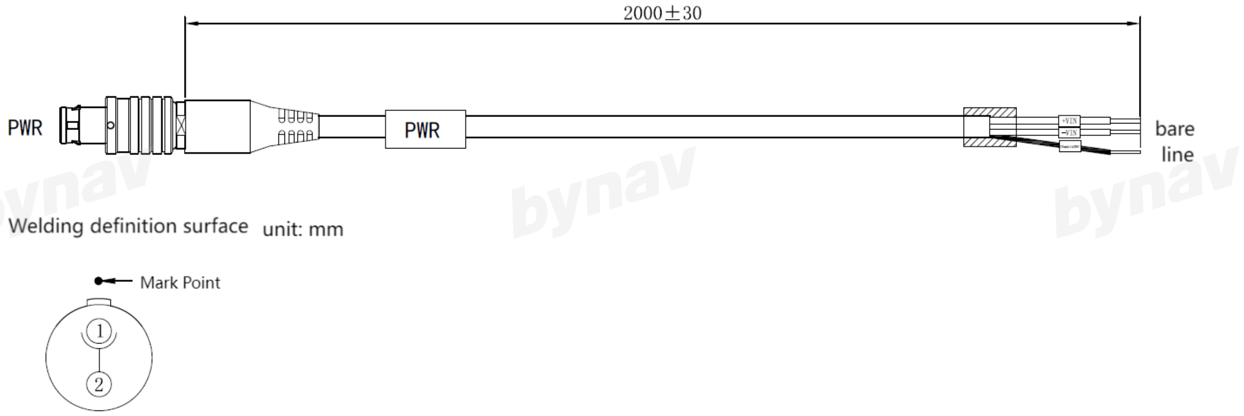


Figure 7-11 X1 PWR Cable

Table 7-13 Power Cable Connectors

Signal	**Direction**	**Comments**	**PWR 2-pin Connector Male**	**Bare wire**
+VIN	Input	DC：+9V~+32V	1	+VIN
-VIN	-		2	-VIN
——	-	Leave unconnected recommended (for electrostatic discharge)	——	ChassisGND

*Note: The direction of signal is defined for X1.

A.7 Communication Cable 1 (COMM1)

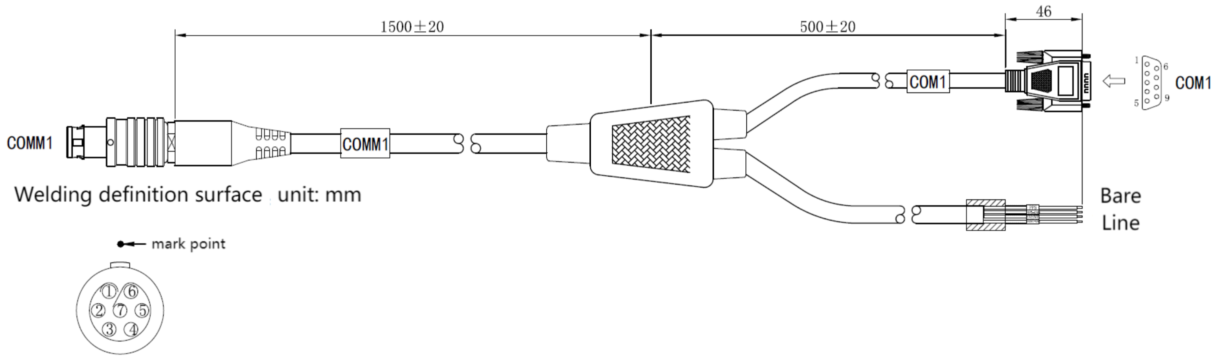


Figure 7-12 XI COMM1 Cable

Table 7-14 Pins of Communication Cable 1 (COMM1)

Signal	**Direction**	**Comments**	**COMM1 7-pin connector male**	**COM1 DB9 female**	**Bare wire**
——	——	Unconnected	1	9	
GND	-		2	5	
RS232_TXD1	output	RS232	3	2	
RS232_RXD1	input		4	3	
GND	-		5		PPS_GND EVENT_GND
PPS	output	3.3V LVTTL	6		PPS
EVENT_IN	input	3.3V LVTTL	7		EVENT_IN

*Note: The direction of signal is defined for X1.

A.8 Communication Cable 2 (COMM2)

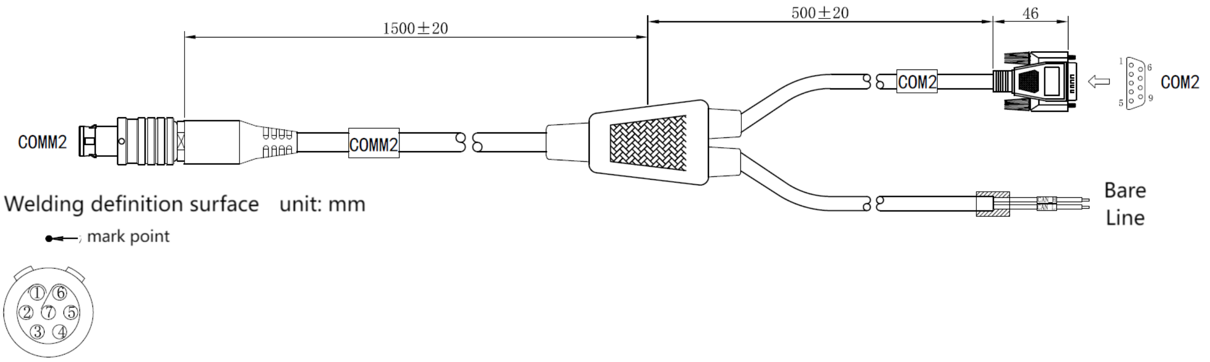


Figure 7-13 X1 COMM2 Cable

Table 7-15 Pins of Communication Cable 2 (COMM2)

Signal	**Direction**	**Comments**	**COMM2 7-pin connector male**	**COM2 DB9 female**	**Bare wire**
Reserved	-	Reserved	1	9	
GND	-		2	5	
RS232_TXD2	output	RS232	3	2	
RS232_RXD2	input		4	3	
GND	-		5		
CAN_H	input/output		6		1
CAN_L	input/output		7		2

*Note: The direction of signal is defined for X1.

Appendix B Frames, Lever Arm and RBV

B.1 Reference Frames Definition

The frames that are most frequently used throughout the integrated navigation documentation are the following:

- The Local-Level Frame (ENU)
- The IMU Body Frame
- The Vehicle Frame
- The User Output Frame

B.1.1 The Local-Level Frame (ENU Coordinates)

The definition of the Local Level Frame is as follows:

E-axis – pointing east (right-handed orthogonal axis intersected by N-axis and U-axis)

N-axis – pointing north (In a plane perpendicular to the U axis, the direction from the user to the North Pole)

U-axis – pointing up (Ellipsoid normal direction)

The origin of the Local Level frame is the navigation center marked on the X1 housing.

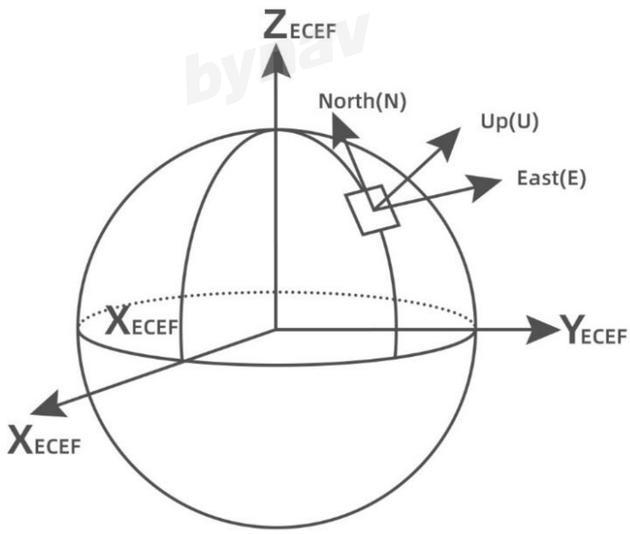


Figure 7-14 The Local-Level Frame (ENU)

B.1.2 The IMU Body Frame

Both the axis and origin point of the IMU Body frame are marked on the X1 housing, and the origin of the IMU Body Frame is the navigation center of X1.

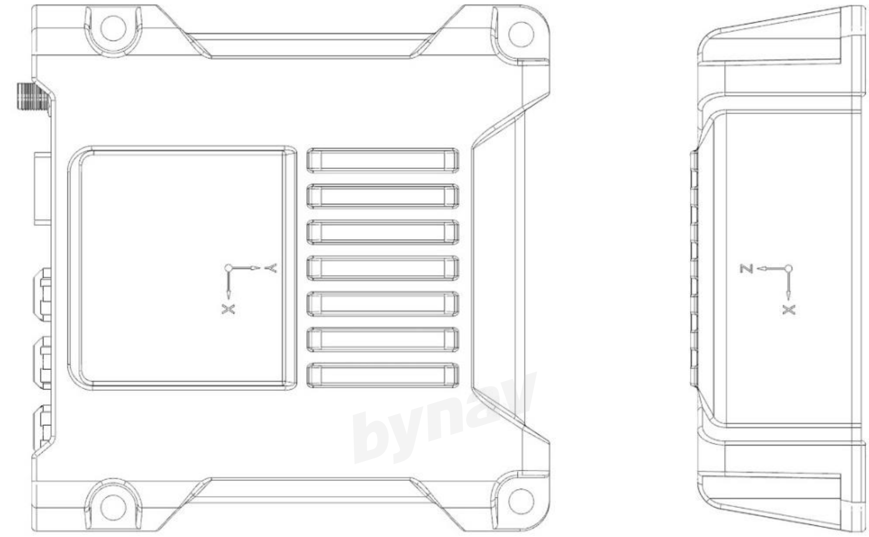


Figure 7-15 IMU Body Frame Marking

B.1.3 The Vehicle Frame

The definition of the Vehicle frame is as follows:

Z-axis – points up through the roof of the vehicle perpendicular to the ground

Y-axis – points out the front of the vehicle in the direction of traveling

X-axis – the right-handed orthogonal axis intersected by Y axis and Z axis

The origin of the Vehicle frame is the navigation center marked on the X1 housing.

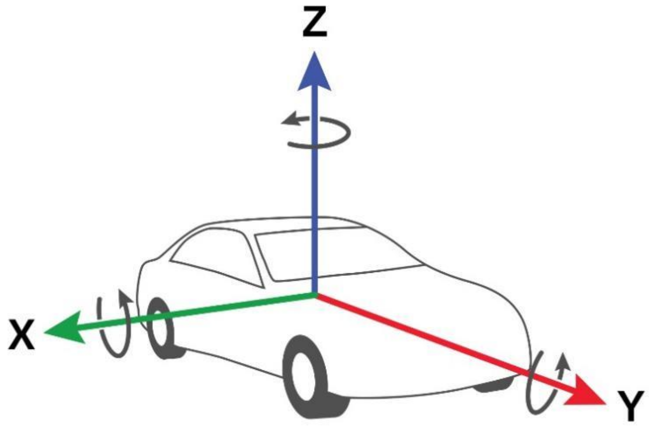


Figure 7-16 The Vehicle Frame

B.1.4 The User Output Frame

Under the User Output frame, the user can specify any point as the origin point, such as the GNSS antenna phase center point that is often used.

By default, the X1 outputs the position and speed of the enclosure navigation center, which is also the origin point of the IMU Body frame. You can set this point to any point using the **SETINSTRANSLATION** command plus the determined frame offset.

By default, the attitude output by X1 is the rotation angle from the Local Level frame (ENU Coordinates) to the IMU Body frame. You can set the attitude as the rotation angle from the Local Level frame to another frame using the **SETINSROTATION** command.

B.2 Antenna Lever Arm and RBV

The integrated navigation system deeply couple GNSS data and INS data. In the GNSS, the reference point for position is the GNSS antenna phase center. In the INS, the reference point for position, velocity and attitude is the navigation center of the enclosure.

So, to provide accurate position, velocity and attitude, the integrated navigation system must know the position of GNSS antenna relative to the X1 navigation center in the Vehicle frame. This parameter determines whether the X1 navigation system can work correctly or not.

B.2.1 Antenna Lever Arm

The three-imensional distances from GNSS antenna phase center to X1 enclosure navigation center are called antenna Lever Arm, which is defined as follow: taking the enclosure navigation center as the origin and defining the X-axis, Y-axis and Z-axis directions be consistent with the Vehicle frame.

Below shows an example of the Lever Arm from X1 to the GNSS dual antenna. In this example, the origin is the enclosure navigation center and the arrow indicates the direction of the axis of the Vehicle frame.

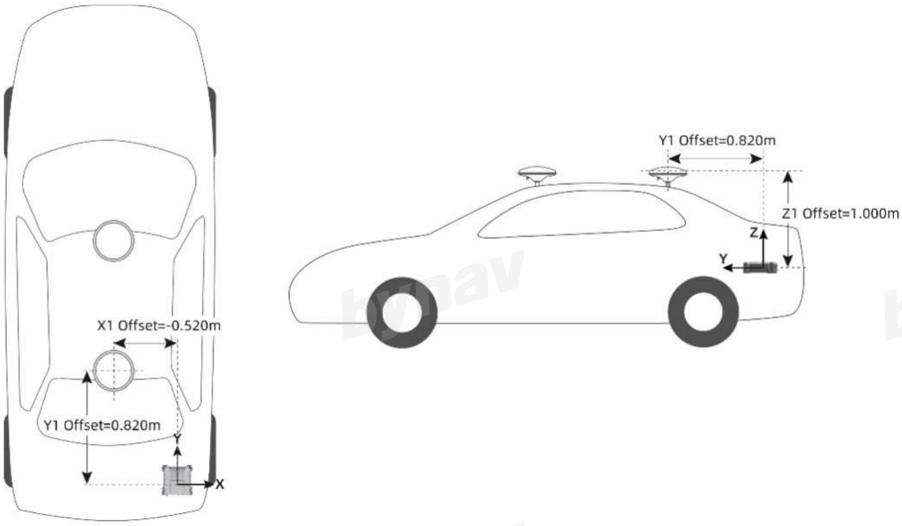


Figure 7-17 Lever Arm from X1 to GNSS Antenna

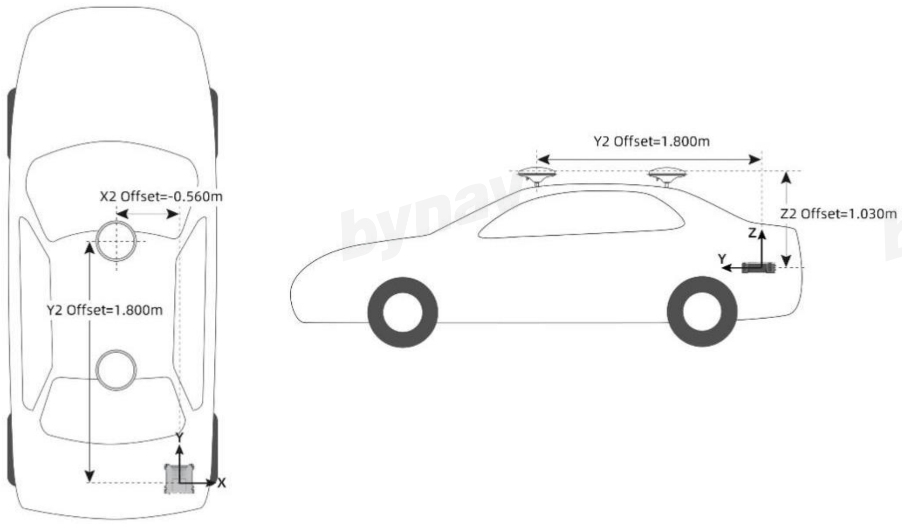


Figure 7-18 Lever Arm from X1 to GNSS Antenna 2

As illustrated, the lever arm measured in this example are:

X1 Offset = -0.520m, Y1 offset = 0.820m, Z1 offset = 1.000m;

X2 Offset = -0.560m, Y2 offset = 1.800m, Z2 offset = 1.030m.

Enter **SETINSTRANSLATION** command to set lever arm:

SETINSTRANSLATION ANT1 -0.520 0.820 1.000 0.05 0.05 0.05 VEHICLE

SETINSTRANSLATION ANT2 -0.560 1.800 1.030 0.05 0.05 0.05 VEHICLE

Note: the smaller the lever arm error, the better, because this error will directly affect the integrated navigation accuracy

B.2.2 Rotation Parameter (RBV)

The error in attitude between the IMU Body Frame and the Vehicle Frame are called rotation parameter (RBV). Specifically, it's the rotation Euler Angle from the IMU Body Frame to the Vehicle Frame.

Below shows one example of Rotation Parameter from IMU Body Frame to Vehicle Frame.

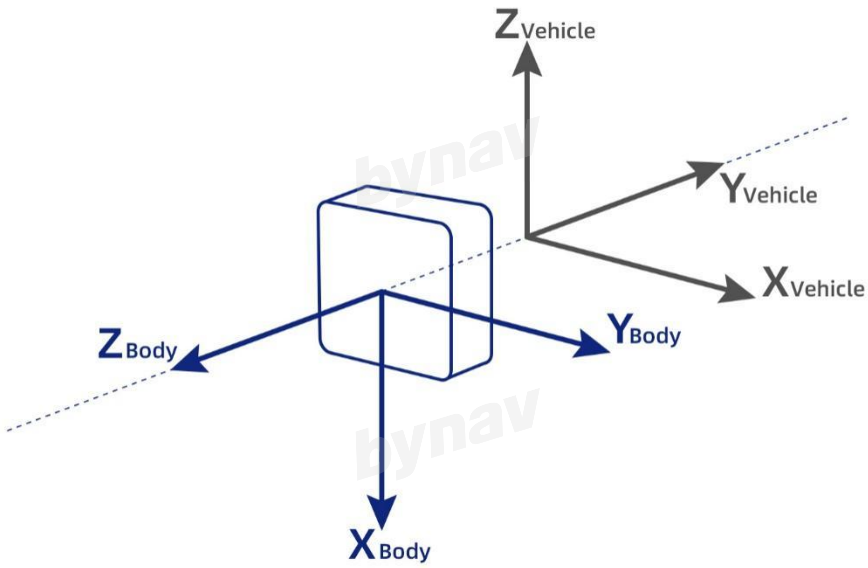


Figure 7-19 RBV from Body Fame to Vehicle Fame

The rotation Euler Angles from the IMU Body frame to the Vehicle frame (RBV) are: X: -90, Y: 0, Z: +90

Keep in mind the following rules:

- You must rotate from the IMU Body frame to the Vehicle frame;
- You must rotate in the order Z→X→Y;
- You must rotate the frame following the right hand rule.

The RBV values are entered using the **SETINSROTATION** command:

SETINSROTATION RBV -90 0 90

Note: the rotation parameter from the IMU Body frame to the Vehicle frame (RBV) should also be measured as accurately as possible, otherwise it would bring more errors in attitude, speed and position.

B.3 RBV Calibration

Dynamic alignment requires that the Rotation parameter from the IMU Body Frame to Vehicle Frame (RBV) is accurate, if the rotational angle is known, configure manually using SETINSROTATION RBV command. Since there is generally an unavoidable error in the installation, a more accurate offset value can be estimated by the automatic calibration program after you configure RBV value into system.

The calibration steps are:

- ·Verify that X1 is properly configured, including accurate lever arm and approximate RBV value (accuracy better than 5 degrees);
- ·Verify that X1 is powered on normally and complete the alignment and error convergence;
- ·Enable RBV calibration using the **INSCALIBRATE** command:
- INSCALIBRATE RBV NEW
- ·Monitor the calibration status using the command **LOG INSCALSTATUS ONTIME 1**;
- ·Keep the carrier go straight on horizontal ground with a speed higher than 5 m/s (18 km/h). Avoid driving on complex roads to prevent introducing unnecessary estimation errors.
- · After the calibration is completed, the estimated value of RBV will be automatically configured. The offset of the calibration can be checked using the **INSCALSTATUS** and **LOG INSCONFIG** commands. Manually save it (using **SAVECONFIG** command) to guarantee the availability in next boot.

The RBV calibration should be performed each time when the X1 is reinstalled.

Disclaimer

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Bynav Technology
Building 12, Phase 1, Zhongdian Software Park,
No.39 Jianshan Road, High-tech Zone, Changsha,
Hunan 410205, China

Tel.: 0731-85058117
Email: en@bynav.com
FAE：
support@bynav.com

www.bynav.com