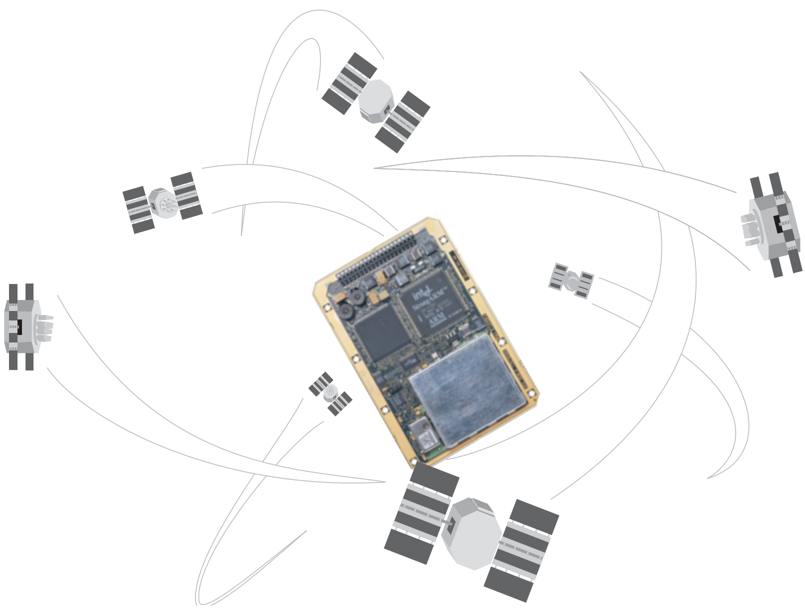
OEM4 Family of Receivers

USER MANUAL - VOLUME 1
Installation and Operation



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OEM4 Family of Receivers Installation & Operation Manual

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OEM4-G2L, or OEM4-G2 GPSCard Receivers	One (1) Year
FlexPak, ProPak-G2, or ProPak-LB	One (1) Year
GPSAntenna™ Series	One (1) Year
Cables and Accessories	Ninety (90) Days
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There are no user serviceable parts in the GPS receiver and no maintenance is required. When the status code indicates that a unit is faulty, replace with another unit and return the faulty unit to NovAtel Inc.

Before shipping any material to NovAtel or Dealer, please obtain a Return Material Authorization (RMA) number from the point of purchase. You may also visit our website at http://www.novatel.com and select *Support | Repair Request* from the side menu.

Once you have obtained an RMA number, you will be advised of proper shipping procedures to return any defective product. When returning any product to NovAtel, please return the defective product in the original packaging to avoid ESD and shipping damage.

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OEM4 Family Firmware UPDATES and UPGRADES

Firmware *updates* are firmware revisions to an existing model, which improves basic functionality of the GPS receiver. During the one-year warranty coverage following initial purchase, firmware updates are supplied free of charge. After the warranty has expired, firmware updates and updated manuals may be subject to a nominal charge.

Firmware *upgrades* are firmware releases, which increase basic functionality of the receiver from one model to a higher level model type. When available, *upgrades* may be purchased at a price, which is the difference between the two model types on the current NovAtel GPS Price List plus a nominal service charge.

Firmware updates and upgrades are accomplished through NovAtel authorized dealers.

Contact your local NovAtel dealer first for more information. To locate a dealer in your area or if the problem is not resolved, contact NovAtel Inc. directly using one of the following methods:

Call the NovAtel GPS Hotline at 1-800-NOVATEL (U.S. & Canada), or 403-295-4900 (international)

Fax: 403-295-4901

E-mail: support@novatel.ca

Website: http://www.novatel.com

Write: NovAtel Inc., Customer Service Dept., 1120 - 68 Avenue NE, Calgary, AB., Canada, T2E 8S5

✉ Before contacting NovAtel Customer Service regarding software concerns, please do the following:

1. Issue a FRESET command

2. Log the following data to a file on your PC for 30 minutes

RXSTATUSB	once
RAWEPHEMB	onchanged
RANGEB	ontime 1
BESTPOSB	ontime 20
RXCONFIGA	once
VERSIONB	once

3. Send the file containing the log to NovAtel Customer Service, using either the NovAtel ftp site at ftp://ftp.novatel.ca/incoming or the support@novatel.ca e-mail address.

If there is a hardware problem that has not been resolved, please send a list of the troubleshooting steps you have taken and their result. See also *Chapter 9 on Page 104*.

Notice

The following notices apply to ProPak-LB and ProPak-G2.

FCC NOTICE

This equipment has been tested and found to comply with the radiated and conducted emission limits for a Class B digital device, for both CISPR 22 and Part 15 of the FCC rules. 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 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
- Connect the equipment to an outlet on a circuit different from that to which the receiver is connected
- Consult the dealer or an experienced radio/TV technician for help

IMPORTANT: In order to maintain compliance with the limits of a Class B digital device, it is required to use properly shielded interface cables (such as Belden #9539 or equivalent) when using the serial data ports, and double-shielded cables (such as Belden #9945 or equivalent) when using the I/O strobe port.

WARNING: Changes or modifications to this equipment not expressly approved by NovAtel Inc. could result in violation of Part 15 of the FCC rules.

CE NOTICE

The enclosures carry the CE mark.

WARNING: This is a Class B product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

EMC

Common Regulatory Testing

• EN55022	Radiated and Conducted Emissions
• CISPR 22	Class B
• EN 50081-1	Generic Emissions Class B
• EN 50082-1	Generic Immunity Class B
• EN 61000-4-2	Electrostatic Discharge Immunity
• EN 61000-4-3	Radiated RF EM Field Immunity Test
• EN 61000-4-4	Electrical Fast Transient/Burst Test
• EN 61000-4-6	Conducted Immunity
• EN 61000-4-8	Magnetic Field Immunity

ProPak-LB Additional Testing

• ISO 7637-1	Conducted Transients

Foreword

Congratulations!

Thank you for purchasing a NovAtel receiver. Whether you have bought a stand alone GPSCard or a packaged receiver you will have also received companion documents for the product. *Volume 1* will help you get the hardware operational and provide further general information. Afterwards, *Volume 2* will be your primary OEM4 family command and logging reference source.

Scope

The *OEM4 Family of Receivers User Manual - Volume 1* contains sufficient information on the installation and operation of the OEM4-G2L and OEM4-G2 GPSCards to allow you to effectively integrate and fully operate them. There is also information on the FlexPak and ProPak enclosures. After the addition of accessories, user-supplied data communications equipment and a power supply, the FlexPak and ProPak are ready to go.

The OEM4 family receivers utilize a comprehensive user-interface command structure, which requires communications through its communications (COM) ports. This manual is volume one of a two volume set. The second volume, the *Command and Log Reference,* lists and describes the various receiver commands and logs. Please remember that since each receiver is shipped from the distributor with a customer-specific list of features, some commands or logs may not be applicable to your model. Other supplementary manuals may be included to accommodate special models and software features with unique functionality. It is recommended that these documents be kept together for easy reference.

It is beyond the scope of this manual to provide details on service or repair. Please contact your local NovAtel dealer for any customer-service related inquiries, see *Customer Service on Page 13*.

User Manual Updates

The most up-to-date version of this manual and any related addendums can be downloaded from the Documentation Updates section of www.novatel.com.

Prerequisites

The OEM4-G2L and OEM4-G2 are OEM products requiring the addition of an enclosure and peripheral equipment before becoming a fully functional GPS receiver. The installation chapters of this document provide information concerning the installation requirements and considerations for the GPSCards and the FlexPak and ProPak enclosures.

Conventions

The terms OEM4-G2 and OEM4-G2L will not be used in this manual unless a specific detail refers to it alone. The term receiver will infer that the text is applicable to an OEM4-G2L or OEM4-G2, either stand-alone or in an enclosure, unless otherwise stated.

In tables where values are missing they should be assumed to be reserved for future use.

Chapter 1 Introduction

1.1 Overview of the OEM4 Family

The OEM4 family is a group of high-performance GPS receivers capable of receiving and tracking the L1 C/A Code, L1 and L2 carrier phase, and L2 P Code (or encrypted Y Code) of up to 12 GPS satellites. With patented Pulse Aperture Correlator (PAC) technology and a powerful 32-bit processor, the OEM4 family receivers offer multipath-resistant processing at high data update rates. Excellent acquisition and re-acquisition times allow the receivers to operate in environments where very high dynamics and frequent interruption of signals can be expected.

In addition, the OEM4 family offers system integrators unparalleled flexibility in areas such as configuration and specification of output data and control signals. Multiple software models are available, allowing you to better fit the receiver to the application while maintaining the option for a compatible upgrade path.

The OEM4 family consists of two types of receivers: GPSCards and FlexPak and ProPak enclosures. The GPSCards, which are provided as printed circuit boards, are ideal for custom integration. The FlexPak and ProPak enclosures offer a complete solution, a protective enclosure that provides an interface to the GPSCard's power, data, and status signals.

1.1.1 Common Features

All OEM4 family receivers have the following features:

- 24 channel "all-in-view" parallel tracking
- Pulse Aperture Correlator (PAC) technology, which is described in *Appendix D*
- Fast reacquisition
- Fully field-upgradeable firmware
- Low power consumption
- 20 Hz raw data and position output rates
- Voltage and temperature monitoring and reporting

At a minimum, the following models are available for each receiver:

- L1 only
- L1/L2
- L1 plus RT-20
- L1/L2 plus RT-2
- L1 plus Satellite-Based Augmentation System (SBAS) support
- L1/L2 plus SBAS support

Those models with dual-frequency capabilities make the following possible:

- Longer baselines in differential positioning mode, due to the reduction of atmospheric errors
- Faster resolution of carrier-phase ambiguities when performing RTK positioning
- Enhanced positioning precision due to the additional measurements

1.2 GPSCards

The OEM4 family GPSCards consist of a single printed circuit board with integrated radio frequency (RF) and digital sections. They are designed for flexibility of integration and configuration. After installation with a power source, mounting structure, GPS antenna, and data communications equipment, NovAtel's GPSCards are ready for the most demanding surveying, positioning, and navigation applications.

Two different GPSCards, described in the sections that follow, are included in the OEM4 family:

- OEM4-G2L
- OEM4-G2

1.2.1 OEM4-G2L GPSCard

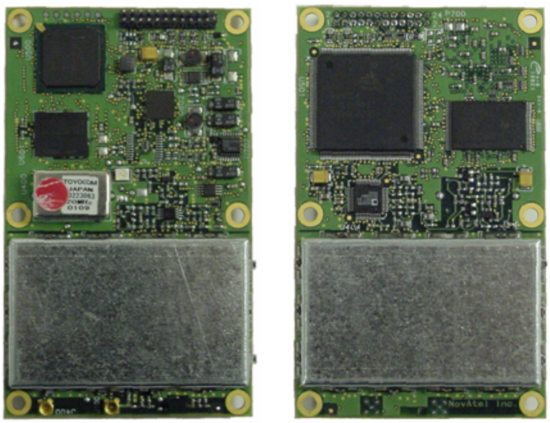
The OEM4-G2L provides the best features of the OEM4 family in a compact, low-power card. In addition to the functionality given in *Section 1.1.1 on Page 17*, the OEM4-G2L offers:

- 40% smaller than the OEM4-G2
- 15% less power consumption compared to the OEM4-G2 and 35% less than the original OEM4
- Two serial ports
- USB support (with firmware version 2.100 or higher)
- An external oscillator input
- Two mark inputs for triggering the output of logs on external events
- Programmable PPS output (with firmware version 2.100 or higher)
- Auxiliary strobe signals for status and synchronization
- Full compatibility with other OEM4 family products

Included with the OEM4-G2L is a wrist-grounding strap to prevent ESD damage when handling the card and a CD containing NovAtel's GPS PC utilities and product documentation.

For technical specifications on the OEM4-G2L, please see *Section A.2, starting on Page 110*.

Figure 1: OEM4-G2L GPSCard



Top **Bottom**

1.2.2 OEM4-G2 GPSCard

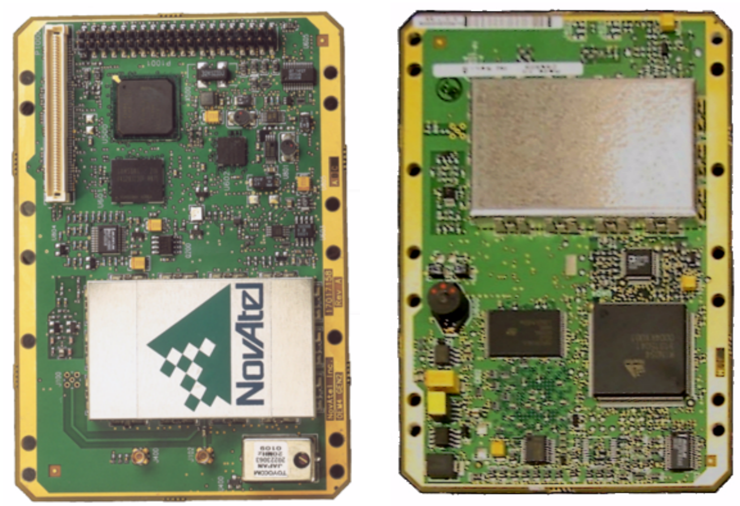
The OEM4-G2 is the second generation of the original OEM4. In addition to what is listed in *Section 1.1.1 on Page 17*, the OEM4-G2 offers:

- An improved processor and memory
- 20% less power consumption compared to the OEM4
- Three serial ports, one of which is user-selectable for RS-232 or RS-422
- USB support (with firmware version 2.100 or higher)
- An external oscillator input
- Two mark inputs for triggering the output of logs on external events
- Programmable PPS output (with firmware version 2.100 or higher)
- Auxiliary strobe signals for status and synchronization
- On-board power conversion, eliminating the need for external power conditioning
- Full compatibility with other OEM4 family products

Included with the OEM4-G2 is a wrist-grounding strap to prevent ESD damage when handling the card and a CD containing NovAtel's GPS PC utilities and product documentation.

For technical specifications on the OEM4-G2, please see *Section A.3, starting on Page 115*.

Figure 2: OEM4-G2 GPSCard



Top **Bottom**

1.3 Enclosures

The OEM4 family GPSCards can be housed in a ProPak or FlexPak enclosure to provide a complete receiver solution. When connected to an antenna and a power source, the enclosure and associated GPSCard together form a fully functioning GPS receiver.

The enclosures offer protection against environmental conditions and RF interference. In addition, they provide an easy-to-use interface to the GPSCard's data, power, and status signals. The enclosures offer GPS integrators an effective, self-contained system for indoor applications while also providing a rugged, water, shock, and vibration resistant housing for outdoor applications.

The table below provides a comparison between the features available on the various enclosures. The sections that follow give details on each of them.

Table 1: Enclosure Features Comparison

Feature	ProPak-G2	ProPak-LB	FlexPak
GPSCard Supported	OEM4-G2	OEM4-G2	OEM4-G2L
Serial Ports	3 ports on 3 DB-9P or 2 LEMO connectors	3 Switchcraft	2 Deutsch
USB	Not available	Not available	Yes
Strobe Port	DB-9S or LEMO[a]	Switchcraft[b]	Deutsch
Input Voltage	+7 to +18 V	+7 to +15 V	+8 to +16 V
OmniSTAR L-Band Differential Corrections[c]	Not available	Yes	Not available

a. For the ProPak-G2 with LEMO connectors, strobe signals are available on the *COM2* connector.
b. For the ProPak-LB, the strobes are available at the COM1 connector, which also provides RS-232 signals for one of the serial ports.
c. A subscription to the OmniSTAR service is required.

1.3.1 FlexPak

NovAtel's FlexPak is a rugged, waterproof housing for the OEM4-G2L positioning engine. As a result, the FlexPak can deliver centimeter-level positioning in a compact, lightweight enclosure. It provides dual-frequency positioning with a USB interface and an API option for supporting custom applications.

The FlexPak offers the following features:

- A shock and dust resistant enclosure
- Waterproof to IEC 60529 standards IPX4 and IPX7
- Low power consumption
- Two RS-232 serial ports
- USB support
- PPS output
- Configurable mark inputs
- Indicators for position, communication status and power

The following accessories are included with the FlexPak:

- 1 automotive power adapter cable
- 1 null-modem serial cable with DB-9 connector
- A CD containing NovAtel’s GPS PC utilities and product documentation

For technical specifications on the FlexPak, please see *Section A.4*, *starting on Page 121*.

Figure 3: FlexPak Enclosure

1.3.2 ProPak-G2

The ProPak-G2 provides a hardware interface between your equipment and the NovAtel OEM4-G2 GPSCard. It is a rugged, sealed enclosure that provides protection against adverse environments. It is available in two versions, one with DB-9 connectors to access data and status signals and the other with LEMO-brand connectors.

The ProPak-G2 offers the following features:

- A mounting enclosure with a PCB interconnect back plane
- Three serial ports provided on either three DB-9P connectors or two LEMO connectors
- Auxiliary status and synchronization signals
- GPS antenna and power ports
- Indicators to provide power and communication status

The following accessories are included with the ProPak-G2:

- 1 automotive power adapter cable
- 2 or more data cables
- A CD containing NovAtel's GPS PC utilities and product documentation

For technical specifications on the ProPak-G2, please see *Section A.5, starting on Page 128*.

Figure 4: ProPak-G2 Enclosure

Figure 5: ProPak-G2 Back End-Cap (DB-9 Version)

1.3.3 ProPak-LB

The NovAtel ProPak-LB provides a hardware interface between your equipment and the NovAtel OEM4-G2 GPSCard. Additionally, within the ProPak-LB, an OmniSTAR L-band receiver provides correction data. As shown in *Figure 6*, the ProPak-LB is a rugged, sealed enclosure, suitable for adverse conditions.

✉ In order to receive OmniSTAR L-band corrections, a subscription to the OmniSTAR service is required. See *Section 4.5 on Page 48* or the *ProPak-LB Quick Start Guide*, provided with the receiver, for details.

In addition to support for OmniSTAR positioning, the ProPak-LB provides the following:

- A rugged, environmentally-sealed enclosure
- 3 serial ports with Switchcraft-brand connectors
- GPS antenna and power ports
- Auxiliary strobe signals for status and synchronization
- Indicator to provide status information

The following accessories are included with the ProPak-LB:

- 1 automotive power adapter cable
- 3 straight serial port cables
- A CD containing NovAtel’s GPS PC utilities and product documentation

For technical specifications on the ProPak-LB, please see *Section A.6, starting on Page 138*.

Figure 6: ProPak-LB

Figure 7: ProPak-LB Back End Cap

Figure 7 shows the six ports on the back end cap of the ProPak-LB that are labeled with icons. *Table 2* provides information on these ports, including the name used to reference each of them throughout this manual.

Table 2: ProPak-LB Interface

Icon	Name	Description
	PWR	DC power input
	RES	Reserved
	COM1	RS232 signals and auxiliary strobe signals
	COM2	RS232 signals with optional flow control
	COM3	RS232 and general I/O signals
	ANT	Antenna connection

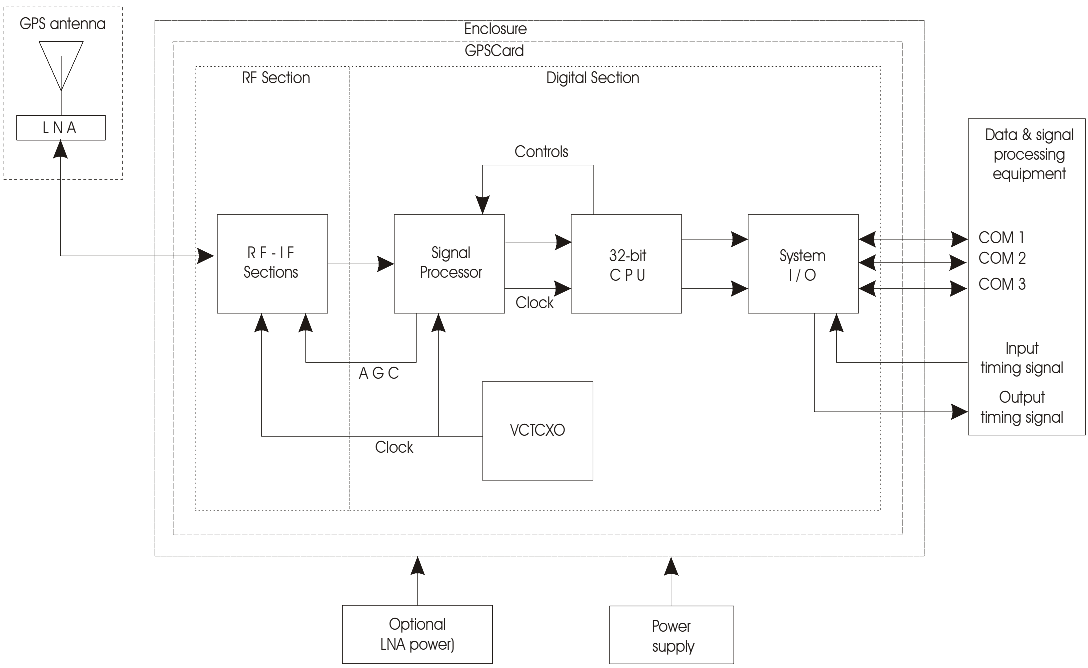
Chapter 2 Receiver System Overview

In addition to a NovAtel OEM4 family GPSCard, a complete GPS receiver system typically contains four other major components:

- A FlexPak or ProPak enclosure or a custom enclosure and wiring harness
- A GPS antenna (and optional LNA power supply)
- A power supply
- Data communications equipment

The overall system is represented in *Figure 8*. A brief description of each section follows the figure. Details of installation and set up are provided in *Chapter 3, Installation and Set Up on Page 28*.

Figure 8: GPS Receiver System Functional Diagram



2.1 GPSCard

NovAtel's GPSCards consist of a radio frequency (RF) and a digital electronics section.

2.1.1 Radio Frequency (RF) Section

The receiver obtains a partially filtered and amplified GPS signal from the antenna via the coaxial cable. The RF section performs the translation from the incoming RF signal to an IF signal usable by the digital section. It also supplies power to the active antenna's LNA through the coaxial cable while maintaining isolation between the DC and RF paths. The RF section can reject a high level of potential interference (e.g., MSAT, Inmarsat, cellular phone, and TV sub-harmonic signals).

2.1.2 Digital Electronics Section

The digital section of the receiver, receives a down-converted, amplified GPS signal which it digitizes and processes to obtain a GPS solution (position, velocity and time). The digital section consists of an analog-to-digital converter, a 32-bit system processor, memory, control and configuration logic, signal processing circuitry, serial peripheral devices, and supporting circuitry.

The digital section performs the translations and calculations necessary to convert the IF analog signals into usable position and status information. It also handles all I/O functions, including the auxiliary strobe signals, which are described in detail in *Section 3.3.1 on Page 36*. For input and output levels please see *Appendix A, Input/Output Strobes on Page 113* for the OEM4-G2L and *Page 118* for the OEM4-G2.

2.2 Enclosure and Wiring Harness

As discussed in *Section 1.3 on Page 20*, an enclosure is necessary to protect the GPSCard from environmental exposure and RF interference. If a FlexPak or ProPak is not being used as the enclosure, a wiring harness will also be required to provide an interface to the GPSCard's antenna and power inputs and data and status signals.

2.3 GPS Antenna

The purpose of the GPS antenna is to convert the electromagnetic waves transmitted by the GPS satellites into RF signals. An active GPS antenna is required for the receiver to function properly. NovAtel's active antennas are recommended.

2.3.1 Optional LNA Power Supply

Power for the antenna LNA is normally supplied by the receiver. However, if a different type of antenna is required that is incompatible with this supply, then you could connect an external power source to the receiver.

External LNA power is not possible with a FlexPak or ProPak receiver.

2.4 Principal Power Supply

A single external power supply capable of delivering 5 W is necessary to operate the receiver. See *Appendix A, Technical Specifications starting on Page 109* for details.

WARNING: If the voltage supplied is below the minimum specification, the receiver will suspend operation. If the voltage supplied is above the maximum specification, the receiver may be permanently damaged, voiding your warranty.

2.5 Data Communications Equipment

A PC or other data communications equipment is necessary to communicate with the receiver and, if desired, to store data generated by the receiver.

Chapter 3 Installation and Set Up

This chapter contains instructions and tips to set up your NovAtel receiver to create a GPS receiver system similar to that described in *Chapter 2, Receiver System Overview on Page 25*.

3.1 Additional Equipment Required

In order for the receiver to perform optimally, the following additional equipment is required:

- If your receiver has been purchased as a GPSCard without an enclosure, an interface for power, communications, and other signals and an enclosure to protect against the environment
- A NovAtel GPS antenna
- A quality coaxial cable (and interconnect adapter cable as necessary)
- Data communications equipment capable of serial communications
- A serial cable (if not included with the receiver)
- A power supply
- A power cable (if not included with the receiver)

CAUTION: **When the OEM4 family receiver is installed in a permanent location, such as in a building, it should be protected by a lightening protection device according to local building codes. See also *Warranty Policy on Page 12*.**

3.1.1 Selecting a GPS Antenna

An active antenna is required because its low-noise amplifier (LNA) boosts the power of the incoming signal to compensate for the line loss between the antenna and the receiver.

NovAtel offers a variety of single and dual-frequency GPS antenna models, as indicated in the table below. All include band-pass filtering and an LNA. The GPS antenna you choose will depend on your particular application. Each of these models offer exceptional phase-center stability as well as a significant measure of immunity against multipath interference. Each one has an environmentally-sealed radome.

Table 3: NovAtel GPS Antenna Models

Models	Frequencies Supported
701, 501, 511, 521, 531	L1 only
702, 502, 503, 512	L1 and L2
600-LB	L1 and L2 plus L-band

3.1.2 Choosing a Coaxial Cable

An appropriate coaxial cable is one that is matched to the impedance of the antenna and receiver being used (50 ohms), and whose line loss does not exceed 10.0 dB. If the limit is exceeded, excessive signal degradation will occur and the receiver may not be able to meet its performance specifications. NovAtel offers a variety of coaxial cables to meet your GPS antenna interconnection requirements, including:

- 5, 15, or 30 m antenna cables with TNC male connectors on both ends (NovAtel part numbers C006, C016 and C032 respectively)
- 22 cm interconnect adapter cable with MMCX male and TNC female connectors (NovAtel part number GPS-C002)

Note that a conversion is required between the female MMCX connector on the OEM4-G2L and OEM4-G2 GPSCards, and the female TNC connector on Novatel's GPS antennas.

Your local NovAtel dealer can advise you about your specific configuration. Should your application require the use of cable longer than 30 m you will find the application note *RF Equipment Selection and Installation* at our website, www.novatel.com, or you may obtain it from NovAtel Customer Service directly.

High-quality coaxial cables should be used because a mismatch in impedance, possible with lower quality cable, produces reflections in the cable that increase signal loss. Though it is possible to use other high-quality antenna cables, the performance specifications of the OEM4 family receivers are warranted only when used with NovAtel-supplied accessories.

3.1.3 Power Supply Requirements

This section contains information on the requirements for the input power to the receiver. See *Appendix A, Technical Specifications starting on Page 109* for more power supply specifications.

WARNING: If the voltage supplied is below the minimum specification, the receiver will suspend operation. If the voltage supplied is above the maximum specification, the receiver may be permanently damaged, voiding your warranty.

3.1.3.1 GPSCards

The OEM4-G2 GPSCard contains a DC to DC converter that is very tolerant to noise and ripple at its input. A tightly regulated input supply to the card is not required, as long as it falls within the given input range. A tightly regulated input supply to the OEM4-G2L GPSCard is required. The power supply used for any GPSCard should be capable of 5 W. The voltage input range for each GPSCard type is given in the table below.

Table 4: Voltage Input Ranges for GPSCards

GPSCard	Power Input Range
OEM4-G2L	+3.3 ± 0.15 VDC
OEM4-G2	+4.5 to +18 VDC

All members of the OEM4 family receivers are designed to prevent internal damage when subjected to a reverse polarity power connection. The OEM4-G2 also provides protection from short over voltage events. It is recommended that appropriate fuses or current limiting be incorporated as a safety precaution on all power lines used. Use a sufficient gauge of wire to ensure that the voltage at the connector is within the GPSCard's requirements.

3.1.3.2 FlexPak and ProPak Enclosures

The FlexPak and ProPak enclosures are supplied with an automobile power adapter with a built-in slow-blow fuse for use with a standard 12 VDC automobile power outlet. NovAtel's Aircraft Power Conditioner can also be used to provide further protection for your receiver.

If a different supply is desired, the table below provides the input range required as well as the type of connector required to mate with the receiver's power connector. The supply should be capable of 5 W.

Table 5: Power Requirements for Enclosures

Enclosure	Power Cable Connector Required	Power Input Range
FlexPak	3-pin Deutsch socket connector[a] labelled	+8 to +16 VDC
ProPak-G2	4-pin LEMO socket connector[a] labelled *PWR*	+7 to +18 VDC
ProPak-LB	2-pin Switchcraft socket connector[a] labelled	+7 to +15 VDC

a. See *Appendix J, Replacement Parts starting on Page 181* for part numbers for the connectors.

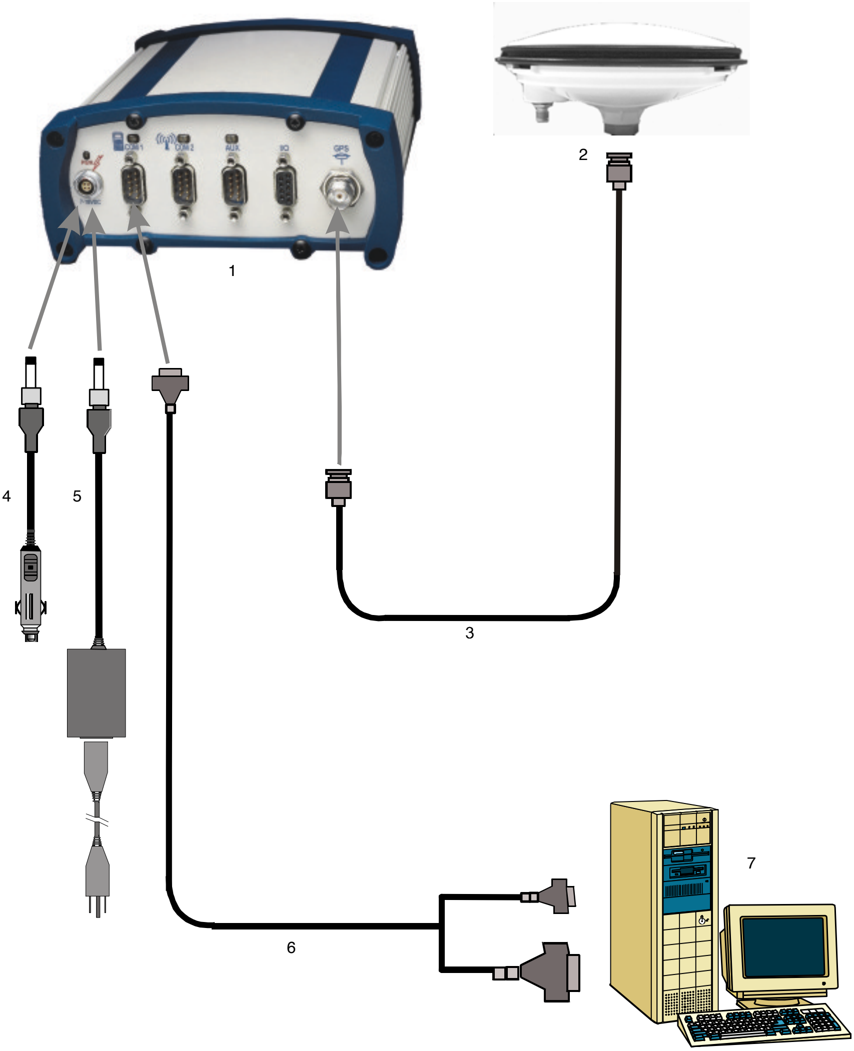
3.2 Installation Overview

Once you have selected the appropriate equipment, complete the following steps to set up and begin using your NovAtel GPS receiver.

1. If your receiver has been provided as a GPSCard without an enclosure, install the card in an enclosure with a wiring harness, as described in *Section 3.2.1 on Page 32*.
2. Mount the GPS antenna to a secure, stable structure, as described in *Section 3.2.2 on Page 34*.
3. Connect the GPS antenna to the receiver using an antenna RF cable, using the information given in *Section 3.2.3 on Page 34*.
4. Apply power to the receiver, as described in *Section 3.2.4 on Page 35*.
5. Connect the receiver to a PC or other data communications equipment by following the information given in *Section 3.2.5 on Page 35*.

Figure 9 on the next page shows a typical set up for an enclosed receiver.

Figure 9: Typical Receiver Installation



Reference	Description
1	Receiver
2	GPSAntenna Model 702 or 701
3	RF Antenna Cable
4	Automobile Power Adapter Cable
5	Optional AC Adapter or Aircraft Power Conditioner
6	Null Modem Data Cable
7	Data Communications Equipment

3.2.1 Installing a GPSCard in a Wiring Harness and Enclosure

To install a GPSCard, begin with the following:

1. Ensure you are taking the necessary precautions against ESD, as described in *Section 3.2.1.1 on Page 32*.
2. Mount the GPSCard in a secure enclosure to reduce environmental exposure and RF interference, as described in *Section 3.2.1.2 on Page 32*.
3. Prepare a wiring harness to interface to the receiver's data, status, and power signals using the information given in *Section 3.2.1.3 on Page 33*.

3.2.1.1 Electrostatic Discharge (ESD) Precautions

Electrostatic discharge is a leading cause of failure of electronic equipment components and printed circuit boards containing ESD-sensitive devices and components. It is imperative that ESD precautions be followed when handling or installing a GPSCard. See *Appendix B, Anti-Static Practices starting on Page 146* for more information on ESD precautions.

Leave the GPSCard in its static-shielding bag or clamshell when not connected in its normal operating environment. When removing the GPSCard from the ESD protection, follow accepted standard anti-static practices. Failure to do so may cause damage to the GPSCard.

When you remove the GPSCard from the original packing box, it is recommended that you save the box and ESD protection for future storage or shipment purposes.

CAUTION

Remember:

- **Always wear a properly grounded anti-static wrist strap when handling the GPSCard.**
- **Always hold the GPSCard by its corners or the RF shield, and avoid direct contact with any of the components.**
- **Do not let the GPSCard come in contact with clothing at any time because the grounding strap cannot dissipate static charges from fabrics.**
- **Failure to follow accepted ESD handling practices could cause damage to the GPSCard.**
- **Warranty may be voided if equipment is damaged by ESD.**

3.2.1.2 Mounting the Printed Circuit Board

The OEM4 family GPSCards are OEM products and therefore the printed circuit board is provided without a housing structure. This allows flexibility in creating a mounting environment to suit particular product and marketing requirements. The mounting and enclosure should provide the following:

- mounting of external connectors
- protection from hostile physical environments (e.g. rain, snow, sand, salt, water, extreme temperatures)
- electromagnetic shielding to protect from hostile RF environments (e.g. nearby transmitters)

- electromagnetic shielding so that the final product itself conforms to RF emissions specifications
- protection from ESD, see *Appendix B, Anti-Static Practices starting on Page 146*

The GPSCard can be held in place by screws. Please see *Appendix A, Technical Specifications starting on Page 109* for mechanical drawings.

3.2.1.3 Preparing the Data, Signal & Power Harness

The wiring harness serves the following interconnect functions:

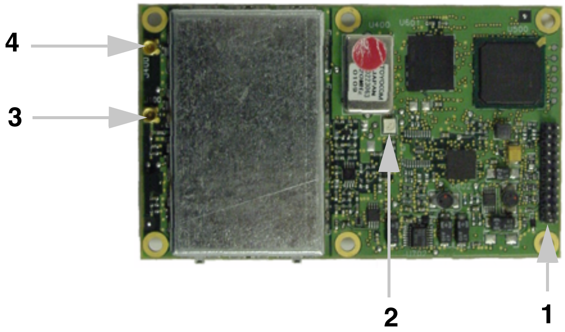
- provide access to the serial communications ports
- provide access to input and output timing strobes
- provide power input(s)
- provide access to control signals

For all GPSCards, the power, status, and data inputs and outputs are accessed from a single connector. Therefore, the harness must be designed to mate with this connector.

Figure 10 shows that the OEM4-G2L uses a 24-pin dual-row male connector with 0.5 mm square pins and 2 mm spacing for the data, power, and status signals. The pin out for this connector is specified in *Section A.2 on Page 110*. The RF connector on the OEM4-G2L is an MMCX female.

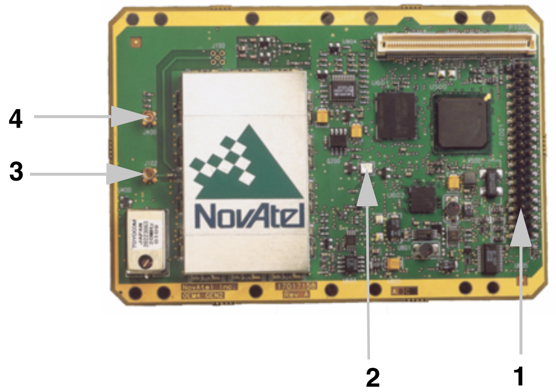
As shown in *Figure 11*, the OEM4-G2 uses a 40-pin dual-row male connector with 0.25” square pins and 0.1” spacing for the data, power, and status signals. The pin out for this connector is specified in *Section A.3 on Page 115*. The RF connector is an MMCX female.

Figure 10: OEM4-G2L Connector and Indicator Locations



.Reference	Description
1	Power, data, and signal connector (24 pin dual row male connector with 0.5 mm square pins and 2 mm spacing)
2	LED status indicator
3	RF signal input and LNA power output (MMCX female connector)
4	External oscillator input (MMCX female connector)

Figure 11: OEM4-G2 Connector and Indicator Locations



.Reference	Description
1	Power, data, and signal connector (40 pin dual row male connector with 0.025î square pins and 0.1î spacing)
2	LED status indicator
3	RF signal input and LNA power output (MMCX female connector)
4	External oscillator input (MMCX female connector)

3.2.2 Mounting the GPS Antenna

Once the GPSCard is installed in a wiring harness and enclosure, the antenna to be used with the receiver must be mounted. The GPS receiver has been designed to operate with any of the NovAtel single-frequency or dual-frequency GPS antenna models. See *Section 3.1.1 on Page 28* for more information.

When installing the antenna system:

- Choose an antenna location that has a clear view of the sky so that each satellite above the horizon can be tracked without obstruction. (For a discussion on multipath, see *Appendix D, Multipath starting on Page 154.)*
- Mount the antenna on a secure, stable structure capable of safe operation in the specific environment.

3.2.3 Connecting the Antenna to the Receiver

Connect the antenna to the receiver using high-quality coaxial cable, as discussed in *Section 3.1.2 on Page 29*.

The FlexPak and ProPak enclosures provide a TNC female connector, which can be connected to the antenna directly with any of NovAtel's coaxial cables. For the GPSCards, an interconnect adapter cable is required to convert the TNC male end of the coaxial cable to the card's MMCX female RF input connector. The location of the RF connector for each of the GPSCards is shown in *Figure 10* and *Figure 11*.

3.2.4 Applying Power to the Receiver

Connect the power supply, set to the voltage given in *Section 3.1.3 on Page 29*, to the wiring harness created previously.

For a FlexPak or ProPak enclosure, connect the power supply to the port described in *Table 5, Power Requirements for Enclosures on Page 30*.

3.2.5 Connecting Data Communications Equipment

In order to communicate with the receiver by sending commands and obtaining logs, a connection to some form of data communications equipment is required. The default configuration available for each of the receiver types is given in the table below. However, if desired, on some of the receivers, the serial ports can be factory configured for either RS232, RS422, or LVTTL operation. Consult NovAtel Customer Service for more details on factory configuration. See *Appendix A, Technical Specifications starting on Page 109* for data connection details.

Table 6: Default Serial Port Configurations

Receiver	COM1	COM2	COM3
OEM4-G2L	RS-232	LVTTL	Not available
OEM4-G2	User-selectable as RS-232 or RS-422. See *Section 3.2.5.1 on Page 36* for more information.	RS-232	LVTTL
FlexPak	RS-232	RS-232 / RS-422	Not available
ProPak-G2	RS-232	RS-232	RS-232
ProPak-LB	RS-232	RS-232	RS-232

Each port may support some, or all, of the following signals:

- Data Terminal Ready (DTR)
- Clear To Send (CTS)
- Transmitted Data (TXD)
- Request To Send (RTS)
- Received Data (RXD)
- Data Carrier Detect (DCD)

On many of the receivers, extra control lines are provided on COM2 for use with modems or other differential correction data links.

The FlexPak and ProPak enclosures are Data Terminal Equipment (DTE) so that TXD, RTS and DTR are outputs while RXD, CTS and DCD are inputs. A null modem cable is required to connect to another DTE like a terminal or a PC.

The port settings (bit rate, parity, etc.) are software-configurable. These are further described in *Chapter 4, Operation on Page 42.* See *Appendix A, Technical Specifications starting on Page 109* for further information on data communications characteristics.

3.2.5.1 User-Selectable Port Configuration (OEM4-G2 Only)

The OEM4-G2 offers a user-selectable configuration for the COM1 port. The configuration is selected using the GPIO_USER1 pin. By default, RS-232 is selected as the GPIO_USER1 input is set low by an internal pull-down resistor. To select RS-422, upon startup apply 3.3 V to GPIO_USER1 or tie it to pin 38 of the 40-pin connector.

Pin 38 on the 40-pin connector is usually an ERROR indicator, and during normal GPSCard operations is set LOW, but for a few seconds during GPSCard initialization, immediately after applying power to the GPSCard, this pin is set HIGH at 3.3 Volts. It drops to LOW a few seconds later when the GPSCard has been fully booted up, around the time that the [COMx] prompt is output from the GPSCard on all COM ports.

GPIO_USER1 needs to be initialized HIGH during this initial boot-up phase in order to set up the COM1 port for RS-422 mode. Therefore, set pin 38 ERROR to HIGH to provide a convenient 3.3 V source that is used to trigger the GPIO_USER1 to set the COM1 port to RS-422 mode.

Your OEM4-G2 hardware revision must be 3.00 or later and you must be running firmware 2.110 or later in order to use this RS-422 feature on the COM1 port of the OEM4-G2 GPSCard.

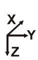
3.3 Additional Features and Information

This section contains information on the additional features of the OEM4 family receivers, which may affect the overall design of your receiver system.

3.3.1 Strobes

On many of the OEM4 family receivers, a set of inputs and outputs that provide status and synchronization signals are given. These signals are referred to as strobes. As shown in *Table 7 on Page 38*, not all strobe signals are provided on all receivers. However, for those products for which strobes are available, you may want to design your installation to include support for these signals.

The OEM4-G2L provides 6 TTL-compatible I/O strobes, which can be located on the connector shown in *Figure 40 on Page 110*. The OEM4-G2 GPSCard has 9 TTL-compatible I/O strobe lines. See *Figure 43, Top-view of 40-Pin Connector on the OEM4-G2 on Page 119*.

The DB-9 version of the ProPak-G2 provides strobe signals at its I/O port, as described in *Table 26 on Page 131*. Access to the ProPak-LB's strobe signals is obtained through the COM1 port, which is labelled 

. See *Table 28 on Page 140* for more information on the ProPak-LB's strobes.

Strobe signals include an input and several outputs as described below:

• Mark Input (Event1, Event2)	A pulse on this input triggers certain logs to be generated. (Refer to the MARKPOS and MARKTIME logs and ONMARK trigger in *Volume 2*). For the OEM4-G2 and OEM4-G2L, the polarity is configurable (see MARKCONTROL in *Volume 2*).
• Measure Output (MSR)	Falling edge is synchronized with internal GPS measurements.
• One Pulse Per Second Output (PPS)	An pulse for which the trailing edge is synchronized with GPS time. For the OEM4-G2 and OEM4-G2L, the polarity and period is configurable using the PPSCONTROL command (see *Volume 2*).
• Position Valid Output (PV)	High when good GPS position and time solution.
• Error Output (ERROR)	High when a receiver hardware failure is detected.
• LED Red Output (STATUS_RED)	Hardware failure when on or pulsing.
• LED Green Output (STATUS_GREEN)	Normal operation when pulsing at 1 Hz.
• Variable Frequency (VARF)	Programmable output range from 0 to 20 MHz (refer to FREQUENCYOUT in *Volume 2*).

See *Appendix A, Technical Specifications starting on Page 109,* for further information on the strobe signal characteristics.

Table 7: Available Strobe Signals on Receivers

Signal	EVENT1	EVENT2	MSR	PPS	PV	ERROR	STATUS _RED	STATUS _GREEN	VARF
OEM4-G2L	Pin 8	Pin 7	Not available	Pin 4	Pin 10	Pin 9	Not available	Not available	Pin 3
OEM4-G2	Pin 11	Pin 31	Pin 32	Pin 7	Pin 2	Pin 38	Pin 13	Pin 28	Pin 9
FlexPak	Pin 4	Pin 6	Not available	COM1/ COM2 port, Pin 10	Not available	COM1/ COM2 port, Pin 13	Not available	Not available	Not available
ProPak-G2 (DB-9 version)	I/O port, pin 4	Not available	Not available	I/O port, pin 2	I/O port, pin 5	Not available	Not available	Not available	I/O port, pin 1
ProPak-G2 (LEMO version)	COM2 port, pin 6	Not available	Not available	COM2 port, pin 10	Not available	Not available	Not available	Not available	Not available
ProPak-LB	COM1 port, pin 2[a]	Not available	Not available	COM1 port, pin 1[a]	Not available	Not available	Not available	Not available	Not available

a. In addition to being an RS-232 communications port, the COM1 connector on the ProPak-LB also provides access to strobe signals.

3.3.2 USB (OEM4-G2 and OEM4-G2L Only)

A USB connection is a fast, bi-directional, simultaneous, and dynamically attachable serial interface. Three peripheral USB ports are supported on the OEM4-G2 and OEM4-G2L using the single interface provided by the USB D(+) and USB D(-) signals, along with firmware version 2.100 or higher. See *Figure 41 on Page 114* and *Figure 43 on Page 119* for information on the pins these signals are provided on. Note that the receivers do not support use as a host device. Although the port for a USB device may appear on some of the other receivers, it is intended for future implementation and should not be used, for any reason, at this time.

3.3.3 Status Indicators

Many of the OEM4 family receivers have LED indicators that provide the status of the receiver. The GPSCards have a single indicator, which is shown in *Figure 10 on Page 33* for the OEM4-G2L, and *Figure 11 on Page 34* for the OEM4-G2. The LED blinks green on and off at approximately 1 Hz to indicate normal operation. If the indicator is red, then the receiver is not working properly. The operation of this indicator is further described in *Section 8.6 on Page 103*.

The FlexPak, ProPak-G2 and ProPak-LB provide the status indicators shown in the tables that follow.

Table 8: FlexPak Status Indicators

Indicator	Indicator Color	Status
COM1	Green	Data is being transmitted from COM1
	Red	Data is being received on COM1
COM2	Green	Data is being transmitted from COM2
	Red	Data is being received on COM2
ANT	Red	Hardware error.
	Green	Valid position computed.
PWR	Red	The receiver is powered

Table 9: ProPak-G2 Status Indicators

Indicator	Indicator Color	Status
COM1	Green	Data is being transmitted from COM1
	Red	Data is being received on COM1
COM2	Green	Data is being transmitted from COM2
	Red	Data is being received on COM2
AUX *(DB-9 version only)*	Green	Data is being transmitted from COM3
	Red	Data is being received on COM3
PWR *(DB-9 version only)*	Red	The receiver is powered

Table 10: ProPak-LB Status Indicators

Indicator	Indicator Color	Status
	Red	Hardware error.
	Green	Valid position computed.
	Red	The receiver is powered.

3.3.4 External Oscillator (OEM4-G2 / -G2L Only)

For certain applications requiring greater precision than what is possible using the on-board 20 MHz, voltage-controlled, temperature-compensated crystal oscillator (VCTCXO), you may wish to connect the OEM4-G2L or OEM4-G2 to an external, high-stability oscillator. The external oscillator can be either 5 MHz or 10 MHz.

Installation consists of simply connecting a cable from the external oscillator to the receiver's external oscillator input connector. For the OEM4-G2L and OEM4-G2, an MMCX female connector is used, as shown in *Figure 10 on Page 33* and *Figure 11 on Page 34*, respectively. The receiver does not have to be powered down during this procedure. If you are handling the OEM4-G2 or OEM4-G2L directly, anti-static practices must be observed.

Once the external oscillator has been installed, the EXTERNALCLOCK command must be issued to define the clock model (e.g. cesium, rubidium or ovenized crystal). If the input clock rate is 5 MHz, the EXTERNALCLOCK command must be issued to change the 10 MHz default rate. For more information on this command, please refer to *Volume 2* of this manual.

3.3.5 External Antenna LNA Power (OEM4-G2 Only)

For the OEM4-G2 it is possible to supply power to the LNA of an active antenna either from the antenna port of the GPSCard itself or from an external source. The internal antenna power supply of the GPSCards can produce +4.50 to +5.25 VDC at up to 100 mA. This meets the needs of any of NovAtel's dual-frequency GPS antennas, so, in most cases, an additional LNA power supply is not required.

If a different antenna is used whose LNA requires voltage capacity beyond what the receiver can produce, then the external LNA power option must be utilized. This simply requires setting a voltage supply between +12 and +30 VDC, 100 mA maximum, and connecting it to pin 40 of the 40-pin connector on the OEM4-G2. See *Appendix A* for more details.

In either case, the LNA power is fed to the antenna through the same coaxial cable used for the RF signals. The internal LNA power source should be disabled using the ANTENNAPOWER command. Refer to *Volume 2* of this manual for more information on this command.

External LNA power is not possible with an OEM4-G2L, a FlexPak or ProPak receiver.

CAUTION

No warranty is made that the receiver will meet its performance specifications if a non-NovAtel antenna is used.

3.3.6 Mounting Bracket (ProPak-G2 and ProPak-LB Only)

Along with the ProPak enclosures, mounting kits have been provided to facilitate mounting the receivers to a surface. This section provides information on how to mount the receivers.

The mounting kits are not designed for use in high-dynamics or high-vibration environments. Contact NovAtel Customer Service if your application requires the ProPak to be mounted in these types of environments.

3.3.6.1 ProPak-G2 and ProPak-LB

To install the mounting bracket provided with the ProPak-G2 and ProPak-LB, refer to the instructions provided with the mounting kit. *Figure 12* and *Figure 13* are included to provide the dimension information for the bracket.

Figure 12: ProPak-G2 with Mounting Bracket

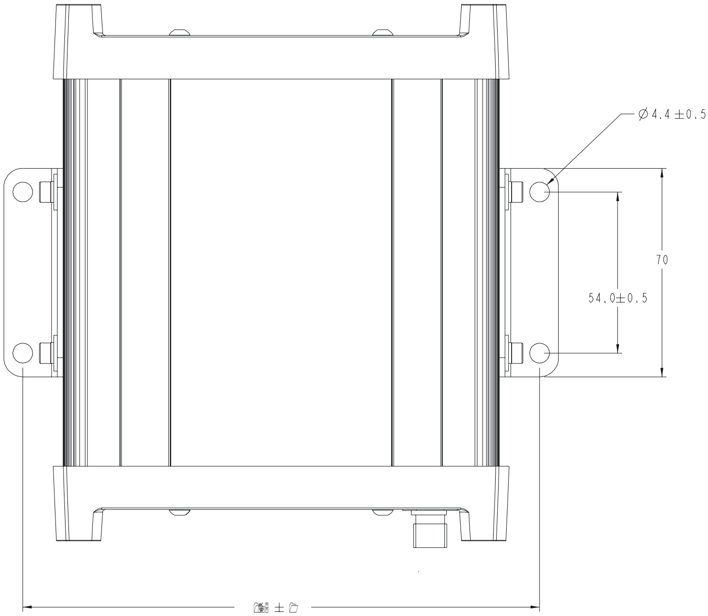
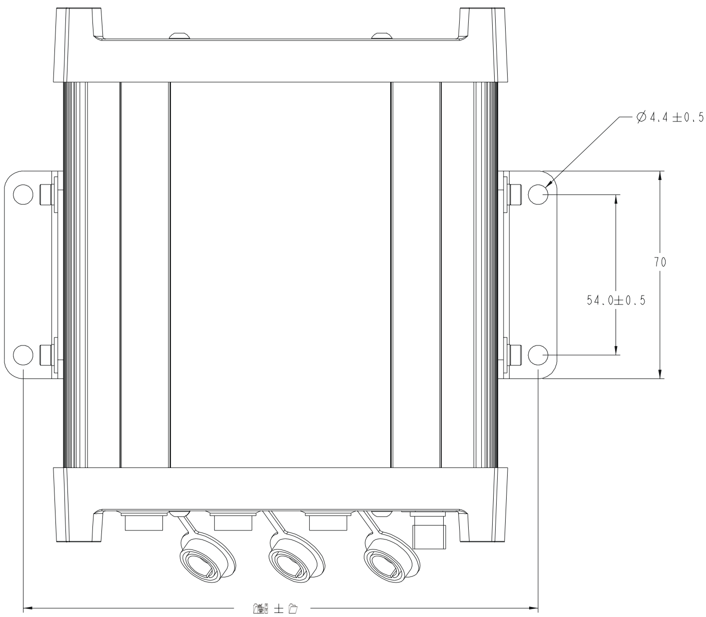


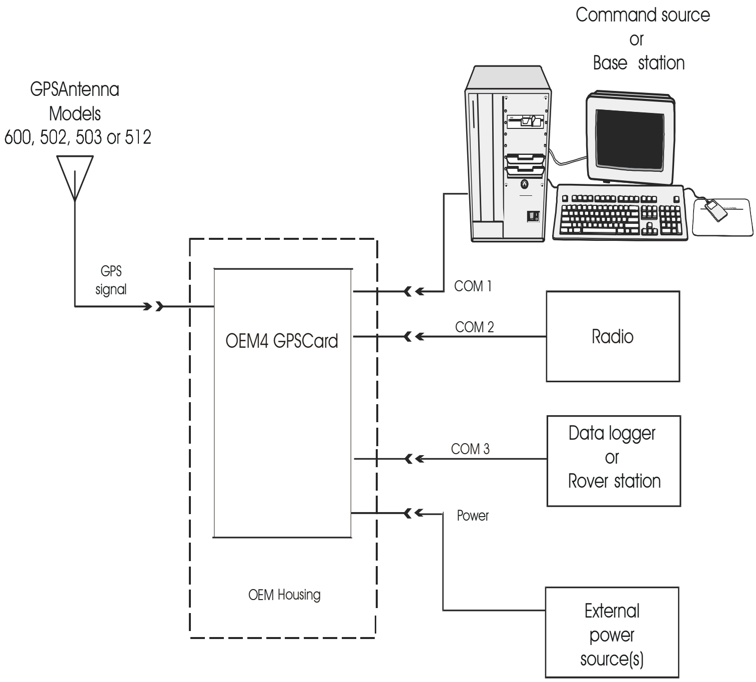
Figure 13: ProPak-LB with Mounting Bracket



Chapter 4 Operation

Before operating the receiver for the first time, ensure that you have followed the installation instructions in *Chapter 3, Installation and Set Up on Page 28.* The following instructions are based on a configuration such as that shown in *Figure 14, Typical Operational Configuration*. It is assumed that a personal computer is used during the initial operation and testing for greater ease and versatility.

Figure 14: Typical Operational Configuration



4.1 Communications with the Receiver

Communication with the receiver is straightforward, and consists of issuing commands through the communication ports from an external serial communications device. This could be either a terminal or an IBM-compatible PC that is directly connected to the receiver serial port using a null-modem cable. If you are using an RTK radio it connects to the receiver's COM port by means of the radio serial cable supplied with the receiver. For information about commands and logs that are useful for basic operation of the receiver, refer to *Volume 2, Command and Log Reference*.

4.1.1 Serial Port Default Settings

The receiver communicates with your PC or terminal via serial port. For communication to occur, both the receiver and the operator interface have to be configured properly. The receiver's COM1, COM2 and COM3 default port settings are as follows:

- **9600 bps, no parity, 8 data bits, 1 stop bit, no handshaking, echo off**

Changing the default settings requires using the *COM* command, which is described in *Volume 2* of this manual. It is recommended that you become thoroughly familiar with the commands and logs detailed in *Volume 2* to ensure maximum utilization of the receiver's capabilities.

The data transfer rate you choose will determine how fast information is transmitted. Take for example a log whose message byte count is 96. The default port settings will allow 10 bits/byte. It will therefore take 960 bits per message. To get 10 messages per second then will require 9600 bps. Please also remember that even if you set the bps to 9600 the actual data transfer rate will be less and depends on the number of satellites being tracked, filters in use, and idle time. It is therefore suggested that you leave yourself a margin when choosing a data rate.

CAUTION: Although the receiver can operate at data transfer rates as low as 300 bps, this is not desirable. For example, if several data logs are active (i.e. a significant amount of information needs to be transmitted every second) but the bit rate is set too low, data will overflow the serial port buffers, cause an error condition in the receiver status and result in lost data.

4.1.2 Communicating Using a Remote Terminal

One method of communicating with the receiver is through a remote terminal. The receiver has been pre-wired to allow proper RS232 interface with your data terminal. To communicate with the terminal the receiver only requires the RX, TX, and GND lines to be used. Handshaking is not required, although it can optionally be used. Ensure the terminal's communications set-up matches the receiver's RS232 protocol.

4.1.3 Communicating Using a Personal Computer

An IBM-compatible PC can be set up to emulate a remote terminal as well as provide the added flexibility of creating multiple-command batch files and data logging storage files. Any standard communications software package that emulates a terminal can be used to establish bidirectional communications with the receiver. No particular terminal type is assured. All data is sent as raw characters.

You can create command batch files using any text editor; these can then be directed to the serial port that is connected to the receiver using a communications software package. This is discussed later in this chapter.

4.2 Getting Started

Included with your receiver are NovAtel's GPSolution and Convert programs. GPSolution is a Microsoft Windows-based graphical user interface which allows you to access the receiver's many features without struggling with communications protocol or writing special software. The Convert utility is a Windows-based utility that allows you to convert between file formats, and strips unwanted records for data file compilation. See *Chapter 7, PC Software and Firmware on Page 87* for more information on the GPSolution and Convert programs.

4.2.1 Starting the Receiver

The receiver's software resides in read-only memory. As such, the unit "self-boots" when turned on and undergoes a complete self-test. If an error condition is detected during a self-test, the self-test status word would change; this self-test status word can be viewed in the header of any data output log. See the chapter on *Messages* in *Volume 2* of this manual for header information. If a persistent error develops, please contact your local NovAtel dealer first. If the problem is still unresolved, please contact NovAtel directly through any of the methods in the Customer Service section at the beginning of this manual on *Page 13*.

When the receiver is first turned on, no activity information is transmitted from the COM ports except for the port prompt. The external data communications equipment screen will display one of these three messages:

[COM1] *if connected to COM1 port*,

[COM2] *if connected to COM2 port*,

or

[COM3] *if connected to COM3 port*

Any of these prompts indicate that the receiver is ready and waiting for command input.

Commands are typed at the interfacing terminal's keyboard, and executed after issuing a carriage return command which is usually the same as pressing the terminal's <Enter> key.

An example of a response to an input command is the FIX POSITION command. It can be entered:

```
[COM2]FIX POSITION 51.11635 -114.0383 1048.2[Carriage Return]
<OK
```

The above example illustrates command input to the receiver's COM2 port which sets the position of the base station receiver in differential operation. Confirmation that the command was actually accepted is the appearance of <**OK**.

If a command is incorrectly entered, the receiver will respond with "<Invalid Message ID" (or a more detailed error message).

For more information on the various commands and logs please refer to the user manual entitled *Volume 2, Command and Log Reference*.

4.2.2 Remote Terminal, PC and GPS Receiver

GPSolution is the preferred option to DOS or a terminal program, however examples of how to use the two latter options follows. For this example, consider a situation where a PC's appropriately-configured COM1 port is connected to the receiver's COM1 port, and where a remote terminal is connected to the receiver's COM2 port.

4.2.2.1 DOS

One way to initiate multiple commands and logging from the receiver is to create DOS boot-up command files relating to specific functions. This will save time when you want to duplicate test situations and minimize set-up time. Any convenient text editor can be used to create command text files.

1. Open a text editor on the PC and type in the command strings to be sent to the receiver upon start up. For example:

```
log com2 bestposa ontime 1
log com2 rangea ontime 1
log com2 rxstatusa onchanged
log com2 psrdopa onchanged
log com2 gpsephema onchanged
log com2 almanaca onchanged
log com2 rxconfiga once
```

✉ 1. Ensure you have used a carriage return (hit the enter key) after typing the last line.

2. If you wish these to become part of the permanent configuration of the card, rather than just using them on boot-up, enter the SAVECONFIG command as the last line.

---

2. Save this with a convenient file name (e.g. C:\GPS\BOOT1.TXT) and exit the text editor.

3. Use the DOS *copy* command to direct the contents of the BOOT1.TXT file to the PC's COM1 port:

```
C:\GPS>copy boot1.txt com1
1 files(s) copied
C:\GPS>
```

4. The receiver is now initialized with the contents of the BOOT1.TXT command file, and logging is directed from the receiver's COM2 port to the remote terminal.

4.2.2.2 Microsoft Windows

As any text editor or communications program can be used for these purposes, the use of Windows 95 is described only as an illustration. The following example shows how Windows 95 accessory programs *Notepad* and *HyperTerminal* can be used to create a boot-file on a PC, and send it to the OEM4. It is assumed that the PC's serial port COM1 is connected to the receiver's COM1 port, and that a remote terminal is connected to the receiver's COM2 port.

1. Open *Notepad* and type in the command strings to be sent to the receiver upon start up. For example:

```
log com2 bestposa ontime 1
log com2 rangea ontime 1
log com2 rxstatusa onchanged
log com2 psrdopa onchanged
log com2 gpsephema onchanged
log com2 almanaca onchanged
log com2 rxconfiga once
```

✉ 1. Ensure you have used a carriage return (hit the enter key) after typing the last line.

2. If you wish these to become part of the permanent configuration of the card, rather than just using them on boot-up, enter the SAVECONFIG command as the last line.

---

2. Save this with a convenient file name (e.g. C:\GPS\BOOT.TXT) and exit *Notepad*.

3. Ensure that the *HyperTerminal* settings are correctly set up to agree with the receiver's communications protocol. These settings can be saved (e.g. C:\GPS\OEMSETUP.HT) for use in future sessions. You may wish to use XON / XOFF handshaking to prevent loss of data.

4. From the ***Transfer*** menu, use the ***Send text file*** selection to locate this file to be sent to the receiver. Once you double-click on the file or select *Open*, *HyperTerminal* will send the file to the receiver.

4.3 Transmitting and Receiving Corrections

Corrections are transmitted from a base station to a rover station to reduce or eliminate errors introduced by system biases, as described in *Section 6.1.1, GPS System Errors on Page 67*. In most cases you will need to provide a data link between the base station and rover station (two NovAtel receivers) in order to receive corrections. Exceptions are the SBAS and OmniSTAR L-band capable receivers. However, if you wish to use other types of corrections for these receivers, a data link must be provided. Generally a link capable of data throughput at a rate of 2400 bits per second or higher is sufficient for the examples shown below.

Next you need to pre-configure the base and rover site receivers before the units are used in your application.

At the base station, enter the following commands:

interfacemode port rx_type tx_type

fix position latitude longitude height

log port message *[trigger [period]]*

For example:

RTCA
```
interfacemode com2 none rtca
fix position 51.11358042 -114.04358013 1059.4105
log com2 rtcaobs ontime 2
log com2 rtcaref ontime 10
log com2 rtca1 ontime 10 3
log com2 rtcaephem ontime 10 7
```

RTCM
```
interfacemode com2 none rtcm
fix position 51.11358042 -114.04358013 1059.4105
log com2 rtcm3 ontime 10
log com2 rtcm22 ontime 10
log com2 rtcm1819 ontime 2
log com2 rtcm1 ontime 10 5
```

CMR
```
interfacemode com2 none cmr
fix position 51.11358042 -114.04358013 1059.4105
log com2 cmrobs ontime 2
log com2 cmrref ontime 10
log com2 cmrdesc ontime 10 5
```

At the rover station, enter:

interfacemode port rx_type tx_type

For example:

RTCA `interfacemode com2 rtca none`
RTCM `interfacemode com2 rtcm none`
CMR `interfacemode com2 cmr none`

For compatibility with other GPS receivers, and to minimize message size, it is recommended that you use the standard form of RTCA, RTCM or CMR corrections as shown in the examples above. This requires using the INTERFACEMODE command, refer to *Volume 2* of this manual, to dedicate one direction of a serial port to only that message type. Once the INTERFACEMODE command is used to change the mode from the default, NOVATEL, you can no longer use NovAtel format messages.

If you wish to mix NovAtel format messages and RTCA, RTCM or CMR messages on the same port, you can leave the INTERFACEMODE set to NOVATEL and log out variants of the standard messages with a NovAtel header. ASCII or binary variants can be requested by simply appending an "A" or "B" to the standard message name. For example on the base station:

```
interfacemode com2 novatel novatel

fix position 51.11358042 -114.04358013 1059.4105

log com2 rtcm1b ontime 2
```

At the rover station you can leave the INTERFACEMODE default settings (interfacemode com2 novatel novatel). The rover receiver will recognize the default and use the corrections it receives with a NovAtel header.

The PSRDIFFSOURCE and RTKSOURCE commands set the station ID values which identify the base stations from which to accept psuedorange or RTK corrections respectively. They are useful commands when the rover station is receiving corrections from multiple base stations. With the PSRDIFFSOURCE command, all types may revert to SBAS if enabled using the SBASCONTROL command. Refer to *Volume 2* of this manual for more details on these commands. See *Section 6.2,Satellite-Based Augmentation System (SBAS) on Page 68* for more information on SBAS.

At the base station it is also possible to log out the contents of the standard corrections in a form that is easier to read or process. These larger variants have the correction fields broken out into standard types within the log, rather than compressed into bit fields. This can be useful if you wish to modify the format of the corrections for a non-standard application, or if you wish to look at the corrections for system debugging purposes. These variants have "DATA" as part of their names (e.g. RTCADATA1, RTCMDATA1, CMRDATAOBS, and more). Refer to *Volume 2* of this manual for details.

Chapter 5, Message Formats on Page 54 describes the various message formats in more detail.

4.4 Enabling SBAS Positioning

Certain models of the OEM4 family of receivers are capable of SBAS positioning. This positioning mode is enabled using the `SBASCONTROL` command. At the time of publication, the WAAS (North America) and EGNOS (Europe) systems are in test mode. As a result, the following commands are typically used to enable WAAS and EGNOS modes, respectively:

```
SBASCONTROL WAAS ENABLE 0 ZEROTOTWO
SBASCONTROL EGNOS ENABLE 120 INGNOREZERO
```

See *Section 6.2, Satellite-Based Augmentation System (SBAS) on Page 68* for more information on SBAS.

4.5 Enabling OmniSTAR Positioning (ProPak-LB Only)

Depending on the model, your ProPak-LB may support OmniSTAR positioning, which allows you to achieve sub-meter, or even decimeter, accuracy. In order to use this positioning mode, a subscription to OmniSTAR's *Virtual Base Station* (VBS) or *High Performance* (HP) service is required.

To obtain a subscription, contact OmniSTAR at 1-800-338-9178 or 713-785-5850. When you contact OmniSTAR, you will be asked to provide the receiver's OmniSTAR serial number (which is different from the NovAtel serial number). To obtain the OmniSTAR serial number, enter the following command in a terminal window or the Console window in GPSolution:

```
LOG OMNIINFO
```

The log that is generated will display the OmniSTAR serial number in the fifth field following the log header. It is a six digit number in the range `700000` to `799999`. This log also provides the status of your subscription. See *Volume 2* of this user manual for more information.

In order to activate your subscription, the receiver must be powered and tracking an OmniSTAR satellite. When advised by OmniSTAR of the appropriate satellite frequency and data link rate for your location, use the `ASSIGNOMNI` command to configure your receiver. For example, if your frequency is 1,525,000 kHz and your data link speed is 1200 baud, enter the following:

```
ASSIGNOMNI USER 1525000 1200
```

To confirm you are tracking the OmniSTAR signal, log the OmniSTAR status information by entering the following command:

```
LOG OMNISTAT
```

4.6 Pass-Through Logging

The pass-through logging feature enables the receiver to redirect any ASCII or binary data that is input at a specified COM port or, if available, USB port to any specified receiver COM or USB port. This capability, in conjunction with the SEND command, can allow the receiver to perform bi-directional communications with other devices such as a modem, terminal, or another receiver.

There are three pass-through logs **PASSCOM1**, **PASSCOM2** and **PASSCOM3**, available on OEM4 family receivers for logging through COM ports. For the OEM4-G2 and OEM4-G2L, there are an additional three, **PASSUSB1**, **PASSUSB2**, and **PASSUSB3**, offered. Refer to *Volume 2* of this manual for more details on individual logs and commands.

A pass-through log is initiated the same as any other log, i.e., LOG [to-port] [data-type] [trigger]. However, pass-through can be more clearly specified as: LOG [to-port] [from-port-AB] [onchanged]. Now, the [from-port-AB] field designates the port which accepts data (i.e., COM1, COM2, COM3, USB1, USB2, or USB3) as well as the format in which the data will be logged by the [to-port] — (A for ASCII or B for Binary).

When the [from-port-AB] field is suffixed with an [**A**], all data received by that port will be redirected to the [to-port] in **ASCII** format and will log according to standard NovAtel ASCII format. Therefore, all incoming ASCII data will be redirected and output as ASCII data. However, any binary data received will be converted to a form of ASCII hexadecimal before it is logged.

When the [from-port-AB] field is suffixed with a [**B**], all data received by that port will be redirected to the [to-port] exactly as it is received. The log header and time-tag adhere to standard NovAtel Binary format followed by the pass-through data as it was received (ASCII or binary).

Pass-through logs are best utilized by setting the [**trigger**] field as **onchanged** or **onnew**. If the data being injected is ASCII then the data will be grouped together with the following rules:

- blocks of 80 characters
- any block of characters ending in a <CR>
- any block of characters ending in a <LF>
- any block remaining in the receiver code when a timeout occurs

If the data being injected is binary then the data will be grouped as follows:

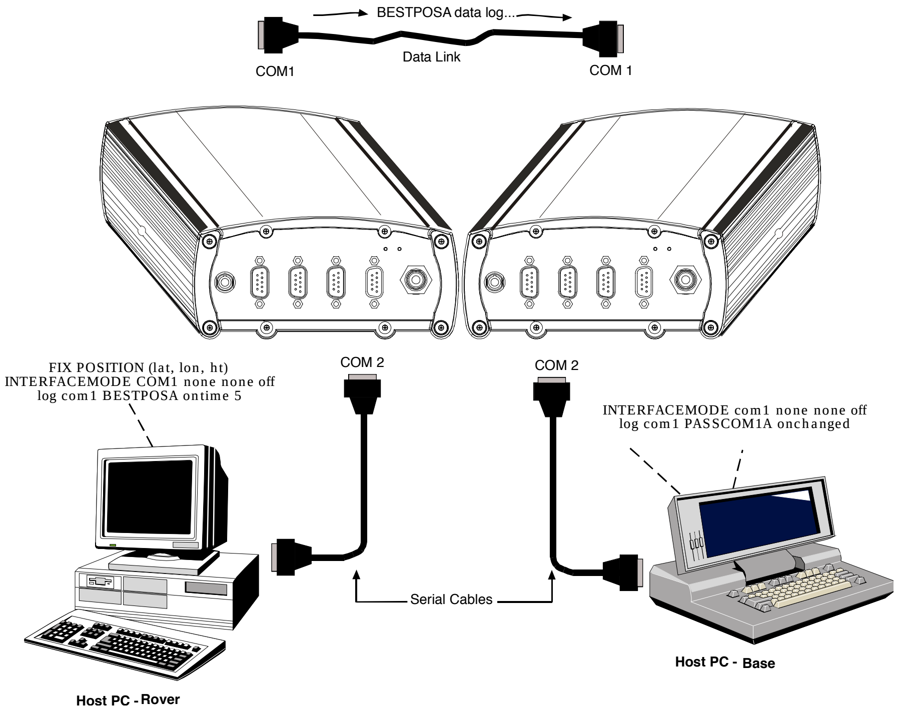
- blocks of 80 bytes
- any block remaining in the receiver code when a timeout occurs

If a binary value is encountered in an ASCII output, then the byte is output as a hexadecimal byte preceded by a backslash and an x. For example 0A is output as \x0A. An actual '\' in the data is output as \\. The output counts as one pass-through byte although it is four characters.

The first character of each pass-through record is time tagged in GPS weeks and seconds.

For example, you could connect two OEM4 family receivers together via their COM1 ports such as in *Figure 15 on Page 50*, a rover station to base station scenario. If the rover station were logging BESTPOSA data to the base station, it would be possible to use the pass-through logs to pass through the received BESTPOSA data to a disk file (let's call it DISKFILE.log) at the base station host PC hard disk.

Figure 15: Pass-Through Log Data



Under default conditions the two receivers will "*chatter*" back and forth with the ***Invalid Command Option*** message (due to the command interpreter in each receiver not recognizing the command prompts of the other receiver). This *chattering* will in turn cause the accepting receiver to transmit new pass-through logs with the response data from the other receiver. To avoid this chattering problem, use the INTERFACEMODE command on the accepting port to disable error reporting from the receiving port command interpreter.

If the accepting port's error reporting is disabled by INTERFACEMODE, the BESTPOSA data record would pass through creating two records.

The reason that two records are logged from the accepting receiver is because the first record was initiated by receipt of the BESTPOSA log's first terminator <CR>. Then the second record followed in response to the BESTPOSA log's second terminator <LF>.

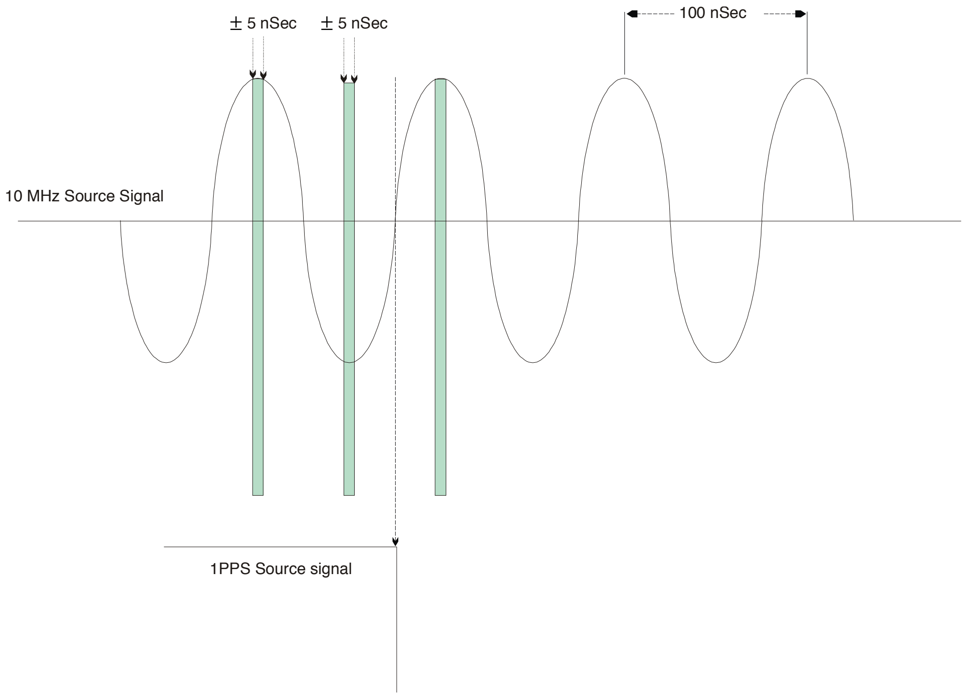
Note that the time interval between the first character received and the terminating <LF> can be calculated by differencing the two GPS time tags (0.08 seconds). This pass-through feature is useful for time tagging the arrival of external messages. These messages could be any user-related data. If the user is using this feature for tagging external events, it is recommended that the command interpreter be disabled so that the receiver does not respond to the messages. See the INTERFACEMODE command in *Volume 2* of this manual.

If the BESTPOSB **binary** log data were input to the accepting port (log com2 passcom1a onchanged), the BESTPOSB binary data at the accepting port is converted to a variation of ASCII hexadecimal before it is passed through to COM2 port for logging.

4.7 T Sync Mod

This section describes the relationship constraints of the input signal phase, see *Figure 16* below, when the T Sync Mod (time synchronization modification) option has been added to an OEM4-G2.

Figure 16: Input Signal Phase Relationship Constraints



The 10 MHz and 1PPS signals must maintain a phase relationship, as in *Figure 16*, when entering the unit. The 1PPS signal must **not** fall within ± 5 nanoseconds (ns) of each peak or dip of the 10 MHz sine wave. These are areas of instability and should be avoided. The best performance is maintained when the 1PPS negative strobe is in phase with the crossover points of the 10 MHz source signal. [1]

To adjust the phase relationship between the 10 MHz and 1PPS signals, add additional RF cable to the 10 MHz line. For example, if using RG58 coaxial cable, each 1 meter length of cable will move the 10 MHz phase by approximately 5 ns.

1. Internal document only: D04388

4.8 Transferring Time Between Receivers

The following is a procedure to transfer time to a "Slave" GPS receiver from a "Master" GPS receiver:

Master	An OEM4 family receiver that is tracking satellites, and has a receiver clock state of FINE or FINESTEERING.
Cold Slave	An OEM4 family receiver that needs to have its clock synchronized with the Master. It may have any clock state including UNKNOWN.
Warm Slave	An OEM4 family receiver that has its clock adjusted to better then 500 ms.

4.8.1 Procedures

To transfer COARSE time (<10 ms) from a Master to a Cold Slave GPS receiver:

1. Connect a COM port from the Master to the Slave (e.g. COM2 on the Master to COM3 on the Slave). Configure both ports to the same baud rate and handshaking configurations.
2. Issue this command to the Master receiver:

   ```
   log com2 timesyncb ontime 1
   ```

3. Issue this command to the Slave receiver:

   ```
   adjust1pps time
   ```

When the Slave receives the TIMESYNC log, it will set its clock allowing for a 100 ms transfer delay.

To transfer FINE time (<50 ns) from a Master GPS to a Cold Slave GPS receiver:

1. Connect a COM port from the Master to the Slave (e.g. COM2 on the Master to COM3 on the Slave). Configure both ports to the same baud rate and handshaking configurations.
2. Issue this command to the Master:

   ```
   log com2 timesyncb ontime 1
   ```

3. Connect the 1PPS signal of the Master to the mark 1 input (Event1) of the Slave.
4. Issue this command to the Slave receiver:

   ```
   adjust1pps markwithtime
   ```

When the Slave receives the 1PPS "event" from the Master, it checks to see if it has received a valid TIMESYNC log within 200 ms of the last 1PPS event. If so, it will set the Slave clock to the exact time of the Master. See *Figure 17, 1PPS Alignment on Page 53*.

To transfer FINE time from a Master to a Warm Slave GPS receiver:

1. Connect the 1PPS signal of the Master to the mark 1 input (Event1) of the Slave.
2. Issue this command to the Slave receiver:

   ```
   adjust1pps mark
   ```

The phase of the Slave clock will be adjusted by the fractional measurement of the Master's 1PPS mark input event. In other words, it will synchronize the Slave’s 1PPS to the incoming 1PPS of the Master, it will NOT adjust the 1 second Time of Week (TOW) counter or the receiver's Week Number. This procedure is used to make small corrections to the Slave's clock.

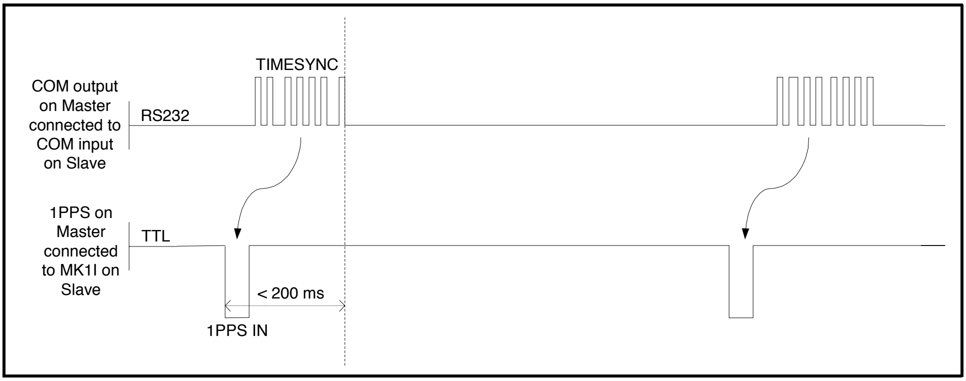


Figure 17: 1PPS Alignment

Chapter 5 Message Formats

The chapter discusses the various industry-standard message formats that can be used with your NovAtel OEM4 family receiver, including RTCA, RTCM, CMR, and NMEA. See *Section 4.3,Transmitting and Receiving Corrections on Page 46* for more information on using these message formats for differential operation.

5.1 RTCA-Format Messages

The RTCA (Radio Technical Commission for Aviation Services) Standard is being designed to support Differential Global Navigation Satellite System (DGNSS) Special Category I (SCAT-I) precision instrument approaches. The RTCA Standard is in a preliminary state. Described below is NovAtel's current support for this standard. It is based on "Minimum Aviation System Performance Standards DGNSS Instrument Approach System: Special Category I (SCAT-I)" dated August 27, 1993 (RTCA/DO-217).

NovAtel has defined three proprietary RTCA Standard Type 7[1] binary-format messages, RTCAOBS, RTCAREF and RTCAEPHEM for base station transmissions. These can be used with either single or dual-frequency NovAtel receivers. The RTCA message format outperforms the RTCM format in the following ways, among others:

- a more efficient data structure (lower overhead)
- better error detection
- allowance for a longer message, if necessary

RTCAREF and RTCAOBS, respectively, correspond to the RTCM Type 3 and Type 59 logs used in single-frequency-only measurements. Both are NovAtel-proprietary RTCA Standard Type 7 messages with an 'N' primary sub-label.

5.1.1 RTCA1

This log enables transmission of RTCA Standard format Type 1 messages from the receiver when operating as a base station. Before this message can be transmitted, the receiver FIX POSITION command must be set. The RTCA log will be accepted by a receiver operating as a rover station over a COM port after an INTERFACEMODE *port* RTCA_INTERFACE command is issued.

The RTCA Standard for SCAT-I stipulates that the maximum age of differential correction (Type 1) messages accepted by the rover station cannot be greater than 22 seconds. Refer to the DGPSTIMEOUT command in *Volume 2* of this manual for information regarding DGPS delay settings.

1.For further information on RTCA Standard messages, you may wish to refer to:

Minimum Aviation System Performance Standards - DGNSS Instrument Approach System: Special Category I (SCAT-I), Document No. RTCA/DO-217 (April 19,1995); Appendix A, Page 21.

The RTCA Standard also stipulates that a base station shall wait five minutes after receiving a new ephemeris before transmitting differential corrections. Refer to the DGPSEPHEMDELAY command in *Volume 2* of this manual for information regarding ephemeris delay settings.

The basic SCAT-I Type 1 differential correction message is as follows:

Format: Message length = 11 + (6*obs): (83 bytes maximum)

Field Type	Data		Scaling	Bits	Bytes
SCAT-I header	–	Message block identifier	-	8	6
	–	Base station ID	-	24	
	–	Message type (this field will always report 00000100)	-	8	
	–	Message length	-	8	
Type 1 header	–	Modified z-count	0.2 s	13	2
	–	Acceleration error bound (In the receiver, this field will report 000)	-	3	
Type 1 data	–	Satellite ID	-	6	6 * obs
	–	Pseudorange correction[a]	0.02 m	16	
	–	Issue of data	-	8	
	–	Range rate correction[a]	0.002 m/s	12	
	–	UDRE	0.2 m	6	
CRC	Cyclic redundancy check		-		3

a. The pseudorange correction and range rate correction fields have a range of ±655.34 meters and ±4.049 m/s respectively. Any satellite which exceeds these limits will not be included.

5.1.2 RTCAEPHEM Type 7

An RTCAEPHEM (RTCA Satellite Ephemeris Information) message contains raw satellite ephemeris information. It can be used to provide a rover receiver with a set of GPS ephemerides. Each message contains a complete ephemeris for one satellite and the GPS time of transmission from the base. The message is 102 bytes (816 bits) long. This message should be sent once every 5-10 seconds (The faster this message is sent, the quicker the rover station will receive a complete set of ephemerides). Also, the rover receiver will automatically set an approximate system time from this message if time is still unknown. Therefore, this message can be used in conjunction with an approximate position to improve time to first fix (TTFF), see *Appendix E, TTFF and Satellite Acquisition on Page 161*.

5.1.3 RTCAOBS Type 7

An RTCAOBS (RTCA base-Station Satellite Observations) message contains base station satellite observation information. It is used to provide range observations to the rover receiver, and should be sent every 1 or 2 seconds. This log is made up of variable-length messages up to 255 bytes long. The maximum number of bits in this message is [140 + (92 x *N*)], where *N* is the maximum number of satellite record entries transmitted. Using the RTKSVENTRIES command, you can define *N* to be anywhere from 4 to 12; the default value is 12.

5.1.4 RTCAREF Type 7

An RTCAREF (RTCA Base Station Position Information) message contains base station position information, and should be sent once every 10 seconds. Each message is 24 bytes (192 bits) long.

If RTCA-format messaging is being used, the optional *station id* field that is entered using the DGPSTXID command can be any 4-character string combining numbers and upper-case letters, and enclosed in double quotation marks (e.g. “RW34”). The station ID will be reported at the rover receiver, in its position log.

Also, the rover receiver will automatically set an approximate position from this message if it does not already have a position. Therefore this message can be used in conjunction with an approximate time to improve TTFF, see *Appendix E, TTFF and Satellite Acquisition on Page 161*.

5.2 RTCM-Format Messages

The Radio Technical Commission for Maritime Services (RTCM) was established to facilitate the establishment of various radio navigation standards, which includes recommended GPS differential standard formats.

The standards recommended by the Radio Technical Commission for Maritime Services Special Committee 104, Differential GPS Service (RTCM SC-104,Washington, D.C.), have been adopted by NovAtel for implementation into the receiver. Because the receiver is capable of utilizing RTCM formats, it can easily be integrated into positioning systems around the globe.

As it is beyond the scope of this manual to provide in-depth descriptions of the RTCM data formats, it is recommended that anyone requiring explicit descriptions of such, should obtain a copy of the published RTCM specifications. See *Appendix G, Standards/References on Page 166* for reference information.

RTCM SC-104[1] Type 3 & 59 messages can be used for base station transmissions in differential systems. However, since these messages do not include information on the L2 component of the GPS signal, they cannot be used with RT-2 positioning. Regardless of whether single or dual-frequency receivers are used, the RT-20 positioning algorithm would be used. This is for a system in which both the base and rover stations utilize NovAtel receivers.

Note that the error-detection capability of an RTCM-format message is less than that of an RTCA-format message. The communications equipment that you use may have an error-detection capability of its own to supplement that of the RTCM message, although at a penalty of a higher overhead. Consult the vendor’s documentation for further information.

If RTCM-format messaging is being used, the optional *station id* field that is entered using the FIX POSITION command can be any number within the range of 0 - 1023 (e.g. 119). The representation in the log message would be identical to what was entered.

1.For further information on RTCM SC-104 messages, you may wish to refer to:

RTCM Recommended Standards for Differential Navstar GPS Service, Version 2.2, RTCM Paper 11-98/SC104-STD (January 15, 1998)

The NovAtel logs which implement the RTCM Standard Format for Type 1, 3, 9, 16, 18, 19 and 22 messages are known as the RTCM1, RTCM3, RTCM9, RTCM16, RTCM18, RTCM19 and RTCM22 logs, respectively, while Type 59N-0 messages are listed in the RTCM59 log.

All receiver RTCM standard format logs adhere to the structure recommended by RTCM SC-104. Thus, all RTCM message are composed of 30 bit words. Each word contains 24 data bits and 6 parity bits. All RTCM messages contain a 2-word header followed by 0 to 31 data words for a maximum of 33 words (990 bits) per message.

Message Frame Header	Data		Bits
Word 1	–	Message frame preamble for synchronization	8
	–	Frame/message type ID	6
	–	Base station ID	10
	–	Parity	6
Word 2	–	Modified z-count (time tag)	13
	–	Sequence number	3
	–	Length of message frame	5
	–	Base health	3
	–	Parity	6

The remainder of this section will provide further information concerning receiver commands and logs that utilize the RTCM data formats.

5.2.1 RTCM1

This is the primary RTCM log used for pseudorange differential corrections. This log follows the RTCM Standard Format for a Type 1 message. It contains the pseudorange differential correction data computed by the base station generating this Type 1 log. The log is of variable length, depending on the number of satellites visible and pseudoranges corrected by the base station. Satellite specific data begins at word 3 of the message.

Structure:

(Follows the RTCM Standard for a Type 1 message)

Type 1 messages contain the following information for each satellite in view at the base station:

- Satellite ID
- Pseudorange correction
- Range-rate correction
- Issue of Data (IOD)

When operating as a base station, the receiver must be in FIX POSITION mode and have the INTERFACEMODE command set before the data can be correctly logged, see *Transmitting and Receiving Corrections on Page 46*.

When operating as a rover station, the receiver COM port receiving the RTCM data must have its INTERFACEMODE command set, see *Transmitting and Receiving Corrections on Page 46*.

REMEMBER: Upon a change in ephemeris, base stations will transmit Type 1 messages based on the old ephemeris for a period of time defined by the DGPSTIMEOUT command. After the timeout, the base station will begin to transmit the Type 1 messages based on new ephemeris.

5.2.2 RTCM3 Base Station Parameters (RTK)

This log contains the GPS position of the base station expressed in rectangular ECEF coordinates based on the center of the WGS-84 ellipsoid. This log uses four RTCM data words following the two-word header, for a total frame length of six 30 bit words (180 bits maximum). This message must be sent at least once every 30 seconds, although it is recommended that it be sent once every 10 seconds.

Also, the rover receiver will automatically set an approximate position from this message if it does not already have a position. Therefore this message can be used in conjunction with an approximate time to improve TTFF, see *Appendix E, TTFF and Satellite Acquisition on Page 161*.

Structure:

(Follows the RTCM SC-104 Standard for a Type 3 message)

Type 3 messages contain the following information:

- Scale factor
- ECEF X-coordinate
- ECEF Y-coordinate
- ECEF Z-coordinate

The receiver only transmits the RTCM Type 3 message (RTCM3) when operating as a base station paired with rover receivers operating in RT-20 Carrier Phase Mode (see *6.5, Carrier-Phase Differential on Page 76* for more information) or for RT-2, periodically transmitting an RTCM Type 18 and RTCM Type 19 (RTCM1819), or RTCM Type 22 message, together with an RTCM Type 3.

✉ This log is intended for use when operating in RT-20 or RT-2 mode.

5.2.3 RTCM9 Partial Satellite Set Differential Corrections

RTCM Type 9 messages follow the same format as Type 1 messages. However, unlike a Type 1 message, Type 9 does not require a complete satellite set. This allows for much faster differential correction data updates to the rover stations, thus improving performance and reducing latency.

Type 9 messages should give better performance with slow or noisy data links.

✉ The base station transmitting the Type 9 corrections must be operating with a high-stability clock to prevent degradation of navigation accuracy due to the unmodeled clock drift that can occur between Type 9 messages. For this reason, only OEM4-G2 receivers with an external oscillator can generate Type 9 messages. All OEM4 family receivers can accept Type 9 messages.

NovAtel recommends a high-stability clock such as the PIEZO Model 2900082 whose 2-sample (Allan) variance meets the following stability requirements:

3.24×10^{-24} s^2/s^2 between 0.5 - 2.0 seconds, and

1.69×10^{-22} T s^2/s^2 between 2.0 - 100.0 seconds

An external clock, such as an OCXO, requires approximately 10 minutes to warm up and become fully stabilized after power is applied; do not broadcast RTCM Type 9 corrections during this warm-up period.

Structure:

(Follows the RTCM Standard SC-104 for a Type 1 message)

Type 9 messages contain the following information for a group of three satellites in view at the base station:

- Scale factor
- User Differential Range Error
- Satellite ID
- Pseudorange correction
- Range-rate correction
- Issue of Data (IOD)

5.2.4 RTCM15 Ionospheric Corrections

RTCM Type 15 messages are designed to support the broadcast of ionospheric delay and rate of change measurements for each satellite as determined by the base station receiver. This message is used to improve the ionospheric de-correlation that would otherwise be experienced by a rover at a long distance from the base station. This log is designed to work in conjunction with Type 1 messages using dual frequency receivers. It is anticipated Type 15 messages will be broadcast every 5-10 minutes.

Type 15 messages are designed to enable the rover to continuously remove the ionospheric component from received pseudorange corrections. The delay and rate terms are added exactly like Type 1 corrections to provide the total ionospheric delay at a given time, and the total ionospheric delay is then subtracted from the pseudorange corrections. The resulting corrections are then "iono-free". The rover subtracts its measurements (or estimates) of ionospheric delay from its own pseudorange measurements and applies the iono-free corrections.

Structure:

(Follows RTCM standard for Type 15 message)

Type 15 messages contain the following information for each satellite in view at the base station:

- Satellite ID
- Ionospheric delay
- Iono rate of change

When operating as a base station, the receiver must be in FIX POSITION mode and have the INTERFACEMODE command set before the data can be correctly logged. You must also by logging the RTCM Type 1 corrections.

When operating as a rover station, the receiver COM port receiving the RTCM data must have its INTERFACEMODE command set.

5.2.5 RTCM16 Special Message

This log contains a special ASCII message that can be displayed on a printer or cathode ray tube. The base station wishing to log this message out to rover stations that are logged onto a computer, must use the SETRTCM16T command to set the required ASCII text message. Once set, the message can then be issued at the required intervals with the "LOG *port* RTCM16 *interval*" command. The Special Message setting can be verified in the RXCONFIGA log. The received ASCII text can be displayed at the rover by logging RTCM16T ONNEW.

The RTCM16 data log follows the RTCM Standard Format. Words 1 and 2 contain RTCM header information followed by words 3 to *n* (where *n* is variable from 3 to 32) which contain the special message ASCII text. Up to 90 ASCII characters can be sent with each RTCM Type 16 message frame.

Structure:

(Follows the RTCM Standard SC-104 for a Type 16 message)

5.2.6 RTCM18 and RTCM19 Raw Measurements (RTK)

RTCM18 provides uncorrected carrier phase measurements and RTCM19 provides uncorrected pseudorange measurements. The measurements are not corrected by the ephemerides contained in the satellite message.

The messages have similar formats. Word 3, the first data word after the header, contains a GPS TIME OF MEASUREMENT field which is used to increase the resolution of the MODIFIED Z-COUNT in the header. Word 3 is followed by pairs of words containing the data for each satellite observed. Appropriate flags are provided to indicate L1 C/A or P-code **or** L2 cross correlated or P-code measurements. The carrier smoothing interval for pseudoranges and pseudorange corrections is also furnished, for a total frame length of six 30 bit words (180 bits maximum).

Structure:

(Follows the RTCM SC-104 Standard for a Type 18 and Type 19 message)

For RT-20 or RT-2, you may periodically transmit a set of RTCM Type 18 and RTCM Type 19 together with an RTCM Type 3 message and an RTCM Type 22 message.

5.2.7 RTCM20 and RTCM21 Measurement Corrections (*RTK*)

RTCM20 provides carrier phase corrections and RTCM21 provides pseudorange corrections. Types 20 and 21 are corrected by the ephemerides contained in the satellite message and are therefore referred to as ‘corrections’.

Message Type 21 is very similar to the standard Type 1 message, but has additional measurement quality information, and can be used to support cross-correlation receivers. Message Type 21 is also useful in non-kinematic applications requiring high accuracy and integrity.

See *Section 5.2.6* above for the message format of the Type 18 and 19 messages that are similar to the Type 20 and 21 messages.

5.2.8 RTCM22 RTCM Extended Base Station Parameters (*RTK*)

Message Type 22 provides firstly, a means of achieving sub-millimeter precision for base station coordinates in a kinematic application, and secondly, base station antenna height above a base, which enables mobile units to reference measured position to the base directly in real time.

The first data word of message Type 22 provides the corrections to be added to each ECEF coordinate. Note that the corrections may be positive or negative.

The second data word, which may not be transmitted, provides the antenna L1 phase center height expressed in integer and fractional centimeters, and is always positive. It has the same resolutions as the corrections. The range is about 10 meters. The spare bits can be used if more height range is required.

5.2.9 RTCM59 Type 59N-0 NovAtel Proprietary Message (*RTK*)

RTCM Type 59 messages are reserved for proprietary use by RTCM base station operators.

Each message is variable in length, limited only by the RTCM maximum of 990 data bits (33 words maximum). The first eight bits in the third word (the word immediately following the header) serve as the message identification code, in the event that the base station operator wishes to have multiple Type 59 messages.

NovAtel has defined only a Type 59N-0 message to date; it is to be used for operation in receivers capable of operating in RT-20 Carrier Phase Differential Positioning Mode. This log is primarily used by a base station to broadcast its RT-20 observation data (delta pseudorange and accumulated Doppler range) to rover RT-20 – capable receivers. Type 59N messages should be sent once every 2 seconds.

☒ 1. The COMSTATSA/B log is very useful for monitoring the serial data link, as well as differential data decode success.

2. This log is intended for use when operating in RT-20 mode.

5.3 CMR Format Messaging

The Compact Measurement Record (CMR) message format was developed by Trimble Navigation Ltd. as a proprietary data transmission standard for use in RTK applications. In 1996 Trimble publicly disclosed this standard and allowed its use by all manufacturers in the GPS industry[1].

The NovAtel implementation allows a NovAtel rover receiver to operate in either RT-2 or RT-20 mode while receiving pseudorange and carrier phase data via CMR messages (version 3.0) from a non-NovAtel base-station receiver. The NovAtel receiver can also transmit CMR messages (version 3.0). The station ID must be ≤ 31 when transmitting CMR corrections, refer to *Volume 2, Chapter 2, Commands*.

The message lengths of the three CMR messages are as follows:

CMROBS = 6 *(frame)* + 6 *(header)* + (8*L1 channels) + (7*L2 channels) : (192 bytes maximum)
CMRREF = 6 *(frame)* + 6 *(header)* + 19: (31 bytes)
CMRDESC = 6 *(frame)* + 6 *(header)* + (variable:26 to 75): (38 bytes minimum; 87 bytes maximum)

🖂 No guarantee is made that the OEM4 will meet its performance specifications if non-NovAtel equipment is used.

5.3.1 Using RT-2 or RT-20 with CMR Format Messages

To enable receiving CMR messages, follow these steps:

1. Issue the COM command to the rover receiver to set its serial port parameters to the proper bit rate, parity, etc. This command is described in detail in *Volume 2* of this manual.
2. Issue the “INTERFACEMODE COMn CMR” command to the rover receiver, where “COMn” refers to the communication port that is connected to the data link. This command is described in detail in the *OEM4 Family User Manual - Volume 2*.

Assuming that the base station is transmitting valid data, your rover receiver will now begin to operate in RT-2 or RT-20 mode. To send CMR messages, do the following:

Periodically transmit three CMR messages at the base station:

- A CMROBS message contains base station satellite observation information, and should be sent once every 1 or 2 seconds.
- A CMRREF message contains base station position information, and should be sent once every 10 seconds. Also, the rover receiver will automatically set an approximate position from this message if it does not already have a position. Therefore this message can be used in conjunction with an approximate time to improve TTFF, see *Appendix E, TTFF and Satellite Acquisition on Page 161*.
- A CMRDESC message contains base station description information and should be sent once every 10 seconds, however, it should interlinked with the CMRREF message.

1.Talbot, N.C. (1996), “Compact Data Transmission Standard for High-Precision GPS”. Proceeding of the ION GPS-96 Conference, Kansas City, MO, September 1996, Vol. I, pp. 861-871

Example:

log CMROBS ontime 1

log CMRREF ontime 10

log CMRDESC ontime 10 5

---

1. For CMR the station ID must be less than 31 (refer to the RTKSOURCE and DGPSTXID commands in Volume 2 of this manual).
2. CMRDESC is logged with an offset of 5 to allow interleaving with CMRREF.
3. Novatel CMR Type 2 messages are for compatibility only. When received, a type 2 message is discarded. For transmission, all fields are permanently set as follows:

Record Length	=	33 bytes
Short Station ID	=	"cref"
COGO Code	=	""
Long Station ID	=	"UNKNOWN"

5.4 NMEA Format Data Logs

The NMEA log structures follow format standards as adopted by the National Marine Electronics Association. The reference document used is "Standard For Interfacing Marine Electronic Devices NMEA 0183 Version 2.00". For further information, see the appendix on *Standards and References* in *Volume 1* of this manual. The following table contains excerpts from Table 6 of the NMEA Standard which defines the variables for the NMEA logs. The actual format for each parameter is indicated after its description.

Field Type	Symbol	Definition
Special Format Fields		
Status	A	Single character field: A = Yes, Data Valid, Warning Flag Clear V = No, Data Invalid, Warning Flag Set
Latitude	llll.ll	Fixed/Variable length field: degreeslminutes.decimal - 2 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.
Longitude	yyyyy.yy	Fixed/Variable length field: degreeslminutes.decimal - 3 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required
Time	hhmmss.ss	Fixed/Variable length field: hourslminuteslseconds.decimal - 2 fixed digits of hours, 2 fixed digits of minutes, 2 fixed digits of seconds and variable number of digits for decimal-fraction of seconds. Leading zeros always included for hours, minutes and seconds to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.
Defined field		Some fields are specified to contain pre-defined constants, most often alpha characters. Such a field is indicated in this standard by the presence of one or more valid characters. Excluded from the list of allowable characters are the following which are used to indicate field types within this standard: "A", "a", "c", "hh", "hhmmss.ss", "llll.ll", "x", "yyyyy.yy"
Numeric Value Fields		
Variable numbers	x.x	Variable length integer or floating numeric field. Optional leading and trailing zeros. The decimal point and associated decimal-fraction are optional if full resolution is not required (example: 73.10 = 73.1 = 073.1 = 73)
Fixed HEX	hh___	Fixed length HEX numbers only, MSB on the left
Information Fields		
Variable text	c--c	Variable length valid character field.
Fixed alpha	aa___	Fixed length field of uppercase or lowercase alpha characters
Fixed number	xx___	Fixed length field of numeric characters
Fixed text	cc___	Fixed length field of valid characters

NOTES:
1. Spaces may only be used in variable text fields.
2. A negative sign "-" (HEX 2D) is the first character in a Field if the value is negative. The sign is omitted if value is positive.
3. All data fields are delimited by a comma (,).
4. Null fields are indicated by no data between two commas (,,). Null fields indicate invalid or no data available.
5. The NMEA Standard requires that message lengths be limited to 82 characters.

Chapter 6 Positioning Modes of Operation

NovAtel's dual frequency GPS receivers have several important performance advantages depending on your positioning requirements. Dual frequency allows direct measurement of the signal delay through the ionosphere and is critical to fast and reliable integer ambiguity resolution when positioning using carrier measurements.

Dual frequency can improve the performance of DGPS, SBAS, and RTK positioning. Using RTCM type 15 messages will allow the DGPS user to apply a local ionospheric correction to their dual frequency receiver to improve code positioning performance on larger baselines (hundreds of km). SBAS positioning is improved by applying a local correction instead of using the SBAS ionospheric grid, and RTK solutions are improved on baselines over 15 km by using an ionosphere free solution.

By default the models with OmniSTAR software only support the standard L1 OmniSTAR VBS service. They are upgradeable to the High Performance (HP) decimeter L1/L2 service via a coded message from an OmniSTAR satellite.

The OEM4 family of receivers operate in the most accurate positioning mode possible with the signals available, and immediately drop to the next positioning mode if the current signal times out.

The following single and dual frequency modes of operation are described further in this chapter:

- Single Point or Autonomous
- Satellite-Based Augmentation System (SBAS)
- Psuedorange Differential
- OmniSTAR
- Carrier-Phase Differential

See *Appendix C, GPS Overview on Page 149* for an overview of GPS positioning.

6.1 Single-Point or Autonomous

The NovAtel OEM4 family receivers are capable of absolute single-point positioning accuracies of 1.8 meters CEP (GDOP < 2; no multipath).

The general level of accuracy available from single-point operation may be suitable for many types of positioning such as ocean going vessels, general aviation, and recreational vessels that do not require position accuracies of better than 1.8 meters CEP. However, increasingly more and more applications desire and require a much higher degree of accuracy and position confidence than is possible with single-point pseudorange positioning. This is where differential GPS (DGPS) plays a dominant role in higher accuracy real-time positioning systems.

By averaging many GPS measurement epochs over several hours, it is possible to achieve a more accurate absolute position. This section attempts to explain how the position averaging function operates and to provide an indication of the level of accuracy that can be expected versus total averaging time.

The POSAVE command implements position averaging for base stations. Position averaging will continue for a specified number of hours or until the averaged position is within specified accuracy limits. Averaging will stop when the time limit or the horizontal standard deviation limit or the vertical standard deviation limit is achieved. When averaging is complete, the FIX POSITION command will automatically be invoked.

If the maximum time is set to 1 hour or larger, positions will be averaged every 10 minutes and the standard deviations reported in the AVEPOS log should be correct. If the maximum time is set to less than 1 hour, positions will be averaged once per minute and the standard deviations reported in the log will likely not be accurate; also, the optional horizontal and vertical standard deviation limits cannot be used.

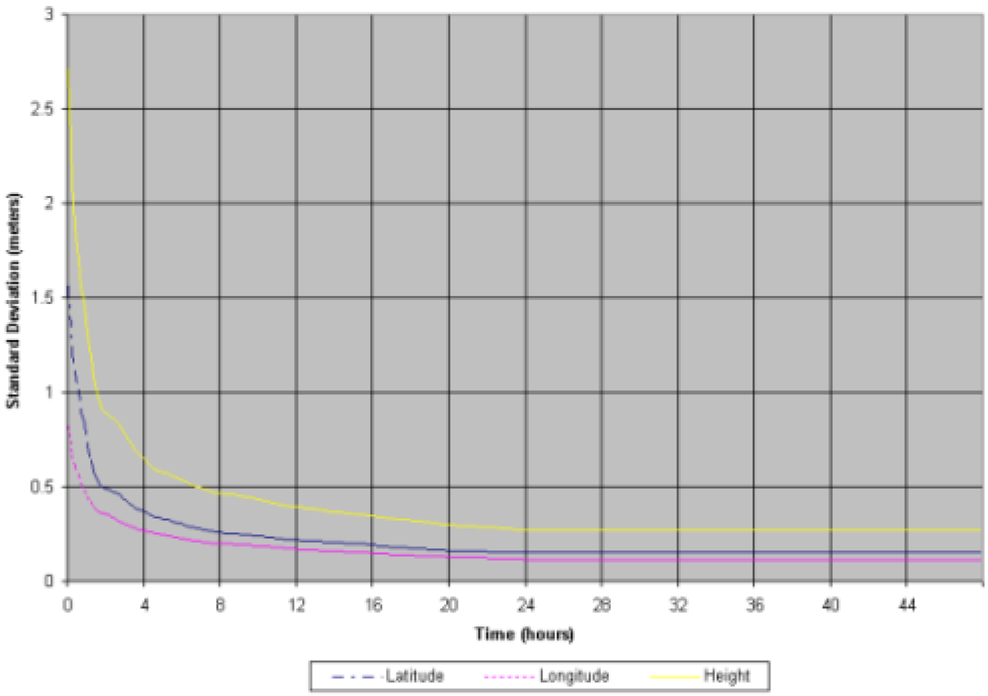
If the maximum time that positions are to be measured is set to 24, for example, you can then log AVEPOS with the trigger ‘onchanged’ to see the averaging status. i.e.,

```
posave 24
log com1 avepos onchanged
```

If desired, you could initiate differential logging, then issue the POSAVE command followed by the SAVECONFIG command. This will cause the receiver to average positions after every power-on or reset, then invoke the FIX POSITION command to enable it to send differential corrections.

The position accuracy that may be achieved by these methods will be dependent on many factors: average satellite geometry, sky visibility at antenna location, satellite health, time of day, etc. The following graph summarizes the results of several examples of position averaging over different time periods. The intent is to provide an idea of the relationship between averaging time and position accuracy. All experiments were performed using a single frequency receiver with an ideal antenna location, see *Figure 18*.

Figure 18: Single-Point Averaging (Typical Results)



The position averaging function is useful for obtaining the WGS84 position of a point to a reasonable accuracy without having to implement differential GPS. It is interesting to note that even a six hour occupation can improve single-point GPS accuracy from over 1.5 meters to better than a meter. This improved accuracy is primarily due to the reductions of the multipath errors in the GPS signal.

Again, it is necessary to keep in mind that the resulting standard deviations of the position averaging can vary quite a bit, but improve over longer averaging times. To illustrate, the position averaging function was run for a period of 40 hours. The resulting standard deviation in latitude varied from 0.152 to 1.5589 meters. Similarly, the variation in longitude and height were 0.117 to 0.819 meters and 0.275 to 2.71 meters respectively. This degree of variation becomes larger for averaging periods of less than 12 hours due to changes in the satellite constellation. The graph provides some indication of the accuracy one may expect from single-point position averaging.

The next section deals with the type of GPS system errors that can affect accuracy in single-point operation.

6.1.1 GPS System Errors

In general, GPS SPS C/A code single-point pseudorange positioning systems are capable of absolute position accuracies of about 1.8 meters or less. This level of accuracy is really only an estimation, and may vary widely depending on numerous GPS system biases, environmental conditions, as well as the GPS receiver design and engineering quality.

There are numerous factors which influence the single-point position accuracies of any GPS C/A code receiving system. As the following list will show, a receiver's performance can vary widely when under the influences of these combined system and environmental biases.

- **Ionospheric Group Delays –** The earth's ionospheric layers cause varying degrees of GPS signal propagation delay. Ionization levels tend to be highest during daylight hours causing propagation delay errors of up to 30 meters, whereas night time levels are much lower and may be as low as 6 meters.

- **Tropospheric Refraction Delays** – The earth's tropospheric layer causes GPS signal propagation delays. The amount of delay is at the minimum (about three metres) for satellite signals arriving from 90 degrees above the horizon (overhead), and progressively increases as the angle above the horizon is reduced to zero where delay errors may be as much as 50 metres at the horizon.

- **Ephemeris Errors –** Some degree of error always exists between the broadcast ephemeris' predicted satellite position and the actual orbit position of the satellites. These errors will directly affect the accuracy of the range measurement.

- **Satellite Clock Errors** – Some degree of error also exists between the actual satellite clock time and the clock time predicted by the broadcast data. This broadcast time error will cause some bias to the pseudorange measurements.

- **Receiver Clock Errors** – Receiver clock error is the time difference between GPS receiver time and true GPS time. All GPS receivers have differing clock offsets from GPS time that vary from receiver to receiver by an unknown amount depending on the oscillator type and quality (TCXO vs. OCXO, etc.). However, because a receiver makes all of its single-point pseudorange measurements using the same common clock oscillator, all measurements will be equally offset, and this offset can generally be modeled or quite accurately estimated to effectively cancel the receiver clock offset bias. Thus, in single-point positioning, receiver clock offset is not a significant problem. However, in pseudorange differential operation, between-receiver clock offset is a source of uncorrelated bias.

- **Multipath Signal Reception** – Multipath signal reception can potentially cause large pseudorange and carrier phase measurement biases. Multipath conditions are very much a function of specific antenna site location versus local geography and man-made structural influences. Severe multipath conditions could skew range measurements by as much as 100 meters or more. See *Appendix D, Multipath on Page 154* for more information.

6.2 Satellite-Based Augmentation System (SBAS)

A Satellite-Based Augmentation System (SBAS) is a type of geo-stationary satellite system that improves the accuracy, integrity, and availability of the basic GPS signals. Accuracy is enhanced through the use of wide area corrections for GPS satellite orbits and ionospheric errors. Integrity is enhanced by the SBAS network quickly detecting satellite signal errors and sending alerts to receivers to not use the failed satellite. Availability is improved by providing an additional ranging signal to each SBAS geostationary satellite.

SBAS includes the Wide-Area Augmentation System (WAAS), the European Geo-Stationary Navigation System (EGNOS), and the MTSAT Satellite-Based Augmentation System (MSAS). At the time of publication, there are two WAAS satellites over the western Atlantic Ocean and the Pacific (PRN 122 and PRN 134 respectively) and one EGNOS satellite over the eastern Atlantic Ocean (PRN 120). SBAS data is available from any of these satellites and more satellites will be available in the future.

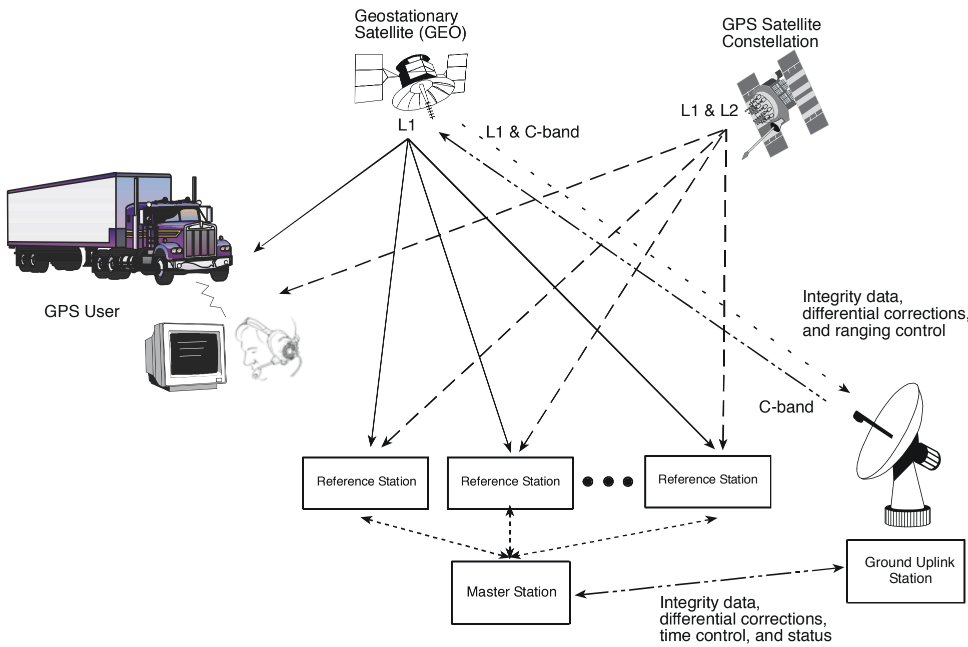
The primary functions of SBAS include:

- data collection
- determining ionospheric corrections
- determining satellite orbits
- determining satellite clock corrections
- determining satellite integrity
- independent data verification
- SBAS message broadcast and ranging
- system operations & maintenance

As shown in *Figure 19, The SBAS Concept*, the SBAS is made up of a series of Reference Stations, Master Stations, Ground Uplink Stations and Geostationary Satellites (GEOs). The Reference Stations, which are geographically distributed, pick up GPS satellite data and route it to the Master Stations where wide area corrections are generated. These corrections are sent to the Ground Uplink Stations which up-link them to the GEOs for re-transmission on the GPS L1 frequency. These GEOs transmit signals which carry accuracy and integrity messages, and which also provide additional ranging signals for added availability, continuity and accuracy. These GEO signals are available over a wide area and can be received and processed by OEM4 family GPS receivers with appropriate firmware. GPS user receivers are thus able to receive SBAS data in-band and use not only differential corrections, but also integrity, residual errors and ionospheric information for each monitored satellite.

The signal broadcast via the SBAS GEOs to the SBAS users is designed to minimize modifications to standard GPS receivers. As such, the GPS L1 frequency (1575.42 MHz) is used, together with GPS-type modulation - e.g. a Coarse/Acquisition (C/A) pseudorandom (PRN) code. In addition, the code phase timing is maintained close to GPS time to provide a ranging capability.

Figure 19: The SBAS Concept



6.2.1 SBAS Receiver

Many models of the NovAtel receivers (including 3151W, L1l2W, WAAS, EGNOS) are equipped with an SBAS option. The ability to simultaneously track two SBAS satellites, and incorporate the SBAS corrections into the position, is available in these models.

These models can output the SBAS data in log format (RAWWAASFRAMEA/B, WAAS0A/B-WAAS27A/B), and can incorporate these corrections to generate differential-quality position solutions. Standard SBAS data messages are analyzed based on RTCA standard DO-229B Change 1 Minimum Operational Performance Standards for GPS/WAAS airborne equipment.

A SBAS-capable receiver will permit anyone within the area of coverage to take advantage of its benefits.

6.2.2 SBAS Commands and Logs

The command SBASCONTROL, enables the use of the SBAS corrections in the position filter. In order to use this command, first ensure that your receiver is capable of receiving SBAS corrections.

Several SBAS specific logs also exist and are all prefixed by the word WAAS except for the RAWWAASFRAME log.

The PSRDIFFSOURCE command sets the station ID value which identifies the base station from which to accept pseudorange corrections. All DGPS types may revert to SBAS, if enabled using the SBASCONTROL command.

Consult *Volume 2* of this manual for more details on individual SBAS commands and logs.

6.3 Pseudorange Differential

There are two types of differential positioning algorithms: *pseudorange* and *carrier phase*. In both of these approaches, the “quality” of the positioning solution generally increases with the number of satellites which can be simultaneously viewed by both the base and rover station receivers. As well, the quality of the positioning solution increases if the distribution of satellites in the sky is favorable; this distribution is quantified by a figure of merit, the Position Dilution of Precision (PDOP), which is defined in such a way that the lower the PDOP, the better the solution. Pseudorange differential is the focus of this section. Carrier-phase algorithms are discussed in *Carrier-Phase Differential on Page 76*.

6.3.1 Pseudorange Algorithms

Pseudorange algorithms correlate the pseudorandom code on the GPS signal received from a particular satellite, with a version generated within the base station receiver itself. The time delay between the two versions, multiplied by the speed of light, yields the *pseudorange* (so called because it contains several errors) between the base station and that particular satellite. The availability of four pseudoranges allows the base station receiver to compute its position (in three dimensions) and the offset required to synchronize its clock with GPS system time. The discrepancy between the base station receiver’s computed position and its known position is due to errors and biases on each pseudorange. The base station receiver sums these errors and biases for each pseudorange, and then broadcasts these corrections to the rover station. The rover receiver applies the corrections to its own measurements; its corrected pseudoranges are then processed in a least-squares algorithm to obtain a position solution.

The “wide correlator” receiver design that predominates in the GPS industry yields accuracies of 3-5 m (SEP). NovAtel’s patented Narrow Correlator tracking technology reduces noise and multipath interference errors, yielding accuracies of 1 m (SEP).

6.3.2 Position Solutions

Due to the many different applications for differential positioning systems, two types of position solutions are possible. NovAtel's carrier-phase algorithms can generate both *matched* and *low-latency* position solutions, while NovAtel's pseudorange algorithms generate only low-latency solutions. These are described below:

1. The *matched* position solution is computed at the rover station when the observation information for a given epoch has arrived from the base station via the data link. Matched observation set pairs are observations by both the base and rover stations which are matched by time epoch, and contain the same satellites. The matched position solution is the most accurate one available to the operator of the rover station, but it has an inherent *latency* – the sum of time delays between the moment that the base station makes an observation and the moment that the differential information is processed at the rover station. This latency depends on the computing speed of the base station receiver, the rates at which data is transmitted through the various links, and the computing speed of the rover station; the overall delay is on the order of one second. Furthermore, this position cannot be computed any more often than the observations are sent from the base station. Typically, the update rate is one solution every two seconds.

2. The *low latency* position solution is based on a prediction from the base station. Instead of waiting for the observations to arrive from the base station, a model (based on previous base station observations) is used to estimate what the observations will be at a given time epoch. These estimated base station observations are combined with actual measurements taken at the rover station to provide the position solution. Because only the base station observations are predicted, the rover station's dynamics will be accurately reflected. The *latency* in this case (the time delay between the moment that a measurement is made by the rover station and the moment that a position is made available) is determined only by the rover processor's computational capacity; the overall delay is of the order of a hundred milliseconds. Low-latency position solutions can be computed more often than matched position solutions; the update rate can reach 10 solutions per second. The low-latency positions will be provided for data gaps between matched positions of up to 30 seconds (for a carrier-phase solution) or 60 seconds (for a pseudorange solution, unless adjusted using the DGPSTIMEOUT command). A general guideline for the additional error incurred due to the extrapolation process is shown in *Table 11*.

Table 11: Latency-Induced Extrapolation Error

Time since last base station observation	Typical extrapolation error (CEP) rate
0-2 seconds	1 cm/sec
2-7 seconds	2 cm/sec
7-30 seconds	5 cm/sec

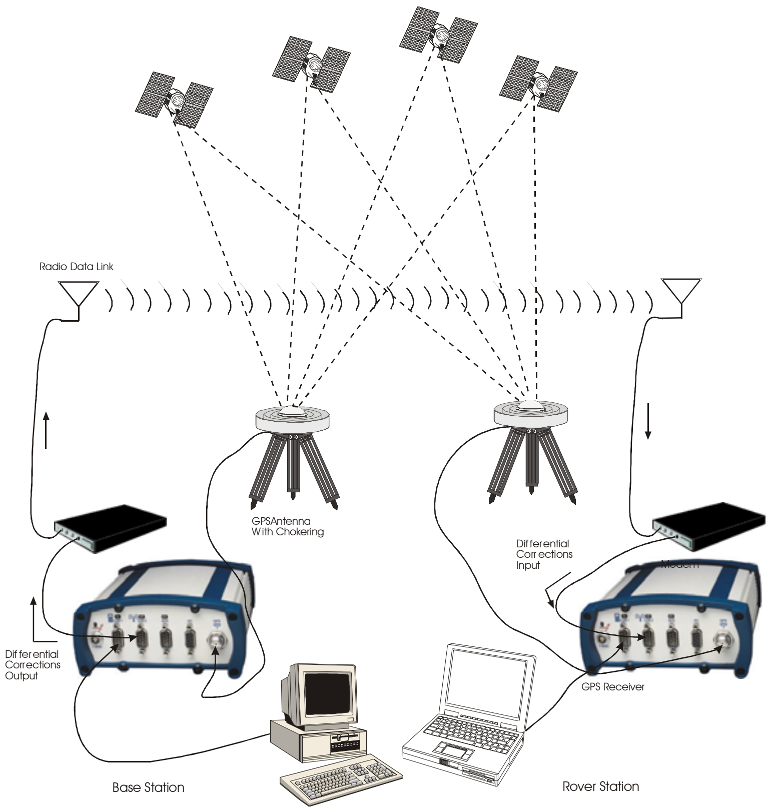
6.3.3 Dual Station Differential Positioning

It is the objective of operating in differential mode to either eliminate or greatly reduce most of the errors introduced by the system biases discussed in *GPS System Errors on Page 67*. Pseudorange differential positioning is quite effective in removing most of the biases caused by satellite clock error, ionospheric and tropospheric delays (for baselines less than 50 km), and ephemeris prediction errors. However, the biases caused by multipath reception and receiver clock offset are uncorrelated between receivers and thus cannot be cancelled by "between receiver single differencing" operation.

Differential operation requires that stations operate in pairs. Each pair consists of a base station and a rover station. A differential network could also be established when there is more than one rover station linked to a single base station.

In order for the differential pair to be effective, differential positioning requires that both base and rover station receivers track and collect satellite data simultaneously from common satellites. When the two stations are in relatively close proximity (< 50 km), the pseudorange bias errors are considered to be nearly the same and can be effectively cancelled by the differential corrections. However, if the baseline becomes excessively long, the bias errors begin to decorrelate, thus reducing the accuracy or effectiveness of the differential corrections.

Figure 20: Typical Differential Configuration



6.3.3.1 The Base Station

The nucleus of the differential network is the base station. To function as a base station, the GPS receiver antenna must be positioned at a control point whose position is precisely known in the GPS reference frame. Typically, the fixed position will be that of a geodetic marker or a pre-surveyed point of known accuracy.

The base receiver must then be initialized to fix its position to agree with the latitude, longitude, and height of the phase centre of the base station GPS receiver antenna. Of course, the antenna offset position from the marker must be accurately accounted for.

Because the base station's position is fixed at a known location, it can now *compute* the range of its known position to the satellite. The base station now has two range measurements with which to work: *computed pseudoranges* based on its known position relative to the satellite, and *measured pseudoranges* which assumes the receiver position is unknown. Now, the base station's measured pseudorange (unknown position) is differenced against the computed range (based on known position) to derive the differential correction which represents the difference between known and unknown solutions for the same antenna. This difference between the two ranges represents the combined pseudorange measurement errors resulting from receiver clock errors, atmospheric delays, satellite clock error, and orbital errors.

The base station will derive pseudorange corrections for each satellite being tracked. These corrections can now be transmitted over a data link to one or more rover stations. It is important to ensure that the base station's FIX POSITION setting be as accurate as possible, as any errors here will directly bias the pseudorange corrections computed, and can cause unpredictable results depending on the application and the size of the base station position errors. As well, the base station's pseudorange measurements may be biased by multipath reception.

6.3.3.2 The Rover Station

A rover station is generally any receiver whose position is of unknown accuracy, but has ties to a base station through an established data link. If the rover station is not receiving differential corrections from the base station, it is essentially utilizing single-point positioning measurements for its position solutions, thus is subject to the various GPS system biases. However, when the rover GPS receiver is receiving a pseudorange correction from the base station, this correction is applied to the local receiver's measured pseudorange, effectively cancelling the effects of orbital and atmospheric errors (assuming baselines < 50 km), as well as eliminating satellite clock error.

The rover station must be tracking the same satellites as the base station in order for the corrections to take effect. Thus, only common satellite pseudoranges will utilize the differential corrections. When the rover is able to compute its positions based on pseudorange corrections from the base station, its position accuracies will approach that of the base station. Remember, the computed position solutions are always that of the GPS receiving antenna phase centre.

6.4 OmniSTAR Positioning

The OmniSTAR system is designed with the following features:

- Worldwide coverage
- Sub-meter to decimeter accuracy over the entire coverage area
- Portable system.

The transmission of corrections are from geostationary satellites. The L-band frequency of OmniSTAR Geostationary Satellites is sufficiently close to that of GPS that a common, single antenna, like the NovAtel GPS-600-LB, may be used.

6.4.1 Coverage

In most world areas, a single satellite is used by OmniSTAR to provide coverage over an entire Continent - or at least very large geographic areas. In North America, a single Satellite is used, but it needs three separate beams to cover the Continent. The three beams are arranged to cover the East, Central, and Western portions of North America. The same data is broadcast over all three beams, but the user system must select the proper beam frequency. The beams have overlaps of several hundred miles, so the point where the frequency must be changed is not critical.

All of the eastern Canadian Provinces, the Caribbean Islands, Central America (south of Mexico), and South America is covered by a single Satellite (AM-Sat). A single subscription is available for all the areas covered by this Satellite.

OmniSTAR currently has several high-powered satellites in use around the World. They provide coverage for most of the World's land areas. Subscriptions are sold by geographic area. Any Regional OmniSTAR Service Center can sell and activate subscriptions for any area. They may be arranged prior to traveling to a new area, or after arrival. Contact OmniSTAR at www.omnistar.com for further details.

6.4.2 Virtual Base Station (VBS)

Two levels of service are available, Virtual Base Station (VBS) and High Performance (HP). The VBS service provides sub-meter accuracy.

OmniSTAR VBS service uses multiple GPS base stations in a solution and reduces errors due to the GPS signals traveling through the atmosphere. It uses a wide area DGPS solution (WADGPS) and data from a relatively small number of base stations to provide consistent accuracy over large areas. A unique method of solving for atmospheric delays and weighting of distant base stations achieves sub-meter capability over the entire coverage area - regardless of your location relative to any base station. This achieves a truly wide-area system with consistent characteristics.

NovAtel's ProPak-LB provides GPS with OmniSTAR L-band corrections in one unit, using a common antenna. This means that, with a subscription to OmniSTAR service, the ProPak-LB is a high quality receiver with sub-meter capabilities.

The North American OmniSTAR Network currently consists of ten permanent base stations in the Continental U.S., plus one in Mexico. These eleven stations track all GPS Satellites above 5 degrees elevation and compute corrections every 600 milliseconds. The corrections are sent to the OmniSTAR Network Control Center (NCC) in Houston via wire networks. At the NCC these messages are checked, compressed, and formed into packets for transmission up to the OmniSTAR satellite transponder. This occurs approximately every few seconds. A packet will contain the latest corrections from each of the North American base stations.

The position from the GPSCard in the receiver is used as the OmniSTAR's first approximation.

After the OmniSTAR processor has taken care of the atmospheric corrections, it then uses its location versus the eleven base station locations, in an inverse distance-weighted least-squares solution. OmniSTAR's Virtual Base Station (VBS) technology generates corrections optimized for the location. It is this technique that enables the OmniSTAR receiver to operate independently and consistently over the entire coverage area without regard to where it is in relation to the base stations.

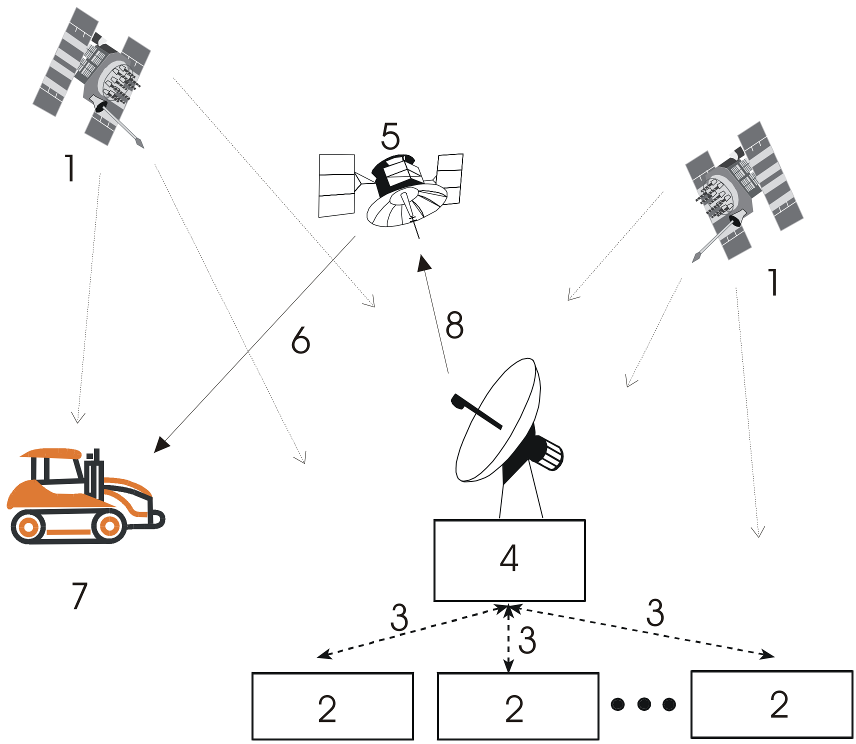


Figure 21: OmniSTAR Concept

Reference	Description
1	GPS satellites
2	Multiple OmniSTAR GPS monitor sites
3	Send GPS corrections via lease line to 4
4	Network Control Center where data corrections are checked and repackaged for uplink to 5
5	L- Band Geostationary Satellite
6	OmniSTAR L-band DGPS signal
7	Correction data are received and applied real-time

8 DGPS uplink

6.4.3 High Performance (HP)

The OmniSTAR High Performance (HP) service gives you more accuracy than the OmniSTAR VBS service. OmniSTAR HP computes corrections in dual-frequency RTK float mode (within about 10 cm accuracy). To obtain OmniSTAR High Performance (HP) corrections, your receiver must have an HP subscription from OmniSTAR.

6.4.4 OmniSTAR Commands and Logs

The ASSIGNOMNI command allows you to set OmniSTAR base station communication parameters.

The PSRDIFFSOURCE command sets the station ID value which identifies the base station from which to accept RTCA1, RTCM1 or OmniSTAR Virtual Base Station (VBS) differential corrections. In the PSRDIFFSOURCE command, OMNISTAR enables OmniSTAR VBS and disables other DGPS types. OmniSTAR VBS produces RTCM-type corrections. AUTO means the first received RTCM or RTCA message has preference over an OmniSTAR VBS message.

The RTKSOURCE command sets the station ID value which identifies the base station from which to accept RTK (RTCM, RTCA, CMR and OmniSTAR High Performance (HP)), differential corrections. In the RTKSOURCE command, OMNISTAR enables OmniSTAR High Performance (HP), if allowed, and disables other RTK types. OmniSTAR HP computes corrections in RTK float mode or within about 10 cm accuracy. For RTK models, AUTO means the NovAtel RTK filter is enabled and the first received RTCM, RTCA or CMR message is selected. For non-RTK models, AUTO means the OmniSTAR HP, if allowed, message is enabled.

The PSRDIFFSOURCE and RTKSOURCE commands are useful when the receiver is receiving corrections from multiple base stations.

Several OmniSTAR specific logs also exist and are all prefixed by the letters OMNI except for the RAWOMNIFRAME and RAWOMNIPACKET logs.

✉ In addition to a ProPak-LB, a subscription to the OmniSTAR service is required. Contact NovAtel for details. Contact information may be found on the back of this manual or you can refer to *Customer Service* on *Page 13*.

Consult *Volume 2* of this manual for more details on individual OmniSTAR commands and logs.

6.5 Carrier-Phase Differential

Carrier-phase algorithms monitor the actual carrier wave itself. These algorithms are the ones used in real-time kinematic (RTK) positioning solutions - differential systems in which the rover station, possibly in motion, requires base-station observation data in real-time. Compared to pseudorange algorithms, much more accurate position solutions can be achieved: carrier-based algorithms can achieve accuracies of 1-2 cm (CEP).

Kinematic GPS using carrier-phase observations is usually applied to areas where the relation between physical elements and data collected in a moving vehicle is desired. For example, carrier-phase kinematic GPS missions have been performed in aircraft to provide coordinates for aerial photography, and in road vehicles to tag and have coordinates for highway features. This method can achieve similar accuracy to that of static carrier-phase, if the ambiguities can be fixed. However, satellite tracking is much more difficult, and loss of lock makes reliable ambiguity solutions difficult to maintain.

A carrier-phase measurement is also referred to as an *accumulated delta range* (ADR). At the L1 frequency, the wavelength is 19 cm; at L2, it is 24 cm. The instantaneous distance between a GPS satellite and a receiver can be thought of in terms of a number of wavelengths through which the signal has propagated. In general, this number has a fractional component and an integer component (such as 124 567 967.330 cycles), and can be viewed as a pseudorange measurement (in cycles) with an initially unknown constant integer offset. Tracking loops can compute the fractional component and the change in the integer component with relative ease; however, the determination of the initial integer portion is less straight-forward and, in fact, is termed the *ambiguity.*

In contrast to pseudorange algorithms where only corrections are broadcast by the base station, carrier-phase algorithms typically “double difference” the actual observations of the base and rover station receivers. Double-differenced observations are those formed by subtracting measurements between identical satellite pairs on two receivers:

$$ADR_{\text{double difference}} = (ADR_{\text{rx A,sat i}} - ADR_{\text{rx A,sat j}}) - (ADR_{\text{rx B,sat i}} - ADR_{\text{rx B,sat j}})$$

An ambiguity value is estimated for each double-difference observation. One satellite is common to every satellite pair; it is called the *reference* satellite, and it is generally the one with the highest elevation. In this way, if there are *n* satellites in view by both receivers, then there will be *n-1* satellite pairs. The difference between receivers A and B removes the correlated noise effects, and the difference between the different satellites removes each receiver’s clock bias from the solution.

In the RTK system, a *floating* (or *“continuous-valued”*) *ambiguity solution* is continuously generated from a Kalman filter. When possible, *fixed-integer ambiguity solutions* are also computed because they are more accurate, and produce more robust standard-deviation estimates. Each possible discrete ambiguity value for an observation defines one *lane*; that is, each lane corresponds to a possible pseudorange value. There are a large number of possible lane combinations, and a receiver has to analyze each possibility in order to select the correct one. For single-frequency receivers, there is no alternative to this brute-force approach. However, one advantage of being able to make both L1 and L2 measurements is that linear combinations of the measurements made at both frequencies lead to additional values with either “wider” or “narrower” lanes. Fewer and wider lanes make it easier for the software to choose the correct lane, having used the floating solution for initialization. Once the correct *wide lane* has been selected, the software searches for the correct *narrow* lane. Thus, the searching process can more rapidly and accurately home in on the correct lane when dual-frequency measurements are available. Changes in the geometry of the satellites aids in ambiguity resolution; this is especially noticeable in L1-only solutions. In summary, NovAtel’s RTK system permits L1/L2 receivers to choose integer lanes while forcing L1-only receivers to rely exclusively on the floating ambiguity solution.

Once the ambiguities are known, it is possible to solve for the vector from the base station to the rover station. This baseline vector, when added to the position of the base station, yields the position of the rover station.

In the NovAtel RTK system, the floating ambiguity and the integer position solutions (when both are available) are continuously compared for integrity purposes. The better one is chosen and output in the receiver's matched-position logs. The "best" ambiguities determined are used with the rover station's local observations and a base station observation model to generate the rover station's low-latency observations.

6.5.1 Real-Time Kinematic (RTK)

RT-2 and RT-20 are real-time kinematic software products developed by NovAtel. They can only be used in conjunction with NovAtel GPS receivers. A quick comparison of RT-2 and RT-20 is shown in the following table:

Table 12: Comparison of RT-2 and RT-20

	RT-2	RT-20
GPS Frequencies Utilized	L1 & L2	L1
Nominal Accuracy	2 cm (CEP)	20 cm (CEP)
Lane Searching	Wide lane and narrow lane	None

NovAtel's RTK software algorithms utilize both carrier and code phase measurements; thus, the solutions are robust, reliable, accurate and rapid. While both RT-20 and RT-2 operate along similar principles, RT-2 achieves its extra accuracy and precision due to its being able to utilize dual-frequency measurements. Dual-frequency GPS receivers have two main advantages over their single-frequency counterparts when running RTK software:

1. resolution of cycle ambiguity is possible due to the use of wide lane searching
2. longer baselines are possible due to the removal of ionospheric errors

Depending on the transmitting/receiving receivers and the message content, various levels of accuracy can be obtained. Please refer to the particular accuracy as shown in the following table:

Table 13: Summary of RTK Messages and Expected Accuracy

Message Formats	Transmitting (Base)	Receiving (Rover)	Accuracy Expected
L1 and L2 RTK: RTCAOBS with RTCAREF RTCM Types 18 and 19 with Types 3 and 22 CMROBS with CMRREF	L1 and L2	RT-2	2 cm CEP (RT-2)
		RT-20	20 cm CEP (RT-20)
	L1 only	RT-2 or RT-20	20 cm CEP (RT-20)
L1 RTK: RTCM Type 59 with Type 3	L1 and L2 or L1 only	RT-2 or RT-20	20 cm CEP (RT-20)
L1 Pseudorange Corrections: RTCM Type 1 RTCA Type 1	L1 and L2 or L1 only	Any differential enabled OEM4	1 m SEP (DGPS)

The RTK system in the receiver provides two kinds of position solutions. The Matched RTK position is computed with buffered observations, so there is no error due to the extrapolation of base station measurements. This provides the highest accuracy solution possible at the expense of some latency which is affected primarily by the speed of the differential data link. The MATCHEDPOS log contains the matched RTK solution and can be generated for each processed set of base station observations. The RTKDATA log provides additional information about the matched RTK solution.

The Low-Latency RTK position and velocity is computed from the latest local observations and extrapolated base station observations. This supplies a valid RTK position with the lowest latency possible at the expense of some accuracy. The degradation in accuracy is reflected in the standard deviation and is summarized in *Section 6.3.2, Position Solutions on Page 71*. The amount of time that the base station observations are extrapolated is provided in the "differential lag" field of the position log. The Low-Latency RTK system will extrapolate for 30 seconds. The RTKPOS log contains the

Low-Latency RTK position when valid, and an "invalid" status when a low-latency RTK solution could not be computed. The BESTPOS log contains the low-latency RTK position when it is valid, and superior to the pseudorange-based position. Otherwise, it will contain the pseudorange-based position. Similarly, RTKVEL and BESTVEL will contain the low-latency RTK velocity.

RT-20 solutions will always use floating L1 ambiguities. When valid L2 measurements are available, RT-2 solutions will have other solution types that depend on convergence time, baseline length, satellite length, satellite geometry and the level of ionospheric activity detected. The Low-Latency RT-2 algorithms further reduce latency by not using the narrow-lane ambiguities. This does not significantly degrade performance because the error induced by extrapolation dominates.

6.5.1.1 RT-2 Performance

The RT-2 software provides the accuracies shown in *Table 14, RT-2 Performance: Static Mode on Page 81*, *Figure 23, Typical RT-2 Horizontal Convergence - Static Mode on Page 82*, *Table 15, RT-2 Performance: Kinematic Mode on Page 81* and *Figure 24, Typical RT-2 Horizontal Convergence - Kinematic Mode on Page 82* for typical multipath, ionospheric, tropospheric, and ephemeris errors, where typical is described as follows:

- A typical multipath environment would provide no carrier-phase double-difference multipath errors greater than 2 cm or pseudorange double-difference multipath errors greater than 2 m on satellites at 11° elevation or greater. For environments where there is greater multipath, please consult NovAtel Customer Service.
- Typical unmodeled ionospheric, tropospheric and ephemeris errors must be within 2σ of their average values, at a given elevation angle and baseline length. It is assumed that the tropospheric correction is computed with standard atmospheric parameters. All performance specifications assume that at least 6 satellites above the mask angle (varies between 11 and 14 degrees) are being tracked on both L1 and L2.

In *Table 14, RT-2 Performance: Static Mode* and *Table 15, RT-2 Performance: Kinematic Mode*, accuracy values refer to horizontal RMS error. The level of position accuracy at any time will be reflected in the standard deviations output with the position.

Table 14: RT-2 Performance: Static Mode

Baseline length	Time since L2 lock-on with at least 6 satellites above mask angle	Horizontal accuracy at the stated time	Runs meeting the stated accuracy at the stated time
< 10 km	70 seconds + 1.5 sec/km	2 cm + 0.5 ppm	75.0%
< 10 km	5 minutes	1 cm + 1 ppm	75.0%
< 15 km	4 minutes	5 cm	66.7%
< 25 km	7 minutes	7 cm	66.7%
< 35 km	10 minutes	35 cm	66.7%
< 35 km	30 minutes	25 cm	66.7%

Table 15: RT-2 Performance: Kinematic Mode

Baseline length	Time since L2 lock-on with at least 6 satellites above mask angle	Horizontal accuracy at the stated time	Runs meeting the stated accuracy at the stated time
< 10 km	120 seconds + 1.5 sec/km	2 cm + 0.5 ppm	75.0%
< 15 km	8 minutes	8 cm	66.7%
< 25 km	14 minutes	10 cm	66.7%
< 35 km	20 minutes	40 cm	66.7%
< 35 km	60 minutes	25 cm	66.7%

RTKPOS or BESTPOS logs contain some error due to predictions from base station observations. The expected error of a RTKPOS or BESTPOS log will be that of the corresponding MATCHEDPOS log plus the appropriate error from *Table 16*.

There are no data delays for a matched log and therefore no need to add an additional error factor.

Table 16: RT-2 Degradation With Respect To Data Delay[1]

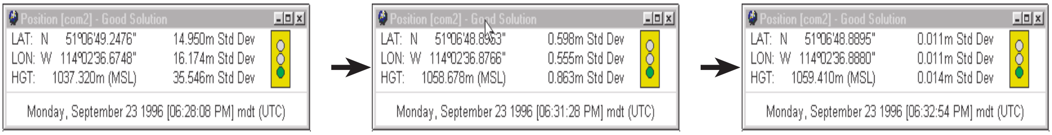
Data Delay (sec)	Distance (km)	Accuracy (CEP)
0 - 2	1	+1 cm/sec
2 - 7	1	+2 cm/sec
7 - 30	1	+5 cm/sec
>30	1	single point or pseudorange differential positioning [2]

[1] Mode = Static or Kinematic

[2] After 30 seconds reverts to pseudorange positioning (single point or differential depending on messages previously received from the base station).

For baselines under 30 km long, the RT-2 solution shows two pronounced steps in accuracy convergence; these correspond to the single-point solution switching to the floating ambiguity solution which in turn switches to the narrow lane solution. If you were monitoring this using NovAtel's *GPSolution* program, the convergence sequence might look something like what is shown in *Figure 22, RT-2 Accuracy Convergence*.

Figure 22: RT-2 Accuracy Convergence



Single-point solution Floating ambiguity solution Narrow lane solution

Figure 23: Typical RT-2 Horizontal Convergence - Static Mode

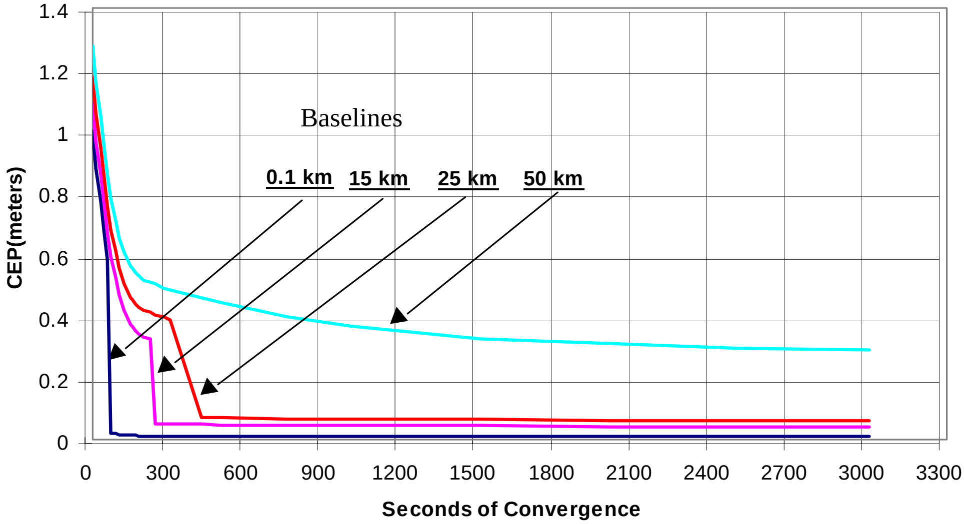
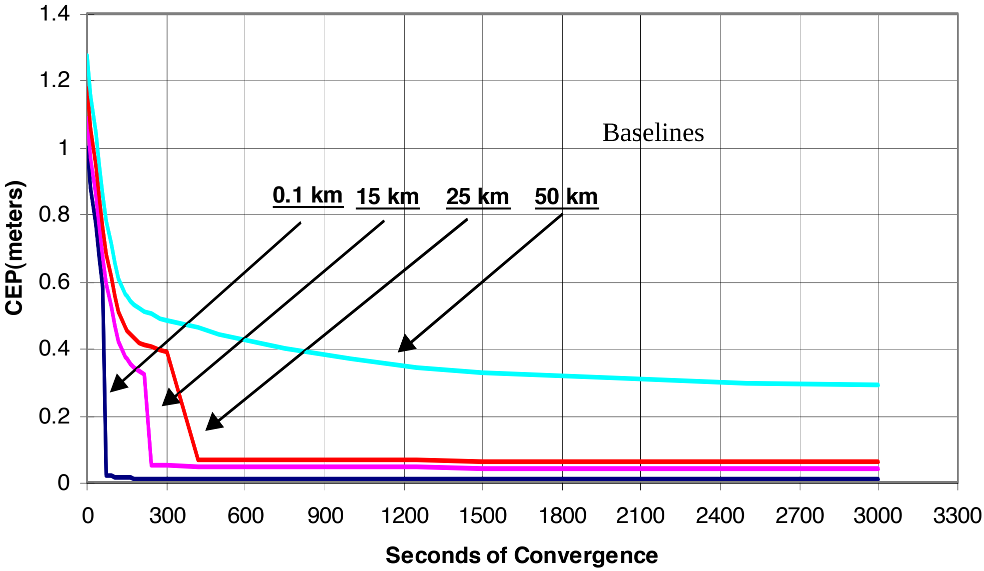


Figure 24: Typical RT-2 Horizontal Convergence - Kinematic Mode



6.5.1.2 RT-20 Performance

As shown in *Table 17, RT-20 Performance on Page 83*, *Figure 25, Typical RT-20 Convergence - Static Mode on Page 84* and *Figure 26, Typical RT-20 Convergence - Kinematic Mode on Page 84* the RT-20 system provides nominal 20 cm accuracy (CEP) after 3 minutes of continuous lock in static mode. After an additional period of continuous tracking (from 10 to 20 minutes), the system typically reaches steady state and position accuracies in the order of 3 to 4 cm. The time to steady state is about 3 times longer in kinematic mode.

RT-20 double-difference accuracies are based on PDOP < 2 and continuous tracking of at least 5 satellites (6 preferred) at elevations of at least 11.5°.

All accuracy values refer to horizontal RMS error, and are based on low-latency positions. The level of position accuracy at any time will be reflected in the standard deviations output with the position.

Table 17: RT-20 Performance

Tracking Time (sec)	Mode [1]	Data Delay (sec)	Distance (km)	Accuracy (CEP)
1 - 180	Static	0	1	100 to 25 cm
180 - 3000	Static	0	1	25 to 5 cm
> 3000	Static	0	1	5 cm or less [2]
1 - 600	Kinematic	0	1	100 to 25 cm
600 - 3000	Kinematic	0	1	25 to 5 cm
> 3000	Kinematic	0	1	5 cm or less [2]
	Either	0 - 2	1	+1 cm/sec
	Either	2 - 7	1	+2 cm/sec
	Either	7 - 30	1	+5 cm/sec
	Either	> 30	1	pseudorange or single point [3]
	Either	0	0 - 10	+0.5 cm/km
	Either	0	10 - 20	+0.75 cm/km
	Either	0	20 - 50	+1.0 cm/km

1 Mode = Static or Kinematic (during initial ambiguity resolution)
2 The accuracy specifications refer to the BESTPOSA/B logs which include about 3 cm extrapolation error. MATCHEDPOSA/B logs are more accurate but have increased latency associated with them.
3 After 30 seconds reverts to pseudorange positioning (single point or differential depending on messages previously received from the base station).

Figure 25: Typical RT-20 Convergence - Static Mode

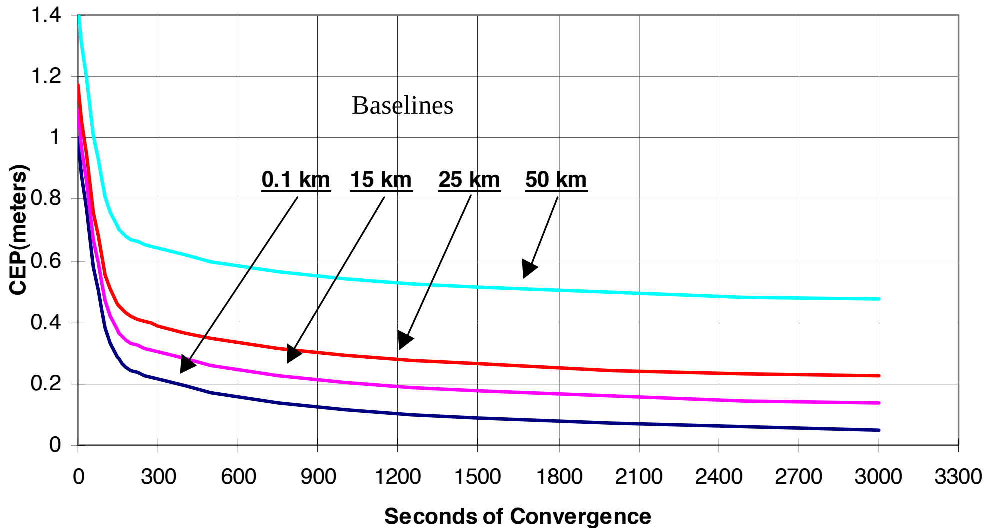
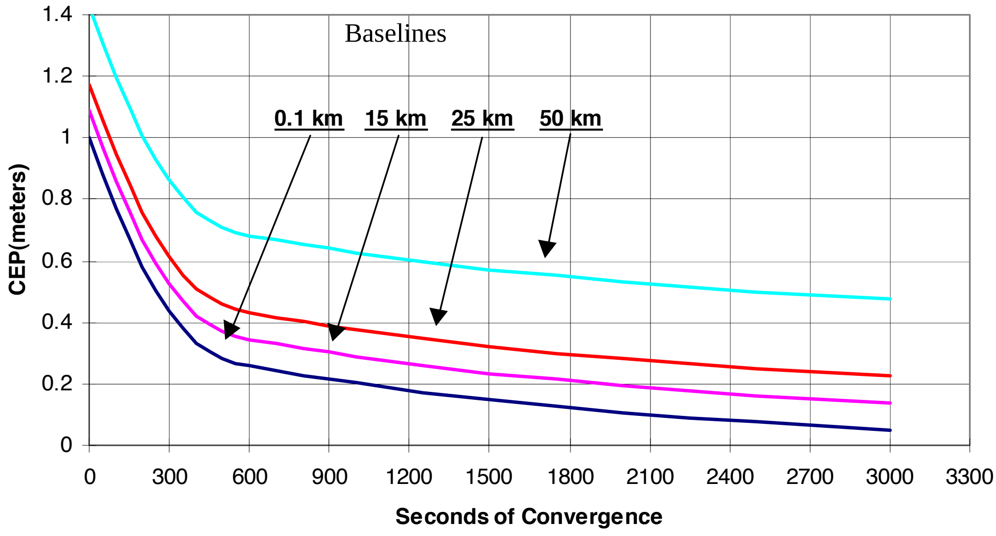


Figure 26: Typical RT-20 Convergence - Kinematic Mode



6.5.1.3 Performance Considerations

When referring to the "performance" of RTK software, two factors are introduced:

1. *Baseline length*: the position estimate becomes less precise as the baseline length increases. Note that the baseline length is the distance between the *phase centres* of the two antennas. Identifying the exact position of your antenna's phase centre is essential; this information is typically supplied by the antenna's manufacturer or vendor.

The RTK software automatically makes the transition between short and longer baselines, but the best results are obtained for baselines less than 10 km. The following are factors which are related to baseline length:

- ephemeris errors - these produce typical position errors of 0.75 cm per 10 km of baseline length.
- ionospheric effects - the dominant error for single-frequency GPS receivers on baselines exceeding 10 km. Differential ionospheric effects reach their peak at dusk and dawn, being at a minimum during hours of darkness. Ionospheric effects can be estimated and removed on dual-frequency GPS receivers, greatly increasing the permissible baseline length, but at the cost of introducing additional "noise" to the solution. Therefore, this type of compensation is only used in cases where the ionospheric error is much larger than the noise and multipath error.
- tropospheric effects - these produce typical position errors of approximately 1 cm per 10 km of baseline length. This error increases if there is a significant height difference between the base and rover stations, as well as if there are significantly different weather conditions between the two sites.

A related issue is that of multipath interference, the dominant error on short differential baselines. Generally, multipath can be reduced by choosing the antenna's location with care, and by the use of the GPS-702 antenna (no need for a choke ring) or a L1/L2 antenna and a choke ring antenna ground plane, see *Appendix D, Multipath on Page 154*.

2. *Convergence time*: the position estimate becomes more accurate and more precise with time. However, convergence time is dependent upon baseline length: while good results are available after a minute or so for short baselines, the time required increases with baseline length. Convergence time is also affected by the number of satellites which can be used in the solution: the more satellites, the faster the convergence.

6.5.1.4 Performance Degradation

The performance will degrade if satellites are lost at the rover or if breaks occur in the differential correction transmission link. The degradations related to these situations are described in the following paragraphs.

Provided lock is maintained on at least 4 SVs and steady state has been achieved, the only degradation will be the result of a decrease in the geometrical strength of the observed satellite constellation. If steady state has not been achieved, then the length of time to ambiguity resolution under only 4-satellite coverage will be increased significantly.

ROVER TRACKING LOSS

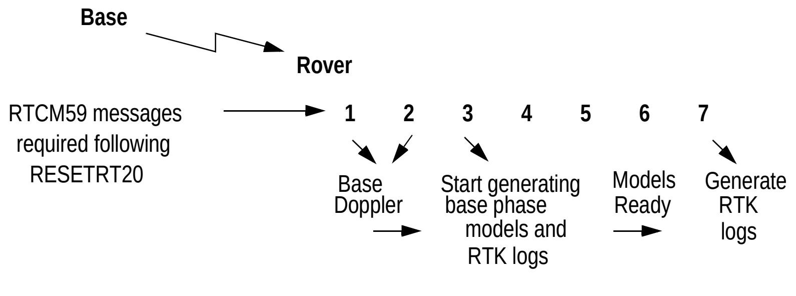
If less than 4 satellites are maintained, then the RTK filter can not produce a position. When this occurs, the BESTPOS and PSRPOS logs will be generated with differential (if RTCM Type 1 messages are transmitted with the Type 59 messages) or single point pseudorange solutions if possible. When the satellites are reacquired, the RTK initialization process described below occurs (see *Figure 27, RT-20 Re-Initialization Process on Page 86*).

DIFFERENTIAL LINK BREAKDOWN

1. Provided the system is in steady state, and the loss of observation data is for less than 30 seconds, the RTK positions will degrade according to the divergence of the base observation extrapolation filters. This causes a decrease in accuracy of about an order of magnitude per 10 seconds without a base station observation, and this degradation is reflected in the standard deviations of the low latency logs. Once the data link has been re-established, the accuracy will return to normal after several samples have been received.

2. If the loss of differential corrections lasts longer than 30 seconds, the RTK filter is reset and all ambiguity and base model information is lost. The timeout threshold for RTK differential corrections is 30 seconds, but for Type 1 pseudorange corrections, the timeout is 60 seconds. Therefore, when the RT-20 can no longer function because of this timeout, the pseudorange filter can produce differential positions for an additional 30 seconds (provided RTCM Type 1 messages were transmitted along with the Type 59 messages) before the system reverts to single point positioning. Furthermore, once the link is re-established, the pseudorange filter produces an immediate differential position while the RTK filter takes an additional 14 seconds to generate its positions. The base models require 7 base observations before they are declared usable, and this will take 14 seconds, based on a 1/2 Hz differential correction rate. The base model must be healthy before solutions are logged to the low latency logs, so there is a delay in the use of real time carrier positioning to the user once the link has been re-established. The RTK logs (MATCHEDPOSA/B) use matched observations only (no extrapolated observations), and these will be available after three base observations are received, but will have about 1.5 seconds latency associated with them.

Figure 27: RT-20 Re-Initialization Process



The RTK system is based on a time-matched double difference observation filter. This means that observations at the rover site have to be buffered while the base station observation is encoded, transmitted, and decoded. Only two seconds of rover observations are saved, so the base station observation transmission process has to take less than 2 seconds if any time matches are to be made. In addition, only rover observations on even second boundaries are retained, so base station observations must also be sent on even seconds if time matches are to be made.

Chapter 7 PC Software and Firmware

Visit the Firmware and Software Updates section of the NovAtel website, www.novatel.com, for the most recent versions of the PC software and receiver firmware.

7.1 GPSolution/Convert Installation

The CD accompanying this manual contains the Windows applications GPSolution and Convert. They are both installed via a standard Install Shield set-up application. Also included on the CD is sample source code, to aid development of software for interfacing with the receiver, and product documentation.

Both applications utilize a database in their operations so the necessary components of the Borland Database Engine (BDE) are installed as well as the necessary database tables and an alias for the database. The install set-up application does all this automatically so the user has only to select where they would like the applications installed on their PC. It is strongly recommended that you close all applications before installing GPSolution and Convert. You must close any applications that may be using the BDE before installing. The install set-up modifies the BDE configuration so that it can recognize the new GPSolution and Convert database.

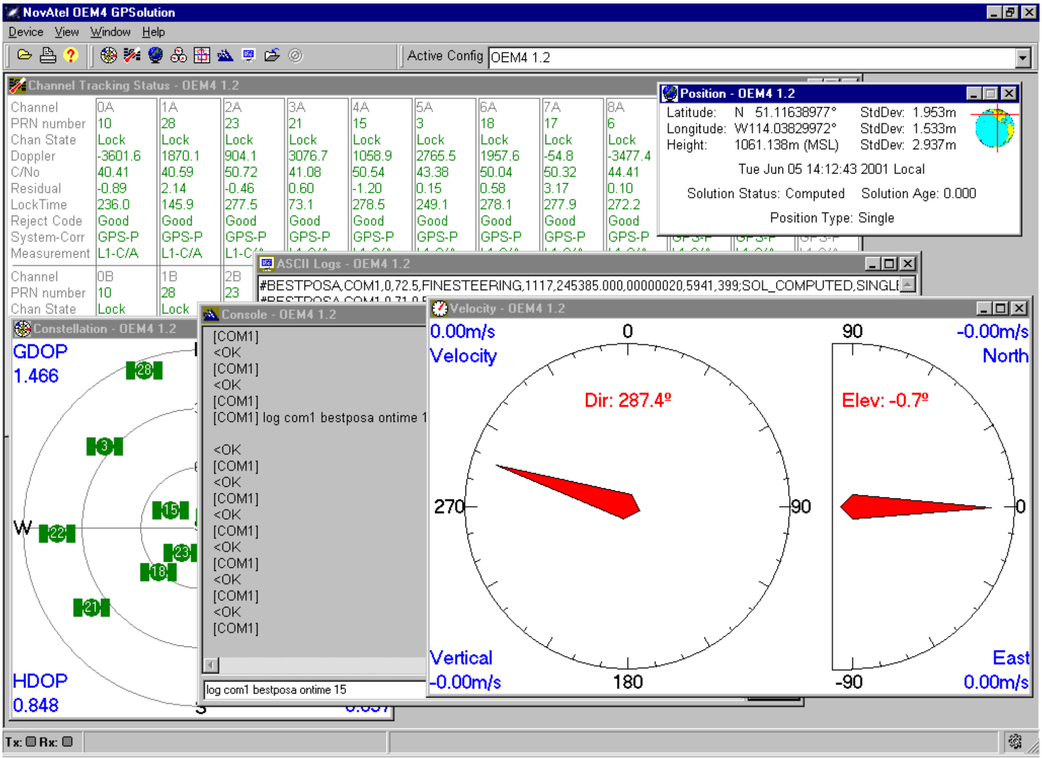
The software operates from your PC's hard drive. You will need to install the software from the CD supplied by NovAtel:

1. Start Microsoft Windows.
2. Place the NovAtel CD in your CD-ROM drive. If the setup utility is not automatically accessible, follow these steps:
    a. Select Run from the Start menu.
    b. Select the Browse button.
    c. Locate Setup.exe on the CD drive and select Open.
    d. Select OK to run the setup utility.
3. Advance through the steps provided by the setup utility.

When the installation is complete, click on a program icon to launch the application.

7.2 GPSolution

GPSolution is a 32-bit Windows application. The application provides a graphical user interface to allow users to set-up and monitor the operation of the NovAtel receiver by providing a series of windows whose functionality is explained in this section. A help file is included with GPSolution. To access the file, select Contents from the Help menu.



Most windows have a popup menu accessible by right clicking on the window with the mouse. They provide the user a way to customize the window by changing the font or to print the window contents. Some of the windows have access to the Options dialog box which contains further settings for certain windows.

- **Constellation Window:** The Constellation window displays the location of the satellites that are being tracked. The PRN numbers are displayed in the center of each satellite symbol.

  Double clicking on the satellite symbol will cause a popup window to appear displaying the information about that PRN such as azimuth, elevation, residual, Doppler, carrier/noise, locktime, pseudorange, tracking state and reject code.

  The concentric circles on the display represent the horizon at 0 degrees (outer edge of the plot) and the zenith, directly overhead at 90 degrees (center of the plot).

  The DOP values of the position are shown in the four corners of the window.

- **Channel Tracking Status Window:** This window provides the user with the tracking status of the satellites in view. Information, such as channel, PRN, channel state, Doppler, carrier / noise, residual, locktime, reject-code, satellite system and measurement is displayed for all satellites being tracked.

  The popup dialog box for this window provides access to the Options dialog box that allows the user to select which fields are displayed in the Channel Tracking Status window.

- **Position Window:** This window displays the receiver's current Latitude, Longitude and Height along with the standard deviations of each.

  The time and date as received from the receiver are displayed.

  The popup dialog box for this window provides access to the "Options" dialog box that allows the user to select what units are displayed for position, velocity, height, time and distance.

- **Velocity and Heading Window:** This window displays direction of travel in the left dial and climb in the right dial.

  The overall velocity is displayed in the top left hand corner, the vertical component of velocity is displayed in the lower left hand corner, the north and east components of velocity are displayed in the top right and bottom right corners of the window respectively.

  The popup dialog box for this window provides access to the "Options" dialog box that allows the user to select velocity filter settings. The user can enable velocity filtering and use a slider control to select a velocity, below which, the receiver will be considered stationary. This setting is useful for preventing GPS signal effects from making a stationary object appear to move.

- **Plan window:** This window displays real-time graphic plotting of the current position of the GPS antenna as computed by the GPS receiver. The latitude and longitude shown at the top of the window is the position of the receiver antenna when the window was opened or after the reset plan button was pressed. The receiver's position is plotted relative to this initial position.

- **Console Window:** This window allows the user to communicate directly to the receiver through the serial port. It is essentially a terminal emulator with added receiver functionality. Commands can be issued to the receiver via the command editor (at the bottom of the window) and sent by pressing the Enter button or simply pressing <Enter> on the keyboard. The command editor has recall functionality similar to DosKey whereby pressing the up arrow on the keyboard will move backward through the previously issued commands and pressing the down arrow will move forward through the previously issued commands. This allows the user to scroll through previously issued commands and then press the <Enter> key to issue that command again.

  Feedback from the receiver will be displayed in the terminal window.

WARNING: **The SAVECONFIG command should be used with caution when communicating with the receiver through GPSolution.**

If you find that GPSolution is unable to locate your OEM4 family receiver, it may be that you have previously used the SAVECONFIG command. In this case, try using a different COM port to communicate to the receiver. Once communication has been established, issue a FRESET STANDARD command. You should now be able to use your original communication port again.

- **ASCII Messages Window**: This window displays ASCII formatted NovAtel logs.

7.3 Convert

Convert is a 32-bit Windows application and is shown in *Figure 28*. Convert will accept GPS file formats and convert them to ASCII, Binary or Rinex format. The application also allows the user to screen out particular logs by selecting the desired logs from the list of available logs. This feature is useful for screening particular logs out of large data files in either ASCII or Binary formats.

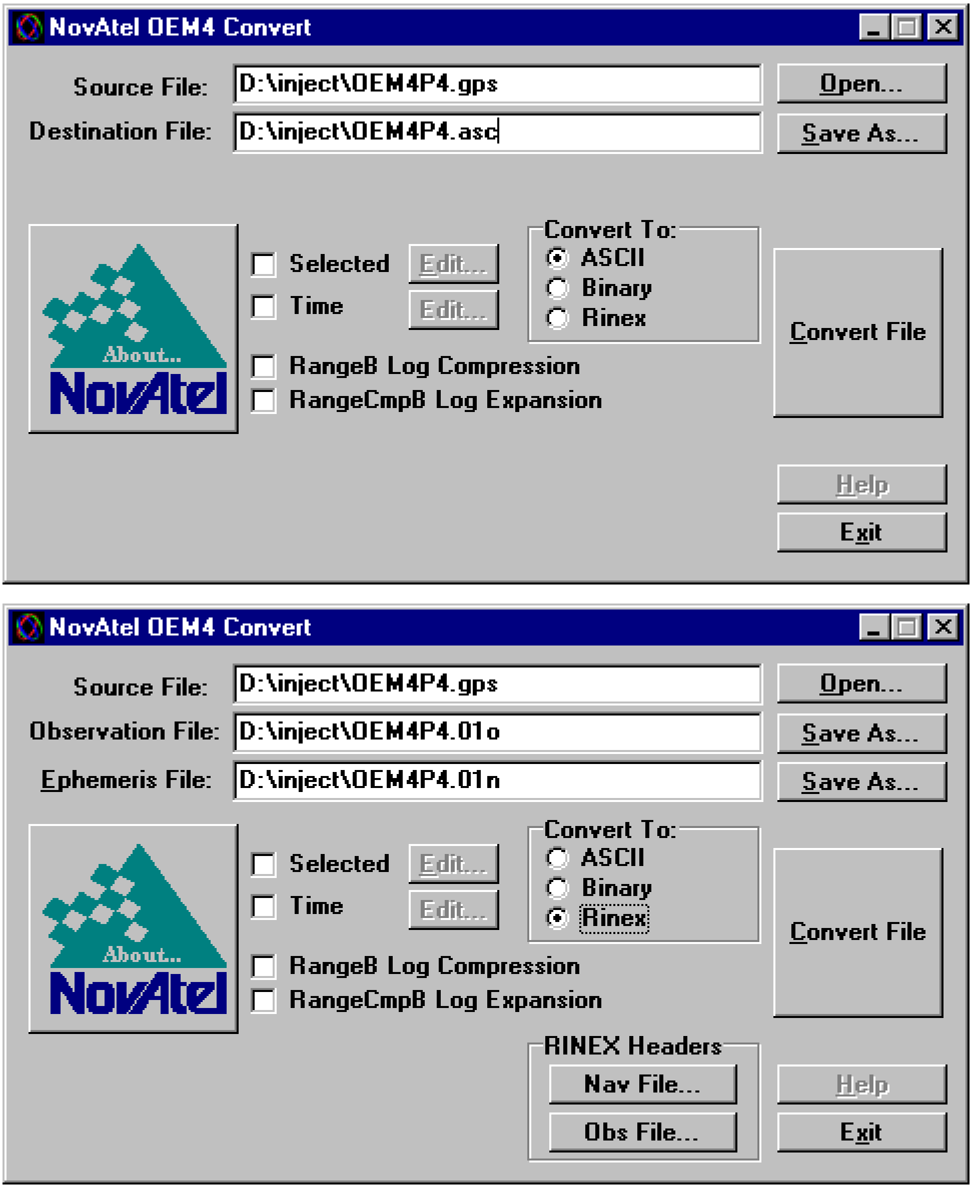


Figure 28: Convert Screen Examples

7.3.1 Rinex Format

The Receiver-Independent Exchange (RINEX) format is a broadly-accepted, receiver-independent format for storing GPS data. It features a non-proprietary ASCII file format that can be used to combine or process data generated by receivers made by different manufacturers. RINEX was originally developed at the Astronomical Institute of the University of Berne. There are three different RINEX file types. Each of the file types consists of a header section and a data section, and includes the following information[1]:

- observation files (carrier-phase measurements; pseudorange / code measurements; times of observations)
- broadcast navigation message files (orbit data for the satellites tracked; satellite clock parameters; satellite health condition; expected accuracy of pseudorange measurements; parameters of single-frequency ionospheric delay model; correction terms relating GPS time to UTC)
- meteorological data files (barometric pressure; dry air temperature; relative humidity; zenith wet tropospheric path delay; time tags)

✉ Although RINEX is intended to be a receiver-independent format, there are many optional records and fields. Please keep this in mind when combining NovAtel and non-NovAtel RINEX data.

The Convert4 utility can be used to produce RINEX files from NovAtel receiver data files.

Selecting the Rinex field, see *Figure 28 on Page 91*, in the Convert To group box causes:

1. The Destination File: field to be replaced by Observation File: and Ephemeris File: fields. Note that "Observation File" refers to the RINEX OBS file, and "Ephemeris File" refers to the RINEX NAV file.

2. The RINEX Headers group box to appear near the bottom of the dialog. This allows you to supply additional information that will appear in the header records of the RINEX output files (e.g. Company Name, Marker Name, Marker Number).

For best results, the NovAtel receiver input data file should contain the logs as in *Table 18*.

Table 18: NovAtel Logs for Rinex Conversion

NovAtel OEM4 Family Log	Recommended Trigger
RANGEA/B, or RANGECMPA/B	ontime 15
BESTPOSA/B	once
IONUTCA/B	onchanged
RAWEPHEMA/B	onchanged
VERSION	once

---

1. For further information on RINEX Version 2 file descriptions, you may wish to consult relevant articles in scientific journal such as: Gurtner, W.G. Mader (1990): “Receiver Independent Exchange Format Version 2.” CSTG GPS Bulletin Vol. 3 No. 3, Sept/Oct 1990, National Geodetic Survey, Rockville.

7.4 Firmware Upgrades & Updates

The receiver stores its program firmware in non-volatile memory, which allows you to perform firmware upgrades and updates without having to return the receiver to the distributor. New firmware can be transferred to the receiver through COM1, and the unit will immediately be ready for operation at a higher level of performance.

The first step in upgrading your receiver is to contact your local NovAtel dealer. Your dealer will assist you in selecting the best upgrade option that suits your specific GPS needs. If your needs are still unresolved after seeing your dealer then you can contact NovAtel directly through any of the methods described in the Customer Service section, *see Page 13*, at the beginning of this manual.

When you call, be sure to have available your receiver model number, serial number, and program revision level. This information can be found by issuing the LOG VERSION command at the port prompt.

After establishing which new model/revision level would best suit your needs, and having described the terms and conditions, you will be issued an authorization code (auth-code). The auth-code is required to unlock the new features according to your authorized upgrade/update model type.

There are two procedures to choose from, depending on the type of upgrade/update you require:

1. If you are upgrading to a higher performance model at the same firmware revision level (e.g. upgrading from an OEM4 - 3151R rev. 1.00, to an OEM4 - RT-2 rev. 1.00), you can use the AUTH command with the issued auth-code.
2. If you are updating to a higher firmware revision level (e.g. updating an OEM4 - RT-2 rev. 1.00 to OEM4 - RT-2 rev. 1.01), you will need to transfer new program firmware to the OEM4 family receiver using the WinLoad utility program. As WinLoad and the update file are generally provided in a compressed file format, you will also be given a decompression password. WinLoad and the update files can be found on NovAtel's FTP site at http:\\www.novatel.ca, or can be sent to you on floppy disk or by e-mail.

Your local NovAtel dealer will provide you with all the information that you require to update or upgrade your receiver.

7.4.1 Upgrading Using the AUTH Command

The AUTH command is a special input command which authorizes the enabling or unlocking of the various model features. Use this command when upgrading to a higher performance OEM4 family model available within the same revision level as your current model (e.g., upgrading from a OEM4 Standard rev. 1.00, to a OEM4 Special rev. 1.00). This command will only function in conjunction with a valid auth-code assigned by GPS Customer Service.

The upgrade can be performed directly from GPSolution's Command Line Screen, or from any other communications program. The procedure is as follows:

1) Power-up the OEM4 family receiver and establish communications over a serial port (see *Chapter 4, Operation on Page 42*)
2) Issue the LOG VERSION command to verify the current firmware model number, revision level, and serial number.
3) Issue the AUTH command, followed by the auth-code and model type. The syntax is as follows:

Syntax:

auth auth-code

where auth is a special command which allows program model upgrades

auth-code is the upgrade authorization code, expressed as hhhh,hhhh,hhhh,hhhh,hhhh,model# where the h characters are an ASCII hexadecimal code, and the model# would be ASCII text

Example:

auth 17cb,29af,3d74,01ec,fd34,oem4rt2

Once the AUTH command has been executed, the OEM4 family receiver will reboot itself. Issuing the LOG VERSION command will confirm the new upgrade model type and version number.

7.4.2 Updating Using the WinLoad Utility

WinLoad is required (instead of the AUTH command) when updating previously released firmware with a newer version of program and model firmware (e.g., updating an OEM4 Standard rev. 1.00 to OEM4 Standard rev. 1.01). WinLoad is a Windows utility program designed to facilitate program and model updates. Once WinLoad is installed and running, it will allow you to select a host PC serial port, bit rate, directory path, and file name of the new program firmware to be transferred to the OEM4 family receiver via its COM1 or COM3 port. The port chosen must have an RS232 interface to the PC.

7.4.2.1 Transferring Firmware Files

To proceed with your program update, you must first acquire the latest firmware revision. You will need a file with a name such as OEMXXXX.EXE (where XXXX is the firmware revision level). This file is available from NovAtel's FTP site (http:\\www.novatel.ca), or via e-mail (support@novatel.ca). If transferring is not possible, the file can be mailed to you on floppy disk. For more information on how to contact NovAtel Customer Service please see *Page 13* at the beginning of this manual.

You will need at least 1 MB of available space on your hard drive. For convenience, you may wish to copy this file to a GPS sub-directory (e.g., C:\GPS\LOADER).

The file is available in a compressed format with password protection; Customer Service will provide you with the required password. After copying the file to your computer, it must be decompressed. The syntax for decompression is as follows:

Syntax:

[filename] [password]

where filename is the name of the compressed file (but not including the .EXE extension)

password is the password required to allow decompression

Example:

oem1001 12345678

A windows-based dialog box is provided for password entry.

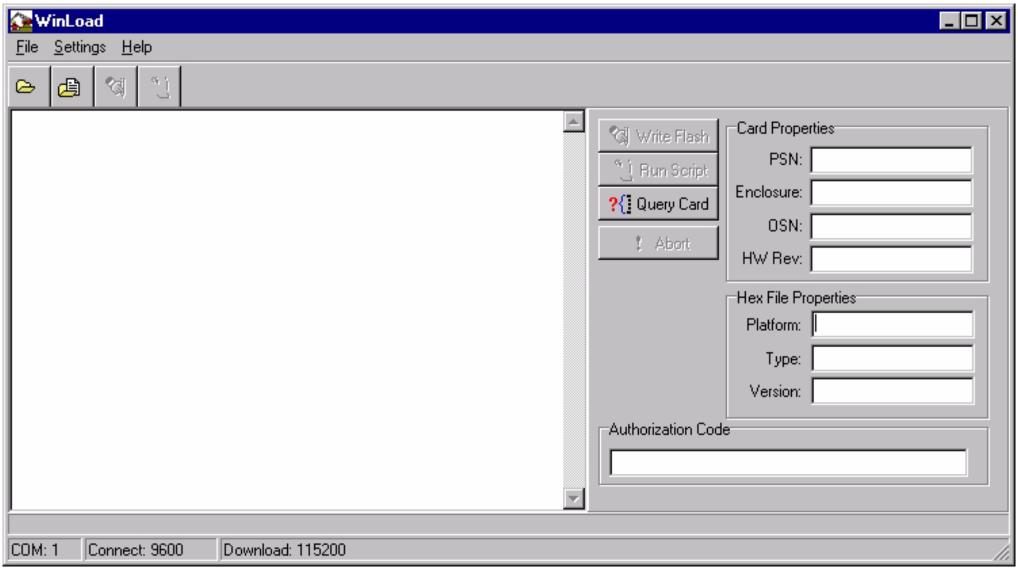
The self-extracting archive will then generate the following files:

WinLoad.exe	WinLoad utility program
HowTo.txt	Instructions on how to use the WinLoad utility
WhatsNew.txt	Information on the changes made in the firmware since the last revision
XXXX.hex	Firmware version update file, where XXXX = program version level (e.g. 1001.hex)

7.4.2.2 Using the WinLoad Utility

WinLoad is a windows based program used to download firmware to OEM4 family GPSCards. The main screen is shown in *Figure 29*.

Figure 29: Main Screen of WinLoad

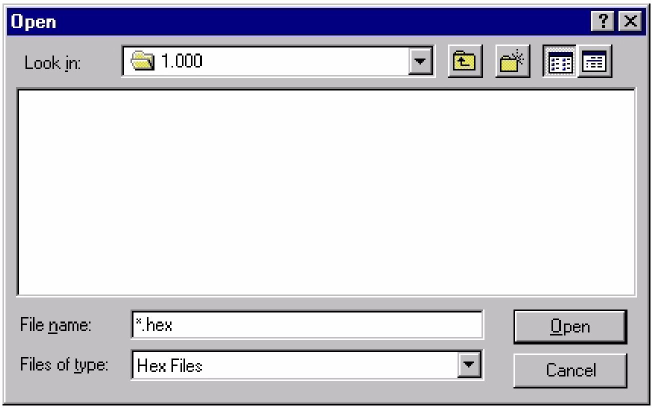


If you are running WinLoad for the first time you will need to make sure the file and communications settings are correct.

7.4.2.2.1 Open a File to Download

From the file menu choose Open. Use the Open dialog to browse for your file, see *Figure 30, WinLoad's Open Dialog on Page 96*.

Figure 30: WinLoadís Open Dialog



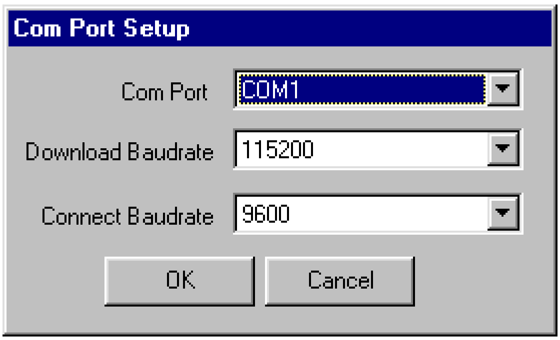
Once you have selected your file, the name should appear in the main display area and in the title bar, see *Figure 31, Open File in WinLoad on Page 97.*

Figure 31: Open File in WinLoad

7.4.2.2.2 Communications Settings

To set the communications port and baud rate, select COM Settings from the Settings menu. Choose the port on your PC from the Com Port dropdown list and the baud rate from the Download Baudrate dropdown list. The baud rate should be as high as possible (the default of 115200 is preferred).

Figure 32: COM Port Setup



7.4.2.2.3 Downloading firmware

To download firmware follow these steps:

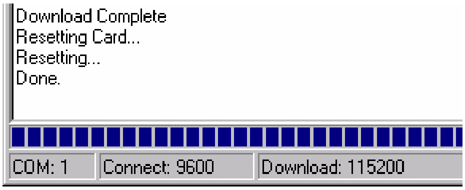
1. Set up the communications port as described in *Communications Settings on Page 97*.
2. Select the file to download, see *Open a File to Download on Page 96.*
3. Make sure the file path and file name are displayed in main display area, see *Figure 31, Open File in WinLoad on Page 97.*
4. Click on the Write Flash button to download the firmware.

5. When the Authorization Code dialog opens, see *Figure 33*, enter the auth code and select OK.

Figure 33: Authorization Code Dialog

6. The receiver should finish downloading and reset. The process is complete when "Done." is displayed in the main display area, see *Figure 34*.

Figure 34: Update Process Complete



7. Close WinLoad.

This completes the procedure required to update an OEM4 family receiver.

Chapter 8 Built-In Status Tests

8.1 Overview

The built in test monitors system performance and status to ensure the receiver is operating within its specifications. If an exceptional condition is detected, the user is informed through one or more indicators. The receiver status system is used to configure and monitor these indicators:

1. Receiver status word
2. Error strobe line
3. RXSTATUSEVENT log
4. RXSTATUS log
5. Status LED

In normal operation the error strobe is driven low and the status LED on the receiver flashes green. When an unusual and non-fatal event occurs (e.g. there is no valid position solution), a bit is set in the receiver status word. Receiver operation continues normally, the error strobe remains off, and the LED continues to flash green. When the event ends (e.g. when there is a valid position solution), the bit in the receiver status word is cleared.

When a fatal event occurs (i.e. in the event of a receiver hardware failure), a bit is set in the receiver error word to indicate the cause of the problem. Bit 0 is set in the receiver status word to show that an error occurred, the error strobe is driven high, and the LED flashes red and yellow showing an error code. An RXSTATUSEVENT log is generated on all ports to show the cause of the error. Receiver tracking is disabled at this point but command and log processing continues to allow you to diagnose the error. Even if the source of the error is corrected at this point, the receiver must be reset to resume normal operation.

The above two paragraphs describe factory default behavior. Customization is possible to better suit an individual application. RXSTATUSEVENT logs can be disabled completely using the UNLOG command. RXSTATUSEVENT logs can be generated when a receiver status bit is set or cleared by using the STATUSCONFIG SET and STATUSCONFIG CLEAR commands. Bits in the receiver status words can also be promoted to be treated just like error bits using the STATUSCONFIG PRIORITY command.

8.2 Receiver Status Word

The receiver status word indicates the current status of the receiver. This word is found in the header of all logs. In addition the receiver status word is configurable.

The receiver gives the user the ability to determine the importance of the status bits. This is done using the priority masks. In the case of the Receiver Status, setting a bit in the priority mask will cause the condition to trigger an error. This will cause the receiver to idle all channels, turn off the antenna, and disable the RF hardware, the same as if a bit in the Receiver Error word is set. Setting a bit in an Auxiliary Status priority mask will cause that condition to set the bit in the Receiver Status word corresponding to that Auxiliary Status.

The STATUS CONFIG command is used to configure the various status mask fields in the

RXSTATUS event log. These masks allow you to modify whether various status fields generate errors or event messages when they are set or cleared. This is meant to allow you to customize the operation of your OEM4 family receiver for your specific needs.

See the RXSTATUS log and the STATUSCONFIG command in *Volume 2* of this manual for more detailed descriptions of these messages.

8.3 Error Strobe Signal

The error strobe line is one of the I/O strobes and is driven low when the receiver is operating normally. When the receiver is in the error state and tracking is disabled, the error strobe is driven high. This can be caused by a fatal error or by an unusual receiver status indication that the user has promoted to be treated like a fatal error. Once on, the error status will remain high until the cause of the error is corrected and the receiver is reset.

8.4 RXSTATUSEVENT Log

The RXSTATUSEVENT log is used to output event messages as indicated in the RXSTATUS log.

On startup, the OEM4 family receiver is set to log the RXSTATUSEVENTA log ONNEW on all ports. You can remove this message by using the UNLOG command.

See the RXSTATUSEVENT log in *Volume 2* of this manual for a more detailed description of this log.

8.5 Receiver Status Log

8.5.1 Overview

The Receiver Status log (RXSTATUS) provides information on the current system status and configuration in a series of hexadecimal words.

The status word is the third field after the header, as shown in the example below.

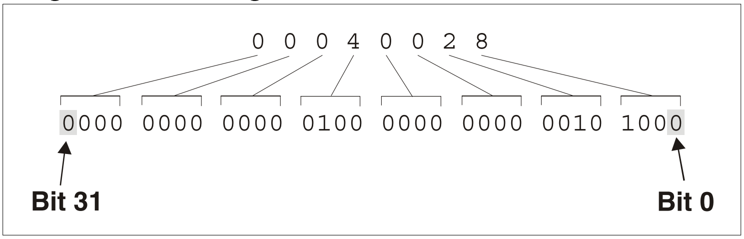
Figure 35: Location of Receiver Status Word

```
<RXSTATUS COM2 0 71.0 FINE 1209 239039.799 00000022 b8d0 754
<     00000022 4
<          00040028 00000000 00000000 00000000
<          00400005 00000008 00000000 00000000
<          00000000 00000000 00000000 00000000
<          00000000 00000000 00000000 00000000
```

Receiver Status Word

Each bit in the status word indicates the status of a specific condition or function of the receiver. If the status word is `00000000`, the receiver is operating normally. The numbering of the bits is shown in *Figure 36* below.

Figure 36: Reading the Bits in the Receiver Status Word



The format of the log is described in *Volume 2* of this manual. If the receiver status word indicates a problem, please also see *Section 9.1, Examining the RXSTATUS Log on Page 106.*

8.5.2 Error Word

The error field contains a 32 bit word. Each bit in the word is used to indicate an error condition. Error conditions may result in damage to the hardware or erroneous data, so the receiver is put into an error state. If any bit in the error word is set, the receiver will set the error strobe line, flash the error code on the status LED, broadcast the RXSTATUSEVENT log on all ports (unless the user has unlogged it), idle all channels, turn off the antenna, and disable the RF hardware. The only way to get out of the error state is to reset the receiver.

It is also possible to have status conditions trigger event messages to be generated by the receiver. Receiver Error words automatically generate event messages. These event messages are output in RXSTATUSEVENT logs (see also *Section 8.5.6, Set and Clear Mask for all Status Code Arrays on Page 102*).

The error word is the first field after the log header in the RXSTATUS log, as shown in the example below, or the third from last field in the header of every log.

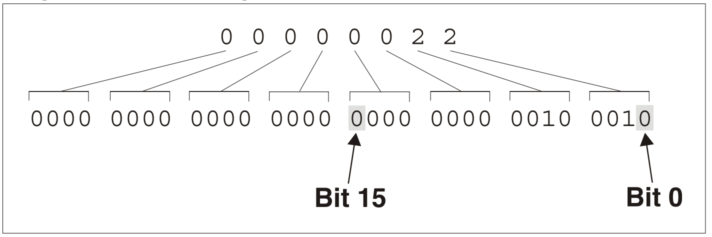
Figure 37: Location of Receiver Error Word

```
<RXSTATUS COM2 0 71.0 FINE 1209 239039.799 00000022 b8d0 754
<     00000022 4
<          00040028 00000000 00000000 00000000
<          00400005 00000008 00000000 00000000
<          00000000 00000000 00000000 00000000
<          00000000 00000000 00000000 00000000
```

Receiver Error Word

The numbering of the bits is shown in *Figure 38 on Page 102*.

Figure 38: Reading the Bits in the Receiver Error Word



See the RXSTATUS and the RXSTATUSEVENT logs in *Volume 2* of this manual for more detailed descriptions of these logs. If the receiver error word indicates an error, please also see *Section 9.1, Table 20, Resolving a Receiver Error Word on Page 106.*

8.5.3 Status Code Arrays

There are 3 status code arrays – the receiver status word, the auxiliary 1 status and the auxiliary 2 status. Each status code array consists of 4, 32 bit words (the status word, a priority mask, a set mask and a clear mask). The status word is similar to the error word, with each of the 32 bits indicating a condition. The mask words are used to modify the behavior caused by a change in one of the bits in the associated status words. Each bit in any of the masks operates on the bit in the same position in the status word. For example setting bit 3 in the priority mask changes the priority of bit 3 in the status word.

8.5.4 Receiver Status Code

The receiver status word is included in the header of all logs. It has 32 bits, which indicate certain receiver conditions. If any of these conditions occur, a bit in the status word is set. Unlike the error word bits the receiver will continue to operate, unless the priority mask for the bit has been set. The priority mask bit will change that of the receiver status word into an error bit. Anything that would result from an error bit becoming active would also occur if a receiver status and its associated priority mask bits are set.

8.5.5 Auxiliary Status Codes

The auxiliary status codes are only seen in the RXSTATUS log. The two bits representing the auxiliary status codes give indication about the receiver state for information only. The bits typically do not cause degradation of the receiver performance. The priority mask for the auxiliary codes does not put the receiver into an error state. Setting a bit in the auxiliary priority mask results in the corresponding bit in the receiver status code to be set if any masked auxiliary bit is set. Bit 31 of the receiver status word indicates the condition of all masked bits in the auxiliary 1 status word. Likewise, bit 32 of the receiver status word corresponds to the auxiliary 2 status word.

See the RXSTATUS log in *Volume 2* of this manual for a more detailed descriptions of this log.

8.5.6 Set and Clear Mask for all Status Code Arrays

The other two mask words in the status code arrays operate on the associated status word in the same way. These mask words are used to configure which bits in the status word will result in the broadcast of the RXSTATUSEVENT log. The set mask is used to turn logging on temporarily while the bit changes from the 0 to 1 state. The clear mask is used to turn logging on temporarily while the bit changes from a 1 to a 0 state. Note the error word does not have any associated mask words. Any bit set in the error word will result in the broadcast of the RXSTATUSEVENT log (unless unlogged).

See the RXSTATUSEVENT log in *Volume 2* of this manual for a more detailed description.

8.6 Status LED

The diagnostic LED provided on the OEM4 family receivers blinks green on and off at approximately 1 Hz to indicate normal operation.

Error bits and status bits that have been priority masked, as errors, will cause the LED to flash a code in a binary sequence. The binary sequence will be a 6 flash (0.5 second on and 0.25 second off per flash) sequence followed by a 1 second delay. The sequence will repeat indefinitely. If there is more than one error or status present, the lowest number will be output. The codes are ordered to have the highest priority condition output first.

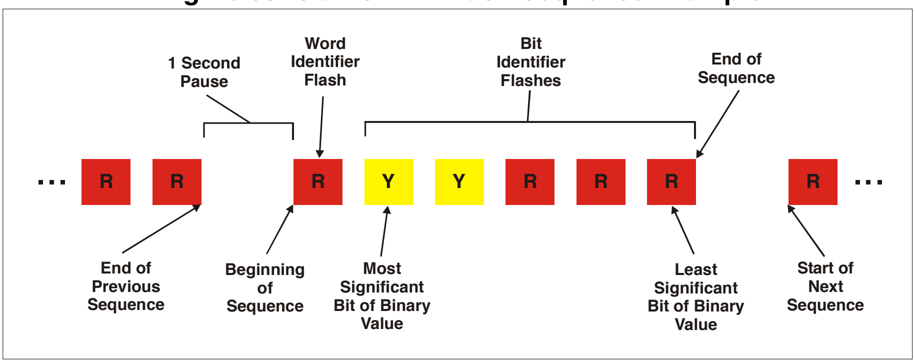
The first flash in the 6 flash sequence indicates if the code that follows is an error bit or a status bit. Error bits will flash red and status bits will flash yellow. The next 5 flashes will be the binary number of the code (most significant bit first). A red flash indicates a one and a yellow flash indicates a zero. For example, for an error bit 6, the binary number is 00110 so the output sequence would be:

Red			Yellow			Yellow			Red			Red			Yellow					
0.25	0.5	0.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5	5.25

followed by a 1 second delay. The sequence repeats indefinitely until the receiver is reset.

In the example below, the first flash in the sequence is red, which means that a bit is set in the receiver error word. The next five flashes give a binary value of `00111`. Converting this value to decimal results in a value of `7`. Therefore, bit 7 of the receiver error word is set, indicating there is a problem with the supply voltage of the receiver's power circuitry.

Figure 39: Status LED Flash Sequence Example



For a complete hexadecimal to binary conversion list see *Appendix F, Unit Conversion on Page 163*. See also, the RXSTATUS log and its tables in *Volume 2* of this manual for more details on this log and receiver error status.

Chapter 9 Troubleshooting

When your receiver appears not to be working properly, often there are simple ways to diagnose and resolve the problem. In many cases, the issue can be resolved within a few minutes, avoiding the hassle and loss of productivity that results from having to return your receiver for repair. This chapter is designed to assist you in troubleshooting problems that occur and includes navigational instructions to bring you to the part of this manual that details resolutions to aid your receiver's operation.

If you are unsure of the symptoms or if the symptoms do not match any of those listed, use the RXSTATUS log to check the receiver status and error words. See *Section 9.1, Examining the RXSTATUS Log, Page 106*.

If the problem is not resolved after using this troubleshooting guide, contact Customer Service, see *Page 13*.

Table 19: Troubleshooting based on Symptoms

Symptom	Related Section
The receiver is not properly powered	Check for and switch a faulty cable. See *Section 3.1.3, Power Supply Requirements, Page 29* and *Section 3.3.3, Status Indicators, Page 38*.
The receiver cannot establish communication	Check for and switch faulty cables and ports. See *Section 3.3.3, Status Indicators, Page 38* and *Section 8.6, Status LED, Page 103*. See also the COMCONFIG log in *Volume 2* of this manual.
The receiver is not tracking satellites	Check for and replace a faulty cable. See *Section 3.1.1, Selecting a GPS Antenna, Page 28*, *Section 3.1.2, Choosing a Coaxial Cable, Page 29*, *Section 3.2.3, Connecting the Antenna to the Receiver, Page 34*, *Section 3.3.5, External Antenna LNA Power (OEM4-G2 Only), Page 40* and *Appendix E, TTFF and Satellite Acquisition, starting on Page 161*.
No data is being logged	See *Section 3.3.3, Status Indicators, Page 38*, and *Section 4.1, Communications with the Receiver, Page 42*.
Random data is being output by the receiver	See *Section 3.3.3, Status Indicators, Page 38*. Refer also to the COMCONFIG log and FRESET command in *Volume 2* of this manual.

Continued on Page 105

A command is not accepted by the receiver	See *Section 4.1, Communications with the Receiver, Page 42* and refer to the FRESET command in *Volume 2* of this manual.
Differential mode is not working properly	See *Section 4.3, Transmitting and Receiving Corrections, Page 46* and refer to the COMCONFIG log in *Volume 2* of this manual.
There appears to be a problem with the receiverís memory	Refer to the NVMRESTORE command in *Volume 2* of this manual.
An environmental or memory failure. The receiver temperature is out of acceptable range or the internal thermometer is not working	See the ENVIRONMENTAL sections in the tables of *Appendix A, Technical Specifications* starting on *Page 111.*
Overload and overrun problems. Either the CPU or port buffers are overloaded	Reduce the amount of logging. See also *Section 4.1.1, Serial Port Default Settings, Page 42*.
The receiver is indicating that an invalid authorization code has been used	Refer to the Version log in *Volume 2* of this manual.
The receiver is being affected by jamming	Move the receiver away from any possible jamming sources.
The receiverís automatic gain control (AGC) functionality is not working properly	See *Section 3.1.2, Choosing a Coaxial Cable, Page 29* and the jamming symptom in this table.

9.1 Examining the RXSTATUS Log

The RXSTATUS log provides detailed status information about your receiver and can be used to diagnose problems. Please refer to *Volume 2* of this manual for details on this log and on how to read the receiver error word and status word. *Tables 20 and 21 on pages 106 to 108* give you actions to take when your receiver has an error flag in either of these words.

Table 20: Resolving a Receiver Error Word

Bit Set	Action to Resolve
0	Issue a FRESET command, refer to *Volume 2* of this manual.
1	Issue a FRESET command, refer to *Volume 2* of this manual.
2	Issue a FRESET command, refer to *Volume 2* of this manual.
4	Contact Customer Service as described on *Page 13.*
5	Check the VERSION log, refer to *Volume 2* of this manual.
6	Issue a FRESET command, refer to *Volume 2* of this manual.
7	See *Section 3.1.3, Power Supply Requirements, Page 29*.
8	Issue a NVMRESTORE command, refer to *Volume 2* of this manual.
9	Check temperature ranges in the ENVIRONMENTAL table sections of *Appendix A, Technical Specifications* starting on *Page 111.*
10	Contact Customer Service as described on *Page 13.*
11	
12	
13	
14	
15	Move the receiver away from any possible jamming sources.

Table 21: Resolving an Error in the Receiver Status Word

Bit Set	Action to Resolve
0	Check the Error Word in the RXSTATUS log. See also *Table 20, Resolving a Receiver Error Word, on Page 106.*
1	Check temperature ranges in the ENVIRONMENTAL table sections of *Appendix A, Technical Specifications* starting on *Page 111.*
2	See *Section 3.1.3, Power Supply Requirements, Page 29*.
3	See *Section 3.1.1, Selecting a GPS Antenna, Page 28*, *Section 3.1.2, Choosing a Coaxial Cable, Page 29*, *Section 3.2.3, Connecting the Antenna to the Receiver, Page 34*, *Section 3.3.5, External Antenna LNA Power (OEM4-G2 Only), Page 40* and *Appendix E, TTFF and Satellite Acquisition, starting on Page 161*.
4	
5	
6	
7	See *Section 4.1.1, Serial Port Default Settings, Page 42*.
8	
9	
10	
11	
14	Move the receiver away from any possible jamming sources.
15	See *Section 3.1.2, Choosing a Coaxial Cable, Page 29* and move the receiver away from any possible jamming sources.
16	Move the receiver away from any possible jamming sources.
17	See *Section 3.1.2, Choosing a Coaxial Cable, Page 29* and move the receiver away from any possible jamming sources.
18	None. Once enough time has passed for a valid almanac to be received, this bit will be set to 0. See also *Appendix E, TTFF and Satellite Acquisition, starting on Page 161*.
19	None. This bit only indicates if the receiver has calculated a position yet. See also *Appendix E, TTFF and Satellite Acquisition, starting on Page 161*.
20	None. This bit is simply a status bit indicating if the receiverís position has been manually fixed and does not represent a problem. Refer also to the FIX command in *Volume 2* of this manual.

Continued on Page 108

21	None. This bit simply indicates if clock steering has been manually disabled. Refer also to the FRESET command in *Volume 2* of this manual.
22	None. This bit only indicates if the clock model is valid. Refer also to the FRESET command in *Volume 2* of this manual.
23	None. This bit indicates whether or not the phase-lock-loop is locked when using an external oscillator. Refer also to the FRESET command in *Volume 2* of this manual.
30	None. This bit indicates if any bits in the auxiliary 2 status word are set. The auxiliary 2 word simply provides status information and does not provide any new information on problems. Refer also to the FRESET command in *Volume 2* of this manual.
31	None. This bit indicates if any bits in the auxiliary 1 status word are set. The auxiliary 1 word simply provides status information and does not provide any new information on problems.Refer also to the FRESET command in *Volume 2* of this manual.

Appendix A Technical Specifications

A.1 OEM4 Family Receiver Performance

PERFORMANCE *(Subject To GPS System Characteristics)*		
Position Accuracy [a]	Standalone:	
	L1 only	1.8 m CEP
	L1/L2	1.5 m CEP
	WAAS:	
	L1 only	1.2 m CEP
	L1/L2	0.8 m CEP
	Code Differential	0.45 m CEP
	RT-20	0.20 m CEP
	RT-2	0.01 m + 1 ppm CEP
	OmniSTAR:	
	VBS	1.0 m CEP
	HP	0.10 m CEP
	Post Processed	5 mm + 1 ppm CEP
Time To First Fix	See *Appendix E, TTFF and Satellite Acquisition*	
Reacquisition	0.5 s L1 (typical)	
	1.5 s L2 (typical)	(Minimum firmware version 2.100 required)
Data Rates	Raw Measurements:	20 Hz
	Computed Position:	20 Hz
	OmniSTAR HP Position:	10 Hz
Time Accuracy [a b]	20 ns RMS	
Velocity Accuracy	0.03 m/s RMS	
Measurement Precision	C/A code phase	6 cm RMS
	L1 carrier phase:	
	Differential	0.75 mm RMS
	L2 P code	25 cm RMS
	L2 carrier phase:	
	Differential	2 mm RMS
Dynamics	Vibration	4 g (sustained tracking)
	Velocity	515 m/s [c]
	Height	18,288 m [c]

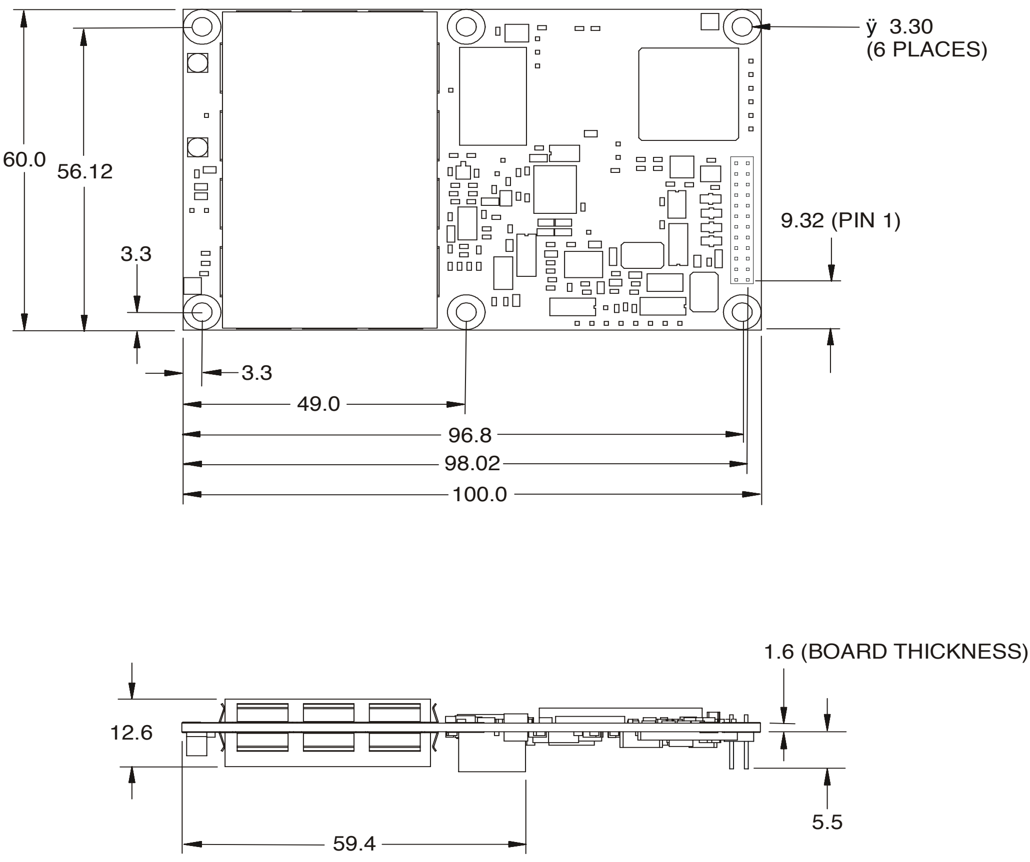
a. Typical values. Performance specifications are subject to GPS system characteristics, U.S. DOD operational degradation, ionospheric and tropospheric conditions, satellite geometry, baseline length and multipath effects.
b. Time accuracy does not include biases due to RF or antenna delay.

A.2 OEM4-G2L GPSCard

PHYSICAL	
Size	60mm x 100mm with connectors
Weight	56 grams

MECHANICAL DRAWINGS

Figure 40: OEM4-G2L Board Dimensions



a. All dimensions are in millimeters.

b. The mounting holes on the OEM4-G2L GPSCard are designed for use with M3 screws.

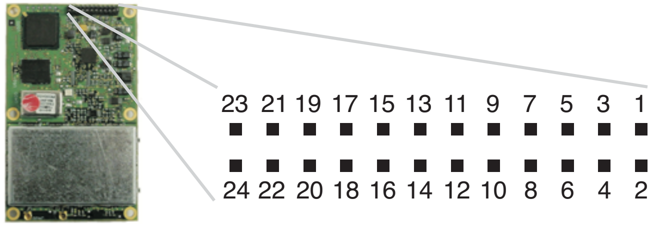
ENVIRONMENTAL	
Operating Temperature	-40∞C to +85∞C
Storage Temperature	-40∞C to +95∞C
Humidity	Not to exceed 95% non-condensing
POWER REQUIREMENTS	
Voltage	+3.3 ± 0.15 VDC
Allowable Input Voltage Ripple	150 mV p-p (max.)
Power consumption	1.8 W (typical)
RF INPUT / LNA POWER OUTPUT	
Antenna Connector (See *Figure 10 on Page 33*)	MMCX female, 50 Ω nominal impedance
RF Input Frequencies	1575.42 MHz (L1), 1227.60 MHz (L2)
LNA Power (output from card)	+4.75 to +5.25 VDC @ 0 - 100 mA
EXTERNAL OSCILLATOR INPUT	
Connector (See *Figure 10 on Page 33)*	MMCX female
External Clock Input	Frequency: 5 MHz or 10 MHz Input Impedance: 50 Ω nominal Input VSWR: 2.0:1 Signal Level: 0 dBm minimum to +13.0 dBm maximum Frequency Stability: ± 0.5 ppm maximum Wave Shape: Sinusoidal

INPUT/OUTPUT DATA INTERFACE	
COM1	
Electrical format	RS232
Bit rates[a]	300, 1200, 4800, 9600 (default), 19200, 38400, 57600, 115200, 230400, 460800, 921600 bps
Lead input	CTS
Lead output	RTS
Signals supported	TX, RX, RTS, CTS
COM2	
Electrical format	LVTTL
Bit rates[a]	300, 1200, 4800, 9600 (default), 19200, 38400, 57600, 115200, 230400 bps
Lead input	CTS
Lead output	RTS
Signals supported	TX, RX, RTS, CTS
USB (Requires Firmware Version 2.100 or HIGHER)	
Signals supported	USB D(+), USB D(-)

a. Baud rates higher than 115,200 bps are not supported by standard PC hardware. Special PC hardware is required for higher rates, including 230400 bps, 460800 bps, and 921600 bps.

INPUT/OUTPUT STROBES	
Event1 (Mark 1 Input)	An input mark for which a pulse greater than 55 ns triggers certain logs to be generated. (Refer to the MARKPOS and MARKTIME logs and ONMARK trigger in *Volume 2*). Polarity is configurable using the MARKCONTROL command discussed in *Volume 2*.
Event2 (Mark 2 Input)	An input mark for which a pulse greater than 105 ns triggers certain logs to be generated. (Refer to the MARK2POS and MARK2TIME logs in *Volume 2*). Polarity is configurable using the MARKCONTROL command discussed in *Volume 2*.
PV (Position Valid)	Output that indicates whether a valid GPS position solution is available. A high level indicates a valid solution or that the FIX POSITION command has been set (refer to the FIX POSITION command in user manual Volume 2).
ERROR	Output for which a high level indicates an error.
PPS (One Pulse Per Second)	A time synchronization output. This is a pulse (1 ms $\pm$ 50 ns minimum) where the trailing edge is synchronized to receiver calculated GPS time. The polarity and period of the pulse can be configured using the PPSCONTROL command described in *Volume 2*.
VARF (Variable Frequency)	A programmable variable frequency output ranging from 0 -20 MHz (refer to the FREQUENCYOUT command in *Volume 2* of this manual). This is a normally high, active low pulse.
$\overline{\text{RESETIN}}$	Reset TTL signal input from external system; active low, > 20 μs duration.
STROBE ELECTRICAL SPECIFICATIONS	
Outputs	Voltage: LVTTL levels Low: minimum 0 VDC and maximum 0.4 VDC @ 5 mA High: minimum 2.4 VDC and maximum 3.3 VDC @ 5 mA
Event1 and Event2 Inputs	Voltage: LVTTL levels Low: minimum 0 VDC and maximum 0.8 VDC High: minimum 2.0 VDC and maximum 5.5 VDC
$\overline{\text{RESETIN}}$ Input	Voltage: LVTTL levels Low: minimum 0 VDC and maximum 0.8 VDC High: minimum 2.4 VDC and maximum 3.3 VDC

Figure 41: Top-view of 24-Pin Connector on the OEM4-G2L



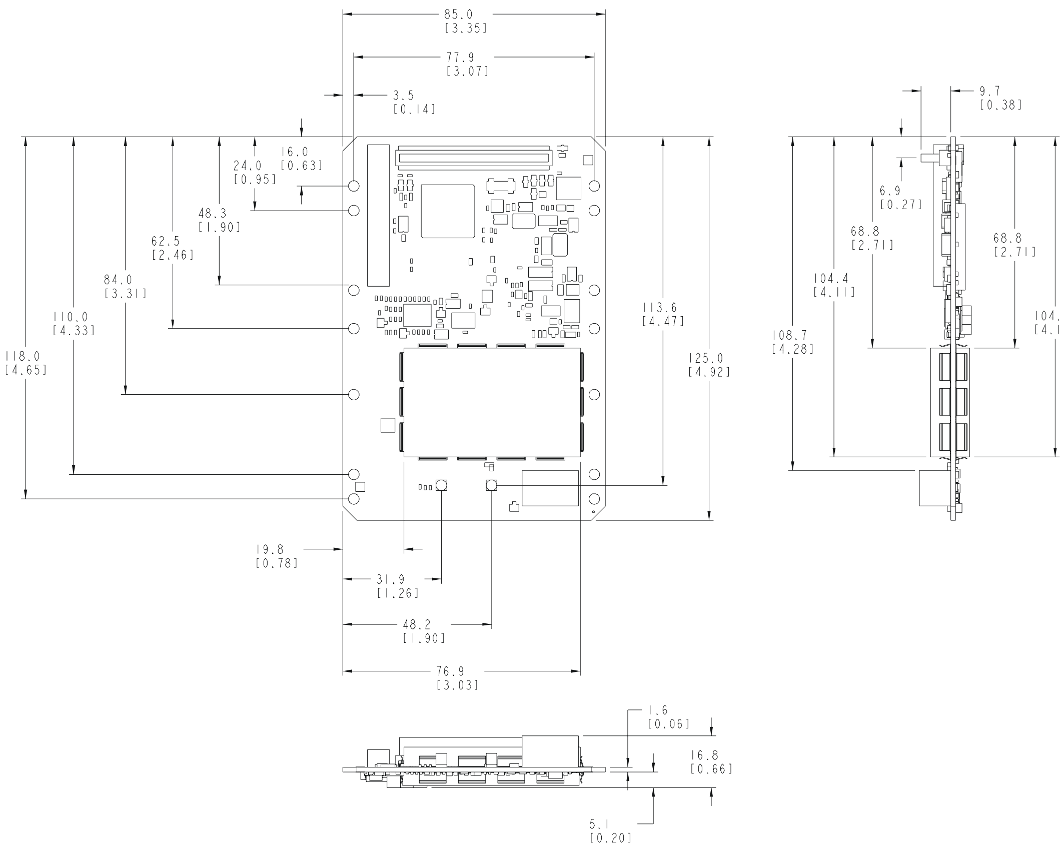
Signal	Descriptions	Pin
GND	Digital Ground	1
GND	Digital Ground	2
VARF	Variable frequency out	3
PPS	Output pulse 1 ms wide for which the trailing edge is used as the reference. Polarity and period can be configured using the PPSCONTROL command described in *Volume 2*.	4
VCC	Voltage input, +3.3 ± 0.15 VDC	5
VCC	Voltage input, +3.3 ± 0.15 VDC	6
Event2	Mark 2 input, which requires a pulse longer than 55 ns. Polarity can be configured using the MARKCONTROL command detailed in *Volume 2*.	7
Event1	Mark 1 input, which requires a pulse longer than 105 ns. Polarity can be configured using the MARKCONTROL command detailed in *Volume 2*.	8
ERROR	Indicates fatal error when high	9
PV	Output indicates 'good solution' or valid GPS position when high.	10
CTS2	Clear to Send for COM 2 input	11
$\overline{\text{RESETIN}}$	Reset TTL signal input from external system; active low.	12
RTS2	Request to Send for COM 2 output	13
RXD2	Received Data for COM 2 input	14
CTS1	Clear to Send for COM 1 input	15
TXD2	Transmitted Data for COM 2 output	16
RTS1	Request to Send for COM 1 output	17
RXD1	Received Data for COM 1 input	18
GPIO_USER0	Reserved. 10 kΩ pull-up resistor.	19
TXD1	Transmitted Data for COM 1 output	20
USB D-	USB interface data (-) (Requires firmware version 2.100 or higher)	21
USB D+	USB interface data (+) (Requires firmware version 2.100 or higher)	22
GND	Digital Ground	23
GND	Digital Ground	24

☒ To create a common ground, tie together all digital grounds (GND) with the ground of the power supply.

A.3 OEM4-G2 GPSCard

PHYSICAL	
Size	85mm x 125mm with connectors
Weight	85 grams
MECHANICAL DRAWINGS	

Figure 42: OEM4-G2 Board Dimensions



a. All dimensions are in millimeters [inches]

b. The mounting holes on the OEM4-G2 GPSCard are designed for use with M3 screws. The hole size is actually 3.45 mm (#29 drill, 0.136î), which is a British Standard ìmedium fitî.

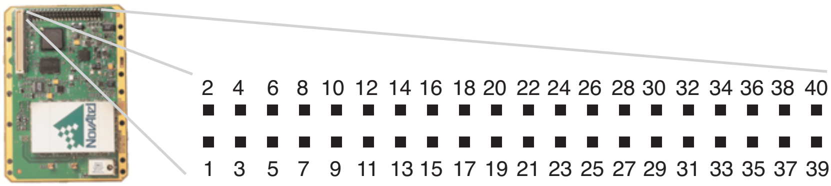
ENVIRONMENTAL	
Operating Temperature	-40∞C to +85∞C
Storage Temperature	-45∞C to +95∞C
Humidity	Not to exceed 95% non-condensing
POWER REQUIREMENTS	
Voltage	+4.5 to +18.0 VDC
Allowable Input Voltage Ripple	100 mV p-p (max.)
Power consumption	2.2 W (typical)
RF INPUT / LNA POWER OUTPUT	
Antenna Connector (See *Figure 11 on Page 34*)	MMCX female, 50 Ω nominal impedance
RF Input Frequencies	1575.42 MHz (L1), 1227.60 MHz (L2)
LNA Power **Internal (Output from card, default)** **External (Optional Input)**	 +4.50 to +5.25 VDC @ 0 - 100 mA +12 to +30 VDC, 100 mA max. (user-supplied)
EXTERNAL OSCILLATOR INPUT	
Connector (See *Figure 11 on Page 34)*	MMCX female
External Clock Input	Frequency: 5 MHz or 10 MHz Input Impedance: 50 Ω nominal Input VSWR:2.0:1 Signal Level: 0 dBm minimum to +13.0 dBm maximum Frequency Stability: ± 0.5 ppm maximum Wave Shape: Sinusoidal

INPUT/OUTPUT DATA INTERFACE	
COM1	
Electrical format	User-selectable. Defaults to RS232 but can be configured for RS422. See *Section 3.2.5.1 on Page 36* for more details. (Can also be factory configured for LVTTL operation)
Bit rates[a]	300, 1200, 4800, 9600 (default), 19200, 38400, 57600, 115200, 230400, 460800, 921600 bps
Lead input	CTS for RS232
Lead output	RTS for RS232
Signals supported	TX, RX, RTS, CTS for RS232 / TXD(+), TXD(-), RXD(+), RXD(-) for RS422
COM2	
Electrical format	RS232 (Can be factory configured for LVTTL operation)
Bit rates[a]	300, 1200, 4800, 9600 (default), 19200, 38400, 57600, 115200, 230400 bps
Lead input	CTS and DCD
Lead output	RTS and DTR
Signals supported	TX, RX, RTS, CTS, DTR, DCD
COM3	
Electrical format	LVTTL (Can be factory configured for RS232 or RS422 operation)
Bit rates[a]	300, 1200, 4800, 9600 (default), 19200, 38400, 57600, 115200, 230400 bps
Lead input	CTS
Lead output	RTS
Signals supported	TX, RX, RTS, CTS
USB (Requires Firmware Version 2.100 or HIGHER)	
Signals supported	USB D(+), USB D(-)

a. Baud rates higher than 115,200 bps are not supported by standard PC hardware. Special PC hardware is required for higher rates, including 230400 bps, 460800 bps, and 921600 bps.

INPUT/OUTPUT STROBES	
MSR (Measure Output)	Normally high, active low where the pulse width is 1 ms. The falling edge is the receiver measurement strobe.
Event1 (Mark 1 Input)	An input mark for which a pulse greater than 65 ns triggers certain logs to be generated. (Refer to the MARKPOS and MARKTIME logs and ONMARK trigger in *Volume 2*). Polarity is configurable using the MARKCONTROL command discussed in *Volume 2*.
Event2 (Mark 2 Input)	An input mark for which a pulse greater than 400 ns triggers certain logs to be generated. (Refer to the MARK2POS and MARK2TIME logs in *Volume 2*). Polarity is configurable using the MARKCONTROL command discussed in *Volume 2*.
PV (Position Valid)	Indicates a valid GPS position solution is available. A high level indicates a valid solution or that the FIX POSITION command has been set (refer to the FIX POSITION command in user manual Volume 2).
ERROR	High level indicates an error.
STATUS_RED	Status output which is high or pulses to indicate that the OEM4-G2 card is not working properly.
STATUS_GREEN	Status output which pulses to indicate that the OEM4-G2 card is working properly.
PPS (One Pulse Per Second)	A time synchronization output. This is a pulse (1 ms ± 50 ns minimum) where the trailing edge is synchronized to receiver calculated GPS time. The polarity and period of the pulse can be configured using the PPSCONTROL command described in *Volume 2*.
VARF (Variable Frequency)	A programmable variable frequency output ranging from 0 -20 MHz (refer to the FREQUENCYOUT command in *Volume 2* of this manual). This is a normally high, active low pulse.
$\overline{\textbf{RESETOUT}}$	Reset TTL signal output to external system; active low, 140 ms duration.
$\overline{\textbf{RESETIN}}$	Reset TTL signal input from external system; active low, > 20 μs duration
STROBE ELECTRICAL SPECIFICATIONS	
Output	Voltage: LVTTL levels Low: minimum 0 VDC and maximum 0.55 VDC @ 24 mA High: minimum 2.4 VDC and maximum 3.6 VDC @ 8 mA
Input	Voltage: LVTTL levels Low: minimum 0 VDC and maximum 0.8 VDC High: minimum 2.0 VDC and maximum 5.5 VDC

Figure 43: Top-view of 40-Pin Connector on the OEM4-G2



Signal	Descriptions	Pin
V_{IN}	Voltage In, +4.5 to +18 VDC	1
PV	Output indicates 'good solution' or valid GPS position when high.	2
USB D+	USB interface data (+) (Requires firmware version 2.100 or higher)	3
GND	Digital Ground	4
USB D-	USB interface data (-) (Requires firmware version 2.100 or higher)	5
GND	Digital Ground	6
PPS	Output pulse 1 ms wide for which the trailing edge acts as the reference. Polarity and period can be configured using the PPSCONTROL command described in *Volume 2*.	7
GND	Digital Ground	8
VARF	Variable frequency out	9
GND	Digital Ground	10
Event1	Mark 1 input, which requires a pulse longer than 65 ns. Polarity can be configured using the MARKCONTROL command detailed in *Volume 2*.	11
GND	Digital Ground	12
STATUS_RED	Indicates the OEM4-G2 card is not working properly when high or pulsing.	13
CTS1/RXD1(-)	COM1 input Clear to Send for RS-232 / Received Data (-) for RS-422	14
TXD1/TXD1(+)	COM1 output Transmitted Data for RS-232 / Transmitted Data (+) for RS-422	15
RTS1/TXD1(-)	COM1 output Request to Send for RS-232 / Transmitted Data (-) for RS-422	16
RXD1/RXD1(+)	COM1 input Received Data for RS-232 / Received Data (+) for RS-422	17
CTS3	Clear to Send for COM 3 input	18
TXD3	Transmitted Data for COM 3 output	19
DCD2	Data Carrier Detected for COM 2 input	20
RXD3	Received Data for COM 3 input	21
RTS3	Request to Send for COM 3 output	22
DTR2	Data Terminal Ready for COM 2 output	23
CTS2	Clear to Send for COM 2 input	24
TXD2	Transmitted Data for COM 2 output	25
RTS2	Request to Send for COM 2 output	26
RXD2	Received Data for COM 2 input	27
STATUS_GREEN	Indicates the OEM4-G2 card is working properly when pulsing at 1 Hz.	28
GPIO_USER0	Reserved. 10 kΩ pull-down resistor.	29
GPIO_USER1	COM1 port configuration selector. 10 kΩ pull-down resistor. (At startup, tie high to set COM1 to RS-422 or leave open for RS-232. See *Section 3.2.5.1 on Page 36* for more details.)	30

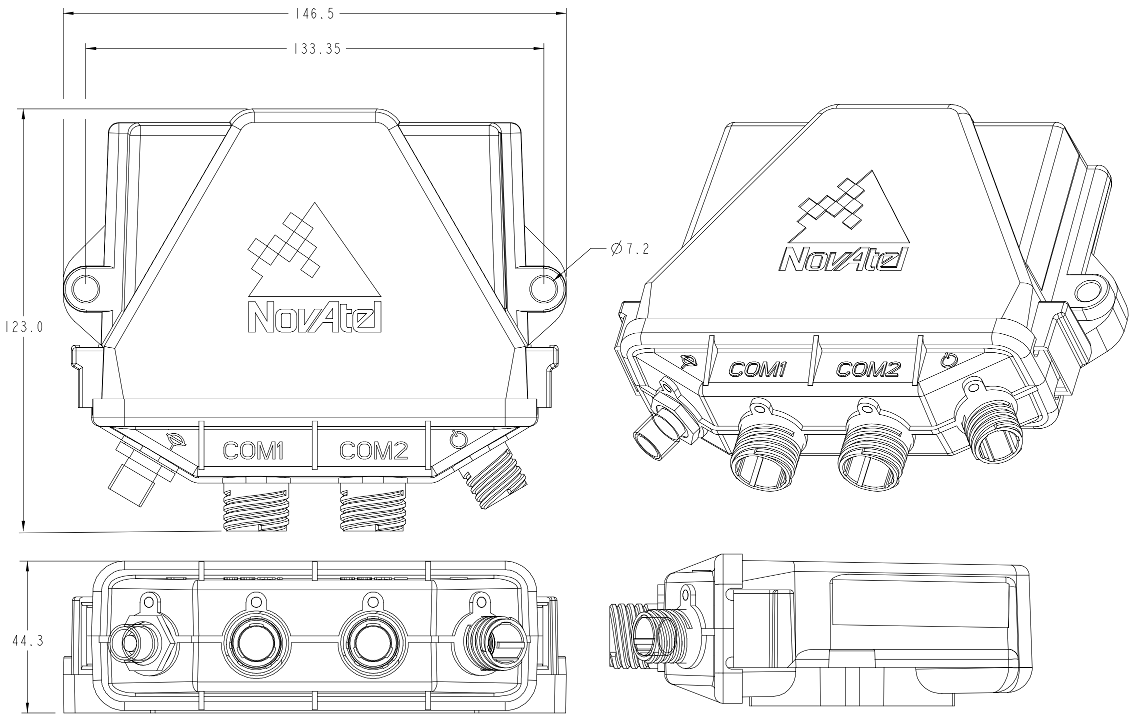
Event2 / GPIO_USER2	Mark 2 input, which requires a pulse longer than 400 ns. Polarity can be configured or processing can be disabled using the MARKCONTROL command detailed in *Volume 2*. 10 kΩ pull-up resistor.	31
MSR	Normally high, active low pulse is 1 ms ± 50 ns wide. Falling edge is used as the reference.	32
$\overline{\text{RESETIN}}$	Reset TTL signal input from external system; active low.	33
GPAI	General purpose analog input (see the RXHWLEVELS log in *Volume 2* of this manual). The voltage range is 0.0 (min) to 3.3 (max) VDC.	34
$\overline{\text{RESETOUT}}$	Reset TTL signal output to external system; active low.	35
GND	Digital Ground	36
GPIO_FR	Reserved. 10 kΩ pull-up resistor.	37
ERROR	Indicates fatal error when high	38
*	Reserved.	39
LNA_PWR	Optional external power to antenna other than a standard NovAtel GPSAntenna (see the ANTENNAPOWER command in *Volume 2* of this manual)	40

☒ To create a common ground, tie together all digital grounds (GND) with the ground of the power supply.

A.4 FlexPak

INPUT/OUTPUT CONNECTORS	
ANT	Waterproof TNC female jack, 50 Ω nominal impedance +4.25 to +5.25 VDC, 90 mA max (output from FlexPak to antenna/LNA)
PWR	3-pin waterproof Deutsch connector +6 to +18 VDC (Deutsch PN 59065-09-98PN)
COM1	13-pin waterproof Deutsch connector (Deutsch P/N 59065-11-35PF)
COM2	13-pin waterproof Deutsch connector (Deutsch P/N 59065-11-35PF)
PHYSICAL	
Size	45 x 147 x 123 mm
Weight	350 g maximum
Mounting System	Integral flange with two 9/32î diameter mounting holes 5-1/4 ì apart
ENVIRONMENTAL	
Operating Temperature	-40∞C to +75∞C
Storage Temperature	-40∞C to +85∞C
Humidity	Not to exceed 95% non-condensing
Waterproof	To IEC 60529 IP X4 and IP X7

DIMENSIONS
a



a. All dimension are in millimeters, please use *Appendix F, Unit Conversion on Page 163* for conversion to imperial measurements.

A.4.1 Port Pin-Outs

The pin numbering for each of the ports, is described in the tables that follow.

Table 22: FlexPak COM1 Port Pin-Out Descriptions

Deutsch RS-232 Only	
Connector Pin No.	**Signal Name**
1	GPIO
2	RXD1
3	CTS1
4	EVENT1
5	GND
6	EVENT2
7	RTS1
8	TX1
9	POUT
10	PPS
11	USB D+
12	USB D-
13	ERROR

✉ For strobe signal descriptions, please see *Section 3.3.1, Strobes on Page 36*.

Table 23: FlexPak COM2 Port Pin-Out Descriptions

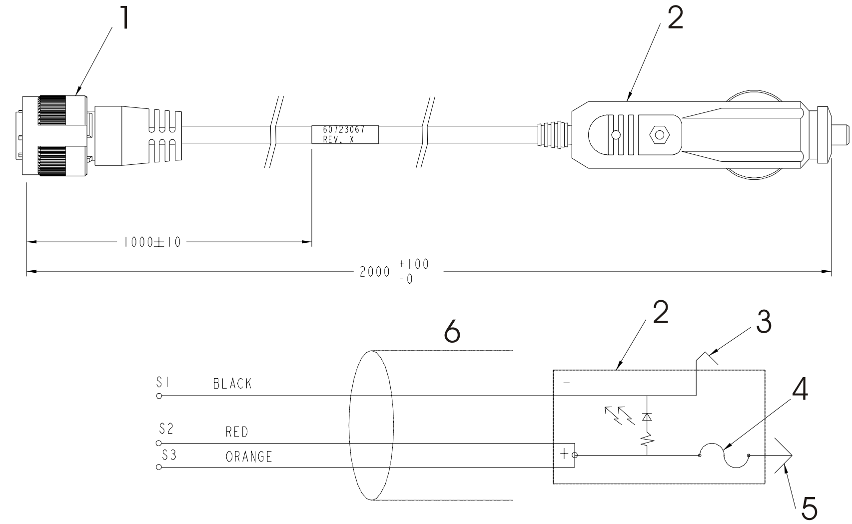
Deutsch RS-232		Deutsch RS-422	
Pin	Function	Pin	Function
1	232	1	422
2	RXD2	2	RXD2(+)
3	CTS2	3	RXD2(-)
4	Event 1	4	Event 1
5	GND	5	GND
6	Event 2	6	Event 2
7	RTS2	7	TXD2(-)
8	TXD2	8	TXD2(+)
9	POUT	9	POUT
10	PPS	10	PPS
11	USB D+	11	USB D+
12	USB D-	12	USB D-
13	ERROR	13	ERROR

A.4.2 Cables

A.4.2.1 Automobile Power Adapter Cable (NovAtel part number 60723067)

The power adapter cable supplied with the FlexPak provides a convenient means for supplying +12 VDC while operating from an automobile. The figure below shows the cable and a wiring diagram of the automobile adapter.

The output of the power adapter uses a 3-pin Deutsch socket (Deutsch part number: 58064-08-98SN). This cable plugs directly into the PWR port on the front of the FlexPak.

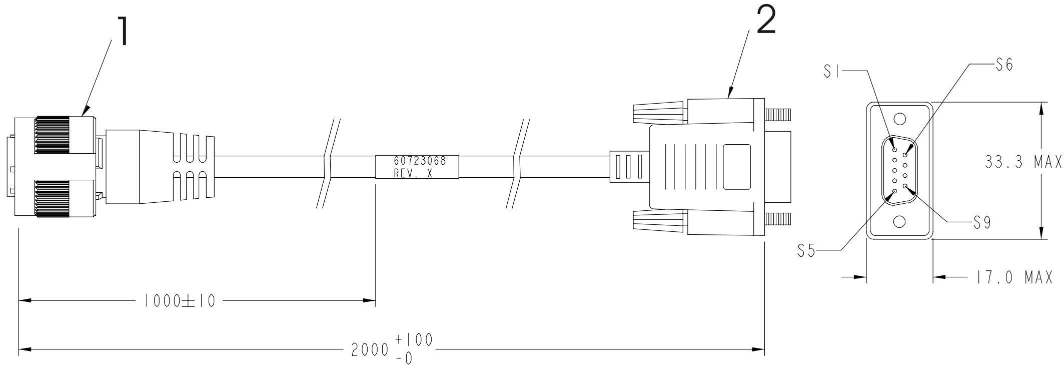


Reference	Description
1	3-pin Deutsch connector
2	Automobile adapter
3	Outer contact
4	3 amp slow-blow fuse
5	Center contact
6	Foil shield

Figure 44: FlexPak Power Cable

A.4.2.2 13-Pin Deutsch to DB9 Serial Cable (NovAtel part number 60723068)

The null-modem serial cable shown below provides a means of interfacing between the COM1 or COM2 port on the FlexPak and another serial communications device, such as a PC. At the FlexPak end, the cable is equipped with a 13-pin Deutsch connector (Deutsch part number: 59064-11-35SF), which plugs directly into a COM port. At the other end, a DB9S connector is provided. The cable is 2 meters in length.



TO RECEIVER	SIGNAL	DB-9 FEMALE TO PC
S1	GPIO	N/C
S2	RXD1	S3
S3	CTS1	S7
S4	EVENT1	N/C
S5	GND	S5
S6	EVENT2	N/C
S7	RTS1	S8
S8	TXD1	S2
S9	POUT	S1,S6
S10	PPS	N/C
S11	USB D+	N/C
S12	USB D-	N/C
S13	ERROR	N/C

Reference	**Description**
1	13-pin Deutsch connector
2	DB9S connector

Figure 45: FlexPak 13-Pin Serial Cable

A.4.2.3 Optional USB Cable (NovAtel part number TBD)

The USB cable shown below provides a means of interfacing between the COM1 or COM2 port on the FlexPak and another serial communications device, such as a PC. At the FlexPak end, the cable is equipped with a 13-pin Deutsch connector (Deutsch part number: 59064-11-35SF), which plugs directly into the COM2 port. See also *Section A.4.2.2, 13-Pin Deutsch to DB9 Serial Cable (NovAtel part number 60723068) on Page 126*. At the other end, a USB connector is provided.

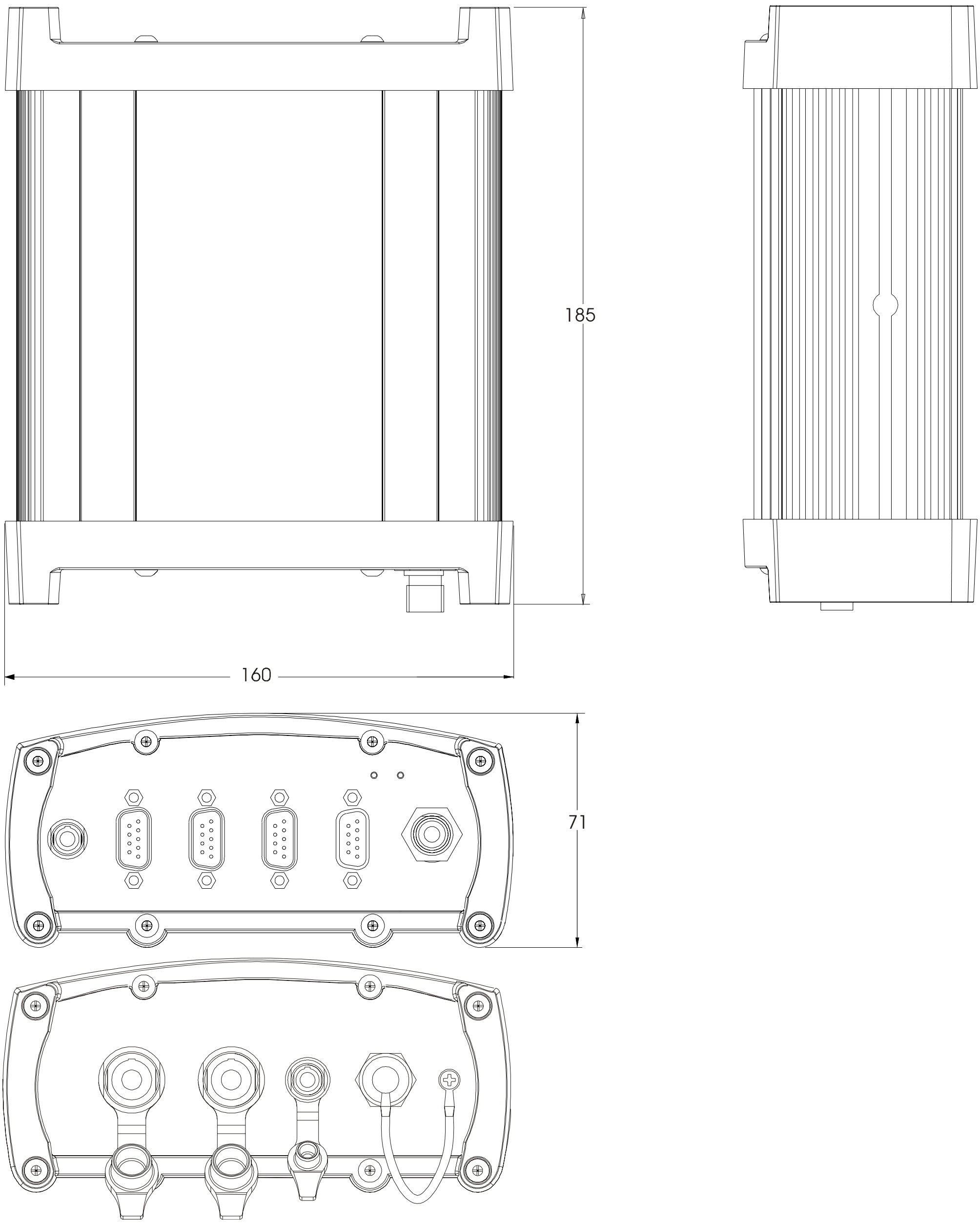
Figure 46: FlexPak USB Cable

A.5 ProPak-G2

There are two versions of the ProPak-G2. One version has DB-9 connectors and the other uses LEMO-brand connectors. Unless otherwise indicated, the information given in this section applies to both versions.

INPUT/OUTPUT CONNECTORS	
Antenna Input	TNC female jack, 50 Ω nominal impedance +4.25 to +5.25 VDC, 90 mA max (output from ProPak to antenna/LNA)
PWR	4-pin LEMO connector +7 to +18 VDC at 2.8 W (typical)
DB-9 Version	
COM1	DB9P connector
COM2	DB9P connector
AUX	DB9P connector
I/O	DB9S connector
LEMO Version	
COM1	10-pin LEMO connector
COM2	10-pin LEMO connector
PHYSICAL	
Size	185 x 160 x 71 mm
Weight	1.0 kg maximum (including OEM4-G2 GPSCard)
ENVIRONMENTAL	
Operating Temperature	-40∞C to +75∞C
Storage Temperature	-45∞C to +95∞C
Humidity	Not to exceed 95% non-condensing

DIMENSIONS [a]



a. All dimension are in millimeters, please use *Appendix F, Unit Conversion on Page 163* for conversion to imperial measurements.

A.5.1 Port Pin-Outs

Table 24: ProPak-G2 (DB-9 Version) Serial Port Pin-Out Descriptions

Connector Pin No.	COM1		COM2	AUX	
	RS232	RS422	RS232 Only	RS232	RS422
1	N/C	N/C	N/C	N/C	N/C
2	RXD1	RXD1(+)	RXD2	RXD3	RXD3(+)
3	TXD1	TXD1(+)	TXD2	TXD3	TXD3(+)
4	N/C	N/C	N/C	POUT	POUT
5	GND	GND	GND	GND	GND
6	N/C	N/C	N/C	N/C	N/C
7	RTS1	TXD1(-)	RTS2	RTS3	TXD3(-)
8	CTS1	RXD1(-)	CTS2	CTS3	RXD3(-)
9	N/C	N/C	N/C	N/C	N/C

Table 25: ProPak-G2 (LEMO Version) Serial Port Pin-Out Descriptions

Connector Pin No.	COM1/COM3		COM2
	RS232	RS422	RS232 Only
1	RTS3	RTS3	N/C
2	RXD1	RXD1(+)	RXD2
3	TXD1	TXD1(+)	TXD2
4	GND	GND	GND
5	GND	GND	GND
6	RXD3	RXD3	Event1
7	RTS1	TXD1(-)	RTS2
8	CTS1	RXD1(-)	CTS2
9	POUT	POUT	POUT
10	TXD3	TXD3	1PPS

Table 26: ProPak-G2 (DB-9 Version) I/O Port Pin-Out Descriptions

Connector Pin No.	Signal Name	Signal Descriptions
1	VARF	Variable frequency out
2	PPS	One pulse per second
3	N/C	Not connected
4	Event1	Mark 1 input
5	PV	Valid position available
6	N/C	Not connected
7	N/C	Not connected
8	GND	Digital ground
9	GND	Digital ground

✉ For strobe signal descriptions, please see *Section 3.3.1, Strobes on Page 36*.

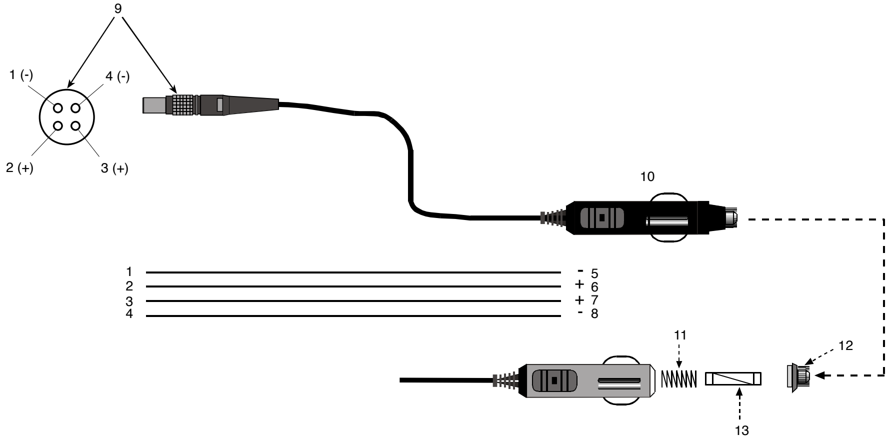
A.5.2 Cables

A.5.2.1 Automobile Power Adapter Cable (NovAtel part number 01017023)

The power adapter cable supplied with the ProPak-G2, see *Figure 47*, provides a convenient means for supplying +12 VDC while operating from an automobile.

Input is provided through the standard automobile power outlet. The output from the power adapter utilizes a 4-pin LEMO connector and plugs directly into the *PWR* input located on the back panel of the ProPak-G2.

For alternate power sources please see *Section 3.1.3 on Page 29*.



Reference	Description	Reference	Description
1	Black	5	Ground
2	Red	6	+7 to +18 VDC
3	Orange	7	+7 to +18 VDC
4	Brown	8	Ground
9	Connector key marking	12	Universal tip
10	Automobile adapter	13	3 Amp slow-blow fuse
11	Spring		

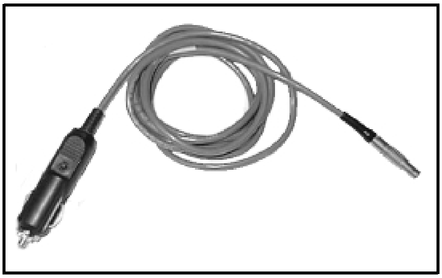
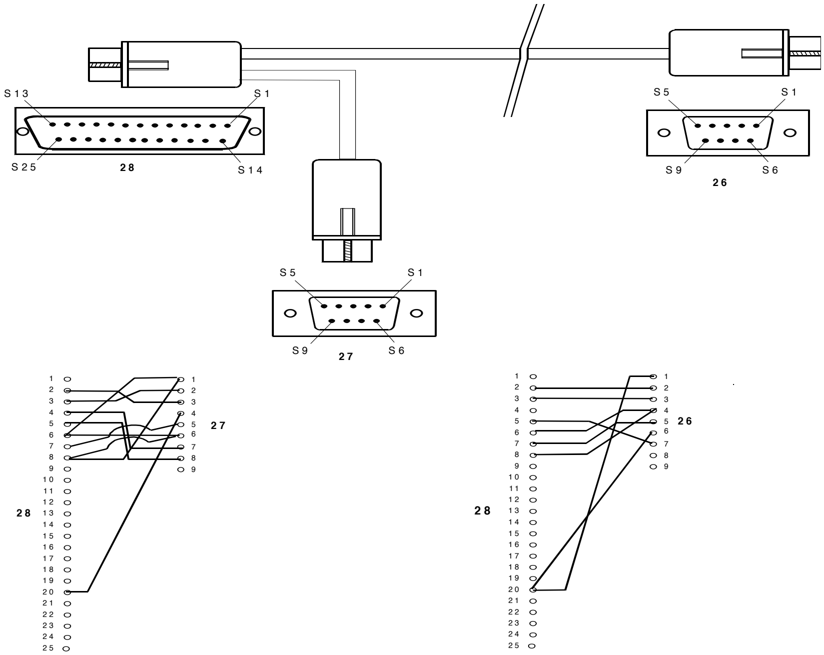


Figure 47: ProPak-G2 Power Cable

A.5.2.2 Y-Type Null-Modem Cable for DB-9 Version (NovAtel part number 60715062)

This cable supplied with the DB-9 version of the ProPak-G2, see *Figure 48*, provides an easy means of communications with a PC. The cable is equipped with a 9-pin connector at the receiver end which can be plugged into the *COM1*, *COM2*, or *AUX* port. At the PC end, both a 9-pin and a 25-pin connector are provided to accommodate most PC serial (RS232) communication ports.



Wiring Table:

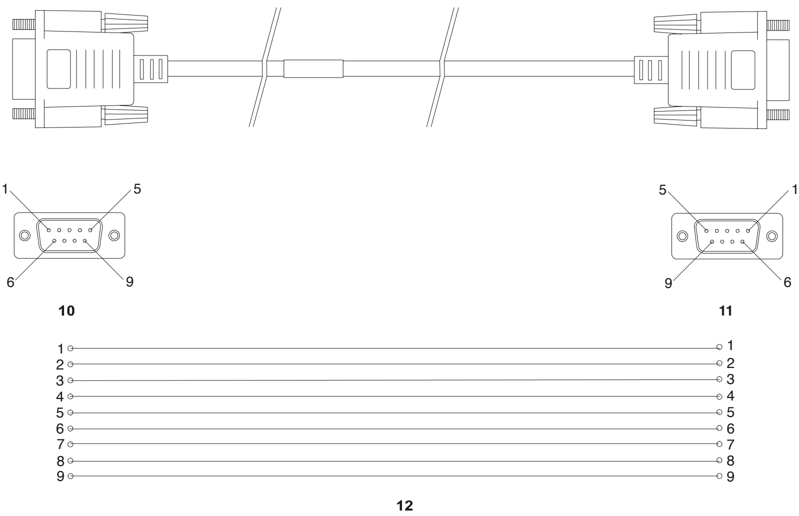
Connector	Pin Number						
From DB25S (28)	2	3	4	5	6 & 8	7	20
To DB9S (26)	2	3	8	7	4	5	1 & 6
To DB9S (27)	3	2	7	8	1 & 6	5	4

Reference	Description	Reference	Description
26	DB9S (Female)	28	DB25S (Female)
27	DB9S (Female)		

Figure 48: ProPak-G2 (DB-9 Version) Y-Type Null Modem Cable

A.5.2.3 Straight Serial Cable for DB-9 Version (NovAtel part number 60723066)

This cable can be used to connect the DB-9 version of the ProPak-G2 to a modem or radio transmitter to propagate differential corrections. The cable is equipped with a female DB9 connector at the receiver end. The male DB9 connector at the other end is provided to plug into your user-supplied equipment (please refer to your modem or radio transmitter user guide for more information on its connectors). The cable is approximately 2 m in length. See *Figure 49*.

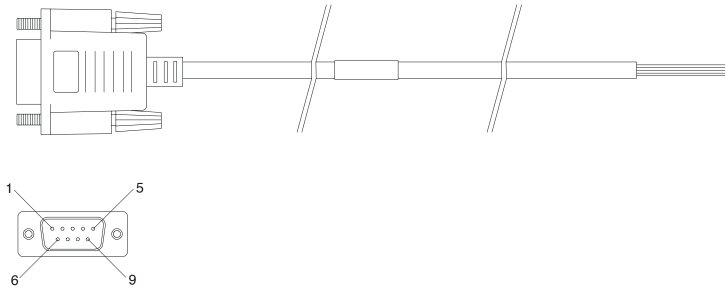


Reference	Description	Reference	Description
10	DB9P (male) connector	12	9-conductor cable
11	DB9S (female) connector		

Figure 49: ProPak-G2 (DB-9 Version) Straight Serial Cable

A.5.2.4 I/O Strobe Port Cable for DB-9 Version (NovAtel part number 60723065)

The strobe lines on the DB-9 version of the ProPak-G2 can be accessed by inserting the male DB9 connector of the I/O strobe port cable into the *I/O* port. The other end of this cable is provided without a connector to provide flexibility. The jacket insulation is cut away slightly from the end but the insulation on each wire is intact. The cable is approximately 2 m in length. See *Figure 50*.



10

11

Wiring Table:

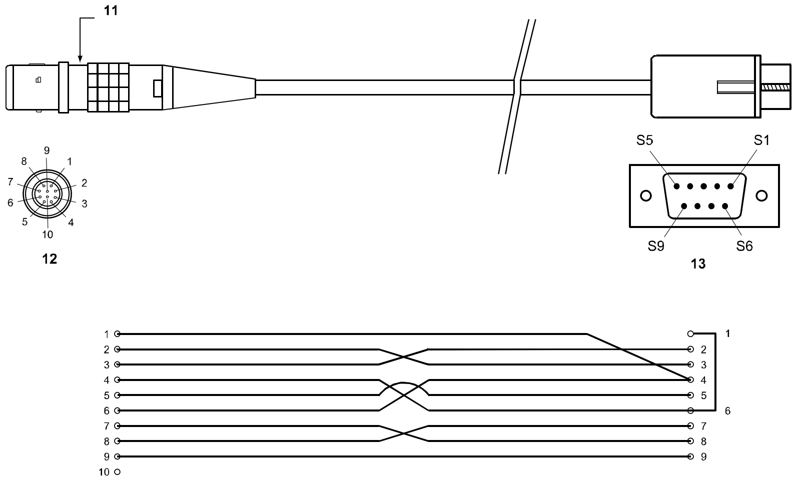
I/O Port Pin	I/O Port Signal	I/O Port Cable Wire Color	I/O Port Pin	I/O Port Signal	I/O Port Cable Wire Color
1	VARF	Black	6	Reserved	Green
2	PPS	Brown	7	Reserved	Blue
3	Reserved	Red	8	GND	Violet
4	Event1	Orange	9	GND	White/Grey
5	PV	Yellow			

Reference	Description	Reference	Description
10	DB9S (male) connector	11	9-conductor cable

Figure 50: ProPak-G2 (DB-9 Version) I/O Strobe Port Cable

A.5.2.5 Null Modem Cable for LEMO Version (NovAtel Part Number 403-0-0036)

The LEMO version of the ProPak-G2 includes a null modem cable, which provides an easy means of communications with a PC. The cable is equipped with a 10-pin LEMO connector at the receiver end which can be plugged into the *COM1* or *COM2* port. At the PC end, a DB-9 connector is provided to accommodate most PC serial (RS232) communication ports.



Reference	Description	Reference	Description
1	Brown	8	Violet
2	Black	9	Grey
3	Red	10	White (not used)
4	Orange	11	Connector key marking
5	Yellow	12	10-pin LEMO connector
6	Green	13	DB9S (female) connector
7	Blue		

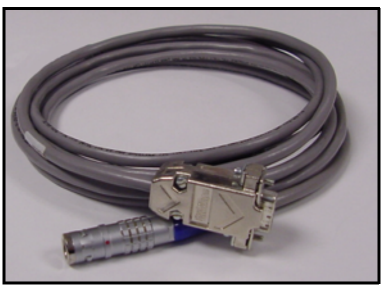
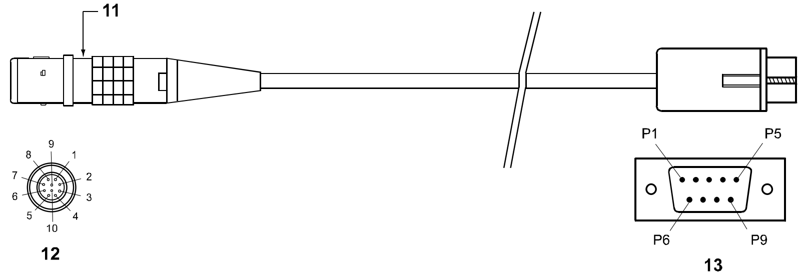


Figure 51: ProPak-G2 (LEMO Version) Null Modem Cable

A.5.2.6 Straight Serial Cable for LEMO Version (NovAtel Part Number 403-0-0037)

This cable can be used to connect the LEMO version of the ProPak-G2 to a modem or radio transmitter to propagate differential corrections. The cable is equipped with a 10-pin LEMO connector at the receiver end that should ideally be plugged into COM2 on the receiver. The male DB-9 connector at the other end is provided to plug into your user-supplied equipment (please refer to your modem or radio transmitter user guide for more information on its connectors). The cable is approximately 2 m in length.



Reference	Description	Reference	Description
1	Brown	8	Violet
2	Black	9	Grey
3	Red	10	White (not used)
4	Orange	11	Connector key marking
5	Yellow	12	10-pin LEMO connector
6	Green	13	DB9P (male) connector
7	Blue		

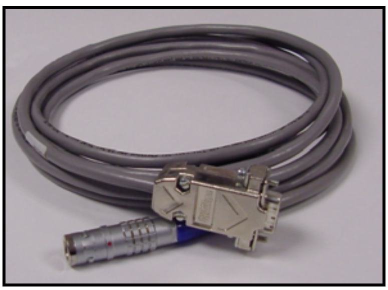


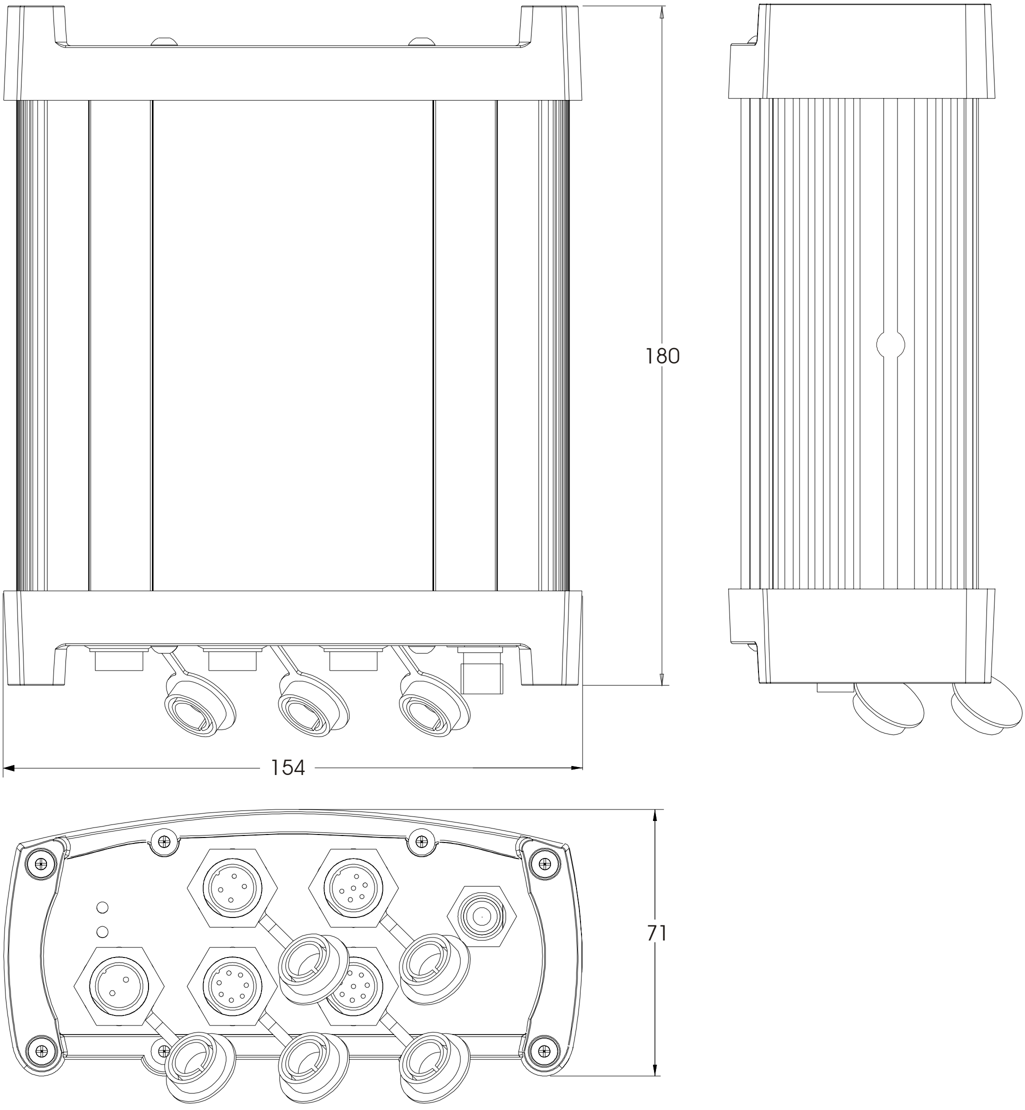
Figure 52: ProPak-G2 (LEMO Version) Straight Serial Cable

A.6 ProPak-LB

INPUT/OUTPUT CONNECTORS	
ANT	TNC female jack, 50 Ω nominal impedance +4.25 to +5.25 VDC, 90 mA max (output from ProPak-LB to antenna/LNA)
PWR	2-pin Switchcraft EN3 connector +7 to +15 VDC at 5 W typical (operating range)[a]
COM1	6-pin Switchcraft EN3 connector
COM2	7-pin Switchcraft EN3 connector
COM3	8-pin Switchcraft EN3 connector
PHYSICAL	
Size	180 x 154 x 71 mm (not including mounting bracket) 180 x 186 x 75 mm (including mounting bracket)
Weight	1.1 kg maximum
ENVIRONMENTAL	
Operating Temperature	-40∞C to +75∞C
Storage Temperature	-40∞C to +90∞C
Humidity	Not to exceed 95% non-condensing

a. The receiver will turn off and be undamaged at voltages between 15 and 30 VDC. Protection is included for brief transients above 30 VDC.

DIMENSIONS
a



a. All dimension are in millimeters, please use *Appendix F, Unit Conversion on Page 163* for conversion to imperial measurements.

A.6.1 Port Pin-Outs

Figure 53 is included to provide the pin numbering for each of the ports, which are described in the tables that follow.

Figure 53: ProPak-LB Port Pin-Outs

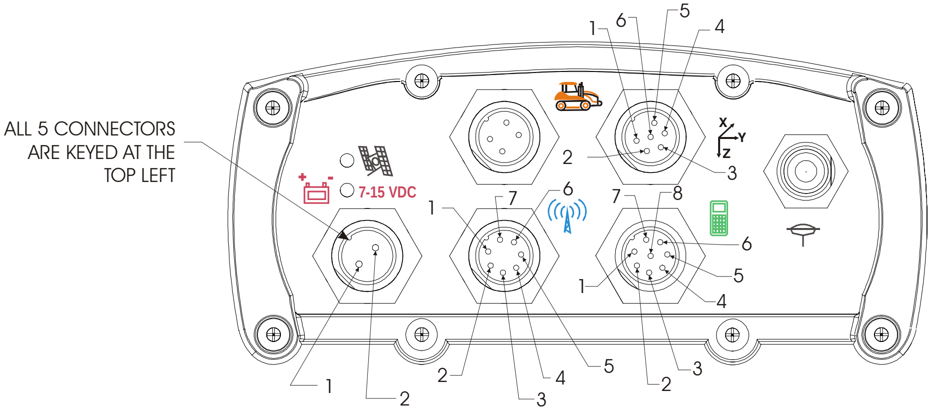


Table 27: ProPak-LB PWR Port Pin-Out Descriptions

Connector Pin No.	Signal Name	Signal Description
1	VIN+	Positive power terminal
2	VIN-	Negative power terminal

Table 28: ProPak-LB COM1 Port Pin-Out Descriptions

Connector Pin No.	Signal Name	Signal Description
1	1PPS	One pulse per second output
2	Event1	Mark 1 input
3	POUT	Power output[a]
4	RXD1	RS232 receive to COM1 on the receiver
5	TXD1	RS232 transmit from COM1 on the receiver
6	GND	Signal/power ground

a. Both COM1 and COM2 have power output pins that can be used to pass power to peripherals. The voltage on each will be approximately 1 V lower than VIN. The maximum continuous current is 500 mA.

✉ For strobe signal descriptions, please see *Section 3.3.1, Strobes on Page 36*.

Table 29: ProPak-LB COM2 Port Pin-Out Descriptions

Connector Pin No.	Signal Name	Signal Description
1	SGND	Signal ground
2	RTS2	RS232 ready to send from COM2 on the receiver
3	CTS2	RS232 clear to send to COM2 on the receiver
4	POUT	Power output[a]
5	RXD2	RS232 receive to COM2 on the receiver
6	TXD2	RS232 transmit from COM2 on the receiver
7	PGND	Power ground[a]

a. Both COM1 and COM2 have power output pins that can be used to pass power to peripherals. The voltage on each will be approximately 1 V lower than VIN. The maximum continuous current is 500 mA.

Table 30: ProPak-LB COM3 Port Pin-Out Descriptions

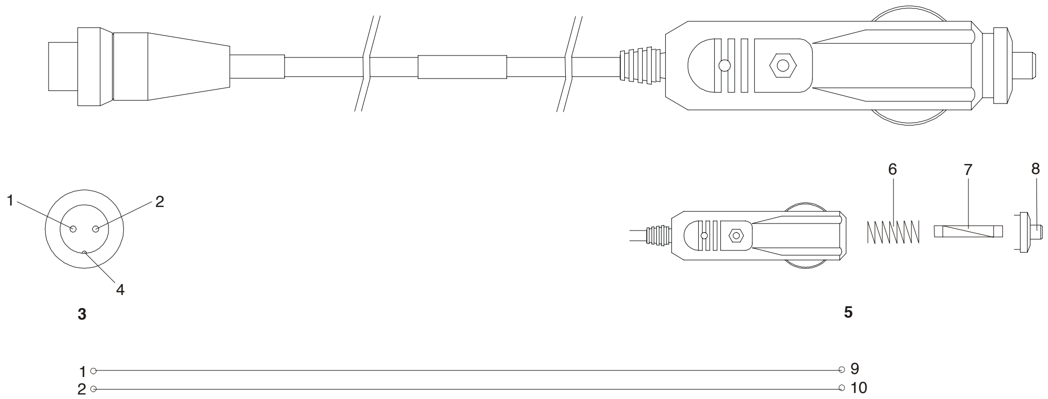
Connector Pin No.	Signal Name	Signal Description
1	Reserved	Reserved
2	GPIO_SR	Reserved
3	RXD3	RS232 receive to COM3 on the receiver
4	TXD3	RS232 transmit from COM3 on the receiver
5	AIN	General purpose analog input (See the *RXHWLEVELS* log in *Volume 2* of this manual.)
6	GPIO_SL	Reserved
7	GND	Digital ground
8	GPIO_GPI	Reserved

A.6.2 Cables

A.6.2.1 Automobile Power Adapter Cable (NovAtel part number 60723064)

The power adapter cable supplied with the ProPak-LB provides a convenient means for supplying +12 VDC while operating from an automobile.

The output of the power adapter uses a 2-pin Switchcraft socket (Switchcraft part number: EN3C2F). This cable plugs directly into the PWR port on the rear end cap of the ProPak-LB.

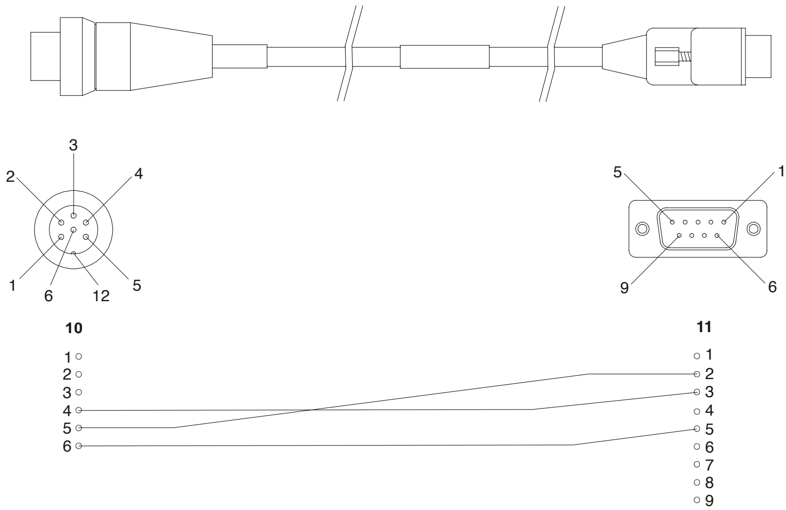


Reference	Description
3	2-pin Switchcraft EN3C2F connector
4	Connector key
5	Automobile power outlet plug
6	Spring
7	Slow blow fuse
8	Universal tip
9	Red
10	Black

Figure 54: ProPak-LB Power Cable

A.6.2.2 6-Pin Switchcraft to DB9 Serial Cable (NovAtel part number 60723061)

The serial cable shown below provides a means of interfacing between the COM1 port on the ProPak-LB and another serial communications device, such as a PC. At the ProPak-LB end, the cable is equipped with a 6-pin Switchcraft connector (Switchcraft part number: EN3C6F), which plugs directly into the COM1 port. At the other end, a DB9S connector is provided. The cable is 2 m in length.

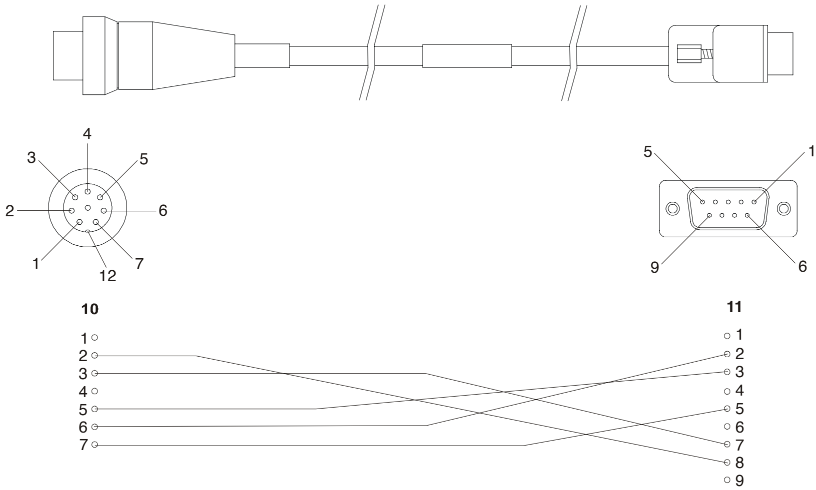


Reference	Description
10	6-pin Switchcraft EN3C6F connector
11	DB9S connector
12	Connector key

Figure 55: ProPak-LB 6-Pin Serial Cable

A.6.2.3 7-Pin Switchcraft to DB9 Serial Cable (NovAtel part number 60723062)

The serial cable shown below provides a means of interfacing between the COM2 port on the ProPak-LB and another serial communications device, such as a PC. At the ProPak-LB end, the cable is equipped with a 7-pin Switchcraft connector (Switchcraft part number: EN3C7F), which plugs directly into the COM2 port. At the other end, a DB9S connector is provided.

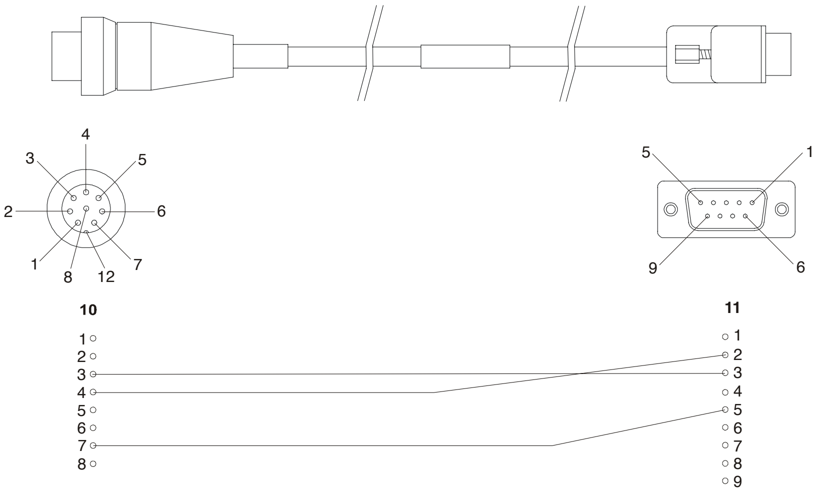


Reference	Description
10	7-pin Switchcraft EN3C7F connector
11	DB9S connector
12	Connector key

Figure 56: ProPak-LB 7-Pin Serial Cable

A.6.2.4 8-Pin Switchcraft to DB9 Serial Cable (NovAtel part number 60723063)

The serial cable shown below provides a means of interfacing between the COM3 port on the ProPak-LB and another serial communications device, such as a PC. At the ProPak-LB end, the cable is equipped with a 8-pin Switchcraft connector (Switchcraft part number: EN3C8F), which plugs directly into the COM3 port. At the other end, a DB9S connector is provided.



Reference	Description
10	8-pin Switchcraft EN3C8Fconnector
11	DB9S connector
12	Connector key

Figure 57: ProPak-LB 8-Pin Serial Cable

Appendix B Anti-Static Practices

B.1 Overview

Static electricity is electrical charge stored in an electromagnetic field or on an insulating body. This charge can flow as soon as a low-impedance path to ground is established. Static-sensitive units can be permanently damaged by static discharge potentials of as little as 40 volts. Charges carried by the human body, which can be thousands of times higher than this 40 V threshold, can accumulate through as simple a mechanism as walking across non-conducting floor coverings such as carpet or tile. These charges may be stored on clothing, especially when the ambient air is dry, through friction between the body and/or various clothing layers. Synthetic materials accumulate higher charges than natural fibers. Electrostatic voltage levels on insulators may be very high, in the order of thousands of volts.

Various electrical and electronic components are vulnerable to electrostatic discharge (ESD). These include discrete components, hybrid devices, integrated circuits (ICs), and printed circuit boards (PCBs) assembled with these devices.

B.2 Handling ESD-Sensitive Devices

ESD-sensitive devices must only be handled in static-controlled locations. Some recommendations for such handling practices follow:

- Handling areas must be equipped with a grounded table, floor mats, and wrist strap.
- A relative humidity level must be maintained between 20% and 80% non-condensing.
- No ESD-sensitive board or component should be removed from its protective package, except in a static-controlled location.
- A static-controlled environment and correct static-control procedures are required at both repair stations and maintenance areas.
- ESD-sensitive devices must be handled only after personnel have grounded themselves via wrist straps and mats.
- Boards or components should never come in contact with clothing, because normal grounding cannot dissipate static charges on fabrics.
- A circuit board must be placed into an anti-static plastic clamshell before being removed from the work location and must remain in the clamshell until it arrives at a static-controlled repair/test center.
- Circuit boards must not be changed or moved needlessly. Handles may be provided on circuit boards for use in their removal and replacement; care should be taken to avoid contact with the connectors and components.
- On-site repair of ESD-sensitive equipment should not be undertaken except to restore service in an emergency where spare boards are not available. Under these circumstances repair station techniques must be observed. Under normal circumstances a faulty or suspect circuit board must be sent to a repair center having complete facilities, or to the manufacturer for exchange or repair.

- Where protective measures have not been installed, a suitable alternative would be the use of a Portable Field Service Grounding Kit. This consists of a portable mat and wrist strap which must be attached to a suitable ground.
- A circuit board in a static-shielding bag or clamshell may be shipped or stored in a cardboard carton, but the carton must not enter a static-controlled area such as a grounded or dissipative bench top or repair zone. Do not place anything else inside the bag (e.g. repair tags).
- Treat all PCBs and components as ESD sensitive. Assume that you will damage the PCB or component if you are not ESD conscious.
- Do not use torn or punctured static-shielding bags. A wire tag protruding through the bag could act as a "lightning rod", funneling the entire charge into the components inside the bag.
- Do not allow chargeable plastics, such as binders, within 0.6 m of unshielded PCBs.
- Do not allow a PCB to come within 0.3 m of a computer monitor.

B.3 Prime Static Accumulators

Table 31 provides some background information on static-accumulating materials.

Table 31: Static-Accumulating Materials

Work Surfaces	• formica (waxed or highly resistive) • finished wood • synthetic mats • writing materials, note pads, etc.
Floors	• wax-finished • vinyl
Clothes	• common cleanroom smocks • personal garments (all textiles) • non-conductive shoes
Chairs	• finished wood • vinyl • fiberglass
Packing and handling	• common polyethylene bags, wraps, envelopes, and bubble pack • pack foam • common plastic trays and tote boxes
Assembly, cleaning, and repair areas	• spray cleaners • common solder sucker • common solder irons • common solvent brushes (synthetic bristles) • cleaning, drying and temperature chambers

B.4 Handling Printed Circuit Boards

ESD damage to unprotected sensitive devices may occur at any time. ESD events can occur far below the threshold of human sensitivity. Follow this sequence when it becomes necessary to install or remove a circuit board:

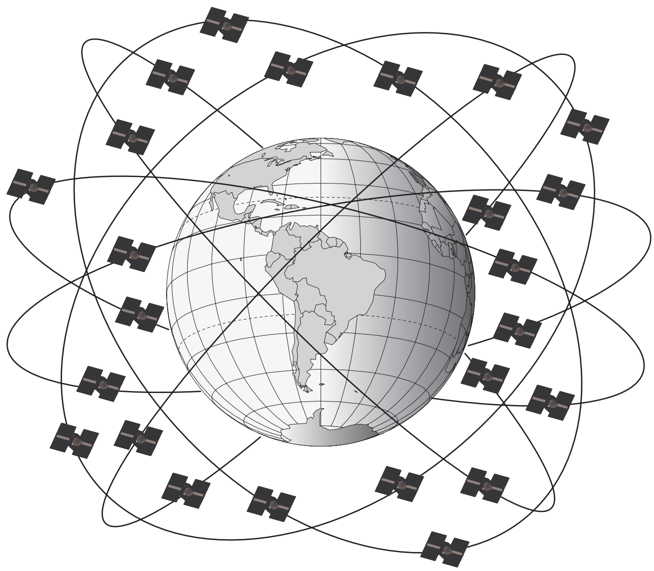
1. After you are connected to the grounded wrist strap, remove the circuit board from the frame and place it on a static-controlled surface (grounded floor or table mat).
2. Remove the replacement circuit board from the static-shielding bag or clamshell and insert it into the equipment.
3. Place the original board into the shielding bag or clamshell and seal it with a label.
4. Do not put repair tags inside the shielding bag or clamshell.
5. Disconnect the wrist strap.

Appendix C GPS Overview

The Global Positioning System (GPS) is a satellite navigation system capable of providing a highly accurate, continuous global navigation service independent of other positioning aids. GPS provides 24-hour, all-weather, worldwide coverage with position, velocity and timing information.

The system uses the NAVSTAR (NAVigation Satellite Timing And Ranging) satellites which consists of 24 operational satellites to provide a GPS receiver with at least six satellites in view at all times. A minimum of four satellites in view are needed to allow the receiver to compute its current latitude, longitude, altitude with reference to mean sea level and the GPS system time.

Figure 58: NAVSTAR Satellite Orbit Arrangement



C.1 GPS System Design

The GPS system design consists of three parts:

- The Space segment
- The Control segment
- The User segment

All these parts operate together to provide accurate three dimensional positioning, timing and velocity data to users worldwide.

C.1.1 The Space Segment

The space segment is composed of the NAVSTAR GPS satellites. The constellation of the system consists of 24 satellites in six 55° orbital planes, with four satellites in each plane. The orbit period of each satellite is approximately 12 hours at an altitude of 20 183 kilometers. This provides a GPS receiver with at least six satellites in view from any point on earth, at any particular time.

The GPS satellite signal identifies the satellite and provides the positioning, timing, ranging data, satellite status and the corrected ephemerides (orbit parameters) of the satellite to the users. The satellites can be identified either by the Space Vehicle Number (SVN) or the Pseudorandom Code Number (PRN). The PRN is used by the NovAtel receiver.

The GPS satellites transmit on two L-band frequencies; one centered at 1575.42 MHz (L1) and the other at 1227.60 MHz (L2). The L1 carrier is modulated by the C/A code (Coarse/Acquisition) and the P code (Precision) which is encrypted for military and other authorized users. The L2 carrier is modulated only with the P code.

C.1.2 The Control Segment

The control segment consists of a master control station, five base stations and three data up-loading stations in locations all around the globe.

The base stations track and monitor the satellites via their broadcast signals. The broadcast signals contain the ephemeris data of the satellites, the ranging signals, the clock data and the almanac data. These signals are passed to the master control station where the ephemerides are re-computed. The resulting ephemerides corrections and timing corrections are transmitted back to the satellites via the data up-loading stations.

C.1.3 The User Segment

The user segment, such as the NovAtel receiver, consists of equipment which tracks and receives the satellite signals. The user equipment must be capable of simultaneously processing the signals from a minimum of four satellites to obtain accurate position, velocity and timing measurements.

C.2 Height Relationships

What is a geoid?

An equipotential surface is any surface where gravity is constant. This surface best represents mean sea-level and not only covers the water but is projected throughout the continents. In North America this surface is most commonly used at its zero value, i.e. all heights are referenced to this surface.

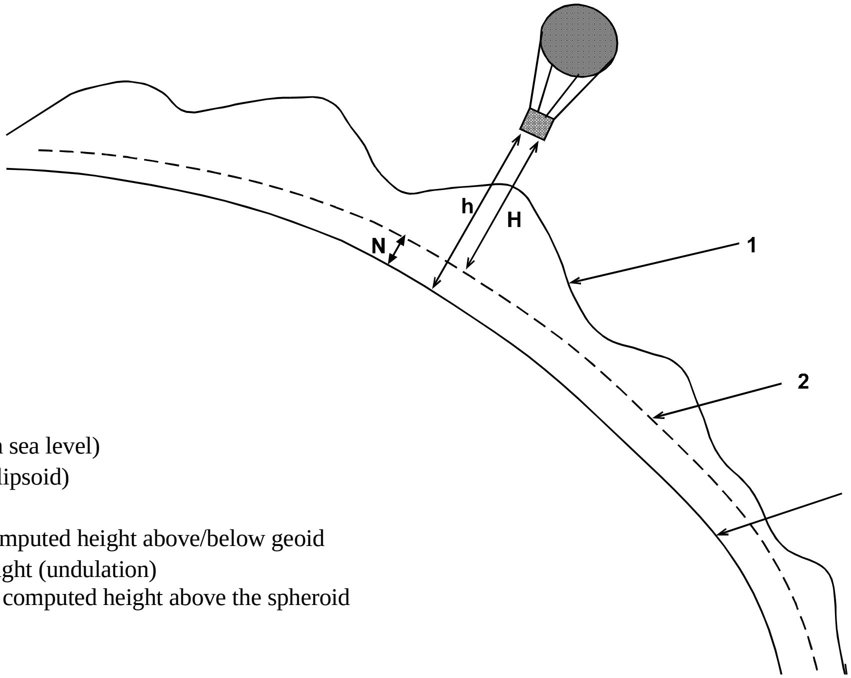
What is an ellipsoid?

An ellipsoid, also known as a spheroid, is a mathematical surface which is sometimes used to represent the earth. Whenever you see latitudes and longitudes describing the location, this coordinate is being referenced to a specific ellipsoid. GPS positions are referred to an ellipsoid known as WGS84 (World Geodetic System of 1984).

What is the relationship between a geoid and an ellipsoid?

The relationship between a geoid and an ellipsoid is shown in *"Illustration of Receiver Height Measurements" on Page 151*.

Figure 59: Illustration of Receiver Height Measurements



References:

1 Topography
2 Geoid (mean sea level)
3 Spheroid (ellipsoid)

H = Receiver computed height above/below geoid
N = Geoidal Height (undulation)
h = GPS system computed height above the spheroid
N = h - H

From the above diagram, and the formula **h = H + N,** to convert heights between the ellipsoid and geoid we require the geoid-ellipsoid separation value. This value is not easy to determine. A world-wide model is generally used to provide these values. NovAtel GPS receivers store this value internally. This model can also be augmented with local height and gravity information. A more precise geoid model is available from government survey agencies e.g. U.S. National Geodetic Survey or Geodetic Survey of Canada (see *Appendix G, Standards/References on Page 166*).

Why is this important for GPS users?

The above formula is critical for GPS users as they typically obtain ellipsoid heights and need to convert these into mean sea-level heights. Once this conversion is complete, users can relate their GPS derived heights to more “usable” mean sea-level heights.

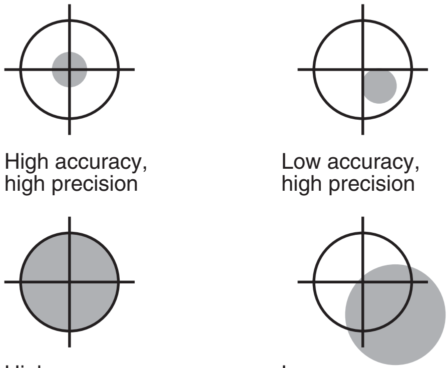
C.3 GPS Positioning

GPS positioning can be categorized as follows:

1. single-point or relative
2. static or kinematic
3. real-time or post-mission data processing

A distinction should be made between *accuracy* and *precision*. *Accuracy* refers to how close an estimate or measurement is to the true but unknown value; *precision* refers to how close an estimate is to the mean (average) estimate. *“Accuracy versus Precision” on Page 152* illustrates various relationships between these two parameters: the true value is "located" at the intersection of the crosshairs, the centre of the shaded area is the "location" of the mean estimate, and the radius of the shaded area is a measure of the uncertainty contained in the estimate.

Figure 60: Accuracy versus Precision[1]



C.3.1 Single-Point vs. Relative Positioning

In *single-point* positioning, coordinates of a GPS receiver at an unknown location are sought with respect to the earth's reference frame by using the known positions of GPS satellites being tracked. The position solution generated by the receiver is initially developed in earth-centered coordinates which can subsequently be converted to any other coordinate system. With as few as four GPS satellites in view, the absolute position of the receiver in three-dimensional space can be determined. Only one receiver is needed.

In *relative* positioning, also known as *differential* positioning, the coordinates of a GPS receiver at an unknown point (the “rover” station) are sought with respect to a GPS receiver at a known point (the “base” station). The concept is illustrated in *Figure 61, Example of Differential Positioning on Page 153*. The relative-position accuracy of two receivers locked on the same satellites and not far removed from each other - up to tens of kilometers - is extremely high. The largest error contributors in single-point positioning are those associated with atmospheric-induced effects. These errors, however, are highly correlated for adjacent receivers and hence cancel out in relative measurements. Since the position of the base station can be determined to a high degree of accuracy using conventional surveying techniques, any differences between its known position and the position computed using GPS techniques can be attributed to various components of error as well as the receiver’s clock bias. Once the estimated clock bias is removed, the remaining error on each pseudorange can be determined. The base station sends information about each satellite to the rover station, which in turn can determine its position much more exactly than would be possible otherwise.

The advantage of relative positioning is that much greater precision (presently as low as 2 mm, depending on the method and environment) can be achieved than by single-point positioning. In order for the observations of the base station to be integrated with those of the rover station, relative positioning requires either a data link between the two stations (if the positioning is to be achieved in

1. Environment Canada, 1993, Guideline for the Application of GPS Positioning, p. 22.
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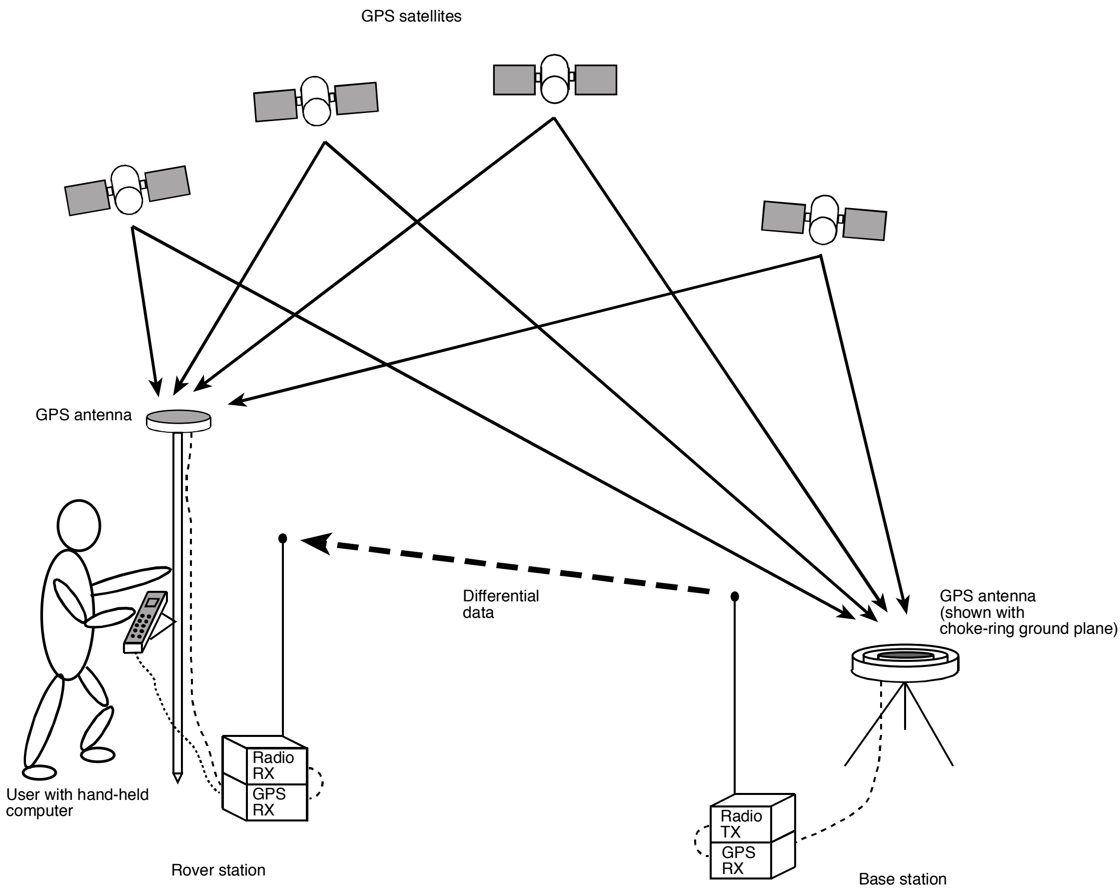
real-time) or else post-processing of the data collected by the rover station. At least four GPS satellites in view are still required. The absolute accuracy of the rover station's computed position will depend on the accuracy of the base station's position.

Figure 61: Example of Differential Positioning



C.3.2 Static vs. Kinematic Positioning

Static and *kinematic positioning* refer to whether a GPS receiver is stationary or in motion while collecting GPS data.

C.3.3 Real-time vs. Post-mission Data Processing

Real-time or *post-mission* data processing refer to whether the GPS data collected by the receiver is processed as it is received or after the entire data-collection session is complete.

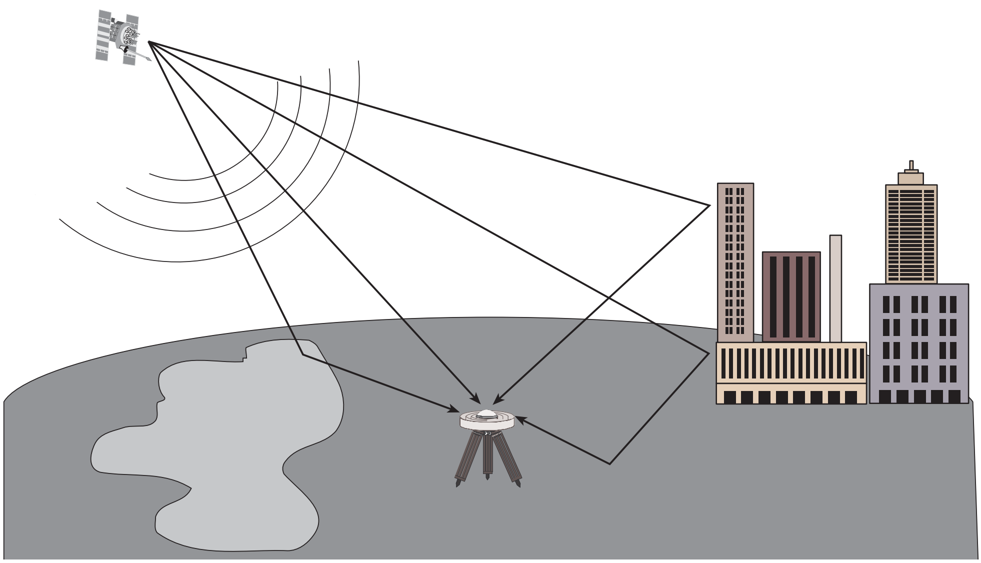
Appendix D Multipath

D.1 Multipath

Multipath signal reception is one of the most plaguing problems that detracts from the accuracy potential of GPS pseudorange differential positioning systems. This section will provide a brief look at the problems of multipath reception and some solutions developed by NovAtel.

Multipath occurs when an RF signal arrives at the receiving antenna from more than one propagation route (multiple propagation paths).

Figure 62: Illustration of GPS Signal Multipath



D.1.1 Why Does Multipath Occur?

When the GPS signal is emitted from the satellite antenna, the RF signal propagates away from the antenna in many directions. Because the RF signal is emitted in many directions simultaneously and is traveling different paths, these signals encounter various and differing natural and man-made objects along the various propagation routes. Whenever a change in medium is encountered, the signal is either absorbed, attenuated, refracted, or reflected.

Refraction and reflection cause the signals to change direction of propagation. This change in path directions often results in a convergence of the direct path signal with one or more of the reflected signals. When the receiving antenna is the point of convergence for these multipath signals, the consequences are generally not favorable.

Whenever the signal is refracted, some signal polarity shifting takes place; and when full reflection occurs, full polarity reversal results in the propagating wave. The consequences of signal polarity shifting and reversal at the receiving antenna vary from minor to significant. As well, refracted and reflected signals generally sustain some degree of signal amplitude attenuation.

It is generally understood that, in multipath conditions, both the direct and reflected signals are present at the antenna and the multipath signals are lower in amplitude than the direct signal. However, in some situations, the direct signal may be obstructed or greatly attenuated to a level well below that of the received multipath signal. Obstruction of direct path signals is very common in city environments where many tall buildings block the line of sight to the satellites. As buildings generally contain an abundance of metallic materials, GPS signal reflections are abundant (if not overwhelming) in these settings. Obstructions of direct path signals can occur in wilderness settings as well. If the GPS receiver is in a valley with nearby hills, mountains and heavy vegetation, signal obstruction and attenuation are also very common.

D.1.2 Consequences of Multipath Reception

Because GPS is a radio ranging and positioning system, it is imperative that ground station signal reception from each satellite be of direct line of sight. This is critical to the accuracy of the ranging measurements. Obviously, anything other than direct line of sight reception will skew and bias the range measurements and thus the positioning triangulation (or more correctly, trilateration). Unfortunately, multipath is almost always present to some degree, due to real world conditions.

When a GPS multipath signal converges at the GPS antenna, there are two primary problems that occur:

1. a multiple signal with amplitude and phase shifting, and
2. a multiple signal with differing ranges.

When a direct signal and multipath signal are intercepted by the GPS antenna, the two signals will sum according to the phase and amplitude of each. This summation of signals causes the composite to vary greatly in amplitude, depending on the degree of phase shift between the direct signal versus the multipath signal. If the multipath signal lags the direct path signal by less than 90° the composite signal will increase in amplitude (relative to the direct signal, depending on the degree of phase shift between 0° and 90°). As well, if the multipath signal lags the direct path signal by greater than 90° but less than 270° the composite signal will decrease in amplitude. Depending on the relative amplitude of the multipath signal (or signals), the composite signal being processed by the receiver correlator may experience substantial amplitude variations, which can play havoc with the receiver's automatic gain control circuitry (AGC) as it struggles to maintain constant signal levels for the receiver correlator. A worst case scenario is when the multipath signal experiences a lag of 180° and is near the same strength as the direct path signal – this will cause the multipath signal to almost completely cancel out the direct path signal, resulting in loss of satellite phase lock or even code lock.

Because a multipath signal travels a greater distance to arrive at the GPS antenna, the two C/A code correlations are, by varying degrees, displaced in time, which in turn causes distortion in the correlation peak and thus ambiguity errors in the pseudorange (and carrier phase, if applicable) measurements.

As mentioned in previous paragraphs, it is possible that the received multipath signal has greater amplitude than the direct path signal. In such a situation the multipath signal becomes the dominant signal and receiver pseudorange errors become significant due to dominant multipath biases and may exceed 150 meters. For single point pseudorange positioning, these occasional levels of error may be tolerable, as the accuracy expectations are at the 1.8 meter CEP level (using standard correlator). However, for pseudorange single differencing DGPS users, the accuracy expectations are at the one to

0.45 meter CEP level (with no multipath). Obviously, multipath biases now become a major consideration in trying to achieve the best possible pseudorange measurements and position accuracy.

If a differential base station is subject to significant multipath conditions, this in turn will bias the range corrections transmitted to the differential rover receiver. And in turn, if the rover receiver also experiences a high level of multipath, the rover receiver position solutions will be significantly biased by multipath from both stations. Thus, when the best possible position solutions are required, multipath is certainly a phenomenon that requires serious consideration.

D.2 Hardware Solutions For Multipath Reduction

A few options exist by which GPS users may reduce the level of multipath reception. Among these include: antenna site selection, special antenna design, and ground plane options.

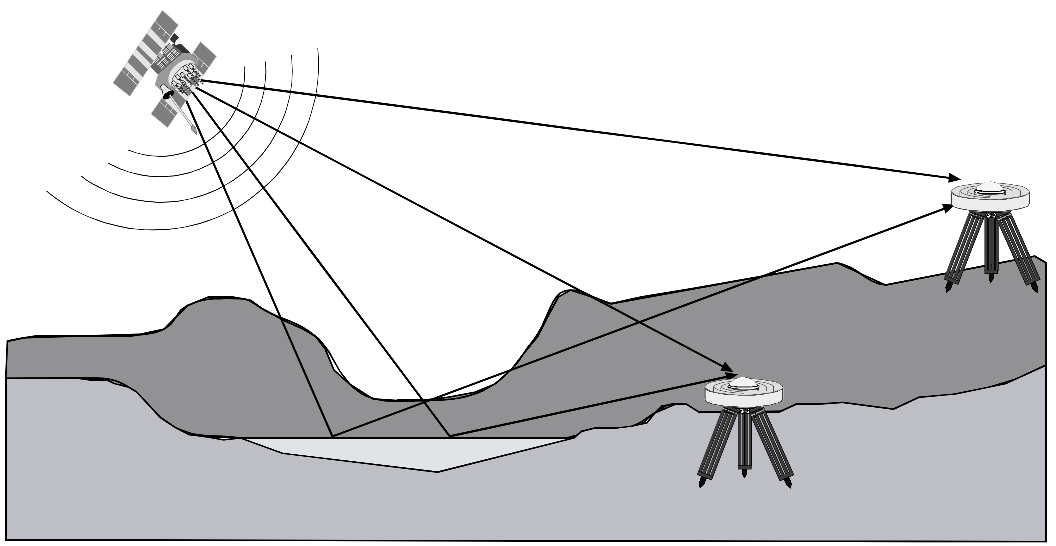
D.2.1 Antenna Site Selection

Multipath reception is basically a condition caused by environmental circumstances. Some of these conditions you may have a choice about and some you may not.

Many GPS reception problems can be reduced, to some degree, by careful antenna site selection. Of primary importance is to place the antenna so that unobstructed line-of-sight reception is possible from horizon to horizon and at all bearings and elevation angles from the antenna. This is, of course, the ideal situation, which may not be possible under actual operating conditions.

Try to place the antenna as far as possible from obvious reflective objects, especially reflective objects that are above the antenna’s radiation pattern horizon. Close-in reflections will be stronger, and typically have a shorter propagation delay allowing for auto correlation of signals with a propagation delay of less than one C/A code chip (300 meters).

Figure 63: GPS Signal Multipath vs. Increased Antenna Height



When the antenna is in an environment with obstructions and reflective surfaces in the vicinity, it is advantageous to mount the antenna as high as possible to reduce the obstructions, as well as reception from reflective surfaces, as much as possible.

Water bodies are extremely good reflectors of GPS signals. Because of the short wavelengths at GPS frequencies, even small ponds and water puddles can be a strong source of multipath reception, especially for low angle satellites. Thus, it can be concluded that water bodies such as lakes and oceans are among the most troublesome multipath environments for low angle signal reception. Obviously, water body reflections are a constant problem for ocean going vessels.

D.2.2 Antenna Designs

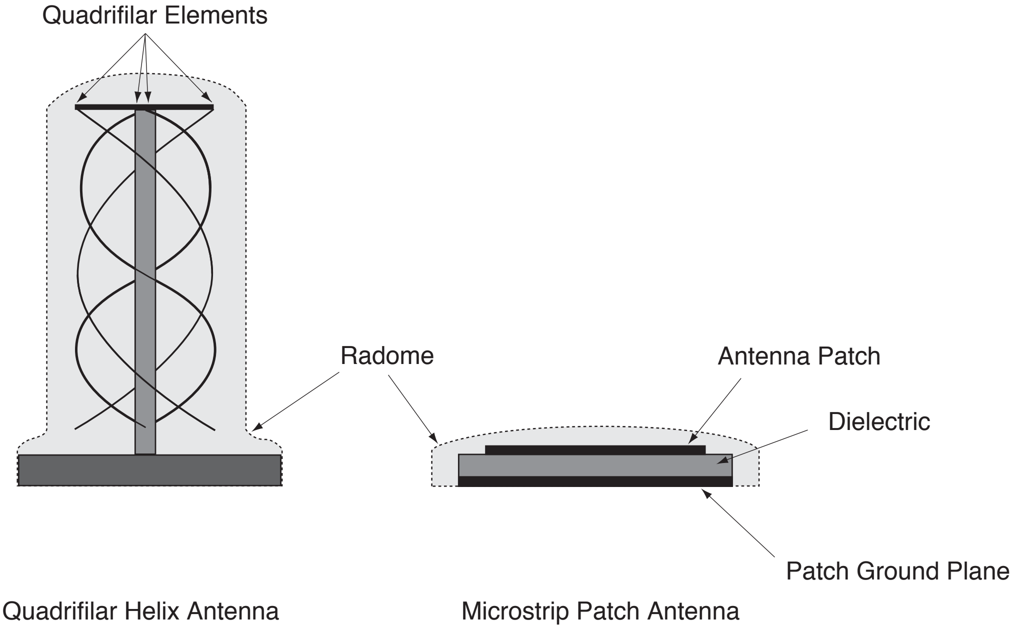
Low angle reflections, such as from water bodies, can be reduced by careful selection of the antenna design. For example, flat plate microstrip patch antennas have relatively poor reception properties at low elevation angles near their radiation pattern horizon.

Quadrifilar helix antennas and other similar vertically high profile antennas tend to have high radiation gain patterns at the horizon. These antennas, in general, are more susceptible to the problems resulting from low angle multipath reception. So, for marine vessels, this type of antenna encourages multipath reception. However, the advantages of good low angle reception also means that satellites can be acquired more easily while rising in the horizon. As well, vessels subject to pitch and roll conditions will experience fewer occurrences of satellite loss of lock.

A good antenna design will also incorporate some form of left hand circular polarization (LHCP) rejection. Multipath signals change polarization during the refraction and reflection process. This means that generally, multipath signals may be LHCP oriented. This property can be used to advantage by GPS antenna designers. If a GPS antenna is well designed for RHCP polarization, then LHCP multipath signals will automatically be attenuated somewhat during the induction into the antenna. To further enhance performance, antennas can be designed to increase the rejection of LHCP signals. NovAtel’s GPSAntenna model 501 is an example of an antenna optimized to further reject LHCP signals by more than 10 dB.

The Model 700 GPSAntenna is an active antenna designed to operate at the GPS L1 and L2 frequencies, 1575.42 and 1227.60 MHz. The microstrip receiving elements are coupled to filters and a low-noise amplifier (LNA). The unit is optimized to receive right-hand-circularly-polarized signals, and its radiation pattern is shaped to reduce signals arriving at low elevation angles; these features decrease the errors associated with electromagnetic interference and multipath. Also, the model 700 gain roll-off compares well to a patch antenna roll-off mounted on a large choke ring ground plane. This antenna provides comparable performance to the choke ring ground plane antenna while being much lighter and smaller.

Figure 64: Illustration of Quadrifilar vs. Microstrip Patch Antennae



D.2.3 Antenna Ground Planes

Nearby objects can influence the radiation pattern of an antenna. Thus, one of the roles of the antenna ground plane is to create a stabilizing artificial environment on which the antenna rests and which becomes a part of the antenna structure and its resultant radiation pattern.

A small ground plane (relative to one wavelength at the operating frequency) may have minimal stabilizing effect, whereas a large ground plane (multiple wavelengths in size) will have a highly stabilizing effect.

Large ground planes also exhibit a shielding effect against RF signal reflections originating below the antenna's radiation pattern horizon. This can be a very effective low angle shield when the antenna is elevated on a hill or other structure above other reflecting surfaces such as vehicles, railway tracks, soil with high moisture content, water bodies, etc.

One of the drawbacks of a "flat plate" ground plane is that it gives a “hard boundary condition”, i.e. allowing electromagnetic waves to propagate along the ground plane and diffract strongly from its edge. The “soft boundary” condition, on the other hand, will prevent the wave from propagating along the surface of the ground plane and thereby reducing the edge diffraction effects. As a result the antenna will exhibit a completely different radiation pattern. The “soft boundary” condition is typically achieved by a quarter wavelength deep, transversely corrugated ground plane surface (denoted as “choke ring ground plane”). When the depth of the corrugation (choke rings) is equal to a quarter wavelength, the surface wave vanishes, and the surface impedance becomes infinite and hence provides the “soft boundary” condition for the electromagnetic field. This results in modifications to the antenna radiation pattern that is characterized by low back lobe levels, no ripples in the main lobe, sharper amplitude, roll-off near the horizon and better phase center stability (there are smaller variations in 2 axes). This is what makes NovAtel's GPS antennas so successful when used with the NovAtel GPSAntenna choke ring ground plane.

D.2.4 NovAtel’s Internal Receiver Solutions for Multipath Reduction

The multipath antenna hardware solutions described in the previous paragraphs are capable of achieving varying degrees of multipath reception reduction. These options, however, require specific conscious efforts on the part of the GPS user. In many situations, especially kinematic, few (if any) of the above solutions may be effective or even possible to incorporate. By far, the best solutions are those which require little or no special efforts in the field on the part of the GPS user. This is what makes NovAtel’s internal receiver solutions so desirable and practical.

NovAtel has placed long term concerted effort into the development of internal receiver solutions and techniques that achieve multipath reduction, all of which are transparent to the receiver user. These achievements have led first to Narrow Correlator tracking technology and now PAC technology.

It utilizes innovative patented correlator delay lock loop (DLL) techniques. As it is beyond the scope of this manual to describe in detail how the correlator techniques achieve the various levels of performance, the following paragraphs will provide highlights of the advantages of PAC technology.

D.2.4.1 Pulse Aperture Correlator Technology (PAC)

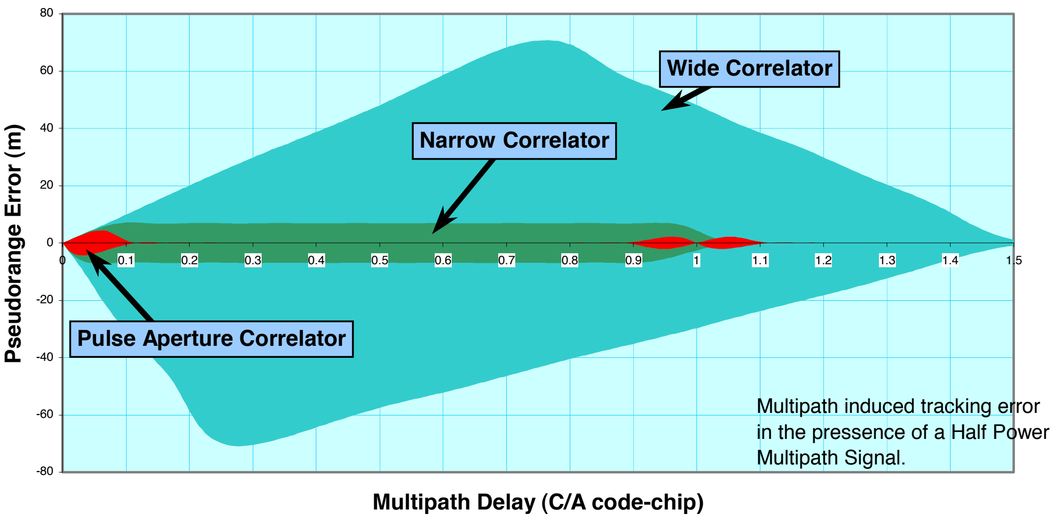
NovAtel's OEM4 family of receivers achieve a higher level of pseudorange positioning performance versus standard (wide) or narrow correlator receivers, by virtue of its celebrated PAC technology. By utilizing PAC tracking techniques, the receiver is capable of pseudorange measurement improvements better than 4:1 when compared to standard (wide) correlation techniques and 2:1 when compared to narrow correlation techniques. The PAC technology dramatically reduces multipath reception (approaching a factor of 16 compared to standard correlators and 8 compared to narrow correlators) by virtue of its very narrow correlation function.

Figure 65, Comparison of Multipath Envelopes on Page 160, illustrates relative multipath-induced tracking errors encountered by the different correlation technologies. As can be seen, standard correlators are susceptible to substantial multipath biases for C/A code chip delays of up to 1.5 chips, with the most significant C/A code multipath bias errors occurring at about 0.25 to 0.75 chips (approaching 80 m error). The Narrow Correlator tracking technology multipath susceptibility peaks at about 0.2 chips (about 10 m error) and remains relatively constant out to 0.95 chips where it rapidly declines to negligible error after 1.1 chips. On the other hand the PAC technology multipath susceptibility peaks at about 0.1 chips (about 5 m error) then reduces to a negligible amount at about the 0.2 chip mark.

While positioning in single point mode, the multipath and ranging improvement benefits of a PAC technology receiver versus narrow or standard correlators, are overridden by a multitude of GPS system biases and errors. In either case positioning accuracy will be in the order of 1.8 m (CEP). However the benefits of PAC technology becomes most significant during pseudorange DGPS operation, where the GPS system biases are largely removed.

Receivers operating DGPS with standard correlators typically achieve positioning accuracies in the two to five meter CEP range (low multipath environment and using a choke ring ground plane or GPS-702 antenna). NovAtel's Narrow Correlator tracking technology receivers are able to achieve accuracies in the order of 0.75m CEP while NovAtel's PAC technology receivers are able to achieve accuracies in the 0.35 to 0.5 m CEP. PAC technology achieves this higher accuracy through a combination of low noise ranging measurements combined with a very narrow correlation window that dramatically reduces the effects of multipath interference and distortion.

Figure 65: Comparison of Multipath Envelopes



D.2.4.2 Summary

Any localized propagation delays or multipath signal reception cause biases to the GPS ranging measurements that cannot be differenced by traditional DGPS single or double differencing techniques. Multipath is recognized as the greatest source of errors encountered by a system operating in single-point or differential mode. It has been discussed that careful site selection and the GPSAntenna Model 700, or good antenna design combined with a choke ring ground plane, are fairly effective means of reducing multipath reception.

Internal receiver solutions for multipath elimination are achieved through various types of correlation techniques, where the "standard correlator" is the reference by which all other techniques can be compared.

PAC technology has a four fold advantage over standard correlators: improved ranging measurements due to a sharper, less noisy correlation peak, and reduced susceptibility to multipath due to rejection of C/A code delays of greater than 1.0 chip. When used with a choke ring ground plane, PAC technology provides substantial performance gains over standard or narrow correlator receivers operating in differential mode.

Appendix E TTFF and Satellite Acquisition

Time to First Fix, or TTFF, is the time it takes the receiver to calculate a position after a reset or upon power-up. The TTFF varies and depends on what is stored in non-volatile memory (NVM) at the time of power-up, and on what other information is available. See *Table 32* for a summary of what can aid in improving TTFF.

The speed at which the receiver locates and locks onto new satellites is improved if the receiver has approximate time and position, as well as an almanac. This allows the receiver to compute the elevation of each satellite so it can tell which satellites are visible and their Doppler offsets, improving TTFF.

Without this information, the receiver must blindly search through all possible satellite PRN codes and Doppler offsets (as in a cold start).

Once satellites are acquired, the receiver will normally have to wait another 18-36 seconds before receiving broadcast ephemeris data to calculate a position. To avoid this delay, the receiver saves ephemeris data in its NVM and will use that data if it is less than 2 hours old.

Table 32: Typical Receiver TTFF

Mode	Information Available to the Receiver				Typical TTFF
	Approx. Position	Approx. Time	Almanac	Recent Ephemeris	
Cold Start	no	no	no	no	50 s
Warm Start	yes	yes	yes	no	40 s
Hot Start	yes	yes	yes	yes	30 s

☒ The TTFF numbers quoted assume an open environment. Poor satellite visibility or frequent signal blockage increases TTFF.

Upon power-up, the receiver does not know its position or time, and therefore, cannot use almanac information to aid satellite acquisition. You can set an approximate GPS time using the SETAPPROXTIME command or RTCAEPHEM message. The RTCAEPHEM message contains GPS week and seconds and the receiver will use that GPS time if the time is not yet known. Several logs provide base station coordinates and the receiver will use them as an approximate position allowing it to compute satellite visibility. Alternately, you can set an approximate position by using the SETAPPROXPOS command.

Approximate time and position must be used in conjunction with a current almanac to aid satellite acquisition. For a summary of the command and logs used to inject an approximated time or position into the receiver, see *Table 33*.

Table 33: Approximate Time and Position Methods

Approximate	Command	Log
Time	SETAPPROXTIME	RTCAEPHEM
Position	SETAPPROXPOS	RTCAREF or CMRREF or RTCM3

Base station aiding can help in these environments. A set of ephemerides can be injected into a rover station by broadcasting the RTCAEPHEM message from a base station. This is also useful in environments where there is frequent loss of lock (GPS ephemeris is three frames long - each frame requires 6 seconds of continuous lock to collect the ephemeris data) or, when no recent ephemerides (new or stored) are available.

Appendix F Unit Conversion

Section *E.1* to *E.4* list commonly used equivalents between the SI (Système Internationale) units of weights and measures used in the metric system, and those used in the imperial system. A complete list of hexadecimal values with their binary equivalents is given in Section *E.5* while an example of the conversion from GPS time of week to calendar day is shown in Section *E.6*.

F.1 Distance

1 meter (m) = 100 centimeters (cm) = 1000 millimeters (mm)

1 kilometer (km) = 1000 meters (m)

1 nautical mile = 1852 m

1 international foot = 0.3048 m

1 statute mile = 1609 m

1 US survey foot = 0.3048006096 m

1 inch = 25.4 mm

F.2 Volume

1 liter (l) = 1000 cubic centimeters (cc)

1 gallon (Imperial) = 4.546 liters

1 gallon (US) = 3.785 liters

F.3 Temperature

degrees Celsius = (5/9) x [(degrees Fahrenheit) - 32]

degrees Fahrenheit = [(9/5) x (degrees Celsius)] + 32

F.4 Weight

1 kilogram (kg) = 1000 grams

1 pound = 0.4536 kilogram (kg)

F.5 Hexadecimal, Binary and Decimal Equivalents

Hex	Binary	Decimal	Hex	Binary	Decimal	Hex	Binary	Decimal	Hex	Binary	Decimal
0	0000	0	4	0100	4	8	1000	8	C	1100	12
1	0001	1	5	0101	5	9	1001	9	D	1101	13
2	0010	2	6	0110	6	A	1010	10	E	1110	14
3	0011	3	7	0111	7	B	1011	11	F	1111	15

Binary	Decimal	Binary	Decimal	Binary	Decimal	Binary	Decimal
10000	16	100101	37	111010	58	1001111	79
10001	17	100110	38	111011	59	1010000	80
10010	18	100111	39	111100	60	1010001	81
10011	19	101000	40	111101	61	1010010	82
10100	20	101001	41	111110	62	1010011	83
10101	21	101010	42	111111	63	1010100	84
10110	22	101011	43	1000000	64	1010101	85
10111	23	101100	44	1000001	65	1010110	86
11000	24	101101	45	1000010	66	1010111	87
11001	25	101110	46	1000011	67	1011000	88
11010	26	101111	47	1000100	68	1011001	89
11011	27	110000	48	1000101	69	1011010	90
11100	28	110001	49	1000110	70	1011011	91
11101	29	110010	50	1000111	71	1011100	92
11110	30	110011	51	1001000	72	1011101	93
11111	31	110100	52	1001001	73	1011110	94
100000	32	110101	53	1001010	74	1011111	95
100001	33	110110	54	1001011	75	1100000	96
100010	34	110111	55	1001100	76	1100001	97
100011	35	111000	56	1001101	77	1100010	98
100100	36	111001	57	1001110	78	1100011	99
						1100100	100[a]

a. These binary to decimal equivalents only go up to decimal 100 for the purpose of example. Please use a calculator for other conversions.

F.6 GPS Time Conversions

The following sections provided examples for converting to and from GPS time.

F.6.1 GPS Time of Week To Day of Week with Time of Day

The value given for GPS Time of Week represents the number of seconds into the week. Therefore, to determine the day and time from that value, calculations are performed to break down the number of seconds into day, hour, minute, and second values.

For example, starting with a GPS Time of Week of *511200 seconds*, the calculations are done as follows:

511200 seconds	Day of Week	511200 / 86400 seconds per day	**5**.916666667 **days**
	Hour	0.916666667 × 86400 / 3600 seconds per hour	**22**.0000 **hours**
	Minute	0.000 × 3600 / 60 seconds per minute	**0**.000 **minutes**
	Second	0.000 × 60 seconds per minute	**0**.000 **seconds**

Therefore, 511200 seconds represents *day 5 (Thursday) + 22 hours, 0 minutes, 0 seconds into Friday.*

F.6.2 Calendar Date to GPS Time

Converting a calendar date to GPS Time is calculated as shown in the example below, using the calendar date *13:30 hours*, *January 28*, *2005*.

Years from January 6, 1980 to January, 28, 2005		25 years
Number of days in 25 years (25 years × 365 days/year)		9,125 days
Add one day for each leap year (a year which is divisible by 4 but not by 100, unless it is divisible by 400 as every 100 years a leap year is skipped)	+	7 days
Add days from January 6 to January 27 (January 28th is not finished)	+	22 days
Total days	=	9,154 days
Total number of seconds (9154 days × 86400 seconds/day)	=	790,905,600 seconds
Total number of weeks (790,905,600 seconds / 604,800 seconds/week)	=	**1307**.714285 **weeks**
Days into week (0.714285 × 7 days/week)		5 days
Number of seconds in 5 days (5 days × 86400 seconds/day)		432,000 seconds
Add number of seconds into the 6th day, January 28th (13.5 hours × 3600 seconds/hour)	+	48,600 seconds
Total seconds into week	=	**480,600 seconds**

The resulting value for GPS Time is *Week 1307, 480,600 seconds*.

Appendix G Standards/References

RTCM STANDARDS REFERENCE

For detailed specifications of RTCM, refer to RTCM SC104 Version 2.1 of "RTCM Recommended Standards For Differential NAVSTAR GPS Service", January 3, 1994

Radio Technical Commission For Maritime Services
1800 Diagonal Road, Suite 600
Alexandria, VA 22314-2480, USA

Phone: +1-703-684-4481 Fax: +1-703-836-4229
E-Mail: information@rtcm.org Website: http://www.rtcm.org/

RTCA STANDARDS REFERENCE

For copies of the Minimum Aviation System Performance Standards DGNSS Instrument Approach System: Special Category-I (SCAT-I), contact:

RTCA, Inc.
1828 L Street, NW
Suite 805
Washington, DC 20036

Phone: 202-833-9339 Fax: 202-833-9434
E-Mail: info@rtca.org Website: http://www.rtca.org

GPS SPS SIGNAL SPECIFICATION REFERENCE

For copies of the Interface Control Document (ICD)-GPS-200, contact:

ARINC Research Corporation
2551 Riva Road
Annapolis, MD 21401-7465

Phone: 410-266-4000 Fax: 410-266-4049
Website: http://www.arinc.com

NMEA REFERENCE

National Marine Electronics Association, NMEA 0183 Standard for Interfacing Marine Electronic Devices, Version 2.00, January 1, 1992

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✉ Website addresses may be subject to change however they are accurate at the time of publication.

Appendix H GPS Glossary

ASCII	A 7-bit wide serial code describing numbers, upper and lower case characters, special and non-printing characters. Typically used for textual data.
Acquisition	The process of locking onto a satellite's C/A code and P code. A receiver acquires all available satellites when it is first powered up, then acquires additional satellites as they become available and continues tracking them until they become unavailable.
Address Field	For sentences in the NMEA standard, the fixed length field following the beginning sentence delimiter "$" (HEX 24). For NMEA approved sentences, composed of a two character talker identifier and a three character sentence formatter. For proprietary sentences, composed of the character "P" (HEX 50) followed by a three character manufacturer identification code.
Almanac	A set of orbit parameters that allows calculation of approximate GPS satellite positions and velocities. The almanac is used by a GPS receiver to determine satellite visibility and as an aid during acquisition of GPS satellite signals.
Almanac Data	A set of data which is downloaded from each satellite over the course of 12.5 minutes. It contains orbital parameter approximations for all satellites, GPS to universal standard time (UTC) conversion parameters, and single-frequency ionospheric model parameters.
Anti-Spoofing	Denial of the P-code by the Control Segment is called Anti-Spoofing. It is normally replaced by encrypted Y-code, [see *P-Code* and *Y-Code*]
Attenuation	Reduction of signal strength
Azimuth	The horizontal direction of a celestial point from a terrestrial point, expressed as the angular distance from 000° (reference) clockwise through 360°. The reference point is generally True North, but may be Magnetic North, or Relative (ship's head).
Base Station	The GPS receiver which is acting as the stationary reference. It has a known position and transmits messages for the rover receiver to use to calculate its position.
Bearing	The horizontal direction of one terrestrial point from another terrestrial point, expressed as the angular distance from a reference direction, usually measured from 000° at the reference direction clockwise through 360°. The reference point may be True North, Magnetic North, or Relative (ship's head).
Carrier	The steady transmitted RF signal whose amplitude, frequency, or phase may be modulated to carry information.
Carrier Phase Ambiguity	The number of integer carrier phase cycles between the user and the satellite at the start of tracking. (Sometimes ambiguity for short)

Carrier Phase Measurements These are "accumulated doppler range" (ADR) measurements. They contain the instantaneous phase of the signal (modulo 1 cycle) plus some arbitrary number of integer cycles. Once the receiver is tracking the satellite, the integer number of cycles correctly accumulates the change in range seen by the receiver. When a "lock break" occurs, this accumulated value can jump an arbitrary integer number of cycles (this is called a cycle slip).

Checksum By NMEA standard, a validity check performed on the data contained in the sentences, calculated by the talker, appended to the message, then recalculated by the listener for comparison to determine if the message was received correctly. Required for some sentences, optional for all others.

Circular Error Probable (CEP) Circular error probable; the radius of a circle such that 50% of a set of events occur inside the boundary.

Coarse Acquisition (C/A) Code A pseudorandom string of bits that is used primarily by commercial GPS receivers to determine the range to the transmitting GPS satellite. The 1023 chip C/A code repeats every 1 ms giving a code chip length of 300 m which, is very easy to lock onto.

Communication Protocol A method established for message transfer between a talker and a listener which includes the message format and the sequence in which the messages are to be transferred. Also includes the signalling requirements such as bit rate, stop bits, parity, and bits per character.

Control Segment The Master Control Station and the globally dispersed Reference Stations used to manage the GPS satellites, determine their precise orbital parameters, and synchronize their clocks.

Coordinated Universal Time (UTC) This time system uses the second-defined true angular rotation of the Earth measured as if the Earth rotated about its Conventional Terrestrial Pole. However, UTC is adjusted only in increments of one second. The time zone of UTC is that of Greenwich Mean Time (GMT).

Course The horizontal direction in which a vessel is to be steered or is being steered; the direction of travel through the air or water. Expressed as angular distance from reference North (either true, magnetic, compass, or grid), usually 000° (north), clockwise through 360°. Strictly, the term applies to direction through the air or water, not the direction intended to be made good over the ground [see *Track*]. Differs from heading.

Course Made Good (CMG) The single resultant direction from a given point of departure to a subsequent position; the direction of the net movement from one point to the other. This often varies from the track caused by inaccuracies in steering, currents, cross-winds, etc. This term is often considered to be synonymous with Track Made Good, however, Course Made Good is the more correct term.

Course Over Ground (COG) The actual path of a vessel with respect to the Earth (a misnomer in that courses are directions steered or intended to be steered through the water with respect to a reference meridian); this will not be a straight line if the vessel's heading yaws back and forth across the course.

Cross Track Error (XTE) The distance from the vessel's present position to the closest point on a great Circle line connecting the current waypoint coordinates. If a track offset has been specified in the receiver SETNAV command, the cross track error will be relative to the offset track great circle line.

Cycle Slip When the carrier phase measurement jumps by an arbitrary number of integer cycles. It is generally caused by a break in the signal tracking due to shading or some similar occurrence.

Dead Reckoning (DR) The process of determining a vessel's approximate position by applying from its last known position a vector or a series of consecutive vectors representing the run that has since been made, using only the courses being steered, and the distance run as determined by log, engine rpm, or calculations from speed measurements.

Destination The immediate geographic point of interest to which a vessel is navigating. It may be the next waypoint along a route of waypoints or the final destination of a voyage.

Differential GPS (DGPS) A technique to improve GPS accuracy that uses pseudorange errors at a known location to improve the measurements made by other GPS receivers within the same general geographic area.

Dilution of Precision (DOP) A numerical value expressing the confidence factor of the position solution based on current satellite geometry. The lower the value, the greater the confidence in the solution. DOP can be expressed in the following forms.

GDOP - uncertainty of all parameters (latitude, longitude, height, clock offset)
PDOP - uncertainty of 3D parameters (latitude, longitude, height)
HTDOP - uncertainty of 2D and time parameters (latitude, longitude, time)
HDOP - uncertainty of 2D parameters (latitude, longitude)
VDOP - uncertainty of height parameter
TDOP - uncertainty of clock offset parameter

Doppler The change in frequency of sound, light or other wave caused by movement of its source relative to the observer.

Doppler Aiding A signal processing strategy, which uses a measured Doppler shift to help a receiver smoothly track the GPS signal, to allow more precise velocity and position measurement.

Double-Difference A mathematical technique comparing observations by differencing between receiver channels and then between the base and rover receivers.

Double-Difference Carrier Phase Ambiguity Carrier phase ambiguities which are differenced between receiver channels and between the base and rover receivers. They are estimated when a double-difference mechanism is used for carrier phase positioning. (Sometimes double-difference ambiguity or ambiguity, for short)

Earth-Centred-Earth-Fixed (ECEF) This is a coordinate-ordinate system which has the X-coordinate in the earth's equatorial plane pointing to the Greenwich prime meridian, the Z-axis pointing to the north pole, and the Y-axis in the equatorial plane 90° from the X-axis with an orientation which forms a right-handed XYZ system.

Elevation	The angle from the horizon to the observed position of a satellite.
Ellipsoid	A smooth mathematical surface which represents the earth's shape and very closely approximates the geoid. It is used as a reference surface for geodetic surveys, refer to the MATCHEDPOS log in user manual *Volume 2, Command and Log Reference.*
Ellipsoidal Height	Height above a defined ellipsoid approximating the surface of the earth.
Ephemeris	A set of satellite orbit parameters that are used by a GPS receiver to calculate precise GPS satellite positions and velocities. The ephemeris is used in the determination of the navigation solution and is updated periodically by the satellite to maintain the accuracy of GPS receivers.
Ephemeris Data	The data downlinked by a GPS satellite describing its own orbital position with respect to time.
Epoch	Strictly a specific point in time. Typically when an observation is made.
Field	A character or string of characters immediately preceded by a field delimiter.
Fixed Ambiguity Estimates	Carrier phase ambiguity estimates which are set to a given number and held constant. Usually they are set to integers or values derived from linear combinations of integers.
Fixed Discrete Ambiguity Estimates	Carrier phase ambiguities which are set to values which are members of a predetermined set of discrete possibilities, and then held constant.
Fixed Field	A field in which the number of characters is fixed. For data fields, such fields are shown in the sentence definitions with no decimal point. Other fields which fall into this category are the address field and the checksum field (if present).
Fixed Integer Ambiguity Estimates	Carrier phase ambiguities which are set to integer values and then held constant.
Flash ROM	Programmable read-only memory.
Floating Ambiguity Estimates	Ambiguity estimates which are not held to a constant value, but are allowed to gradually converge to the correct solution.
Geometric Dilution of Precision (GDOP)	[See *DOP*]
Geoid	The shape of the earth if it were considered as a sea level surface extended continuously through the continents. The geoid is an equipotential surface coincident with mean sea level to which at every point the plumb line (direction in which gravity acts) is perpendicular. The geoid, affected by local gravity disturbances, has an irregular shape.
Geodetic Datum	The reference ellipsoid surface that defines the coordinate system.

Geostationary A satellite orbit along the equator that results in a constant fixed position over a particular reference point on the earth’s surface. (GPS satellites are not geostationary.)

Global Positioning System (GPS) Full name is NAVSTAR Global Positioning System. A space-based radio Positioning system which provides suitably equipped users with accurate position, velocity and time data. GPS provides this data free of direct user charge worldwide, continuously, and under all weather conditions. The GPS constellation consists of 24 orbiting satellites, four equally spaced around each of six different orbital planes. The system is being developed by the Department of Defence under U.S. Air Force management.

Great Circle The shortest distance between any two points along the surface of a sphere or ellipsoid, and therefore the shortest navigation distance between any two points on the Earth. Also called Geodesic Line.

Handshaking Predetermined hardware or software activity designed to establish or maintain two machines or programs in synchronization. Handshaking concerns the exchange of messages or packets of data between two systems with limited buffers. Hardware handshaking uses voltage levels or pulses in wires to carry the handshaking signals. Software handshaking uses data units (e.g. ASCII characters) carried by some underlying communication medium.

Horizontal Dilution of Precision (HDOP) [See *DOP*]

Horizontal and Time Dilution of Precision (HTDOP) [See *DOP*]

Heading The direction in which a vessel points or heads at any instant, expressed in degrees 000° clockwise through 360° and may be referenced to True North, Magnetic North, or Grid North. The heading of a vessel is also called the ship's head. Heading is a constantly changing value as the vessel oscillates or yaws across the course due to the effects of the air or sea, cross currents, and steering errors.

Integer Ambiguity Estimates Carrier phase ambiguity estimates which are only allowed to take on integer values.

Iono-Free Carrier Phase Observation A linear combination of L1 and L2 carrier phase measurements which provides an estimate of the carrier phase observation on one frequency with the effects of the ionosphere removed. It provides a different ambiguity value (non-integer) than a simple measurement on that frequency.

Kinematic The user’s GPS antenna is moving. In GPS, this term is typically used with precise carrier phase positioning, and the term dynamic is used with pseudorange positioning.

L1 Frequency The 1575.42 MHz GPS carrier frequency which contains the course acquisition (C/A) code, as well as encrypted P-code, and navigation messages used by commercial GPS receivers.

L2 Frequency	The 1227.60 MHz. secondary GPS carrier frequency, containing only encrypted P-code, used primarily to calculate signal delays caused by the ionosphere.
Lane	A particular discrete ambiguity value on one carrier phase range measurement or double difference carrier phase observation. The type of measurement is not specified (L1, L2, L1-L2, iono-free)
L-Band	The range of radio frequencies that includes the GPS carrier frequencies L1 and L2 and the OmniSTAR satellite broadcast signal.
Local Observation Set	An observation set, as described below, taken by the receiver on which the software is operating as opposed to an observation taken at another receiver (the base station) and transmitted through a radio link.
Local Tangent Plane	A coordinate system based on a plane tangent to the ellipsoid's surface at the user's location. The three coordinates are east, north and up. Latitude, longitude and height positions operate in this coordinate system.
Low-latency Solution	A position solution which is based on a prediction. A model (based on previous base station observations) is used to estimate what the observations will be at a given time epoch. These estimated base station observations are combined with actual measurements taken at the rover station to provide a position solution.
Magnetic Bearing	Bearing relative to magnetic north; compass bearing corrected for deviation.
Magnetic Heading	Heading relative to magnetic north.
Magnetic Variation	The angle between the magnetic and geographic meridians at any place, expressed in degrees and minutes east or west to indicate the direction of magnetic north from true north.
Mask Angle	The minimum GPS satellite elevation angle permitted by a particular receiver design. Satellites below this angle will not be used in position solution.
Matched Observation Set Pair	Observations from both the base station and the local receiver which have been matched by time epoch, contain the same satellites, and are corrected for any known offsets.
Measurement Error Variance	The square of the standard deviation of a measurement quantity. The standard deviation is representative of the error typically expected in a measured value of that quantity.
Measurement Time Epoch	The point in time at which a receiver takes a measurement.
Multipath Errors	GPS positioning errors caused by the interaction of the GPS satellite signal and its reflections.
Non-Volatile Memory	A type of memory device that retains data in the absence of a power supply.

Null Field By NMEA standard, indicates that data is not available for the field. Indicated by two ASCII commas, i.e., ",," (HEX 2C2C), or, for the last data field in a sentence, one comma followed by either the checksum delimiter "*" (HEX 2A) or the sentence delimiters <CR><LF> (HEX 0D0A). [Note: the ASCII Null character (HEX 00) is <u>not</u> to be used for null fields.]

Obscuration Term used to describe periods of time when a GPS receiver's line-of-sight to GPS satellites is blocked by natural or man-made objects.

Observation Any measurement. The two observations used in NovAtel's RTK algorithms are the pseudorange measurement and the carrier phase measurement.

Observation Set A set of receiver measurements taken at a given time which includes one time for all measurements, and the following for each satellite tracked: PRN number, pseudorange or carrier phase or both, lock time count, signal strength, and tracking status. Either L1 only or L1 and L2 measurements are included in the set. The observation set is assumed to contain information indicating how many satellites it contains and which ones have L1-only and which ones have L1/L2 pairs.

OmniSTAR A wide-area GPS correction service, using L-band satellite broadcast frequencies (1525 - 1560 MHz). Data from many widely-spaced Reference Stations is used in a proprietary multi-site solution. OmniSTAR Virtual Base Station (VBS) types achieve sub-meter positioning over most land areas worldwide while OmniSTAR High Performance (HP) types achieve 10 cm accuracy. Use of the OmniSTAR service requires a subscription.

Origin Waypoint The starting point of the present navigation leg, expressed in latitude and longitude.

Parallel Receiver A receiver that monitors four or more satellites simultaneously with independent channels.

Parity The even or odd quality of the number of ones or zeroes in a binary code. Parity is often used to determine the integrity of data especially after transmission.

Perigee The point in a body's orbit at which it is nearest the earth.

P-Code Precise code or protected code. A pseudorandom string of bits that is used by GPS receivers to determine the range to the transmitting GPS satellite. P-code is replaced by an encrypted Y-code when Anti-Spoofing is active. Y-code is intended to be available only to authorized (primarily military) users. [See *Anti-Spoofing*, *C/A Code* and *Y-Code*]

PDOP Position Dilution of Precision [See *DOP*]

Precise Positioning Service (PPS) The GPS positioning, velocity, and time service which is available on a continuous, worldwide basis to users authorized by the U.S. Department of Defence (typically using P-Code).

PRN Number A number assigned by the GPS system designers to a given set of pseudorandom codes. Typically, a particular satellite will keep its PRN (and hence its code assignment) indefinitely, or at least for a long period of time. It is commonly used as a way to label a particular satellite.

Pseudolite	An Earth-based transmitter designed to mimic a satellite. May be used to transmit differential corrections.
Pseudorange	The calculated range from the GPS receiver to the satellite determined by taking the difference between the measured satellite transmit time and the receiver time of measurement, and multiplying by the speed of light. Contains several sources of error.
Pseudorange Measurements	Measurements made using one of the pseudorandom codes on the GPS signals. They provide an unambiguous measure of the range to the satellite including the effect of the satellite and user clock biases.
Receiver Channels	A GPS receiver specification which indicates the number of independent hardware signal processing channels included in the receiver design.
Reference Satellite	In a double difference implementation, measurements are differenced between different satellites on one receiver in order to cancel the correlated errors. Usually one satellite is chosen as the "reference", and all others are differenced with it.
Reference Station	See *Base Station*
Relative Bearing	Bearing relative to heading or to the vessel.
Remote Station	See *Rover Station*
Residual	In the context of measurement, the residual is the misclosure between the calculated measurements, using the position solution and actual measurements.
Root Mean Square (RMS)	A probability level of 68%.
Route	A planned course of travel, usually composed of more than one navigation leg.
Rover Station	The GPS receiver which does not know its position and needs to receive measurements from a base station to calculate differential GPS positions. (The terms remote and rover are interchangeable.)
RT-20	NovAtel's Double Differencing Technology for real-time kinematic (RTK) carrier phase floating ambiguity resolution.
Radio Technical Commission for Aeronautics (RTCA)	An organization which developed and defined a message format for differential positioning. See *Appendix G on Page 166* for further information.
Radio Technical Commission for Maritime Services (RTCM)	An organization which developed and defined the SC-104 message format for differential positioning. See *Appendix G on Page 166* for further information.
Real-Time Kinematic (RTK)	A type of differential positioning based on observations of carrier phase. In this document it is also used with reference to RT-2 and RT-20.

Satellite-Based Augmentation System (SBAS) A type of geo-stationary satellite system that improves the accuracy, integrity, and availability of the basic GPS signals. This includes WAAS, EGNOS, and MSAS. See *Satellite-Based Augmentation System (SBAS) on page 68*.

Selected Waypoint The waypoint currently selected to be the point toward which the vessel is travelling. Also called "to" waypoint, destination or destination waypoint.

Sequential Receiver A GPS receiver in which the number of satellite signals to be tracked exceeds the number of available hardware channels. Sequential receivers periodically reassign hardware channels to particular satellite signals in a predetermined sequence.

Spherical Error Probable (SEP) The radius of a sphere, centred at the user’s true location, that contains 50 percent of the individual three-dimensional position measurements made using a particular navigation system.

Spheroid Sometimes known as ellipsoid; a perfect mathematical figure which very closely approximates the geoid. Used as a surface of reference for geodetic surveys.

Standard Positioning Service (SPS) A positioning service made available by the United States Department of Defence which is available to all GPS civilian users on a continuous, worldwide basis (typically using C/A Code).

Space Vehicle ID (SV) Sometimes used as SVID. A unique number assigned to each satellite for identification purposes. The ‘space vehicle’ is a GPS satellite.

TDOP Time Dilution of Precision [See *DOP*]

Three-Dimensional Coverage The number of hours-per-day when four or more satellites are available with acceptable positioning geometry. Four visible satellites are required to determine location and altitude.

Three-Dimensional (3D) Navigation Navigation mode in which altitude and horizontal position are determined from satellite range measurements.

Time-To-First-Fix (TTFF) The actual time required by a GPS receiver to achieve a position solution. This specification will vary with the operating state of the receiver, the length of time since the last position fix, the location of the last fix, and the specific receiver design.

Track A planned or intended horizontal path of travel with respect to the Earth rather than the air or water. The track is expressed in degrees from 000° clockwise through 360° (true, magnetic, or grid).

Track Made Good The single resultant direction from a point of departure to a point of arrival or subsequent position at any given time; may be considered synonymous with Course Made Good.

True Bearing Bearing relative to true north; compass bearing corrected for compass error.

True Heading Heading relative to true north.

Two-Dimensional The number of hours-per-day with three or more satellites visible. Three

Coverage visible satellites can be used to determine location if the GPS receiver is designed to accept an external altitude input.

Two-Dimensional (2D) Navigation Navigation mode in which a fixed value of altitude is used for one or more position calculations while horizontal (2D) position can vary freely based on satellite range measurements.

Undulation The distance of the geoid above (positive) or below (negative) the mathematical reference ellipsoid (spheroid). Also known as geoidal separation, geoidal undulation, geoidal height.

Update Rate The GPS receiver specification which indicates the solution rate provided by the receiver when operating normally.

UTC [See *Coordinated Universal Time*]

VDOP Vertical Dilution of Precision [See *DOP*]

Variable Field By NMEA standards, a data field which may or may not contain a decimal point and which may vary in precision following the decimal point depending on the requirements and the accuracy of the measuring device.

World Geodetic System 1984 (WGS84) An ellipsoid designed to fit the shape of the entire Earth as well as possible with a single ellipsoid. It is often used as a reference on a worldwide basis, while other ellipsoids are used locally to provide a better fit to the Earth in a local region. GPS uses the centre of the WGS-84 ellipsoid as the centre of the GPS ECEF reference frame.

Waypoint A reference point on a track.

Wide Lane A particular integer ambiguity value on one carrier phase range measurement or double difference carrier phase observation when the difference of the L1 and L2 measurements is used. It is a carrier phase observable formed by subtracting L2 from L1 carrier phase data: $\Phi' = \Phi_1 - \Phi_2$. The corresponding wavelength is 86.2 cm

Y-Code An encrypted form of P-Code. Satellites transmit Y-Code in replace of P-Code when Anti-Spoofing is in effect. [See *P-Code* and *Anti-Spoofing*]

Appendix I GPS Acronyms

1PPS	One Pulse Per Second
2D	Two Dimensional
3D	Three Dimensional
A/D	Analog-to-Digital
ADC	Analog-to-Digital Converter
ADR	Accumulated Doppler Range
AGC	Automatic Gain Control
AS	Anti-Spoofing
ASCII	American Standard Code for Information Interchange
AVL	Automated Vehicle Locations
BIH	Bureau l'International de l'Heure
BIST	Built-In-Self-Test
BPS	Bits per Second
C/A Code	Coarse/Acquisition Code
CAN	Controller Area Network
CEP	Circular Error Probable
CMR	Compact Measurement Record
CoCom	Coordinating Committee on Multilateral Export Controls
CPU	Central Processing Unit
CR	Carriage Return
CRC	Cyclic Redundancy Check
CTP	Conventional Terrestrial Pole
CTS	Conventional Terrestrial System or Clear To Send
dB	Decibel
DCD	Data Carrier Detected
DCE	Data Communications Equipment (Modem)
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
DLL	Delay Lock Loop
DOP	Dilution Of Precision
DRAM	Dynamic Random Access Memory
DSP	Digital Signal Processor
DSR	Data Set Ready
DTE	Data Terminal Equipment
DTR	Data Terminal Ready
ECEF	Earth-Centred-Earth-Fixed
EGNOS	European Geo-Stationary Navigation System
ESN	Electronic Serial Number
ESD	Electrostatic Discharge
FEC	Forward Error Correction
FPGA	Field-Programmable Gate Array
FR	Factory Reset
FTS	Frequency and Time Standard
GDOP	Geometric Dilution Of Precision
GLONASS	Global Navigation Satellite System

GMT	Greenwich Mean Time
GND	Ground
GPS	Global Positioning System
GPAI	General Purpose Analog Input
HDOP	Horizontal Dilution Of Precision
HP	High Performance (*see also* OmniSTAR *in Appendix H, GPS Glossary*)
HTDOP	Horizontal position and Time Dilution Of Precision
IC	Integrated Circuit
IF	Intermediate Frequency
IGRF	International Geometric Reference Field
I/O	Input/Output
INS	Inertial Navigation System
IODE	Issue of Data (Ephemeris)
IRQ	Interrupt Request
LAAS	Local Area Augmentation System
LF	Line Feed
LHCP	Left Hand Circular Polarization
LNA	Low Noise Amplifier
LO	Local Oscillator
LSB	Least significant bit
MET	Multipath Elimination Technology
MEDLL	Multipath Estimation Delay Lock Loop
MKI	Mark Input
MSAS	MTSAT Satellite Based Augmentation System
MSB	Most significant bit
MSL	Mean sea level
MSR	Measure Output
MTSAT	Multi-Functional Transport Satellite
N/C	Not Connected
NAVSTAR	NAVigation Satellite Timing And Ranging (synonymous with GPS)
NCO	Numerically Controlled Oscillator
NMEA	National Marine Electronics Association
OCXO	Oven Controlled Crystal Oscillator
OEM	Original Equipment Manufacturer
PAC	Pulse Aperture Correlator
PC	Personal Computer
P Code	Precise Code
PDF	Power Distribution Function
PDOP	Position Dilution Of Precision
PLL	Phase Lock Loop
PPS	Precise Positioning Service or Pulse Per Second
PRN	PseudoRandom Noise number
PV	Position Valid
RAM	Random Access Memory
RF	Radio Frequency
RHCP	Right Hand Circular Polarization
ROM	Read Only Memory
RTCA	Radio Technical Commission for Aviation Services

RTCM	Radio Technical Commission for Maritime Services
RTK	Real Time Kinematic
RTS	Request To Send
RXD	Received Data
SBAS	Satellite-Based Augmentation System
SCAT-I	Special Category I
SEP	Spherical Error Probable
SNR	Signal-to-Noise Ratio
SPS	Standard Positioning Service
SV	Space Vehicle
SVN	Space Vehicle Number
TCXO	Temperature Compensated Crystal Oscillator
TDOP	Time Dilution Of Precision
TTFF	Time-To-First-Fix
TXD	Transmitted Data
UART	Universal Asynchronous Receiver Transmitter
USB	Universal Serial Bus
UDRE	User Differential Range Error
UTC	Coordinated Universal Time
VARF	Variable Frequency
VBS	Virtual Base Station (*see also* OmniSTAR *in Appendix H, GPS Glossary*)
VDOP	Vertical Dilution of Precision
WAAS	Wide Area Augmentation System
WGS	World Geodetic System
XTE	Crosstrack Error

Appendix J Replacement Parts

The following are a list of the replacement parts available for your NovAtel GPS receiver. Should you require assistance or need to order additional components, please contact your local NovAtel dealer or Customer Service representative.

J.1 FlexPak

Part Description	NovAtel Part
Automobile power adapter cable (*Page 125*)	60723067
13-pin Deutsch to DB9 null modem serial cable (*Page 126*)	60723068
13-pin Deutsch to USB connector cable (*Page 127*)	TBD

J.2 ProPak-G2

Part Description	NovAtel Part
I/O strobe cable for DB-9 version (*Figure 50 on Page 135*)	60723065
Straight serial data cable for DB-9 version (*Figure 49 on Page 134*)	60723066
Null modem serial data cable for DB-9 version (*Figure 48 on Page 133*)	60715062
Power cable: LEMO 4-pin socket to automobile power outlet plug (*Figure 47 on Page 132*)	01017023
Straight serial data cable for LEMO version (*Figure 52 on Page 137*)	403-0-0037
Null modem serial data cable for LEMO version (*Figure 51 on Page 136*)	403-0-0036

J.3 ProPak-LB

Part Description	NovAtel Part
Automobile power adapter cable (*Page 142*)	60723064
6-pin Switchcraft to DB9 serial cable (*Page 143*)	60723061
7-pin Switchcraft to DB9 serial cable (*Page 144*)	60723062
8-pin Switchcraft to DB9 serial cable (*Page 145*)	60723063

J.4 Accessories

Part Description		NovAtel Part
OEM4 Family Compact Disc with PC utilities		01017190
OEM4 Family User Manual Volume 1, Installation and Operation		OM-20000046
OEM4 Family User Manual Volume 2, Commands and Log Reference		OM-20000047
Optional NovAtel GPSAntennas:	Model 702 (L1/L2)	GPS-702
	Model 701 (L1-only)	GPS-701
	Model 600-LB (L1/L2/OmniSTAR L-band)	GPS-600-LB
	Model 511 (L1 only)	GPS-511
	Model 521 (L1 only)	GPS-521
	Model 502 (L1/L2)	GPS-502
	Model 503 (L1/L2)	GPS-503
	Model 512 (L1/L2)	GPS-512
Optional RF Antenna Cable:	5 meters	C006
	15 meters	C016
	30 meters	C032
	22 cm interconnect adapter cable	GPS-C002

J.5 Manufacturerís Part Numbers

The following original manufacturer’s part numbers, for the ProPak cables, are provided for information only and are not available from NovAtel as separate parts:

J.5.1 FlexPak

Part Description	Deutsch Part
3-pin plug connector on automobile power adapter cable (*Page 125*)	58064 - 09 - 98SN
13-pin plug connector on null modem serial cable (*Page 126*)	59084 - 11 - 35SF

J.5.2 ProPak-G2

Part Description	LEMO Part
4-pin socket connector on power cable (*Figure 47 on Page 132*)	FGG.0B.304.CLAD52Z
10-pin plug connector on serial and null modem cables for LEMO version (*Figures 51 and 52 starting on Page 136*)	FGG.1K.310.CLAC60Z

J.5.3 ProPak-LB

Part Description	Switchcraft Part
2-pin socket connector on automobile power adapter cable (*Page 142*)	EN3C2F
6-pin socket connector on serial cable (*Page 143*)	EN3C6F
7-pin socket connector on serial cable (*Page 144*)	EN3C7F
8-pin socket connector on serial cable (*Page 145*)	EN3C8F

Appendix K Specifications Archive

This appendix gives some details on OEM4 family products that are now obsolete. Obsolete products are still supported but are not available. In a future hardware revision, these models will no longer be supported.

K.1 Installation and Setup

The voltage input range for each GPSCard type is given in the table below.

Table 34: Voltage Input Ranges for GPSCards

GPSCard	Power Input Range
OEM4	+6 to +18 VDC
Euro4	+5.0 ± 0.125 VDC

All PowerPak and ProPak enclosures provide a TNC female connector, which can be connected to the antenna directly with any of NovAtel's coaxial cables. For the GPSCards, an interconnect adapter cable is required to convert the TNC male end of the coaxial cable to the card's specific RF input connector type, which is given in the table below.

Table 35: GPSCard RF Input Connectors

GPSCard	RF Input Connector
OEM4	MMCX female
Euro4	SMB right-angle male

Connect the power supply, set to the voltage given in the table below, to the wiring harness.

Table 36: GPSCard Power Inputs

GPSCard	Power Input Range
OEM4	+6 to +18 VDC
Euro4	+5.0 ± 0.125 VDC

For a PowerPak or ProPak enclosure, connect the power supply to the port described in *Table 37* below.

Table 37: Enclosure Power Inputs

Enclosure	Power Input Port	Power Input Range
PowerPak-4	Standard 2.1 mm center-positive receptacle labelled *6-18V DC*	+6 to +18 VDC
PowerPak-4E	Standard 2.1 mm center-positive receptacle labelled *10 - 36V DC*	+10 to +36 VDC
ProPak-4E	4-pin LEMO male connector	+10 to +36 VDC

The default configuration available for each of the receiver types is given in the table below.

Table 38: Default Serial Port Configurations

Receiver	COM1	COM2	COM3
OEM4	RS-232	RS-232	LVTTL
Euro4	RS-232	RS-232	RS-232
PowerPak-4	RS-232	RS-232	RS-232
PowerPak-4E	RS-232	RS-232	Not available
ProPak-4E	RS-232	RS-232	Not available

Table 39: PowerPak-4 Status Indicators

Indicator	Indicator Color	Status
VALID POSITION	Red	Hardware error
	Green	Valid position computed
STATUS	Red, Yellow, or Both	The GPSCard is not working properly
	Flashing Green	The GPSCard is working properly
PWR	Red	The receiver is powered

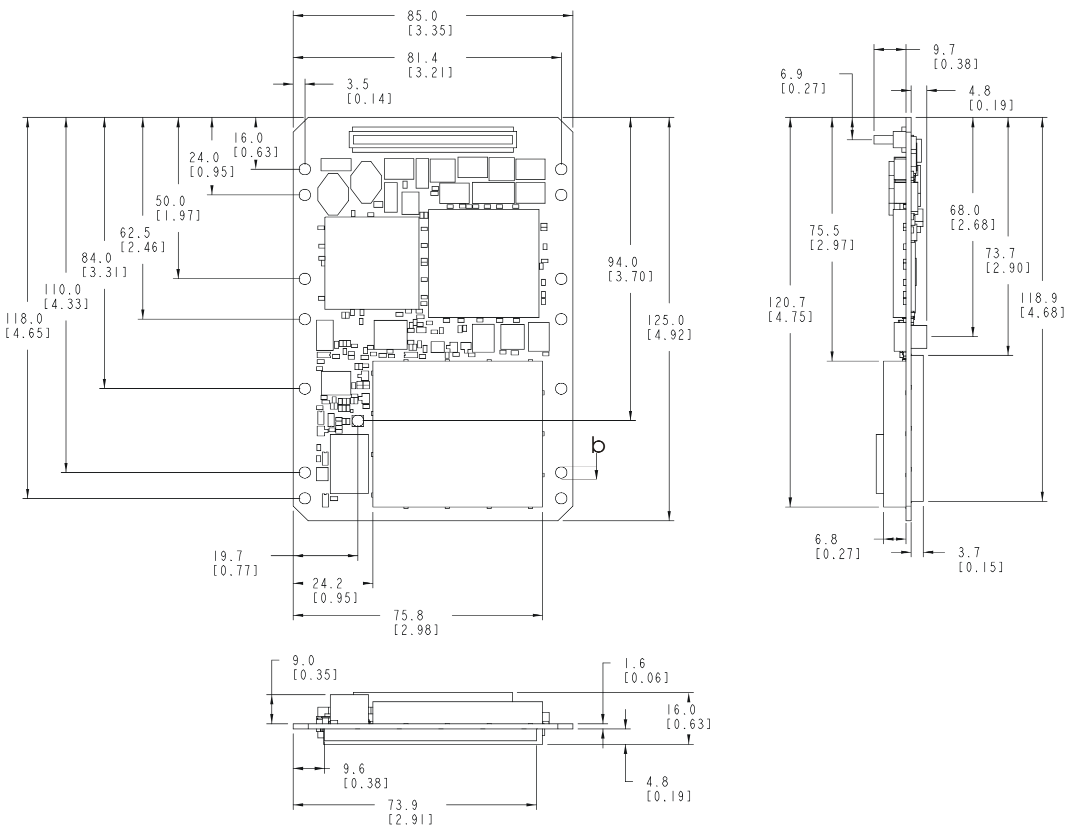
Table 40: PowerPak-4E Status Indicators

Indicator	Indicator Color	Status
VALID POSITION	Red	Hardware error
	Green	Valid position computed
POWER	Red	The receiver is powered

K.2 OEM4 GPSCard

PHYSICAL	
Size	85mm x 125mm with connectors
Weight	120 grams
MECHANICAL DRAWINGS	

Figure 66: OEM4 Board Dimensions



a. All dimensions are in millimeters [inches].
b. The mounting holes on the OEM4 GPSCard are designed for use with M3 screws. The hole size is actually 3.45mm (#29 drill, 0.136"), which is a British Standard "medium fit".

ENVIRONMENTAL	
Operating Temperature	-40∞C to +85∞C
Storage Temperature	-45∞C to +95∞C
Humidity	Not to exceed 95% non-condensing
POWER REQUIREMENTS	
Voltage	+6 to +18 VDC
Allowable Input Voltage Ripple	100 mV p-p (max.)
Power consumption	2.7 W (typical)
RF INPUT / LNA POWER OUTPUT	
Antenna Connector	MMCX connector, 50 Ω nominal impedance
RF Input Frequencies	1575.42 MHz (L1), 1227.60 MHz (L2)
LNA Power	
Internal (Output from card, default)	+4.50 to +5.25 VDC @ 0 - 100 mA
External (Optional Input)	+12 to +30 VDC, 100 mA max. (user-supplied)

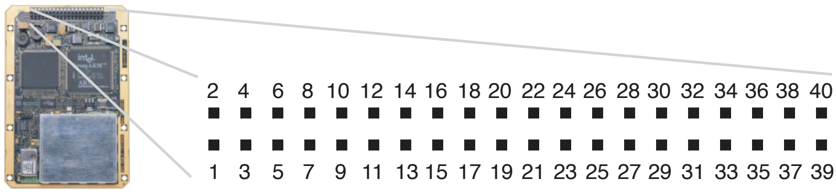
INPUT/OUTPUT DATA INTERFACE	
COM1 AND COM2	
Electrical format	RS232 (Can be factory configured for LVTTL operation)
Bit rate[a]	300, 1200, 4800, 9600 (default), 19200, 57600, 115200, 230400 bps
Lead input	CTS (and DCD on COM2)
Lead output	RTS (and DTR on COM2)
Signals supported	TX, RX, RTS, CTS, DTR, DCD (DTR and DCD are on COM2 only)
COM3	
Electrical format	LVTTL (Can be factory configured for RS232 operation)
Bit rate[a]	300, 1200, 4800, 9600 (default), 19200, 57600, 115200, 230400 bps
Lead input	CTS
Lead output	RTS
Signals supported	TX, RX, RTS, CTS

a. Baud rates higher than 115,200 bps are not supported by standard PC hardware. Special PC hardware is required for higher rates, including 230,400 bps.

INPUT/OUTPUT STROBES	
MSR (Measure Output)	Normally high, active low where the pulse width is 1 ms. The falling edge is the receiver measurement strobe.
Event1 (Mark 1 Input)	An input mark (negative pulse > 55 ns), time tags output log data to the time of the falling edge of the mark input pulse.
PV (Position Valid)	Indicates a valid GPS position solution is available. A high level indicates a valid solution or that the FIX POSITION command has been set (refer to the FIX POSITION command in user manual Volume 2).
ERROR	Output for which a high level indicates an error.
STATUS_RED	Status output which is high or pulses to indicate that the OEM4 card is not working properly.
STATUS_GREEN	Status output which pulses to indicate that the OEM4 card is working properly.
PPS (One Pulse Per Second)	A one-pulse-per-second time synchronization output. This is an active low pulse (1 ms ± 50 ns minimum) where the falling edge is synchronized to receiver calculated GPS time.
VARF (Variable Frequency)	A programmable variable frequency output ranging from 0 -20 MHz (refer to the FREQUENCYOUT command in *Volume 2* of this manual). This is a normally high, active low pulse.
$\overline{\text{RESETOUT}}$	Reset TTL signal output to external system; active low, 100 ms duration.
$\overline{\text{RESETIN}}$	Reset TTL signal input from external system; active low, > 1 μsec duration

STROBE ELECTRICAL SPECIFICATIONS		
Output	Voltage:	LVTTL levels
	Low:	minimum 0 VDC and maximum 0.55 VDC @ 24 mA
	High:	minimum 2.4 VDC and maximum 3.6 VDC @ 8 mA
Input	Voltage:	LVTTL levels
	Low:	minimum 0 VDC and maximum 0.8 VDC
	High:	minimum 2.0 VDC and maximum 5.5 VDC

Figure 67: Top-view of 40-Pin Connector on the OEM4



Signal	Descriptions	Pin
V_{IN}	Voltage In, +6 to +18 VDC	1
PV	Output indicates 'good solution' or valid GPS position when high.	2
*	Reserved	3
GND	Digital Ground	4
*	Reserved	5
GND	Digital Ground	6
PPS	Normally high, active low output pulse is 1 ms wide @ 1 Hz. Falling edge is used as the reference.	7
GND	Digital Ground	8
VARF	Variable frequency out	9
GND	Digital Ground	10
Event1	Normally high, active low input pulse must exceed 55 ns in duration. The falling edge is the reference. LVTTL (contact closure compatible)	11
GND	Digital Ground	12
STATUS RED	Indicates the OEM4 card is not working properly when high or pulsing.	13
CTS1	Clear to Send for COM 1 input	14
TXD1	Transmitted Data for COM 1 output	15
RTS1	Request to Send for COM 1 output	16
RXD1	Received Data for COM 1 input	17
CTS3	Clear to Send for COM 3 input	18
TXD3	Transmitted Data for COM 3 output	19
DCD2	Data Carrier Detected for COM 2 input	20
RXD3	Received Data for COM 3 input	21
RTS3	Request to Send for COM 3 output	22
DTR2	Data Terminal Ready for COM 2 output	23
CTS2	Clear to Send for COM 2 input	24
TXD2	Transmitted Data for COM 2 output	25
RTS2	Request to Send for COM 2 output	26
RXD2	Received Data for COM 2 input	27
STATUS GREEN	Indicates the OEM4 card is working properly when pulsing at 1 Hz.	28
GPIO_USER0	Reserved. 10 kΩ pull-down resistor.	29
GPIO_USER1	Reserved. 10 kΩ pull-down resistor.	30
GPIO_USER2	Reserved. 10 kΩ pull-down resistor.	31
MSR	Normally high, active low pulse is 1 ms ± 50 ns wide. Falling edge is used as the reference.	32
$\overline{\text{RESETIN}}$	Reset TTL signal input from external system; active low.	33

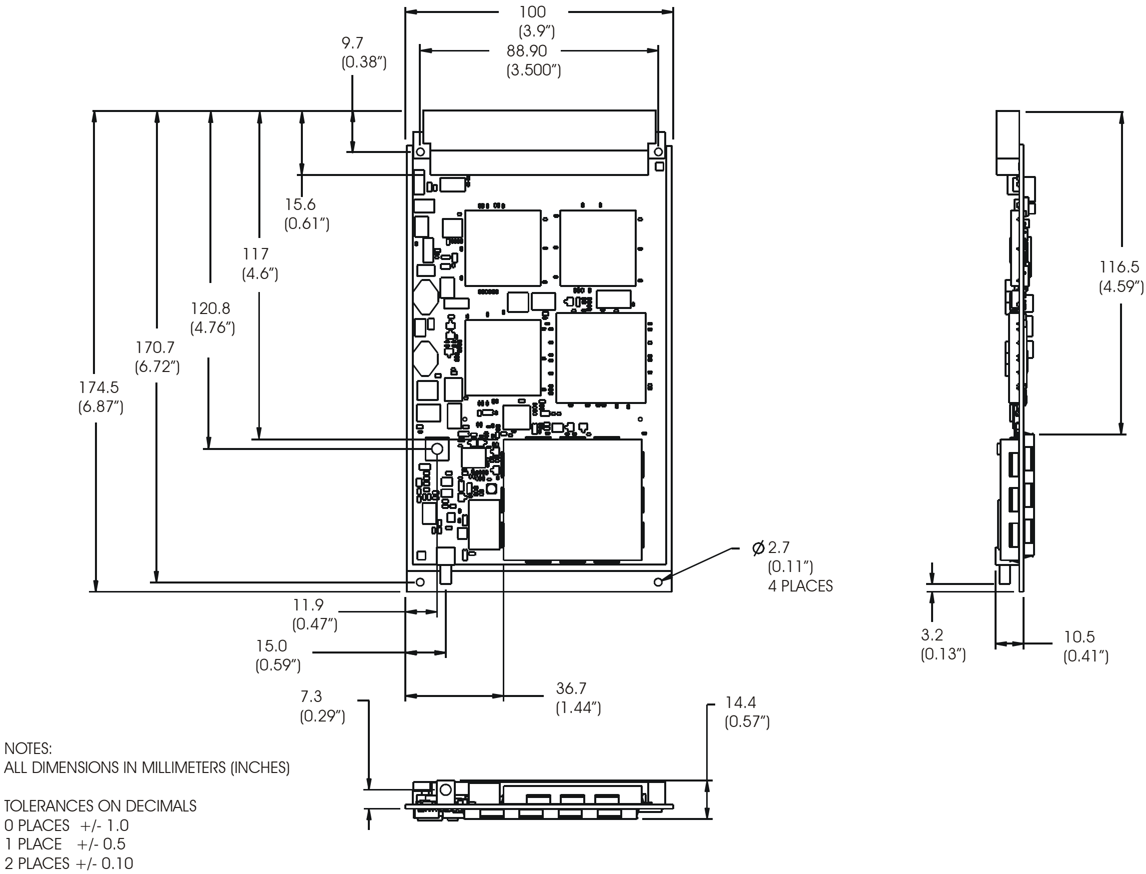
GPAI	General purpose analog input (see the RXHWLEVELS log in *Volume 2* of this manual).	34
$\overline{\text{RESETOUT}}$	Reset TTL signal output to external system; active low.	35
GND	Digital Ground	36
GPIO_FR	Reserved. 10 kΩ pull-up resistor.	37
ERROR	Indicates fatal error when high	38
*	Reserved.	39
LNA_PWR	Optional external power to antenna other than a standard NovAtel GPSAntenna (see the ANTENNAPOWER command in *Volume 2* of this manual)	40

☒ To create a common ground, tie together all digital grounds (GND) with the ground of the power supply.

K.3 Euro4 GPSCard

PHYSICAL	
Size	100 mm x 167 mm excluding the 64 position I/O connector
Weight	135 grams
MECHANICAL DRAWINGS	

Figure 68: Euro4 Board Dimensions



ENVIRONMENTAL	
Operating Temperature	-40∞C to +85∞C
Storage Temperature	-45∞C to +95∞C
Humidity	Not to exceed 95% non-condensing
POWER REQUIREMENTS	
Voltage	+5.0 ± 0.125 VDC
Allowable Input Voltage Ripple	50 mV p-p (max.)
Power consumption	2.3 W (typical)
RF INPUT / LNA POWER OUTPUT	
Antenna Connector	SMB right-angle male jack, 50 Ω nominal impedance
RF Input Frequencies	1575.42 MHz (L1), 1227.60 MHz (L2)
LNA Power **Internal (Output from card, default)** **External (Optional input)**	 +4.50 to +5.25 VDC @ 0 - 100 mA +12 to +30 VDC, 100 mA max. (user-supplied)
EXTERNAL OSCILLATOR INPUT	
Connector	SMB straight (vertical) male jack
External Clock Input	Frequency: 5 MHz or 10 MHz Input Impedance: 50 Ω nominal Input VSWR:2.0:1 Signal Level: 0 dBm minimum to +13.0 dBm maximum Frequency Stability: ± 0.5 ppm maximum Wave Shape: Sinusoidal

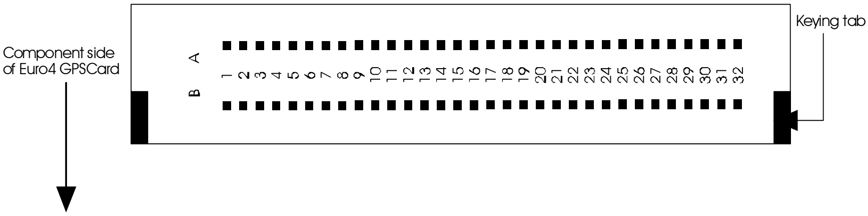
INPUT/OUTPUT DATA INTERFACE	
COM1, COM2 AND COM3	
Electrical format	RS232 (Can be factory configured for LVTTL or RS422 operation)
Bit rate[a]	300, 1200, 4800, 9600 (default), 19200, 57600, 115200, 230400 bps
Lead input	CTS (and DCD on COM2)
Lead output	RTS (and DTR on COM2)
Signals supported	TX, RX, RTS, CTS, DTR, DCD (DTR and DCD are on COM2 only)

a. Baud rates higher than 115,200 bps are not supported by standard PC hardware. Special PC hardware is required for higher rates, including 230,400 bps.

INPUT/OUTPUT STROBES	
MSR (Measure Output)	Normally high, active low where the pulse width is 1 ms. The falling edge is the receiver measurement strobe.
Event1 (Mark1 Input)	An input mark (negative pulse > 55 ns), time tags output log data to the time of the falling edge of the mark input pulse.
PV (Position Valid)	Output indicates a ëgood solutioní or a valid GPS solution when high.
ERROR	Output that Indicates fatal error warning when high.
STATUS_RED	Status output which is high or pulses to indicate that the OEM4 card is not working properly.
STATUS_GREEN	Status output which pulses to indicate that the OEM4 card is working properly.
PPS (One Pulse Per Second)	Normally high, active low pulse is 1 ms wide @ 1 Hz. Falling edge is used as the reference.
VARF (Variable Frequency)	A programmable variable frequency output ranging from 0 - 20 MHz (refer to the FREQUENCYOUT command in *Volume 2* of this manual). This is a normally high, active low pulse.
RESETOUT	Reset TTL signal output to external system; active high.
$\overline{\textbf{RESETIN}}$	Reset TTL signal input from external system; active low, > 1 μs duration.

STROBE ELECTRICAL SPECIFICATIONS		
Output	Voltage:	LVTTL levels
	Low:	minimum 0 VDC and maximum 0.55 VDC @ 24 mA
	High:	minimum 2.4 VDC and maximum 3.6 VDC @ 8 mA
Input	Voltage:	LVTTL levels
	Low:	minimum 0 VDC and maximum 0.8 VDC
	High:	minimum 2.0 VDC and maximum 5.5 VDC

Figure 69: Front-view of 64-Pin Connector on the Euro4



Signal	Descriptions	Row A Pin
GND	Digital Ground	1
5VIN	Voltage in, 5 VDC ± 0.125 VDC	2
Reserved for future use.		3
GND	Digital Ground	4
GPIO_USER0	Reserved. 10 kΩ pull-down resistor.	5
GPIO_USER1	Reserved. 10 kΩ pull-down resistor.	6
GND	Digital Ground	7
RTS1(-)/NC	COM1 Request to send (-) for RS422 / not connected for RS232 and LVTTL	8
TXD1(+)/TXD1	COM1 Transmitted data (+) for RS422 / transmitted data for RS232 and LVTTL	9
RXD1(+)/RXD1	COM1 Received data (+) for RS422 / received data for RS232 and LVTTL	10
RXD1(-)/NC	COM1 Received data (-) for RS422 / not connected for RS232 and LVTTL	11
RTS3(-)/NC	COM3 Request to send (-) for RS422 / not connected for RS232 and LVTTL	12
TXD3(+)/TXD3	COM3 Transmitted data (+) for RS422 / transmitted data for RS232 and LVTTL	13
RXD3(+)/RXD3	COM3 Received data (+) for RS422 / received data for RS232 and LVTTL	14
GND	Digital Ground	15
RTS2(-)/DTR2	COM2 Request to send (-) for RS422 / data terminal ready for RS232 and LVTTL	16
TXD2(+)/TXD2	COM2 Transmitted data (+) for RS422 / transmitted data for RS232 and LVTTL	17
RXD2(+)/RXD2	COM2 Received data (+) for RS422 / received data for RS232 and LVTTL	18
RXD2(-)/DCD2	COM2 Received data (-) for RS422 / data carrier detected for RS232 and LVTTL	19
TXD3(-)/NC	COM3 Transmitted data (-) for RS422 / not connected for RS232 and LVTTL	20
CTS3(-)/NC	COM3 Clear to send (-) for RS422 / not connected for RS232 and LVTTL	21
RXD3(-)/NC	COM3 Received data (-) for RS422 / not connected for RS232 and LVTTL	22
GND	Digital Ground	23
GND	Digital Ground	24
GND	Digital Ground	25
GND	Digital Ground	26
GND	Digital Ground	27
GND	Digital Ground	28
GND	Digital Ground	29
GND	Digital Ground	30
GND	Digital Ground	31
GPIO_FR	Reserved. 10 kΩ pull-up resistor.	32

Figure 69 continued

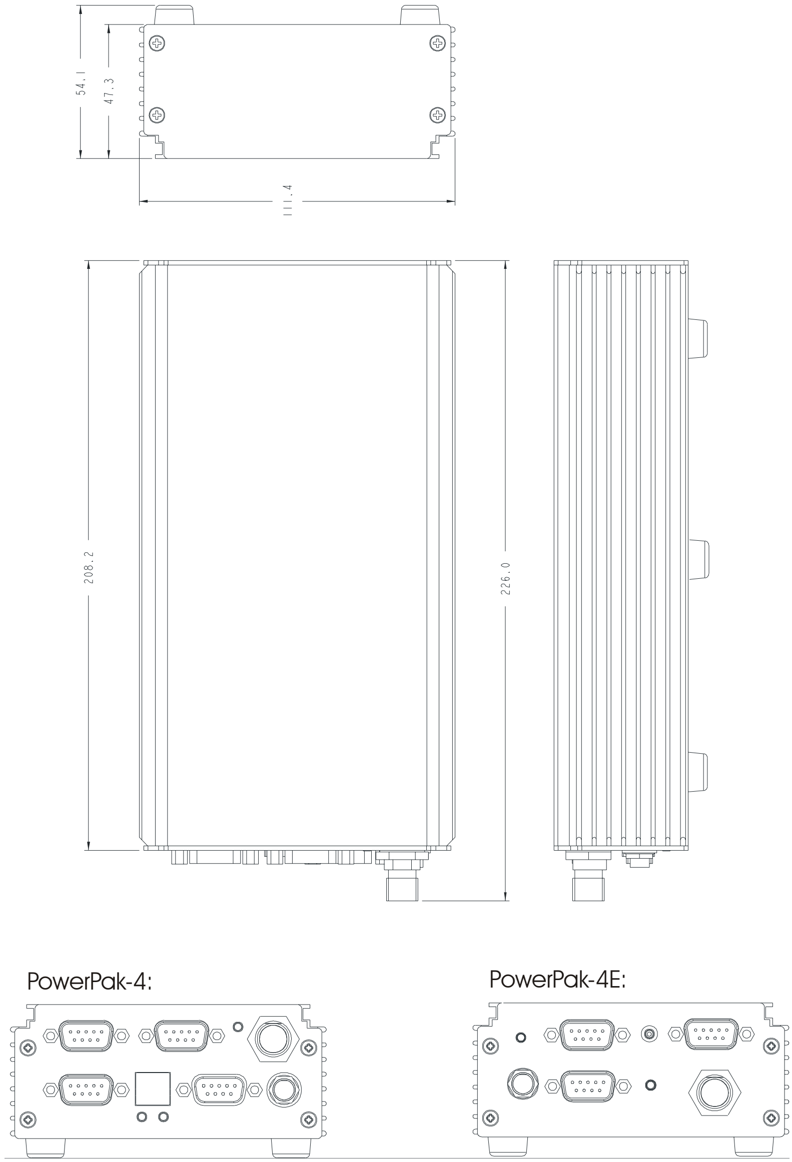
Signal	Descriptions	Row B Pin
GND	Digital Ground	1
5VIN	Voltage in, 5 VDC ± 0.125 VDC	2
Reserved for future use.		3
LNA_PWR	Optional external power to antenna other than a standard NovAtel GPSAntenna (see *Section 3.3.5, External Antenna LNA Power (OEM4-G2 Only) on Page 40* and the ANTENNAPOWER command in *Volume 2* of this manual).	4
STATUS_RED	Indicates the Euro4 is not working properly when high or pulsing	5
STATUS_GREEN	Indicates the Euro4 is working properly when pulsing at 1 Hz	6
Reserved for future use.		7
TXD1(-)/NC	COM1 transmitted data (-) for RS422 / not connected for RS232 and LVTTL	8
CTS1(+)/CTS1	COM1 clear to send (+) for RS422 / clear to send for RS232 and LVTTL	9
RTS1(+)/RTS1	COM1 request to send (+) for RS422 / request to send for RS232 and LVTTL	10
CTS1(-)/NC	COM1 clear to send (-) for RS422 / not connected for RS232 and LVTTL	11
GPAI	General purpose analog input (see the RXHWLEVELS log in *Volume 2* of this manual).	12
CTS3(+)/CTS3	COM3 clear to send (+) for RS422 / clear to send for RS232 and LVTTL	13
RTS3(+)/RTS3	COM3 request to send (+) for RS422 / request to send for RS232 and LVTTL	14
ERROR	Indicates fatal error warning.	15
TXD2(-)/NC	COM2 transmitted data (-) for RS422 / not connected for RS232 and LVTTL	16
CTS2(+)/CTS2	COM2 clear to send (+) for RS422 / clear to send for RS232 and LVTTL	17
RTS2(+)/RTS2	COM2 request to send (+) for RS422 / request to send for RS232 and LVTTL	18
CTS2(-)/NC	COM2 clear to send (-) for RS422 / not connected for RS232 and LVTTL	19
Reserved for future use.		20
VARF	Variable frequency out	21
PPS	Normally high, active low pulse is 1 ms wide @ 1 Hz. Falling edge is used as the reference.	22
MSR	Normally high, active low pulse is 1 ms ± 50 ns wide. Falling edge is used as the reference.	23
Event1	Normally high, active low pulse must exceed 55 ns in duration. The falling edge is the reference. LVTTL (contact closure compatible).	24
PV	Output indicates a ëgood solutioní or a valid GPS solution when high.	25
GPIO_USER2	Reserved. 10 kΩ pull-down resistor.	26
Reserved for future use.		27
$\overline{\text{RESETIN}}$	Reset TTL signal input from external system; active low.	28
RESETOUT	Reset TTL signal output to external system; active high.	29
GPIO_USER3	Reserved. 10 kΩ pull-down resistor.	30
Reserved for future use.		31
GPIO_USER4	Reserved. 10 kΩ pull-down resistor.	32

1. For pins that can be configured as RS422, RS232 or LVTTL, the signals are shown as RS422/RS232/LVTTL. RS422 is balanced; there are two connections per signal indicated as (+) and (-).
2. CTS, DCD and DSR are inputs while RTS and DTR are outputs.
3. To create a common ground, tie together all digital grounds (GND) with the ground of the power supply.

K.4 PowerPak-4/PowerPak-4E

INPUT/OUTPUT CONNECTORS	
Antenna Input	TNC female jack, 50 Ω nominal impedance +4.25 to +5.25 VDC, 90 mA max (output from PowerPak to antenna/LNA)
Power **PowerPak-4** **PowerPak-4E**	2.1 mm plug with screw-on retaining nut, centre positive +6 to +18 VDC at 2.8 W typical +10 to +36 VDC at 3.3 W typical
COM1 **COM2** **COM3 (PowerPak-4 only)** **Strobes**	DE9P connector DE9P connector DE9P connector DE9S connector
External Oscillator Input (PowerPak-4E only)	SMB straight (vertical) male jack Frequency: 5 MHz or 10 MHz Input Impedance: 50 Ω nominal Input VSWR: 2.0:1 Signal Level: 0 dBm minimum to +13.0 dBm maximum Frequency Stability: ± 0.5 ppm maximum Wave Shape: Sinusoidal
PHYSICAL	
Size	208 x 111 x 47 mm
Weight **PowerPak-4** **PowerPak-4E**	 800 g maximum (including OEM4 GPSCard) 980 g maximum (including Euro4 GPSCard)
ENVIRONMENTAL	
Operating Temperature	-40∞C to +75∞C
Storage Temperature	-45∞C to +95∞C
Humidity	Not to exceed 95% non-condensing

DIMENSIONS [a]



a. All dimension are in millimeters, please use *Appendix F, Unit Conversion on Page 163* for conversion to imperial measurements.

K.4.1 Port Pin-Outs

Table 41: PowerPak Serial Port Pin-Out Descriptions

Connector Pin No.	COM1		COM2		COM3 (PowerPak-4 only)
	RS232	RS422	RS232	RS422	RS232 Only
1	N/C	RXD1(-)	DCD2	RXD2(-)	N/C
2	RXD1	RXD1(+)	RXD2	RXD2(+)	RXD3
3	TXD1	TXD1(+)	TXD2	TXD2(+)	TXD3
4	N/C	RTS1(-)	DTR2	RTS2(-)	N/C
5	GND	GND	GND	GND	GND
6	N/C	CTS1(-)	N/C	CTS2(-)	N/C
7	RTS1	RTS1(+)	RTS2	RTS2(+)	RTS3
8	CTS1	CTS1(+)	CTS2	CTS2(+)	CTS3
9	N/C	TXD1(-)	N/C	TXD2(-)	N/C

Table 42: PowerPak I/O Port Pin-Out Descriptions

Connector Pin No.	PowerPak-4E Signal Name	PowerPak-4 Signal Name	Signal Descriptions
1	VARF	VARF	Variable frequency out
2	PPS	PPS	One pulse per second
3	MSR	Reserved	Measure output I Reserved for future use
4	Event1	Event1	Mark 1 input
5	PV	PV	Valid position available
6	GND	ERROR	Digital ground I Error indicator
7	GND	Reserved	Digital ground I Reserved for future use
8	GND	GND	Digital ground
9	GND	GND	Digital ground

✉ For strobe signal descriptions, please see *Section 3.3.1, Strobes on Page 36*.

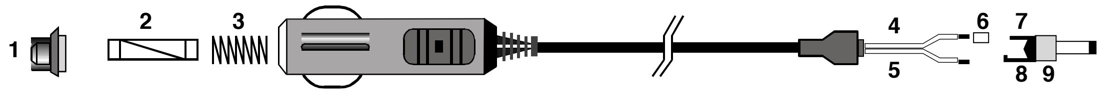
K.4.2 Cables

K.4.2.1 Automobile Power Adapter Cable (NovAtel part number 01014989)

The power adapter cable supplied with the PowerPak, see *Figure 70*, provides a convenient means for supplying +12 VDC while operating from an automobile.

Input is provided through the standard automobile power outlet. The output from the power adapter utilizes a standard 2.1 mm plug where the center is a female contact (positive) and the outer jacket contact is negative and plugs directly into the power jack located on the front panel of the PowerPak.

For alternate power sources please see *Section 3.1.3 on Page 29*.

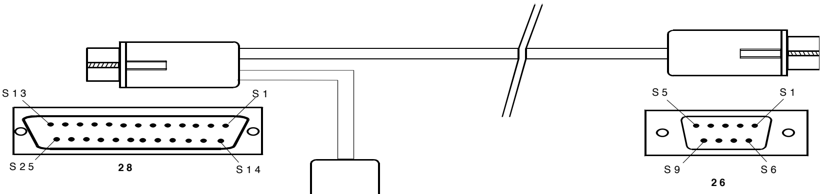


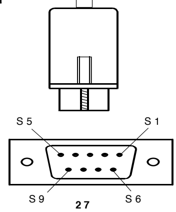
Reference	Description
1	Universal tip
2	Slow blow fuse
3	Spring
4	Positive line
5	Negative line (has text printed on it)
6	Shrinkable tubing
7	Positive
8	Negative
9	Retaining nut

Figure 70: PowerPak Power Adapter

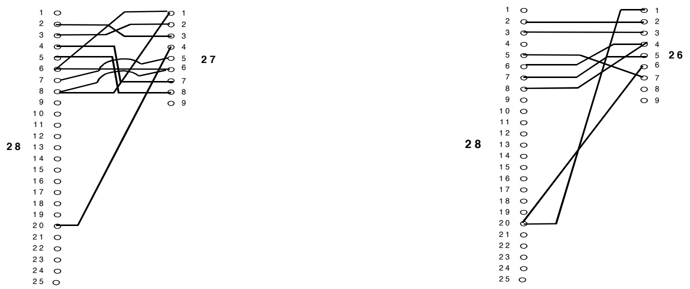
K.4.2.2 Y-Type Null-Modem Cable (NovAtel part number 60715062)

This cable supplied with the PowerPak, see *Figure 71*, provides an easy means of communications with the receiver's RS232 port from a PC. The cable is equipped with a 9-pin connector at the PowerPak end which can be plugged into either COM1 or COM2. At the PC end, both a 9-pin and a 25-pin connector are provided to accommodate most PC serial (RS232) communication ports.





Caution!: This cable is not supplied, and will not work, with a PowerPak-4E unit configured for RS422 communication.



Wiring Table:

Connector	Pin Number						
From DB25S (28)	2	3	4	5	6 & 8	7	20
To DE9S (26)	2	3	8	7	4	5	1 & 6
To DE9S (27)	3	2	7	8	1 & 6	5	4

Reference	Description	Reference	Description
26	DE9S (Female)	28	DB25S (Female)
27	DE9S (Female)		

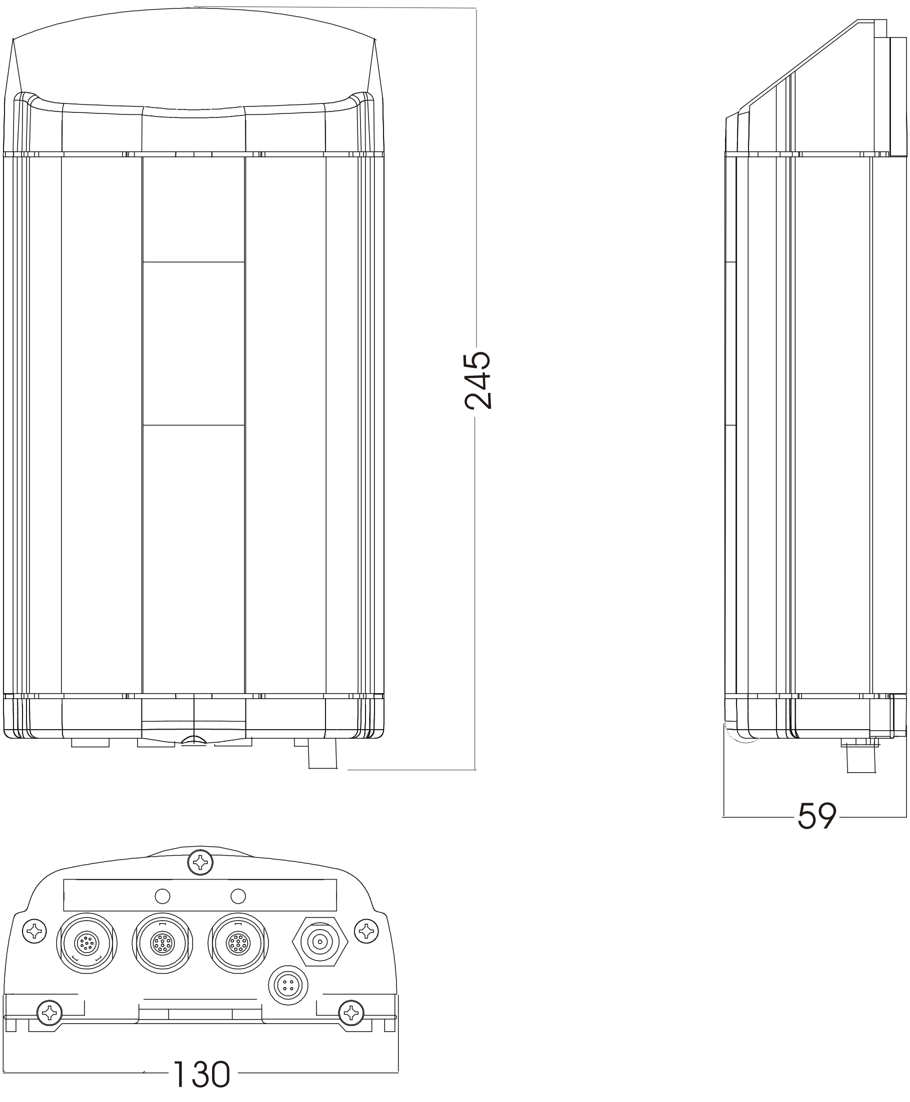
Figure 71: PowerPak Y-Type Null Modem Cable

K.5 ProPak-4E

INPUT/OUTPUT CONNECTORS	
Antenna Input	TNC female jack, 50 Ω nominal impedance +4.25 to +5.25 VDC, 90 mA max (output from ProPak-4E to antenna/LNA)
Power	4-pin LEMO +10 to +36 VDC continuous at 3.3 W typical
COM1 **COM2** **Strobes**	10-pin LEMO 10-pin LEMO 8-pin LEMO
PHYSICAL	
Size	245 x 130 x 59 mm
Weight	1.2 kg maximum (including Euro4 GPSCard)
ENVIRONMENTAL	
Operating Temperature	-40∞C to +65∞C
Storage Temperature	-45∞C to +95∞C
Humidity	Not to exceed 95% non-condensing

DIMENSIONS

a



a. All dimension are in millimeters, please use *Appendix F, Unit Conversion on Page 163* for conversion to imperial measurements.

K.5.1 Port Pin-Outs

Table 43: ProPak-4E Serial Port Pin-Out Descriptions

Connector Pin No.	COM1		COM2	
	RS232	RS422	RS232	RS422
1	N/C	RXD1(-)	DCD2	RXD2(-)
2	RXD1	RXD1(+)	RXD2	RXD2(+)
3	TXD1	TXD1(+)	TXD2	TXD2(+)
4	N/C	RTS1(-)	DTR2	RTS2(-)
5	GND	GND	GND	GND
6	N/C	CTS1(-)	N/C	CTS2(-)
7	RTS1	RTS1(+)	RTS2	RTS2(+)
8	CTS1	CTS1(+)	CTS2	CTS2(+)
9	N/C	TXD1(-)	N/C	TXD2(-)

Table 44: ProPak-4E I/O Port Pin-Out Descriptions

Connector Pin No.	Signal Name	Signal Description
1	VARF	Variable frequency out
2	PPS	One pulse per second
3	MSR	Measure output
4	Event1	Mark 1 input
5	PV	Valid position available
6	GND	Digital ground
7	GND	Digital ground
8	GND	Digital ground

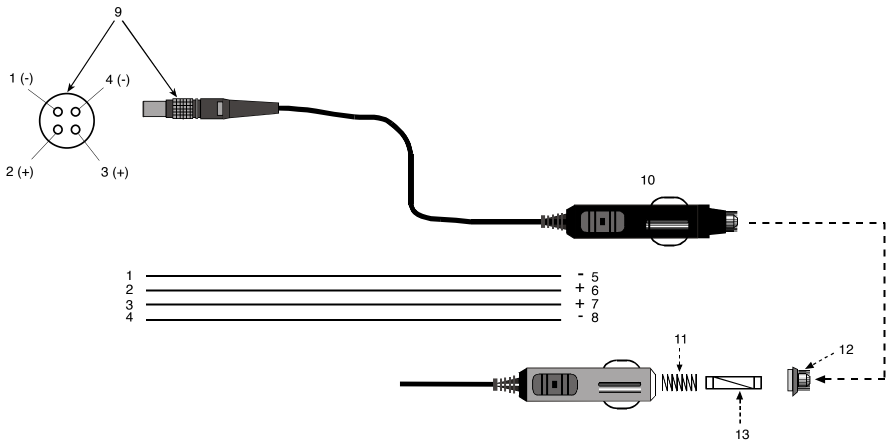
✉ For strobe signal descriptions, please see *Section 3.3.1, Strobes on Page 36*.

K.5.2 Cables

K.5.2.1 Automobile Power Adapter Cable (NovAtel part number 01016331)

The power cable supplied, see *Figure 72*, allows you to connect a DC power source of your choice. It is conveniently equipped with an automobile power adapter for supplying +12 VDC while operating from an automobile. The output from the power adapter utilizes a 4-pin LEMO connector (LEMO part number: FGJ.0B.304.CNLD52Z). For field replacement of the LEMO connector, please see *Appendix J, Page 181* for a list of the manufacturers' part numbers.

The input power cable is fuse protected and has been charged from 4 amp to 2.5 amp. The automobile power adapter is equipped with a 3 Amp slow-blow fuse, located inside the adapter tip. The tip can be unscrewed to allow replacement of the fuse, if necessary. To ensure optimum performance when replacing the fuse first spring load the fuse. The adapter has an LED on its side panel to indicate that power is connected.



Reference	Description	Reference	Description
1	Brown	5	Ground
2	Orange	6	+10 to +36 VDC
3	Red	7	+10 to +36 VDC
4	Black	8	Ground
9	Red marker at top	12	Universal tip
10	Automobile adapter	13	3 amp slow-blow fuse
11	Spring		

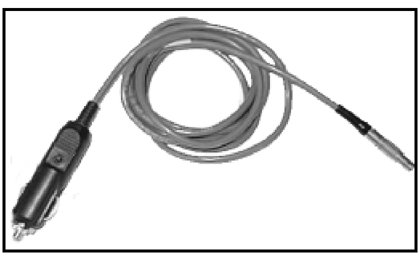
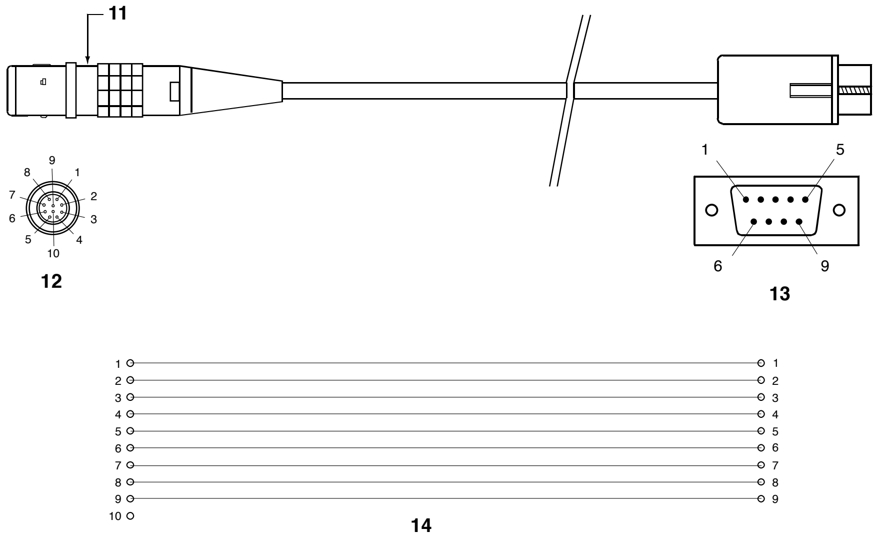


Figure 72: ProPak-4E Power Cable

K.5.2.2 Straight Serial Port Cable (NovAtel part number 01016383)

The straight serial cable, see *Figure 73*, is used to connect the ProPak-4E to a modem or radio transmitter to propagate differential corrections. The end connectors are a 10-pin LEMO plug (LEMO part number: FGG.1K.310.CLAC55Z) to a 9-pin D-connector (DE9P plug). This cable looks identical to the null modem serial cable, see *Page 206*, but its use and part number differs. For field replacement of the LEMO connector, please see *Appendix J, Page 181* for a list of the manufacturers' part numbers.

The 10-pin plug on each cable can be plugged into either the COM1 or COM2 port on the ProPak-4E.



Reference	Description	Reference	Description
1	Brown	8	Violet
2	Black	9	Gray
3	Red	10	White
4	Orange	11	Red marker at top
5	Yellow	12	LEMO 10-pin plug
6	Green	13	DE9P (male)
7	Blue	14	10-conductor cable

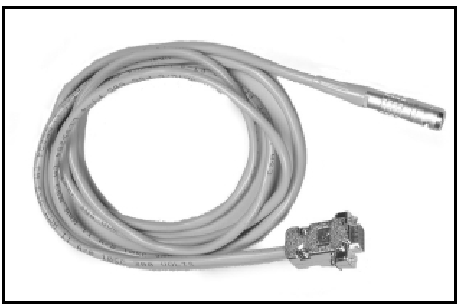
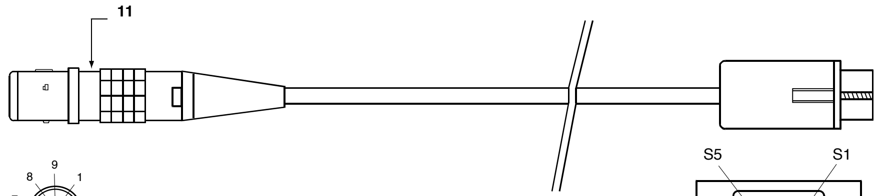
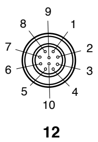


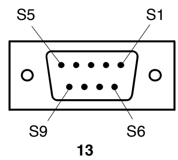
Figure 73: ProPak-4E Straight Serial Cable

K.5.2.3 Null Modem Serial Port Cable (NovAtel part number 01016329)

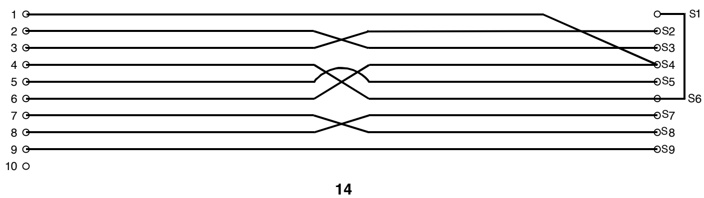
The null modem serial cable, see *Figure 74*, is used to connect the ProPak-4E to a serial (RS232) communication port on a terminal or computer. The end connectors are a 10-pin LEMO plug (LEMO part number: FGG.1K.310.CLAC55Z) to 9-pin D-connector (DE9S socket). This cable looks identical to the straight serial cable, see *Page 205*, but its use and part number differs. For field replacement of the LEMO connector, please see *Appendix J*, *Page 181* for a list of the manufacturers' part numbers.







Caution!: This cable is not supplied, and will not work, with a ProPak-4E unit configured for RS422 communication.



Reference	Description	Reference	Description
1	Brown	S1	White (not used, jumpered to S6)
2	Black	S2	Red
3	Red	S3	Black
4	Orange	S4	Green from 6 and Brown from 1
5	Yellow	S5	Yellow
6	Green	S6	Orange
7	Blue	S7	Violet
8	Violet	S8	Blue
9	Gray	S9	Gray
10	White	13	DE9S (female)
11	Red marker at top	14	10-conductor cable
12	LEMO 10-pin plug		

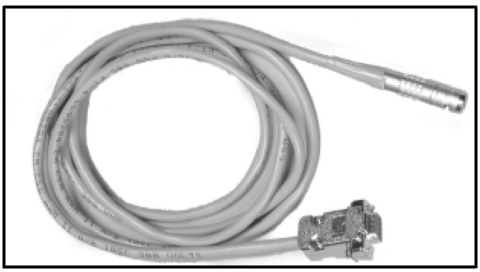
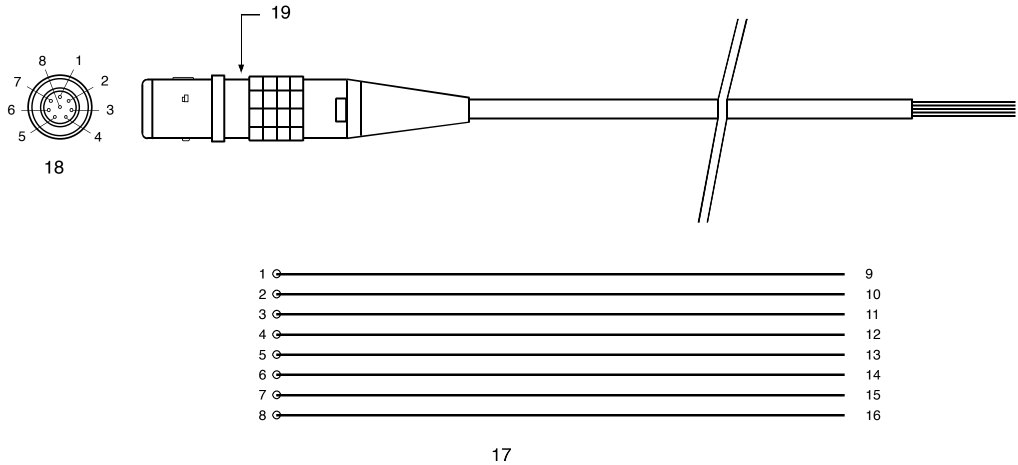


Figure 74: ProPak-4E Null Modem Cable

K.5.2.4 I/O Strobe Port Cable (NovAtel part number 01016330)

The ProPak-4E I/O strobe lines, see *Figure 75*, are available on the ProPak-4E back end-cap from the 8 pin LEMO connector (LEMO part number: FGL.1K.308.CLLC45Z). For field replacement of the LEMO connector, please see *Appendix J, Page 181* for a list of the manufacturers' part numbers. See also *Input/Output Strobes on Page 188* for a list of the pinouts and descriptions for each of the I/O strobes along with electrical specifications.



Reference	Description	Reference	Description
1	Brown	11	MSR
2	Black	12	Event1
3	Red	13	STATUS
4	Orange	14	GND
5	Yellow	15	GND
6	Green	16	GND
7	Blue	17	8-conductor wire
8	White	18	LEMO 8-pin socket
9	VARF	19	Red marker at top of connector
10	1PPS		

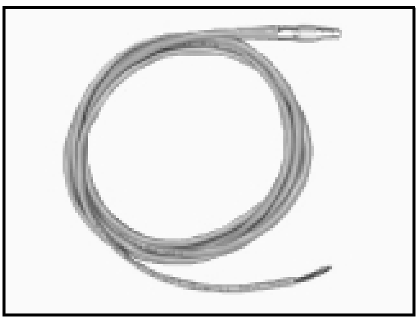


Figure 75: ProPak-4E Strobe Cable

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