RT-Base

**GNSS
Base
Station**

RT-Base
User Manual

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Introduction

The RT-Base is a GNSS Base Station suitable for transmitting Differential corrections to the OxTS inertial and GNSS navigation systems and other products that use GPS/GLONASS. The position accuracy of Differential and RTK GNSS receivers is improved when using the RT-Base.

Four models of the RT-Base exist; the RT-Base-20 can supply L1 corrections suitable for 20cm positioning and the RT-Base-2 can supply L1/L2 corrections suitable for 2cm positioning. Two more models, the RT-Base-20G and RT-Base-2G are GPS/GLONASS versions. All models are identical in their operation.

The RT-Base is available with several different radio options. Different radios are required for license free operation in different countries.

Overview

Figure 1, below, gives an overview of how Differential GNSS works. The information from each satellite is measured by both the RT-Base and by the GNSS receiver in the car. The RT-Base works out the error in the satellite's information and transmits it to the car using a radio link. The GNSS receiver in the car then applies the correction to each satellite's measurement before it computes position and time.

Figure 1. Differential GNSS overview

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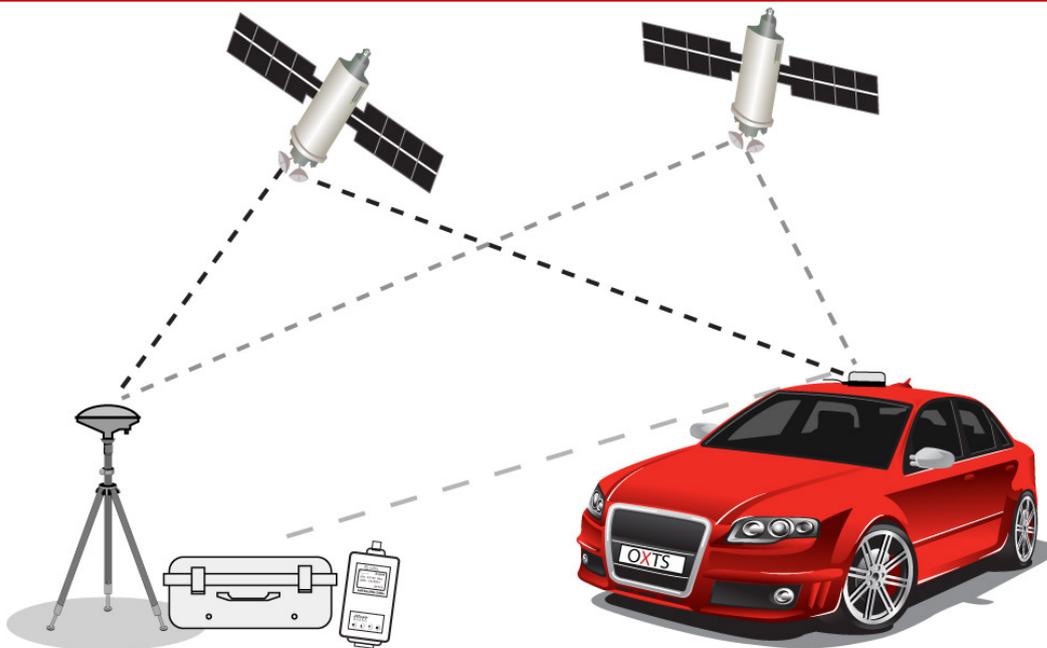
For RTK (Real-Time Kinematic) Carrier-Phase measurements the principle is the same, but the GNSS receiver in the car also has to figure out the difference in the number of carrier-phase cycles between the RT-Base and the car. The RT-Base measures the carrier-phase of the signals from each satellite and transmits it to the car.

Differential GNSS works in real-time because the corrections from each satellite vary slowly and predictably. The GNSS receiver in the car uses a model to predict the error from each satellite. It can update its model when the radio link transmits new data. It is not necessary for the GNSS receiver in the car to wait until the radio has transmitted the correction before it outputs its latest value.

Table 1, below, lists information about each of the different correction types available.

Table 1. Summary of differential correction types

Correction	Measurement	Accuracy	Max Age (typical)	RT-Base Model
Differential	L1 Pseudo-Range	45cm[1]	60s	RT-Base-20 RT-Base-2
L1 (GPS only)	L1 Carrier-Phase	20cm	30s	RT-Base-20 RT-Base-2
L1/L2 (GPS only)	L1/L2 Carrier-Phases	2cm	30s	RT-Base-2 only
L1 (GPS + GLONASS)	L1 Carrier-Phase	20cm	30s	RT-Base-20G RT-Base-2G
L1/L2 (GPS + GLONASS)	L1/L2 Carrier-Phases	2cm	30s	RT-Base-2G only

Note 1: Using the smoothing of the Inertial Navigation System the RT can achieve 40cm of position accuracy using Differential GNSS.

For Pseudo-Range (not carrier-phase) Differential GNSS the corrections can be up to 60s old (depending on the GNSS receiver in the car). For RTK corrections (20cm and 2cm) the corrections can be up to 30s old (again, depending on the GNSS receiver in the car).

Features

The RT-Base is a self-contained unit that includes:

- The Base-Station GNSS receiver.

- Battery suitable for over 12 hours of operation.

- Radio Modem.

- Mains Power Supply and Battery Charger.

- GNSS Antenna, 15m Cable and Tripod.

- Radio Modem Aerial, Cable and Magnetic Mount.

The RT-Base also includes a Remote Radio Modem and Antenna for use on the vehicle.

The Radio Modem in your RT-Base will be factory configured for use in a particular country or territory. Typically the radio can transmit between 2 km and 5 km line-of-sight. Trees, buildings, hills and other obstructions limit the range that can be used.

The RT-Base is also suitable for use as a general base-station for other products, such as the Datron MicroSAT. The RT-Base transmits corrections in RTCA, RTCA2 or RTCM V3 format, which are accepted by many GNSS receivers.

Table 2. Overview of different radios

Radio	Specification
SATEL	380 - 480 MHz band, up to 1 W, typically 5 km. License free bands available for many European countries. Radio will typically cover 8 bands with 25 kHz channel spacing, except for SATEL Easy radios which have a much wider range of configurable frequency.
SATEL	869 MHz band, up to 500 mW, typically 2 km. License free across most of European Union.
Freewave	900 MHz band, up to 1 W, typically >10 km. License free in USA, Brazil, Canada.
Futaba	2.4 GHz band, 10 mW, maximum 2 km. License free in Japan.

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Scope of delivery

Table 3, Table 4 and Table 5, list all the items that are delivered with an RT-Base and the respective radio modem.

The customer must check that the radio can be used without a license or obtain a suitable license before using the RT-Base. Oxford Technical Solutions cannot be held responsible for using this equipment illegally without the correct radio license.

Table 3. Summary of the RT-Base components with SATEL radio

Qty	Description
1	RT-Base Unit
1	GPS-C006 15m GPS Antenna Cable
1	GPS-702-GG GPS Antenna[1]
1	SATEL Satelline-3ASd Radio Modem (for remote vehicle)
2	Radio Modem Aerial/Antenna with 3m cable and Magnetic Mount
1	Tripod
1	IEC Mains Cable (UK, EU and US-style plugs can be specified)
1	77C0002B Power Cable
1	Internal Radio Link – fit to use internal radio
1	RT-Base User Manual
1	RT-Base Quick Guide

Note 1: Other GNSS antenna models might be supplied depending on the RT-Base model

Table 4. Summary of the RT-Base components with Freewave radio

Qty	Description
1	RT-Base Unit
1	GPS-C006 15m GPS Antenna Cable
1	GPS-702-GG GPS Antenna[1]
1	Freewave FGR-115RC 900MHz Radio (for remote vehicle)
1	14C0044B Freewave Radio Cable
1	Car Antenna (short) with 20ft cable
1	Base-Station Antenna (long) with 20ft cable
1	Tripod
1	IEC Mains Cable (UK, EU and US-style plugs can be specified)
1	77C0002B Power Cable
1	Internal Radio Link – fit to use internal radio
1	RT-Base User Manual
1	RT-Base Quick Guide

Note 1: Other GNSS antenna models might be supplied depending on the RT-Base model

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Table 5. Summary of the RT-Base components with Futaba radio

Qty	Description
1	RT-Base Unit
1	GPS-C006 15m GPS Antenna Cable
1	GPS-702-GG GPS Antenna[1]
3	Radio Antenna, SMA connector and Magnetic Base
2	2m SMA-SMA Antenna Extension Cable
1	5m SMA-SMA Antenna Extension Cable
1	TNC-SMA Adaptor (fitted to one of the Radio Antennas)
1	Tripod
1	IEC-US Mains Lead
1	77C0002B Power Cable
1	14C0045A RT3000 Futaba Radio Cable
1	Internal Radio Link – fit to use internal radio
1	Futaba Radio Modem (for remote vehicle)
1	RT-Base User Manual
1	RT-Base Quick Guide

Note 1: Other GNSS antenna models might be supplied depending on the RT-Base model

Figure 2. RT-Base components

Specification

The technical specification of the RT-Base unit is shown in Table 6, below.

Table 6. Technical specification (except Radio Modem)

Parameter	Specification
Mains Power	110-240 V AC. 50-60 Hz. 3 A Max.
Battery	12 V, 7Ah, Sealed Lead-Acid
Charge Time	2 hours
Operating Time	> 10 hours
Operating Temperature	0 to 50°C
Charge Temperature	10 to 40°C
Environment	IP65 – with lid closed
Relative Humidity	95 %, non-condensing
Corrections	RTCA, RTCA2, RTCM V3
Frequency	1 Hz
Format	RS232
Dimensions	486 x 392 x 192 mm
Weight	12.6 kg

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Warranty

Oxford Technical Solutions Limited warrants the RT-Base products to be free of defects in materials and workmanship, subject to the conditions set forth below, for a period of one year from the Date of Sale.

'Date of Sale' shall mean the date of the Oxford Technical Solutions Limited invoice issued on delivery of the product. The responsibility of Oxford Technical Solutions Limited in respect of this warranty is limited solely to product replacement or product repair at an authorised location only. Determination of replacement or repair will be made by Oxford Technical Solutions Limited personnel or by personnel expressly authorised by Oxford Technical Solutions Limited for this purpose.

In no event will Oxford Technical Solutions Limited be liable for any indirect, incidental, special or consequential damages whether through tort, contract or otherwise. This warranty is expressly in lieu of all other warranties, expressed or implied, including without limitation the implied warranties of merchantability or fitness for a particular purpose. The foregoing states the entire liability of Oxford Technical Solutions Limited with respect to the products herein.

Conformance notices

The RT-Base complies with the radiated and conducted emission limits Class B of FCC CFR 47, Class B of Part 15 of the FCC rules, with the conducted emissions limits for Class A of EN 61326, with the radiated emissions limits for Class B of EN 61326 and immunity limits of EN 61326. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Re-orient or relocate the receiving antenna

- Increase the separation between the equipment and the receiver

It is occasionally possible for the LCD display of the RT-Base unit to become black following electrostatic discharge, however the RT-Base continues to work correctly.

The RT-Base incorporates a GNSS receiver. Any GNSS receiver will not be able to track satellites in the presence of strong RF radiations within 70 MHz of either GNSS frequencies (1575 MHz (L1), 1228 MHz (L2)).

The RT-Base conforms to the requirements for CE.

Regulator Testing Standards

- EN55022

- EN61000-4-2

- EN61000-4-3

- EN61000-4-4

- EN61000-4-5

- EN61000-4-6

- EN61000-4-11

- FCC CFR 47: Class B

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Operation

Follow these steps to operate your RT-Base unit correctly.

Charging

Before using the RT-Base for the first time charge the battery in the unit by connecting it to the mains. A switch next to the mains plug can be used to turn the mains power on or off. The RT-Base takes about 2 hours to fully charge.

Choosing a suitable location

For correct operation of the RT-Base it is essential to locate the GNSS antenna in a location where it has a full view of the sky, down to an elevation of 10 degrees in all directions. It must also be away from reflective objects, like buildings and trees.

Figure 3. RT-Base location away from buildings, trees and reflective objects

The RT-Base unit should not be left in direct sunlight or the internal temperature may exceed the specification. The temperature range of the unit is restricted because of the internal battery.

Connecting the RT-Base system

1. Connect the GNSS Antenna to the tripod or to a secure pole. The mounting should ensure that the antenna does not move, including in wind or gusts (such as when a car drives past).

2. Connect the GNSS Antenna Cable to the GNSS Antenna and to the GNSS Antenna input on the RT-Base unit.

3. Ensure that the link wire is fitted between the two 9-way D-type connectors to activate the internal radio, see section Using an external radio for more details.

    Note: Never extend or shorten the GNSS Antenna Cable. The loss in the cable is carefully matched to the GNSS Receiver and lengthening or shortening the cable will reduce the performance of the RT-Base system.

4. Connect the GNSS Cable to the GNSS Antenna TNC on the front of the RT-Base.

    Note: Never connect the GNSS Antenna to the Radio Aerial connector. The use of two TNC connectors is required since they have much better ground properties compared to BNC connectors. The Radio Aerial output has a high-power signal that may damage the antenna.

5. Locate the Radio Modem Aerial at least 2m away from the GNSS Antenna. Clip the Radio Modem Aerial on a metal object, such as the roof of a car. Connect the Radio Modem Aerial to the Radio Aerial connector on the RT-Base unit.
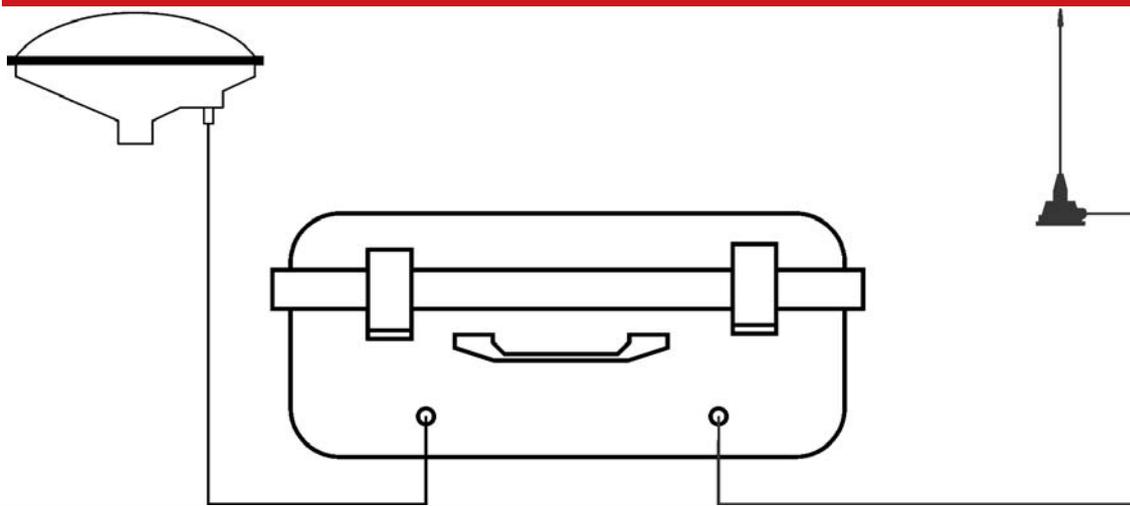
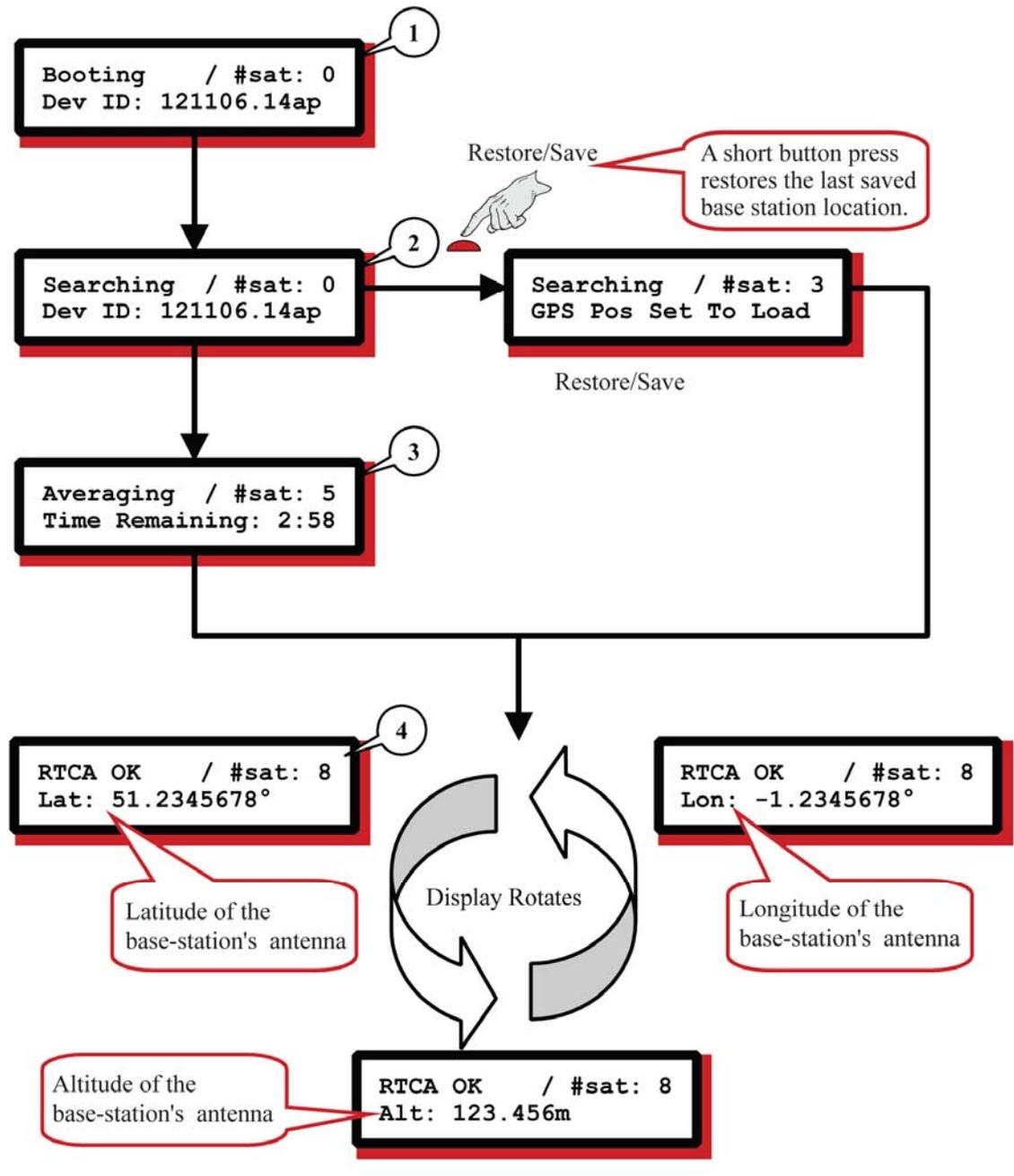**Figure 4. RT-Base connections**

Figure 4, above, shows the connections for the GNSS Antenna and the Radio Aerial.

Using the RT-Base system

After turning on the RT-Base unit, it follows the sequence in Figure 5, below.

Figure 5. RT-Base flowchart

Step 1. The RT-Base unit boots the GNSS receiver.

Step 2. The GNSS receiver starts searching for satellites. This normally takes about 90s, but can take up to 20 minutes if the unit has been turned off for a long period of time or has been moved a significant distance since last time it was used.

The number following the "#sat:" counts the number of satellites being *tracked*.

Step 3. Once the GNSS receiver has found its position it averages the position for three minutes. This does not give a very repeatable position. For repeatable performance the averaged position should be saved and restored next time.

To use the Restore/Save button you must have the GNSS Antenna in exactly the same location (ideally to 2mm or better) as when the position was saved.

Once the Position Averaging has started you cannot use the Restore feature any longer. Turn the RT-Base off and on again if you need to use the Restore feature.

Step 4. In Step 4 the RT-Base unit starts transmitting corrections (the radio will be inactive until now). The display shows the Latitude, Longitude and Altitude of the location of the GNSS Antenna.

Once at Step 4, a short press of the Restore/Save button will save this location. This will overwrite the last saved location and can be restored next time the RT-Base unit is started. Next time you use the RT-Base just press the button (less than 2 seconds) during either the "Booting" or "Searching" states and the last saved base station position will be loaded.

ESD notice

- The LCD display is sensitive to electro-static discharge (ESD).

- The display may go blank when ESD occurs to some parts of the RT-Base.

- Other components in RT-Base continue to operate correctly even if display appears blank due to ESD.

Changing the differential correction format

There are a number of different standards for the differential corrections which will improve the position accuracy of moving GNSS receivers. The RT-Base supports three of these differential correction formats: RTCA, RTCA2 and RTCM V3.

The differential correction format of the RT-Base can be changed so that the RT-Base can be used with GNSS and GLONASS RT units. The differential correction formats can be changed in a matter of seconds, saving you time if you have one base station but need to use different RT units (GLONASS and non-GLONASS) at different times.

Please note: By default the RT-Base uses the RTCA standard for transmitting its differential corrections. You do not need to change the differential correction format unless you have a GLONASS-capable RT unit (RT2004 or RT with the letter "G" after the model number, e.g. RT3002G) and a GLONASS base station (RT-Base-20G or RT-Base-2G).

How to change the differential correction format

The RT-Base firmware will allow the differential correction format to be selected from a choice of RTCA, RTCA2 and RTCM V3. Changing the differential correction format on your RT-Base is quick and easy.

1. Just hold down the button for more than 5 seconds which enables you to navigate through the formats.

2. After the button has been held down for 5 seconds, the display will indicate that the RT-Base is in "Diff Mode" (correction format selection mode) and will report the currently configured differential correction format (e.g. by showing one of "Select RTCA", "Select RTCA2" or "Select RTCMv3".

3. Every two seconds the differential format selection will cycle to the next differential format; when the button is released, the format being displayed will be selected and the display will show which format has been selected.

The RT-Base firmware will remember the last differential format configured, and restore this configuration on power-up.

What the RT-Base transmits in each mode

An RT-Base configured to output RTCA corrections outputs the following messages:

- RTCAOBS (L1/L2 pseudo-range and carrier-phase) every second.
- RTCAREF (base station position) every 10 seconds.
- RTCA1 (pseudo-range corrections) every second.

An RT-Base configured to output RTCA2 corrections outputs the following messages:

- RTCAOBS2 (L1/L2 GNSS+GLONASS pseudo-range and carrier-phase) every second
- RTCAREF (base station position) every 10 seconds
- RTCA1 (pseudo-range corrections) every second

An RT-Base configured to output RTCM V3 corrections outputs the following messages:

- RTCM1004 (L1/L2 GNSS pseudo-range and carrier-phase) every second
- RTCM1012 (L1/L2 GLONASS pseudo-range and carrier-phase) every second
- RTCM1005 (base station antenna position) every 10 seconds
- RTCM1007 (base station antenna descriptor) every 10 seconds. The base station firmware always configures the base station antenna as a Novatel GNSS-702-GGL

Compatibility with RT models

Please note that different models are only compatible with some of the differential correction formats. If you have a unit which is not GLONASS capable, then you can just keep the default differential correction format RTCA. If you have a GLONASS capable RT system, then you should choose the RTCA2 or RTCM format.

The table below lists the formats that the products can use in order to achieve integer ambiguity carrier-phase positioning accuracies of around 2cm.

Table 7. Integer ambiguity carrier-phase position modes

Product	RTCA	RTCA2	RTCM V3
RT3002, RT3003, RT4002, RT4003 (OEM4) [1]	Yes	No	Yes
RT3002, RT3003, RT4002, RT4003 (OEMV) [1]	Yes	Yes	Yes
RT3002G, RT3003G, RT4002G, RT4003G	Sub-optimal	Yes	Yes
RT2002	Yes	Yes	Yes
RT2002G	Sub-optimal	Yes	Yes
RT2004	No	Yes	No
Survey+	Yes	Yes	Yes
Survey+G	Sub-optimal	Yes	Yes

Note: Products not listed above cannot achieve integer ambiguity carrier-phase positioning accuracies.

Note 1: Products with serial numbers higher than about 150 are likely to have OEMV or OEM6 cards in them.

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The table below lists the formats that the products can use in order to achieve floating ambiguity carrier-phase positioning accuracies (of around 20cm).

Table 8. Integer ambiguity carrier-phase position modes

Product	RTCA	RTCA2	RTCM V3
RT3002, RT3003, RT4002, RT4003, RT3020, RT3022, RT4020, RT4022 (OEM4) [1]	Yes	No	Yes
RT3002, RT3003, RT4002, RT4003, RT3020, RT3022, RT4020, RT4022 (OEMV) [1]	Yes	Yes	Yes
RT3002G, RT3003G, RT4002G, RT4003G, RT3020G, RT3022G, RT4020G, RT4022G	Sub-optimal	Yes	Yes
RT2002	Yes	Yes	Yes
RT2002G, RT2004	Sub-optimal	Yes	Yes
Survey+	Yes	Yes	Yes
Survey+G	Sub-optimal	Yes	Yes

Note: Products not listed above cannot achieve floating ambiguity carrier-phase positioning accuracies.

Note 1: Products with serial numbers higher than about 150 are likely to have OEMV or OEM6 cards in them.

Discussion on repeatability

Differential Corrections for GNSS change the way that a GNSS receiver works. When using Differential Corrections the GNSS receiver is effectively measuring the position *relative* to the base-station, not the absolute position on earth. This leads to several effects that the user should be aware of:

1.   If the base-station antenna is moved then the remote GNSS receivers move too. It is important to put the GNSS antenna in a location where it cannot move or be moved. See Figure 6.

2.   The base-station has to measure its own position. If the base-station gets this position wrong then the remote GNSS receivers will also be wrong. They will be correct relative to the base-station, but they will have the same error on the earth that the base-station has. This is important when turning the RT-Base off and on again. See Figure 7.

Figure 6. Shifting base-station antenna example

Shifting the base-station antenna shifts the remote position as well.
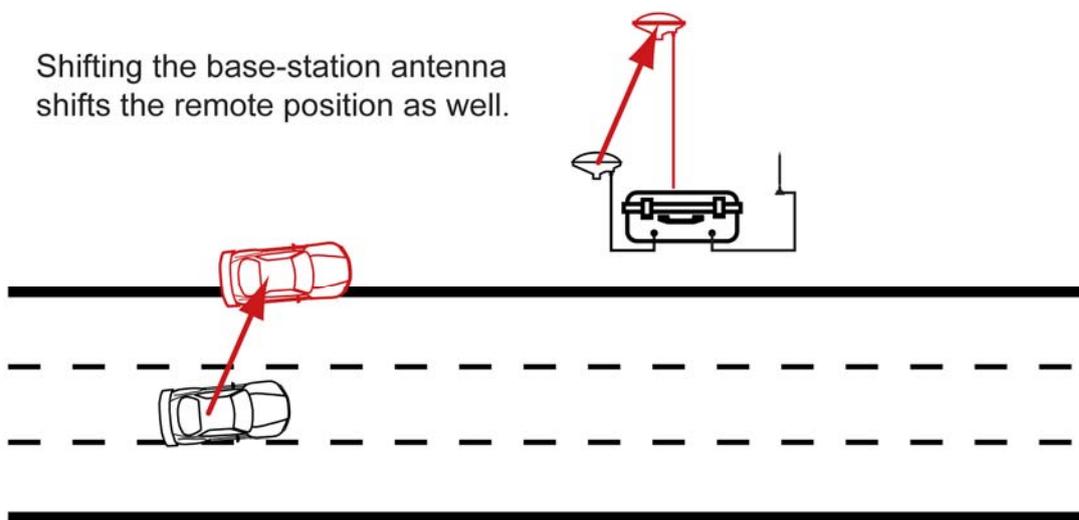
The problem of shifting the antenna typically occurs when:

•   The tripod is knocked over and picked up again. It is hard to get the antenna back to the same location accurate to 1cm.

•   If the RT-Base is used one day, packed up then returned to the same location the next day. It is very hard to replace the tripod in the same location. It is better to have a pole that is fixed to the ground if you intend to use the same surveyed location on several days.

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Figure 7. Averaging to a different position example
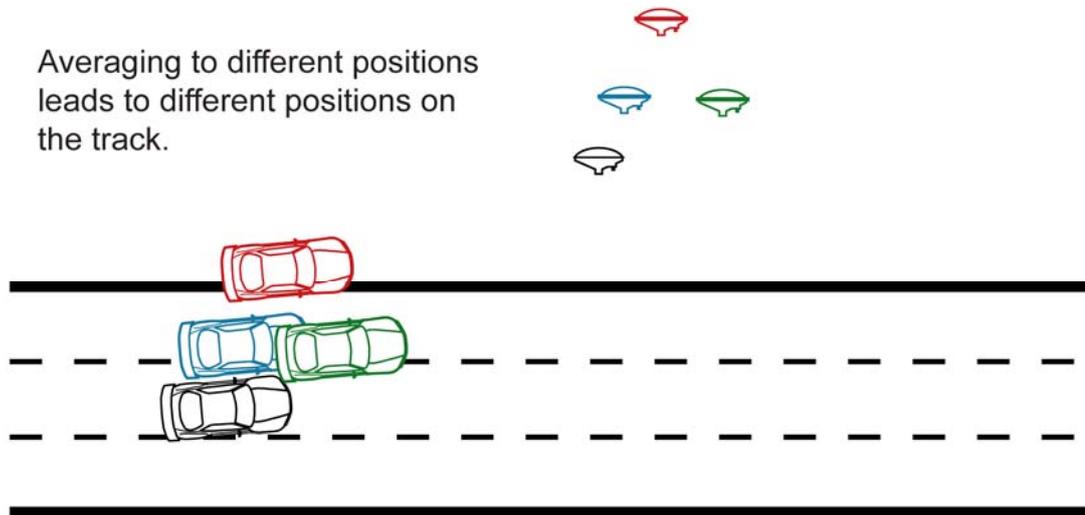
The problem of averaging to a different position happens each time that the RT-Base goes through its averaging process. There is nothing magical about the RT-Base that allows it to get its own position accurate to 2cm or better. It is subject to the same errors that all GNSS receivers have and can only average its position to about 1.8m CEP.

If the user is prepared to wait a long time (typically more than 24 hours) then GNSS is able to improve the accuracy of the base-station antenna so it is accurate to 2cm or better. However, since the timescale for this is long it is not usually practical, except for permanent installations. (Even when you have a permanent installation it is not required since all it does is allows you to relate your measurements to a surveyors measurements and this is rarely required).

To overcome the problem of averaging the save/restore feature of the RT-Base should be used. When using the Save/Restore feature the RT-Base will save the position where it last averaged and then use this next time (instead of averaging again). This way the error is the same each time and the repeatability is perfect. You must remember to put the antenna in the same location each time, accurate to 1cm or better, when using the Save/Restore feature.

Using an external radio

It is possible to disable the internal radio and use an external radio instead. This is useful if you need to use the RT-Base in several countries and different radios are required to conform to the local licensing laws.

On the RT-Base panel are two 9-way D-type connectors: Radio Configuration and GNSS Configuration. These are linked to activate the internal radio. To use an external radio disconnect the link wire; the GNSS Configuration connector is wired as a standard 9-way D-type connector with the exception of the ring pin, which has power on it. Table 9 gives the pin connections for the GNSS Configuration connector.

Table 9. Pin connections of the GNSS configuration connector

Pin	Direction	Signal
1		N/C
2	In	Receive
3	Out	Transmit
4		N/C
5	Out	Ground
6		N/C
7		N/C
8		N/C
9	Out	Power from internal batteries

To use the internal radio, replace the link cable.

The RT-Base does not use the hardware handshake lines, so it is necessary to use a modem that does not need these lines. You cannot use a modem that requires software handshaking since the data on the RT-Base will include the XON and XOFF characters as part of its data. You have to use a modem that can transmit all the data sent.

The settings of the data sent from the RT-Base are given in Table 10. The radio modem must use these settings or the data will not be transmitted correctly.

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Table 10. Serial port settings for RT-Base transmissions

Parameter	Setting
Baud Rate	9600
Data Bits	8
Parity	None
Stop Bits	1

The Power Output pin of the GNSS Configuration connector supplies between 11V and 15V, depending on whether the internal batteries are charging or flat. If you are using a standard modem cable then take care in case this power damages the modem. You will probably have to make a special cable so that the signals and power from this connector can go to the radio modem correctly.

Note that this output is not fused individually; shorting the power on this connector will blow the main fuse in the RT-Base. You are recommended to always make connections to the GNSS Configuration port when the power is off.

When using an external modem it is not possible to close the top of the RT-Base. Without the top closed the RT-Base is not rated to IP65 and protection from moisture is required.

Special configuration of the RT-Base

Sometimes it is necessary to store more than one position for the base-station antenna. For example, the RT-Base may be used at more than one location. The software in the RT-Base cannot do this and the extra positions have to be stored elsewhere and then programmed to the RT-Base using a computer.

Setting the base-station position

If you want to use a previously computed position (to match earlier surveys or work) and this is not the position saved in the RT-Base you can follow the procedure here.

3. Remove the link cable that connects the radio configuration connector to the GNSS configuration connector. Connect a null modem serial cable between a PC COM serial port and the GNSS configuration connector.

4. Run a serial port application, such as Hyperterminal. Configure the communications for 9600 baud, 8 data bits, no parity, 1 stop bit, no handshaking and no flow control (same as Table 10, above).

5. The RT-Base may be sending some undecipherable data over this port; these are the differential corrections. Ignore the data sent from the RT-Base.

6. Type the following commands:

```
FIX NONE↵

FIX POSITION xx.xxxxxxxx yy.yyyyyyyy zzz.zzz↵
```

where `xx.xxxxxxxx` is the Latitude in degrees; `yy.yyyyyyyy` is the Longitude in degrees and `zzz.zzz` is the Altitude in meters. You should enter at least 8 decimal places for the Latitude and Longitude and three decimal places for the Altitude. The altitude must be entered in EGM96, not WGS-84.

It is often difficult to type these correctly, especially since the RT-Base will be sending data all the time. It is usually easier to type them into an editor, such as Notepad, and then paste them into the serial port application.

7. Check on the RT-Base display that the position you have requested has been received correctly and that the display matches the values you have entered.

You can save this location to the RT-Base by pressing the Save/Restore button on the RT-Base. Otherwise, the previously saved position will remain in the RT-Base but the new location will be used until power-off.

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To use the RT-Base immediately you need to reconnect the Link Cable between the Radio Configuration and GNSS Configuration connectors. This must be done very carefully if the power is left on since it is possible to short between Pin 9 of the GNSS Configuration connector and the connector chassis; this will blow the internal fuse. It is recommended to save the new location to the RT-Base; turn off the RT-Base connect the Link Cable; turn the RT-Base on again and press the Save/Restore button to restore the new location.

Saving the RT-Base position

You can save the RT-Base Position by writing down the Latitude, Longitude and Altitude values that are displayed in the LCD display. You should write down all 8 decimal places for the Latitude and Longitude.

Revision history

Table 11. Revision history

Revision	Comments
030617	Initial Version
051116	Added Repeatability Discussion; External Radio connection; external configuration of position (requires Software Dev Id: 050919.14ap or later).
070316	Updated images, incl. different radio modems.
121113	Update for GLONASS compatibility. Differential correction format of RT-Base configurable in the field for GLONASS support.
131210	Update images, formatting and additional products.

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