RAC High Precision Satellite Positioning Receiver Specification

RAC high precision GNSS receiver

Achieve high-precision satellite positioning without differential stations and ground-basedaugmentation networks

Real-time Array Calibration

Product Model: RAC-F1

Hardware version: RAC-D0030124R_V1.1

Software Version: GLN2-BSS-UV1.24-191020

Document Revision History

Version	Revision Date	Version Description
V1.0	2016/5/18	New Document
V1.1	2016/12/15	Performance index parameters are detailed
V1.2	2017/6/18	Input command optimization changes
V2.0	2021/6/09	Detail optimization

Disclaimer

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1. Product Description

1.1 Product Overview

Product Name: RAC-F1 High-precision satellite positioning receiver

Figure 1.1 Appearance of RAC-F1 high-precision satellite positioning receiver

This product is a G-MOUSE-like satellite receiver (hereinafter referred to as G-MOUSE), a complete GPS satellite positioning receiver. It features an integrated satellite reception antenna and offers omnidirectional high-precision positioning capabilities. The positioning accuracy can reach less than 1.2 meters in static mode and less than 0.6 meters in dynamic mode. It meets the stringent requirements of industrial-grade positioning and personal usage needs.

Through technological innovation, the product boasts two core competitive advantages: no need for differential stations and no use of L2 or B3 precise signals, which significantly reduces costs. Unlike traditional high-precision satellite positioning technologies, our technology eliminates the reliance on differential technology, dramatically lowering costs. This is the most significant advantage that sets our product apart from similar products worldwide.

The product is characterized by high precision, high sensitivity, low power consumption, and a compact size. Its extremely high tracking sensitivity greatly expands its positioning coverage area.

1.2 Product Features

UART (3.3V TTL level)/RS232/IIC/CAN interface outputs, enabling faster applications.

KDS 0.5PPM high-precision TCXO for improved frequency stability.

Rich data output rates: 115200bps (default) [Optional: 9600/38400].

Output protocols: NMEA 0183 V3.0/UBX.

Supports adjustable data refresh rates: 1Hz-10Hz.

Self-developed antenna oscillator ensures phase center alignment with the geometric center, minimizing the impact of antenna measurement errors.

Supports optional A-GPS services, inertial navigation, magnetometer, and pressure sensors.

GPS, BD, GLONASS hybrid engine options available.

Lead-free manufacturing process, compliant with RoHS standards.

1.3 Certification Testing

The positioning chip has passed AEC-Q100 certification.

The positioning module has passed ISO16750 test.

The positioning products have passed ISO7637 test.

The production line complies with ISO/TS-16949 certification.

1.4 Application

Autonomous vehicles, positioning, navigation, and tracking products.

UAV applications, agricultural plant protection machines, and precision agriculture.

UTC time synchronization and timekeeping applications.

Widely used in channel measurement and marine surveys.

Trajectory recording and GPS data point calibration products.

High-precision map creation, area measurement, and distance measurement for surveying products.

Road construction, earthquake monitoring, bridge deformation monitoring, landslide monitoring, and container operations at docks.

1.5 Performance Indicators

Sensitivity	Track	- 165dBm
	Capture	- 148dBm
TTFF (Time to First Fix)	Cold Start	average 42S (Open Sky)
	Warm start	Average<5S
	Hot Start	Average<1S
Type	22 Tracking channels, 56 Capture channels	
	frequencyGPSL11575.42MHz C/Acode BDSB11561.098MHz	
Positioning accuracy	External static positioning accuracy:1.2m（2σ）	
	External dynamic positioning accuracy:0.6m（2σ）	
	Internal static positioning accuracy:0.6m（2σ）	
	Internal dynamic positioning accuracy:0.2m（2σ）	

	Coordinate system	Coordinate basis:WGS-84
Speed accuracy	0.1m/s	
Time pulse (configurable)	1s (default)	
Update rate	1-10Hz (Optional)	
PPS	100ms（1pps=1Hz=1times/second)	
Operational restrictions	High	<18000m
	Speed	<100m/s
	Acceleration	<8g
Data Format	The default output information for the NMEA 0183 general protocol is: NMEA-0183 - RMC.	

Power Specifications

Power supply	DC 5.0V (Ripple voltageVpp<200mv)
Working current	Track:260mA Capture:280mA
Standby current	<5uA
Functional Interface	UART/IIC/RS232/CAN

Physical properties

Temperature	Operating temperature	- 30℃~80℃
	Storage temperature	- 40℃~85℃

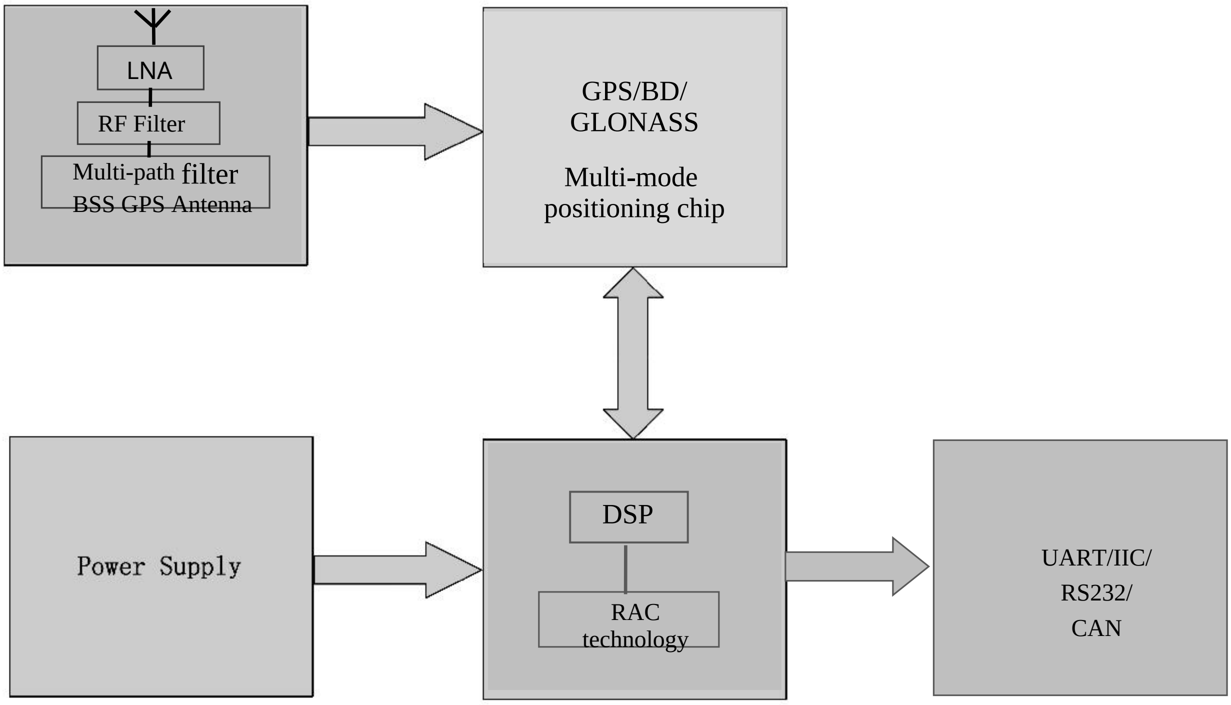
1.6 Product port definition

The product output can support UART or IIC output, etc. The default is UART output (IIC, etc. can be expanded). The specific port definition is shown in the figure below:

Pin NO.	Pin Name	I/O	Remark
1	GND	land	Ground (yellow line)
2	VCC	power supply	DC 5.0VPeak current206mA(Red line)
3	RX	enter	TTLSerial port receiving (blue line)
4	TX	Output	TTLSerial port send (white line)

5	SDA	data	Reserved geomagnetic IIC data (green)
6	SCL	clock	Reserved geomagnetic IIC clock (orange)

1.7 Functional Block Diagram



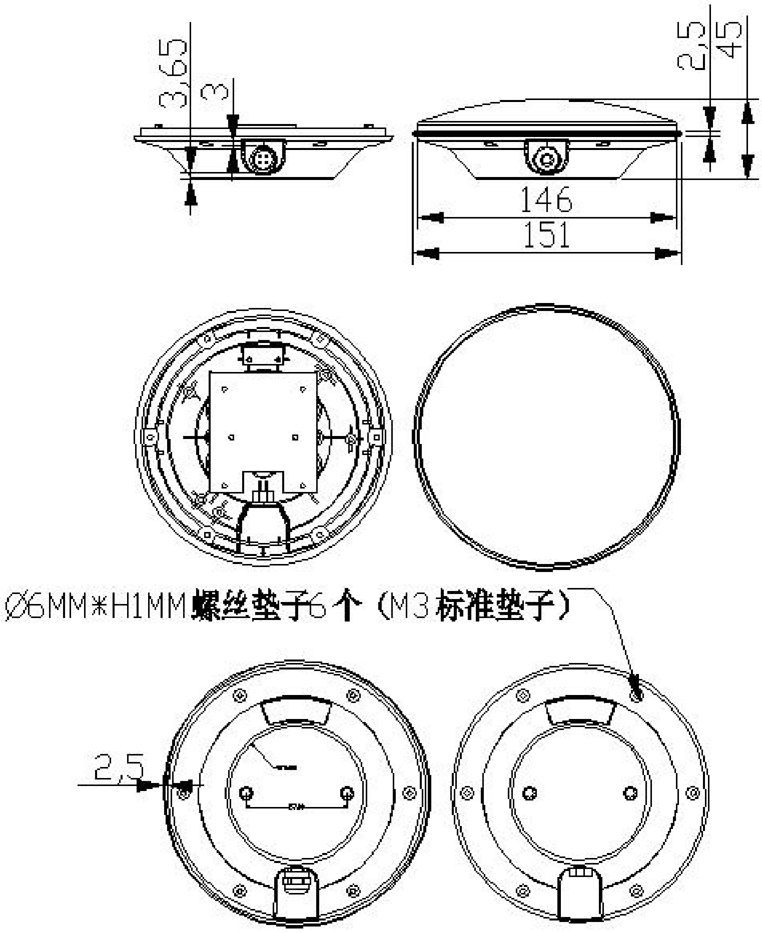
The RAC-F1 high-precision positioning receiver utilizes a high-precision antenna with a self-developed antenna oscillator, ensuring that the phase center aligns with the geometric center, thereby minimizing the impact of antenna measurement errors. The antenna receives satellite signals from the sky and transmits them to the chip's RF unit. The chip's RF unit then forwards the signals to the chip's baseband unit, where they undergo a series of processing steps before being sent to the DSP. After being processed by RAC's proprietary algorithm, high-precision positioning data and 1PPS signals are output via serial port, RS232, or CAN interfaces, while magnetometer data is output via the IIC interface.

1.8 Product size

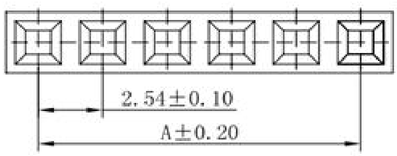
Overall size: Length151mm*high45mm(There is a strong magnet inside the bottom shell)

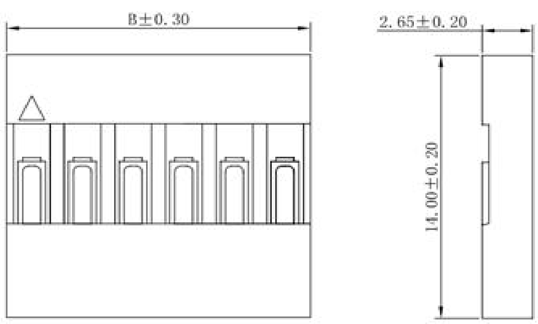
PCB size: Diameter120mm*high12mm

Bottom case screw specifications: StandardM5Specifications (full thread)



1.9 Interface terminal size





H2544-04: 7.62*10.16mm

1*4P 2.54mm pitch DuPont terminal

2. Input and Output Statements

2.1 Input Statement

2.1.1 Instruction Format

BSS-(command 1)-(command 2)-(command 2).....(command n) (CR)(LF)

2.1.2 Instruction Description

BSS is the command header, and every command must start with "BSS";

Each command must use a "-" (hyphen, minus sign) to separate parameters;

Each command must end with "carriage return and line feed";

When selecting the NMEA0183 protocol mode, GPRMC is output by default;

In the UBX protocol, the following five pieces of information are output by default: posllh, sol, dop, velned, and status;

When switching from NMEA protocol to UBX protocol or from UBX protocol to NMEA protocol, a power cycle is required. If there is a stored ephemeris battery, it needs to be powered off for a few hours until the battery is drained for the change to take effect.

2.1.3 Command List

Order	Illustrate
0183	Choose one of the two, indicating that the NMEA0183 protocol is selected
UBX	Choose one of the two, indicating that the UBX protocol is selected
115200	Select one of the three options, indicating the serial port baud rate is 115200
38400	Select one of the three options, indicating the serial port baud rate is 38400
9600	Select one of the three options, indicating the serial port baud rate is 9600
10HZ	Select one of the three options, indicating that the serial port output frequency is 10HZ
5HZ	Select one of the three options, indicating that the serial port output frequency is 5HZ
1HZ	Select one of the three options, indicating that the serial port output frequency is 1HZ
RHXZ	Indicates that the geomagnetic sensor is enabled.
D10	Choose one of the three, indicating that the number of geomagnetic outputs in one frame of GPS time is 10 times
D5	Choose one of the three, indicating that the number of geomagnetic outputs in one frame of GPS time is 5 times

Order	Illustrate
D1	Choose one of the three, indicating that the number of geomagnetic outputs in one frame of GPS time is 1
VTG	GPVTG command, only enabled when NMEA0183 protocol is selected
GGA	GPGGA command, only enabled when NMEA0183 protocol is selected
PVT	PVT command, only enabled when UBX protocol is selected
ALL	Only valid for NMEA0183 protocol, all commonly used GPS commands are enabled, including RMC, VTG, GGA, GSA, GSV, to facilitate observation of satellite information

Note: Due to the relatively low data transmission rate of the serial port, the output frequency of GPS data and geomagnetic data is closely related. Incorrect settings may result in data output errors or loss.

Simplified command: When only the RMC command is output, the relationship between the serial port baud rate and the output frequency is as follows:

At 9600 baud, the serial output frequency is 5Hz, and the geomagnetic output is D1.
At 38400 baud, the maximum serial output frequency is 10Hz, and the maximum geomagnetic output is D10.
At 115200 baud, the maximum serial output frequency is 10Hz, and the maximum geomagnetic output is D10 .

Multiple commands: When multiple GPS commands are output, the relationship between the serial port baud rate and the output frequency is as follows:

At 9600 baud, the serial output frequency is 1Hz, and the geomagnetic output is D1.
At 38400 baud, the maximum serial output frequency is 5Hz, and the maximum geomagnetic output is D5.
At 115200 baud, the maximum serial output frequency is 10Hz, and the maximum geomagnetic output is D10 .

Example: Change to NMEA0183 protocol, set baud rate to 115200, frequency to 10Hz, enable VTG, GGA, and geomagnetic data (one frame of geomagnetic data, GPS outputs one geomagnetic data point), the command is as follows:

BSS-0183-115200-VTG-GGA-10HZ-RHXZ-D1

Change to UBX protocol, set baud rate to 115200, frequency to 10Hz, enable PVT and geomagnetic data (one frame of geomagnetic data, GPS outputs one geomagnetic data point), the command is as follows:

BSS-UBX-115200-10HZ-PVT-RHXZ-D1

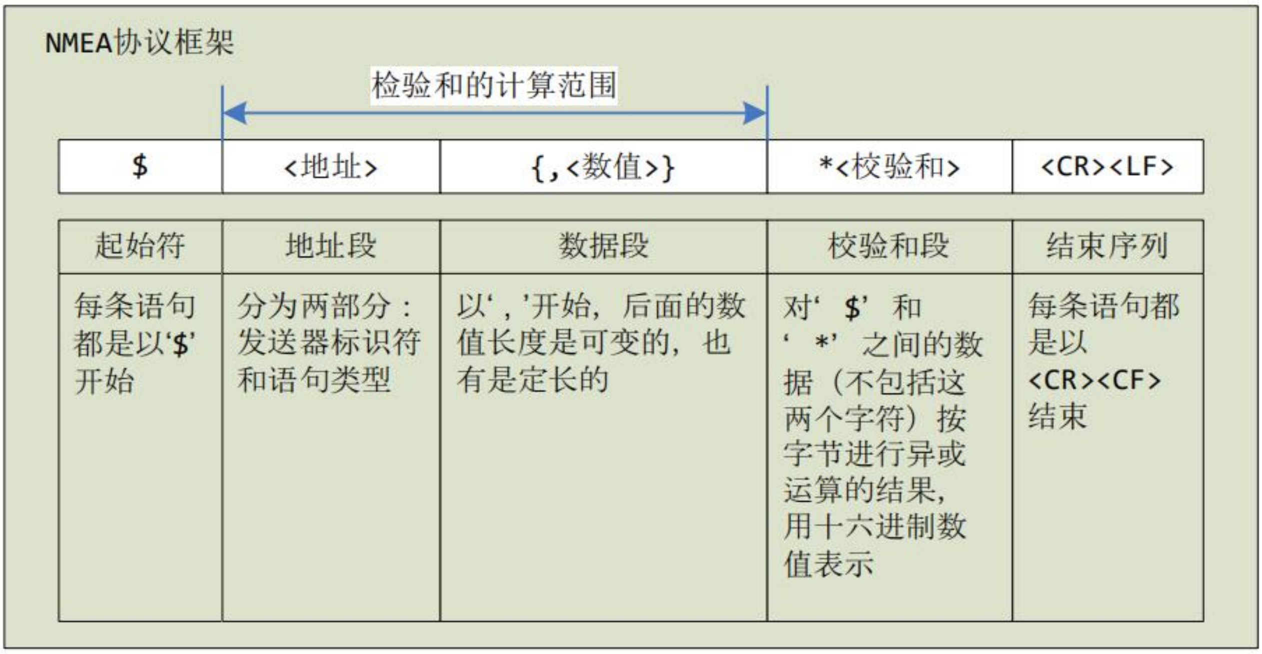
After modification, the serial terminal will display the following

```
Seting parameter success
Saving parameter
Saving parameter success
reseting system
Please wait
```

2.2 Output Statement

2.2.1 NMEA 0183protocol

NMEA 0183 is a standard format developed by the National Marine Electronics Association (NMEA) for marine electronic devices. It has now become the unified RTCM (Radio Technical Commission for Maritime Services) standard protocol for GPS navigation equipment. The NMEA 0183 protocol uses ASCII code to transmit GPS positioning information. The data format and protocol framework are as follows:



Statement output:

	Information	Illustrate
1	RMC	Recommended minimum dedicated navigation data
2	VTG	Ground speed and heading
3	GGA	Receiver positioning data
4	GSA	DOP and effective satellites
5	GSV	Visible satellites
6	GLL	Geographic location - Latitude/Longitude

2.2.1.1 Minimum dedicated navigation data recommended by RMC

Information	RMC
Describe	Recommended minimum positioning information
Tpe	Output
Format	$--RMC,UTCtime,status,lat,uLat,lon,uLon,spd,cog,UTCdate,mv,mvE,mode*CS<CR><LF>
Example	$GNRMC,084103.00,A,2233.39544,N,11356.55665,E,0.035,,220618,,,A*7A
Parameter Description	

Fields	Name	Format	Parameter Description
1	$--RMC	String	Message ID, RMC statement header, '--' is the system identifier
2	UTC time	hhmmss.ss	The current location's UTC time
3	status	character	Position valid flag. V = invalid data A = valid data
4	lat	ddmm.mmmmm	Latitude, the first two characters represent degrees, the following characters represent minutes
5	uLat	character	Latitude direction: N-North, S-South
6	lon	dddmm.mmmmm	Longitude, the first 3 characters represent degrees, the following characters represent minutes
7	uLon	character	Longitude direction: E-East, W-West
8	spd	Numeric	Ground speed, in knots
9	cog	Numeric	True heading over ground, in degrees
10	UTC date	ddmmyy	Date (dd for day, mm for month, yy for year)
11	mv	Numeric	Magnetic declination, in degrees. Fixed to be empty
12	mvE	character	Magnetic declination direction: E-East, W-West. Fixed to empty
13	Mode	character	Mode indication (A = autonomous positioning, D = differential, R = RTK, E = estimation, N = invalid data)
14	navStatus	character	Navigation status indicator (V means the device does not provide navigation status information)NMEA v4.1 and above only
15	CS	Hexadecimal value	Checksum, the XOR result of all characters between $ and * (excluding $ and *)
16	<CR><LF>	character	Carriage return and line feed

2.2.1.2 VTG Ground Speed and Course

Information	VTG		
Describe	Speed over ground and heading over ground information.		
Type	Output		
Format	$--VTG,cogt,T,cogm,M,sog,N,kph,K,mode*CS<CR><LF>		
Example	$GNVTG,75.20,T,,M,0.009,N,0.017,K,A*02		
Parameter Description			
Fields	name	Format	Parameter Description
1	$--VTG	String	Message ID, VTG statement header, '--' is the system identifier
2	cogt	Numeric	Course relative to true north, in degrees
3	T	character	True north indication, fixed at T
4	cogm	Numeric	Heading relative to magnetic north, in degrees
5	M	character	Magnetic north indication, fixed at M
6	sog	Numeric	Ground speed, in knots
7	N	character	Speed unit is knot, fixed as N
8	kph	Numeric	Ground speed in kilometers per hour
9	K	character	Speed unit, kilometers per hour, fixed as K
10	mode	character	Mode indication (A = autonomous positioning, D = differential, R = RTK, E = estimation, N = invalid data)
11	CS	Hexadecimal value	Checksum, all characters between $ and * (excluding $ and *)XOR result

12	<CR><LF>	character	Carriage return and line feed

2.2.1.3 GGA receiver positioning data

Information	GGA		
Describe	Receiver time, location and positioning related data		
Type	Output		
Format	$--GGA,UTCtime,lat,uLat,lon,uLon,FS,numSv,HDOP,msl,uMsl,sep,uSep,diff Age,diffSta *CS<CR><LF>		
Example	$GNGGA,235316.00,2959.99250,S,12000.00900,E,1,06,1.21,62.77,M, 0.00,M,,*7B		
Parameter Description			
Fields	name	Format	Parameter Description
1	$--GGA	String	Message ID, GGA statement header, '--' is the system identifier
2	UTC time	hhmmss.ss	The current location's UTC time
3	lat	ddmm.mmmmm	Latitude, the first two characters represent degrees, the following characters represent minutes
4	uLat	character	Latitude direction: N-North, S-South
5	lon	dddmm.mmmmm	Longitude, the first 3 characters represent degrees, the following characters represent minutes
6	uLon	character	Longitude direction: E-East, W-West
7	FS	Numeric	GPS positioning status (0 = no positioning, 1 = non-differential positioning, 2 = differential positioning)
8	numSv	Numeric	The number of satellites used for positioning, 00~12
9	HDOP	Numeric	Horizontal Dilution of Precision (HDOP<1.2 is high-precision positioning)
10	msl	Numeric	Altitude, that is, the height of the receiver antenna relative to the geoid high
11	uMsl	character	Altitude unit, meter, fixed character M
12	sep	Numeric	The distance between the reference ellipsoid and the geoid, "-" indicates The geoid is lower than the reference ellipsoid
13	uSep	character	Altitude unit, meter, fixed character M
14	diffAge	Numeric	Differential time (from the last differential signal received)Seconds, non-differential positioning, this item is empty)
15	diffStat	Numeric	The ID of the differential reference station (empty for non-differential positioning)
16	CS	Hexadecimal value	Checksum, all characters between $ and * (excluding $ and *)XOR result
17	<CR><LF>	character	Carriage return and line feed

2.2.1.4 GSA DOP and effective satellites

Information	GSA		
Describe	Satellite number and DOP information used for positioning.		
Type	Output		
Format	$--GSA,smode,FS{,SVID},PDOP,HDOP,VDOP,systemId*CS<CR><LF>		
Example	$GNGSA,A,3,05,21,31,12,18,29,,,,,,,2.56,1.21,2.25,1*01		
Parameter Description			
Fields	name	Format	Parameter Description
1	$--GSA	String	Message ID, GSA statement header, '--' is the system identifier
2	smode	character	Mode switch indication (M = Manual, A = Automatic)
3	FS	number	Positioning status flag (1 = not positioned, 2 = 2D positioning, 3 = 3D positioning)
4	{,SVID}	Numeric	Satellite number used for positioning
5	PDOP	Numeric	Position Dilution of Precision (PDOP)
6	HDOP	Numeric	Horizontal Dilution of Precision (HDOP)
7	VDOP	Numeric	Vertical Dilution of Precision (VDOP)
8	System Id	Numeric	GNSS system ID defined by NMEA (Note [1])NMEA v4.1 and above only
9	CS	Hexadecimal value	Checksum, all characters between $ and * (excluding $ and *)XOR result
10	<CR><LF>	character	Carriage return and line feed
Remark[1] GNSS system ID			
System ID	Describe		
1	GPS system		
2	GLONASS system		
4	BDS system		

2.2.1.5 GSV visible satellite information

Information	GSV		
Describe	The satellite number and elevation, azimuth, carrier-to-noise ratio, etc. of the visible satellite. The number of {satellite number, elevation, azimuth, carrier-to-noise ratio} parameter groups in each GSV sentence is variable, with a maximum of 4 groups and a minimum of 0 groups.		
Type	Output		
Format	$--GSV,numMsg,msgNo,numSv{,SVID,ele,az,cn0}*CS<CR><LF>		
Example	$GPGSV,3,1,12,02,39,117,25,04,02,127,,05,40,036,24,08,10,052,*7E $GPGSV,3,2,12,09,35,133,,10,01,073,,15,72,240,22,18,05,274,*7B $GPGSV,3,3,12,21,10,316,,24,16,176,,26,65,035,42,29,46,277,18*7A		
Parameter Description			
Fields	name	Format	Parameter Description
1	$--GSV	String	Message ID, GSV statement header, '--' is the system identifier

2	numMsg	number	Each GSV sentence outputs information about up to 4 visible satellites. Therefore, when the system has more than 4 visible satellites, multiple GSV statements will be required.
3	msgNo	number	Current statement number
4	numSv	Numeric	Total number of visible satellites
5	{,SVID,ele , az,cn0}	Numeric	They are: Satellite number; Elevation angle, ranging from 0 to 90, in degrees; Azimuth angle, ranging from 0 to 359, in degrees; Carrier-to-noise ratio, ranging from 0 to 99, in degrees. dB, if the current satellite is not tracked, the output is empty.
6	signalId	Numeric	GNSS signal ID defined by NMEA (0 represents all signals)NMEA v4.1 and above only
7	CS	Hexadecimal value	Checksum, all characters between $ and * (excluding $ and *)XOR result
8	<CR><LF>	character	Carriage return and line feed

2.2.1.6 GLL Geographic Location – Latitude/Longitude

Information	GLL		
Describe	Information such as latitude, longitude, positioning time and positioning status.		
Type	Output		
Format	$--GLL,lat,uLat,lon,uLon, UTCtime,valid,mode*CS<CR><LF>		
Example	$GNGLL,2959.99250,S,12000.00900,E,235316.00,A,A*4E		
Parameter Description			
Fields	name	Format	Parameter Description
1	$--GLL	String	Message ID, GLL statement header, '--' is the system identifier
2	lat	ddmm.mmmmm	Latitude, the first two characters represent degrees, the following characters represent minutes
3	uLat	character	Latitude direction: N-North, S-South
4	lon	dddmm.mmmmm	Longitude, the first 3 characters represent degrees, the following characters represent minutes
5	uLon	character	Longitude direction: E-East, W-West
6	UTC time	hhmmss.ss	The current location's UTC time
7	valid	character	Data status (A = valid positioning, V = invalid positioning)
8	mode	character	Mode indication (A = autonomous positioning, D = differential, E = estimated, N = invalid data)
9	CS	Hexadecimal value	Checksum, all characters between $ and * (excluding $ and *)XOR result
10	<CR><LF>	character	Carriage return and line feed

2.2.2 UBX protocol

The UBX protocol is a proprietary protocol developed by u-blox, and it has the following key characteristics:
Compact: Uses 8-bit binary data.
Checksum protection: Employs a low-overhead checksum algorithm.
Modular: Uses a two-stage message identifier (Class and Message ID).

The structure of a UBX protocol packet is shown in Figure 1. As seen in the diagram, each message consists of three parts: header, data, and checksum. The header is two bytes: 0xB5 0x62, which identifies the start of a UBX protocol data transmission.

CLASS is one byte, representing the category of the test data message.
ID is one byte, indicating the specific parameter output under a given CLASS.
LENGTH indicates the length of the data section (in bytes).
CK_A and CK_B are two checksum bytes, used for data verification from the CLASS to the Payload section.

SYNC Char1	SYNCChar2	CLASS	ID	LENGTH (little endian)	PayLoad	CK_A	CK_B

The following introduces the commonly used UBX data packets.

1. UBX-NAV-POSLLH (0x01 0x02)

Message	NAV-POSLLH					
Description	Geodetic Position Solution					
Message Structure	Header	Class	ID	Length (Bytes)	Payload	Checksum
	0xB5 0x62	0x01	0x02	28	see below	CK_A CK_B
Payload Contents:						

Byte Offset	Number Format	Scaling	Name	Unit	Description
0	U4	-	iTOW	ms	GPS time of week of the navigation epoch.
4	I4	1e-7	lon	Deg	Longitude
8	I4	1e-7	lon	Deg	Latitude
12	I4	-	height	mm	Height above ellipsoid
16	I4	-	oeLh	mm	Height above mean sea level

20	U4	-	Hc	mm	Horizontal accuracy estimate
24	U4	-	vv	mm	Vertical accuracy estimate

2. UBX-NAV-STATUS (0x01 0x03)

Message	NAV-STATUS					
Description	Receiver Navigation Status					
Message Structure	Header	Class	ID	Length (Bytes)	Payload	Checksum
	0xB5 0x62	0x01	0x03	16	see below	CK_ACK_B

Payload Contents:

Byte Offset	Number Format	Scaling	Name	Unit	Description
0	U4	-	iTOW	ms	GPS time of week of the navigation epoch.
4	U1	-	gpsFix	-	GPSfix Type, this value does not qualify a fix as valid and within the limits. See note on flag gpsFixOk below. 0x00 = no fix 0x01 = dead reckoning only 0x02 = 2D-fix 0x03 = 3D-fix 0x04=GPS+dead reckoning combined 0x05 = Time only fix 0x06..0xff = reserved
5	X1	-	flags	-	Navigation Status Flags
6	X1	-	fixStat	-	Fix Status Information

7	X1	-	flags2	-	further information about navigation output
8	U4	-	ttff	ms	Time to first fix (millisecond time tag)
12	U4	-	msss	mm	Milliseconds since Startup/Reset

3. UBX-NAV-DOP (0x01 0x04)

Message	NAV-DOP					
Description	Dilution of precision					
Message Structure	Header	Class	ID	Length (Bytes)	Payload	Checksum
	0xB5 0x62	0x01	0x04	18	see below	CK_A CK_B
Payload Contents:						

Byte Offset	Number Format	Scaling	Name	Unit	Description
0	U4	-	iTOW	ms	GPS time of week of the navigation epoch.
4	U2	0.01	gDOP	-	Geometric DOP
6	U2	0.01	pDOP	-	Position DOP
8	U2	0.01	TDOP	-	Time DOP
10	U2	0.01	vDOP	-	Vertical DOP
12	U2	0.01	HkDOP	-	Horizontal DOP
14	U2	0.01	nDOP	-	Northing DOP
16	U2	0.01	eDOP	-	Easting DOP

4. UBX-NAV-SOL (0x01 0x06)

Message	NAV-SOL

Description	Navigation Solution Information					
Message Structure	Header	Class	ID	Length (Bytes)	Payload	Checksum
	0xB5 0x62	0x01	0x06	52	see belo w	CK_A CK_B

Payload Contents:

Byte O ffset	Number Format	Scaling	Name	Unit	Description
0	U4	-	iTOW	ms	GPS time of week of the navigation epoch.
4	I4	-	f	ns	Fractional part of iTOW (range: +/-500000). The precise GPS time of week in seconds is: (iTOW * 1e-3) + (fTOW * 1e-9)
8	I2	-	week	weeks	GPS week number of the navigation epoch
10	U1	-	gpsFix	-	GPSfix Type, range 0..5 0x00 = No Fix 0x01 = Dead Reckoning only 0x02 = 2D-Fix 0x03 = 3D-Fix 0x04 = GPS + dead reckoning combined 0x05 = Time only fix 0x06..0xff: reserved
11	X1	-	flags	-	Fix Status Flags
12	I4	-	eX	cm	ECEF X coordinate
16	I4	-	eCE	cm	ECEF Y coordinate
20	I4	-	eCEf	cm	ECEF Z coordinate
twenty four	U4	-	pAcc	cm	3D Position Accuracy Estimate
28	I4	-	xvX	cm/s	ECEF X velocity
32	I4	-	VxD	cm/s	ECEF Y velocity

36	I4	-	VxD	cm/s	ECEF Z velocity
40	U4	-	sAcc	cm/s	Speed Accuracy Estimate
44	U2	0.01	pDOP	-	Position DOP
46	U1	-	Reserved1	-	Reserved
47	U1	-	numSV	-	Number of SVs used in Nav Solution

5. UBX-NAV-PVT (0x01 0x07)

Message	NAV-PVT					
Description	Navigation Position Velocity Time Solution					
Message Structure	Header	Class	ID	Length (Bytes)	Payload	Checksum
	0xB5 0x62	0x01	0x07	92	see below	CK_A CK_B

Payload Contents:

Byte Offset	Number Format	Scaling	Name	Unit	Description
0	U4	-	iTOW	ms	GPS time of week of the navigation epoch.
4	U2	-	year	y	Year (UTC)
6	U1	-	month	month	Month, range 1..12 (UTC)
7	U1	-	day	d	Day of month, range 1..31 (UTC)
8	U1	-	hour	h	Hour of day, range 0..23 (UTC)
9	U1	-	min	min	Minute of hour, range 0..59 (UTC)
10	U1	-	sec	s	Seconds of minute, range 0..60 (UTC)
11	X1	-	valid	-	Validity flags (see graphic below)
12	U4	-	tAcc	ns	Time accuracy estimate (UTC)
16	I4	-	nano	ns	Fraction of second, range -1e9 .. 1e9 (UTC)

20	U1	-	fixType	-	GNSSfix Type: 0: no fix 1: dead reckoning only 2: 2D-fix 3: 3D-fix 4: GNSS + dead reckoning combined 5: time only fix
21	X1	-	Flags	-	Fix status flags
22	X1	-	flags2		Additional flags
23	U1	-	numSV	-	Number of satellites used in Nav Solution
24	I4	1e-7	lon	deg	Longitude
28	I4	1e-7	lat	deg	Latitude
32	I4	-	height	mm	Height above ellipsoid
36	I4	-	oeLh	mm	Height above mean sea level
40	U4	-	Hc	mm	Horizontal accuracy estimate
44	U4	-	vv	mm	Vertical accuracy estimate
48	I4	-	Nv	mm/s	NED north velocity
52	I4	-	ewE	mm/s	NED east velocity
56	I4	-	D	mm/s	NED down velocity
60	I4	-	gSpeed	mm/s	Ground Speed (2-D)
64	I4	1e-5	headMot	deg	Heading of motion (2-D)
68	U4	-	sAcc	mm/s	Speed accuracy estimate
72	U4	1e-5	headAcc	deg	Heading accuracy estimate (both motion and vehicle)
76	U2	0.01	pDOP	-	Position DOP
78	U1[6]	-	reserved1	-	Reserved
84	I4	1e-5	headVeh	deg	Heading of vehicle (2-D)

88	I2	1e-2	magDec	deg	Magnetic declination
90	U2	1e-2	magAcc	deg	Magnetic declination accuracy

6. UBX-NAV-VELNED (0x01 0x12)

Message	NAV-VELNED					
Description	Velocity Solution in NED					
Message Structure	Header	Class	ID	Length (Bytes)	Payload	Checksum
	0xB5 0x62	0x01	0x12	36	see below	CK_A CK_B

Payload Contents:					
Byte Offset	Number Format	Scaling	Name	Unit	Description
0	U4	-	iTOW	ms	GPS time of week of the navigation epoch.
4	I4	-	Nv	cm/s	North velocity component
8	I4	-	ewE	cm/s	East velocity component
12	I4	-	D	cm/s	Down velocity component
16	U4	-	speed	cm/s	Speed (3-D)
20	U4	-	gSpeed	cm/s	Ground speed (2-D)
twenty four	I4	1e-5	heading	deg	Heading of motion 2-D
28	U4	-	sAcc	cm/s	Speed accuracy Estimate
32	U4	1e-5	cC	deg	Course/Heading accuracy estimate

7. UBX-NAV-SAT (0x01 0x35)

Message	NAV-SAT					
Description	Satellite Information					
Message Structure	Header	Class	ID	Length (Bytes)	Payload	Checksum

		0xB5 0x62	0x01	0x35	8+12*numxD	see below	CK_A CK_B

Payload Contents:					
Byte Offset	Number Format	Scaling	Name	Unit	Description
0	U4	-	iTOW	ms	GPS time of week of the navigation epoch.
4	U1	-	version	-	Message version (1 for this version)
5	U1	-	numSvs	-	Number of satellites
6	U2	-	reserved1	-	Reserved
8 + 12*N	U1	-	gnssId	-	GNSS identifier for assignment
9 + 12*N	U1	-	svId	-	Satellite identifier for assignment
10+ 12*N	U1	-	cno	dBHz	Carrier to noise ratio (signal strength)
11+ 12*N	I1	-	elev	deg	Elevation (range: +/-90), unknown if out of range
12+ 12*N	I2	-	azim	deg	Azimuth(range 0-360), unknown if elevation is out of range
14+ 12*N	I2	0.1	prRes	m	Pseudo range residual
16+ 12*N	X4	-	flags	-	Bitmask

8.UBX-NAV-TIMEUTC (0x01 0x21)

Message	NAV-TIMEUTC					
Description	UTC Time Solution					
Message Structure	Header	Class	ID	Length (Bytes)	Payload	Checksum
	0xB5 0x62	0x01	0x21	20	see below	CK_A CK_B
Payload Contents:						
Byte Offset	Number Format	Scaling	Name	Unit	Description	

0	U4	-	iTOW	ms	GPS time of week of the navigation epoch.
4	U4	-	tAcc	ns	Time accuracy estimate (UTC)
8	I4	-	nano	ns	Fraction of second, range -1e9 .. 1e9 (UTC)
12	U2	-	year	y	Year, range 1999..2099 (UTC)
14	U1	-	month	month	Month, range 1..12 (UTC)
15	U1	-	day	d	Day of month, range 1..31 (UTC)
16	U1	-	hour	h	Hour of day, range 0..23 (UTC)
17	U1	-	min	min	Minute of hour, range 0..59 (UTC)
18	U1	-	sec	s	Seconds of minute, range 0..60 (UTC)
19	X1	-	valid		Validity Flags

9. UBX -MON-HW (0x0A 0x09)

Message	MON-HW					
Description	Hardware Status					
Message Structure	Header	Class	ID	Length (Bytes)	Payload	Checksum
	0xB5 0x62	0x0A	0x09	60	see below	CK_A CK_B
Payload Contents:						

Byte Offset	Number Format	Scaling	Name	Unit	Description
0	X4	-	pinSel	-	Mask of Pins Set as Peripheral/PIO
4	X4	-	pinBank	-	Mask of Pins Set as Bank A/B
8	X4	-	pinDir	-	Mask of Pins Set as Input/Output
12	X4	-	pinVal	-	Mask of Pins Value Low/High
16	U2	-	noisePerMS	-	Noise Level as measured by the GPS Core

18	U2	-	agc	-	AGC Monitor (counts SIGHI xor SIGLO, range 0 to 8191)
20	U1	-	aStatus	-	Status of the Antenna Supervisor State Machine (0=INIT, 1=DONTKNOW, 2= OK, 3=SHORT,4=OPEN)
21	U1	-	aPower	-	Current PowerStatus of Antenna (0= OFF, 1=ON, 2=DONTKNOW)
22	X1	-	flags	-	Flags
23	U1	-	reserved1	-	Reserved
24	X4	-	usedMask	-	Mask of Pins that are used by the Virtual Pin Manager
28	U1[17]	-	VP	-	Array of Pin Mappings for each of the 17 Physical Pins
45	U1	-	jamInd	-	CW Jamming indicator, scaled (0 = no CW jamming, 255 = strong CW jamming)
46	U1[2]	-	reserved2	-	Reserved
48	X4	-	pinIrq	-	Mask of Pins Value using the PIO Irq
52	X4	-	pullH	-	Mask of Pins Value using the PIO Pull High Resistor
56	X4	-	pullL	-	Mask of Pins Value using the PIO Pull Low Resistor

2.3 Reference Program

2.3.1 NMEA0183Protocol Verification Reference Program

```
unsigned char Calc_GPS_Sum( const char* Buffer ) {

    unsigned char i, j, k, sum;
    sum = 0;
    for ( i = 1; i < 255; i++ ) //ifrom1The beginning is to flash the $ start character {

        if ( ( Buffer[i] != '*' ) && ( Buffer[i] != 0x00 ) ) //Determine the end character {

            sum ^= Buffer[i]; //GPSThe checksum algorithm isXOR }

        else
        {
            break;
        }
    }
    j = Buffer[i + 1]; //Get the two characters after the

    terminator k = Buffer[i + 2];

    if ( isalpha( j ) ) //Determines whether the character is an English letter. If it is an English
     letter, it returns a non-zero value, otherwise it returns zero. {
        if ( isupper( j ) ) //If the character is an uppercase English letter, it returns a
        non-zero value, otherwise it returns zero {
            j -= 0x37;//Forced to16Base }

        else
        {
            j -= 0x57;//Forced to16Base }

    }
    else
    {

        if ( ( j >= 0x30 ) && ( j <= 0x39 ) ) {

            j -= 0x30;//Forced to16Base
        }
    }


    if ( isalpha( k ) ) //Determines whether the character is an English letter. If it is an
    English letter, it returns a non-zero value, otherwise it returns zero. {
        if ( isupper( k ) ) //If the character is an uppercase English letter, it returns a
        non-zero value, otherwise it returns zero {
            k -= 0x37; //Forced to16Base  k -=
        }
        else
        {
            0x57; //Forced to16Base

        }
    }
```

```
        else
        {
                if ( ( k >= 0x30 ) && ( k <= 0x39 ) ) {

                        k -= 0x30; //Forced to16Base }

        }

        j = ( j << 4 ) + k; //Force merge to16Base //
        gps_sum = j;

        if ( sum == j )
        {
                return Valid; //Checksum
        OK }
        else
        {
                return Invalid; //Checksum
        Error }
}
```

2.3.2 UBXProtocol Verification Reference Program

```
//fromCLASSarrivePayLoadAll data
unsigned int CalcCheckAB(unsigned char *Bytes, unsigned char len) {

        unsigned char i,a,b ;
        unsigned int result;
result = 0;
a = 0;
b = 0;
    for ( i = 0; i < len ; i++) {

a+=Bytes[i];
b+=a;
    }
result = a<<8|b;
return result;
}
```

3. Contact Us

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4. Appendix 1 (Test Method)

4.1 Overview

This document primarily introduces the basic testing methods for high-precision satellite positioning receivers. The main tests include checking whether the device powers on and functions properly, verifying data output, and assessing whether the positioning accuracy is within the expected range. These tests are applicable to devices with meter-level, sub-meter-level, and decimeter-level precision.

4.2 Test content

4.2.1 Test Preparation

(1) Install the USB TO TTL serial port board driver (CH340);

(2) Install the serial port tool on the PC, such as "sscom5.12 serial port tool";

(3) Connect the serial port board to the locator, as shown below:

北斗GPS接收机 模块接口端		USB TO TTL 串口板		
黑线 GND	⟷	GND		
红线 DC5V	⟷	DC5V	⟷	电脑USB端口
黄线 RX	⟷	TX		
白线 TX	⟷	RX		

(4) Test environment with clear sky.
(5) After completing the above steps, check the corresponding COM port driver in the Device Manager on the computer to ensure it is functioning properly, as shown in the image below:

4.2.2 Test steps

(1) Open the serial port tool, such as "sscom5.12 Serial Port Tool" or HyperTerminal, and select the baud rate of 115200 and the corresponding COM port number, as shown below:

If the data exceeds 1MB, check the "Receive data to file" option. Before testing, also ensure the

"Add carriage return and line feed" option is checked.
The serial port information after connection is as follows:

Setting parameter success
Saving parameter
Saving parameter success
Resetting system
Please wait

(2) When the serial port outputs the following information, the device indicates successful positioning:

$GPRMC,033301.30,A,2236.361122,N,11351.963318,E,0.005,,280917,,,A*70
$GPRMC,033301.40,A,2236.361121,N,11351.963311,E,0.004,,280917,,,A*7C

$GPRMC,033301.50,A,2236.361124,N,11351.963312,E,0.008,,280917,,,A*77
$GPRMC,033301.60,A,2236.361124,N,11351.963312,E,0.004,,280917,,,A*78
$GPRMC,033301.70,A,2236.361123,N,11351.963306,E,0.004,,280917,,,A*7B
$GPRMC,033301.80,A,2236.361123,N,11351.963306,E,0.007,,280917,,,A*77
$GPRMC,033301.90,A,2236.361124,N,11351.963297,E,0.004,,280917,,,A*7B
$GPRMC,033302.00,A,2236.361124,N,11351.963297,E,0.006,,280917,,,A*73
$GPRMC,033302.10,A,2236.361123,N,11351.963296,E,0.005,,280917,,,A*77
$GPRMC,033302.20,A,2236.361123,N,11351.963290,E,0.007,,280917,,,A*70
$GPRMC,033302.30,A,2236.361123,N,11351.963290,E,0.005,,280917,,,A*73

4.2.3 Test Example

(1) Office test: 1/4 sky static test, as shown below:

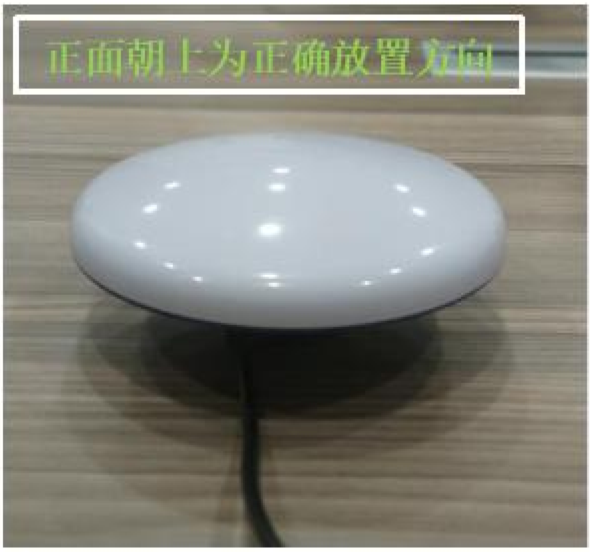
Place the RAC high-precision satellite positioning receiver on a windowsill and securely mount it using a bracket. Connect it to the laptop. Turn off the indoor signal amplifier. Repeat the testing steps as outlined in the previous content.

Note: The measured data in this environment only verifies that the receiver can receive data normally and there is no hardware problem.

(2) Place the device on a vehicle and conduct a dynamic test while driving, as shown below:

Place the RAC high-precision satellite positioning receiver in the center of the center console under the windshield. (Note that the receiver should be placed with the front facing up) Connect the laptop. Repeat the above (test content) steps to test

(3) Placement method



V. Appendix 2 (Test Report)

5.1 Overview

This report describes the performance test results of the RAC high-precision satellite positioning receiver, including comparisons with RTK positioning technology under different environments. The RAC technology does not rely on any ground-based or space-based augmentation systems or inertial navigation technologies. It achieves decimeter-level dynamic positioning accuracy using only L1 or B1 frequency band signals, eliminating the need for ground-based augmentation networks in high-precision satellite positioning.

The technology comparison is shown in the table below:

Positioning Technology	Use Geography scope	Service Fee	Data charges	External antenna	Signal blocking environment	Use Operation	High Dynamics
RAC	Any in the world Place	none	none	none	insensitive	Easy	support
RTD	Base station broadcast scope	have	have	have	sensitive	Registration required networking	Not supported
RTK	Ground-based network scope	have	have	have	sensitive	Registration required networking	Not supported

5.2 Test platform

To test and evaluate the performance of the RAC high-precision satellite positioning receiver in different environments and signal strengths, and to compare it with RTK under actual application signal conditions, the following tests were conducted:Static testing on rooftop platforms.Long-duration, long-range testing in typical environments, including:Multi-lane highwaysTree-lined streetsElevated highwaysUrban canyons (narrow streets surrounded by tall buildings)

Test equipment:

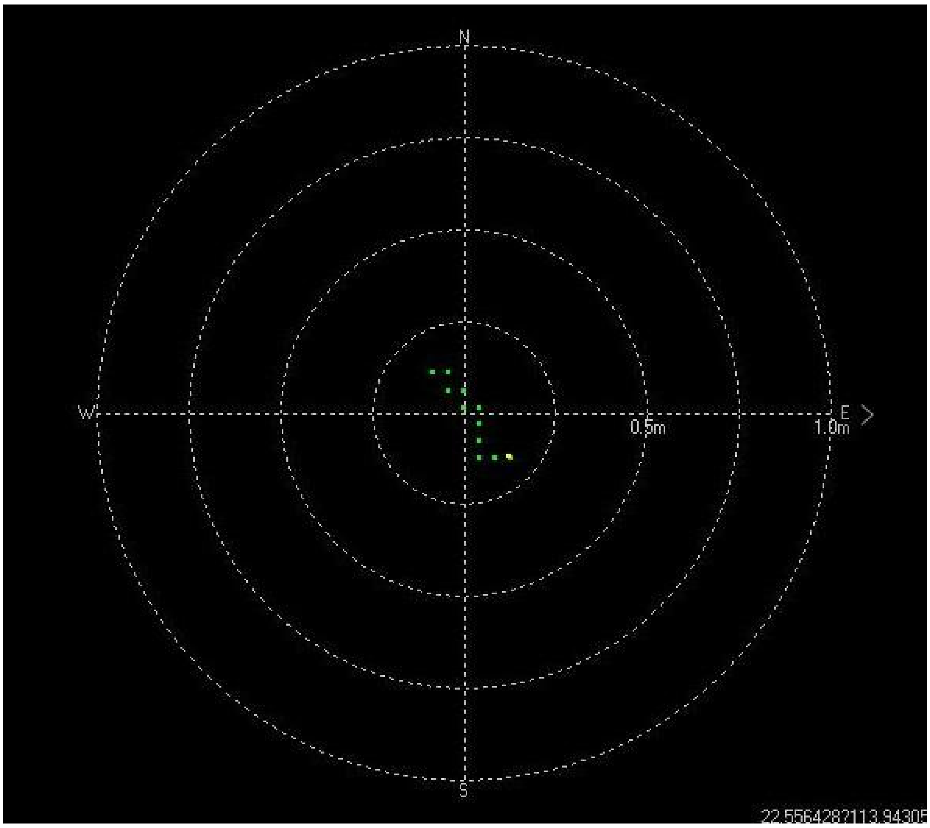
Model	Content	Remark
RAC-F1	Receiver + serial cable	Antenna built-in
Sinan T300	Whole machine + Qianxun Zhicun	

Equipment installation pictures

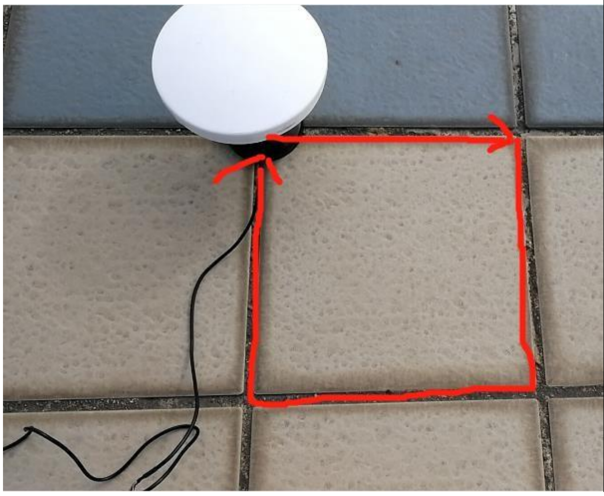
5.3 Test Results

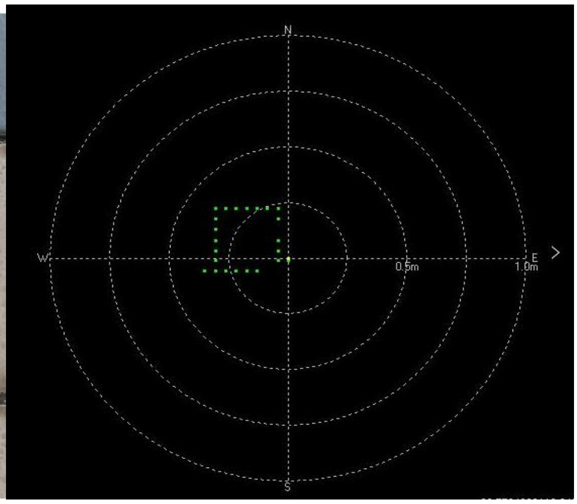
5.3.1 Actual signal static test

1. In an open sky environment, after being placed statically for 30 minutes, the static positioning accuracy is within 25 cm, as shown in the figure below.



2. In an open sky environment, the movement trajectory is in the shape of a square with a side length of 25 cm, as shown in the figure below:





5.3.2 Actual signal dynamic test

Testing Roadmap

5.3.2.1 Shenzhen Expressway Multi-lane Road Condition Test

The test location is on the Beijing-Hong Kong-Macau Expressway in Shenzhen, where the lane lines are clearly visible. This setup is used to evaluate the positioning performance of the RAC high-precision receiver compared to RTK devices. Both devices were installed at the center of the vehicle's roof and securely fixed. The overall route and driving trajectory are shown in the figure below:

Green: RAC Red: RTK

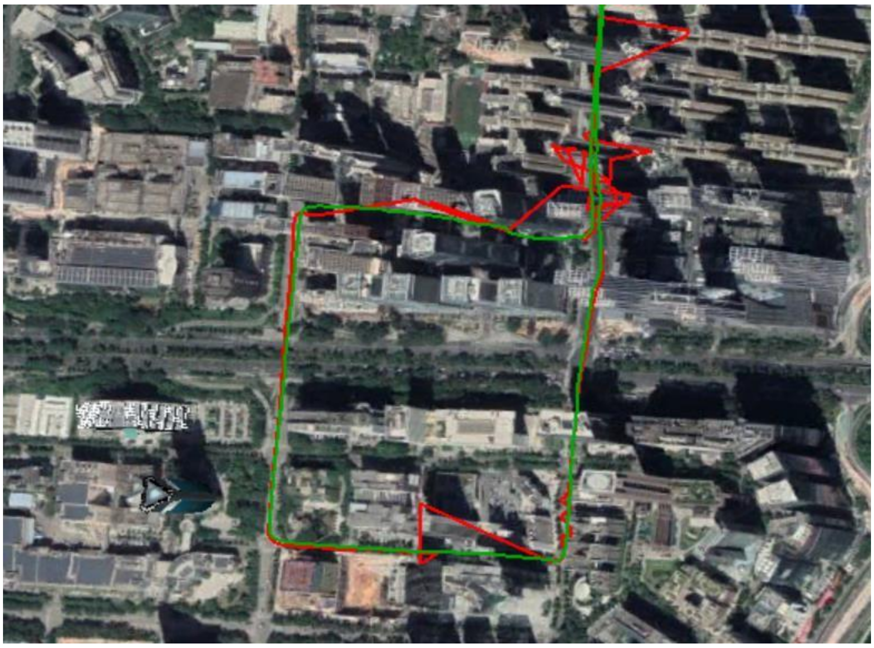
5.3.2.2 Boulevard Road Condition Test

The test location is on the Shenzhen 107 Auxiliary Road heading towards Xixiang, a section with dense tree coverage. This test is designed to verify the sensitivity of RAC accuracy to signal obstructions. The overall route and trajectory are shown in the figure below:

Green: RAC Red: RTK

5.3.2.3 Urban Canyon Road Condition Test

The test location is in the Dachong CBD area of Nanshan District, Shenzhen, which is a densely built-up urban area. This test is designed to evaluate the sensitivity and positioning performance of the RAC device compared to the RTK device in an environment with high-density urban buildings. The trajectory map is shown below:



Green: RAC Red: RTK

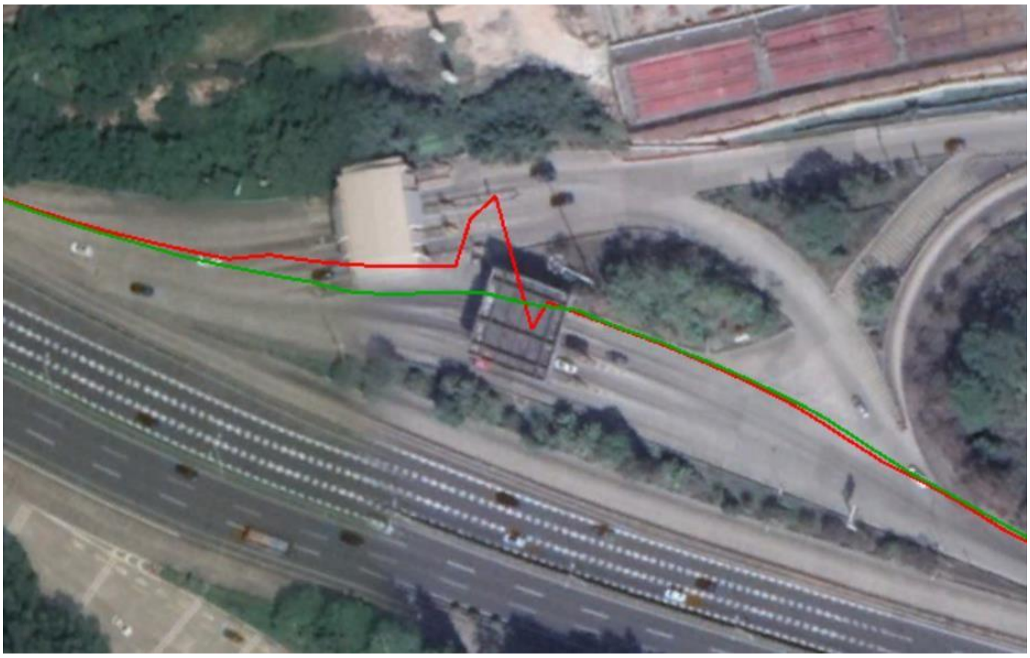
5.3.2.4 Viaduct road condition test

The test location is near the Humen Bridge in Dongguan, where the test was conducted under multi-level interchange road conditions. This test compares the positioning performance of the RAC device with the RTK device. The overall route and trajectory map are shown below:

Green: RAC Red: RTK

5.3.2.5 Short-term road occlusion test

The test location is near the Nantou Toll Station in Shenzhen, where the test was conducted to evaluate the sensitivity of the RAC device and the RTK device during brief signal obstructions. The overall route and trajectory map are shown below:



Green: RAC Red: RTK

5.4 In conclusion

This report describes the comparison of performance between the RAC high-precision satellite positioning receiver and RTK devices in different environments. The test data reveals the following differences in positioning performance between the RAC device and the RTK device:

In environments with brief satellite signal interference, such as on overpasses and toll stations, RTK devices are more sensitive than the RAC device, but there were instances of positioning offset.

In urban canyon sections, where tall buildings cause severe signal obstruction, both RAC devices and RTK devices exhibited positioning offset.

In relatively open areas, both the RAC device and the RTK device maintained overlapping positioning trajectories, achieving high-precision positioning results.

As described above, the RAC high-precision positioning system offers advantages over RTK devices in terms of lower cost, fewer restrictions on usage scenarios, easier operation, and meeting positioning accuracy requirements. This makes it particularly advantageous for applications in vehicle networking.