# Chapter EM1: GPS Calculations

One of WinFrog's add-on modules is the **GPS Calculations Extension Module (GPS Calcs)**. Configured with this module, WinFrog is able to do the following:

- internally calculate positions from raw pseudorange measurements
- apply corrections from up to 5 RTCM sources into a DGPS solution
- provide UKOAA statistical testing of the GPS results
- Reference Station Integrity Monitoring (RSIM) for RTCM sources
- GPS pod positioning using inverse DGPS solutions

This functionality is only available through the **GPS Calculations Extension Module**. The core WinFrog software package is only able to provide positioning information in real-time if: a separate device is internally calculating a position, is correctly interfaced to WinFrog, and is outputting positioning information in a recognized format.

The **GPS Calcs** module utilizes the same basic methodology to calculate a position as most GPS receivers; by measuring distances to numerous points (satellites) of known coordinates, then combining the information into a least squares solution to get the final coordinates.

GPS receivers measure the distance to each satellite (termed a pseudorange) by observing the time it takes for a signal to travel from the satellite to the receiver. The positions of the satellites are known based on mathematical predictions made as a result of the observations made by GPS control stations located around the earth. By combining at least four ranges to four satellites of known positions, the receiver's latitude, longitude, and ellipsoidal height can be determined.

This is a very simplified explanation of how a position is derived by GPS. The following sections provide further detail on how GPS works and how WinFrog GPS calculations are configured to calculate a position using GPS.

**Note:** Datum transformations from WGS84 to the Working Ellipsoid are performed on the calculated receiver position before it is used for positioning a vehicle. If a problem is encountered executing the transformation, a pop-up message will appear providing details. For example, if the Geodetics are configured to use the NADCON transformation and the position being transformed does not lie within the specified area, the transformation will fail and a pop-message appears stating "Datum Shift Error: Input outside NADCON zone". The message only appears the first time a transformation fails, resetting when a successful transformation is executed. When a transformation fails, the status is displayed in the respective Calculation window and the position data is not used.

# Pseudorange Positioning

Pseudoranges are GPS time measurements that are not corrected for the lack of synchronization between the clocks onboard the GPS satellites and the clock onboard the GPS receiver.

The distance to a satellite is based on the time it takes for the signal to travel from the satellite to the receiver. If the clock on the receiver is not on the exact same time reference as the satellite clock, the time measurement will be in error. Since the signals transmitted by the satellites travel at the speed of light (186,000 miles per second), even the slightest error in the timing will result in a substantial error in the range measured to the satellite. The use of these "uncorrected" GPS measurements will obviously result in an inaccurate position solution. The receiver clock error must be removed before an accurate position can be determined. This is accomplished in most GPS receivers (and the WinFrog GPS calculations) by utilizing measurements made simultaneously to numerous satellites. An approximate three-dimensional (3D) position is derived by combining pseudoranges from at least four satellites. Mathematically, the position can be derived by using only three pseudoranges. The fourth pseudorange provides a mathematical redundancy to allow for the calculation of the receiver clock error. By applying an adjustment to the observed pseudoranges, the receiver clock error is resolved and, ultimately, removed.

Numerous additional errors also exist in a standalone GPS position solution, requiring additional corrections to be applied. If no corrections are applied, the positioning accuracy of GPS is approximately no better than 100 meters. This is far below what is required for most survey applications. The methods used to correct a single point position are described in further detail in the following sections.

With the **GPS Calculations Extension Module**, WinFrog partially takes the place of the GPS receiver. WinFrog allows for the configuration of satellite cut-off elevation angles, minimum **D**ilution **O**f **P**recision (**DOP**) values, and minimum **Signal-to-Noise** ratios. In addition, WinFrog can be configured to apply RTCM format differential corrections to improve positioning accuracy and to apply carrier phase smoothing to the code solution, resulting in GPS position solutions with reduced noise.

By taking over the calculations from the GPS receiver, the **GPS Calculations** module provides you with much greater control over the way the GPS position is calculated and, subsequently, much greater positional quality assurance.

WinFrog relies on third party hardware to provide the pseudorange information and the "ephemeris" required to calculate a position. **Ephemeris** is a set of satellite orbit parameters used by the GPS receiver to calculate precise GPS satellite positions and velocities. The ephemeris predicts where the satellites are at every instant of time.

Not all GPS receivers made are able to provide the pseudorange and ephemeris information required by WinFrog's **GPS Calcs.**

WinFrog currently supports the following GPS devices for processing pseudoranges:

- Ashtech Sensor II
- Magnavox MX9400
- NavStar XR5
- NavStar PR
- NovAtel Console
- NovAtel Tele
- NovAtel RS232
- GPS Pod (see the section entitled **GPS Pod Positioning** for more information)
- Trimble Cyclic
- Trimble TSIP

See the section below named **Adding GPS Devices** for more information on using these devices with WinFrog's **GPS Calcs Module**.

# Differential GPS (DGPS)

As mentioned above, standard GPS positioning does not provide the accuracy required for most survey applications. The application of **Differential GPS (DGPS)** corrections can improve positional accuracy to acceptable (meter) levels.

As the name implies, DGPS measurements utilize the differencing of GPS observations between receivers to improve accuracy. The basis in the theory behind DGPS corrections is that the mobile GPS receiver is experiencing the same positional errors as the **Base Station** (AKA **Reference Station**) GPS receiver. In standard **C/A Code** DGPS positioning, the base station GPS receiver is placed on a fixed point of known coordinates. Approximately every second, the base station receiver calculates its position and compares it to an entered known position. It then calculates the correction required to be added to each of the pseudoranges (in meters) so that the calculated position would match the known position.

These corrections are called **Pseudorange Corrections**, sometimes abbreviated as **PRC**. These corrections, as well as **Rate of Range Correction** (AKA **RRC**) data are transmitted in real-time and applied by the rover GPS receiver as they are received. Typically, the DGPS data are transmitted and received via a UHF or MF radio link. The resulting corrected rover (mobile) position is then referred to as a DGPS position.

# RTCM Data

In order to enable the use of more than one brand of GPS receiver for DGPS positioning (for either **Base Station** or **Rover** applications), a standard message format was introduced to which almost all GPS receiver manufacturers conform. This format is called **RTCM**, which is an acronym for the name of the committee that created it: the **Radio Technical Commission for Maritime Services**. The RTCM standard defines not just **PRC** and **RRC** data, but a total of 64 messages related to GPS and marine navigation. RTCM Message types **1** and **9** provide the most relevant data for meter-level DGPS positioning systems as they include PRC, RRC, and satellite health information.

With the universality of the RTCM message format, numerous sources of DGPS corrections are available, depending on the user's location. One source of RTCM corrections is the United States Coast Guard Navbeacon Service. This service consists of several networks of **M**edium **F**requency (MF) DGPS transmitting stations, covering almost all of the United States coastal areas. These corrections are transmitted 24 hours a day, 365 days a year, and are available at no cost to the user, save for the cost of the MF receiver.

RTCM corrections are also available in larger metropolitan areas from several commercial sources. These systems often utilize existing FM radio frequencies to broadcast the corrections. Fugro SkyFix offers RTCM corrections from a worldwide network of more than 60 reference stations, broadcast using the INMARSAT satellite communications system.

# DGPS Solutions in WinFrog

As mentioned previously, WinFrog's **GPS Calculations Extension Module** can implement RTCM format DGPS corrections into its calculations to increase the resultant positional accuracy. This implementation is not limited to utilizing corrections from only one DGPS reference station. The GPS Calcs module can use the RTCM corrections from up to five different reference stations, combining them to produce what is referred to as a "**Multi-Ref**" (short for Multiple Reference Station) solution. WinFrog independently applies the corrections from each reference station to the observed pseudoranges, resulting in the same number of independent solutions. These independent solutions are then combined in a least-squares weighted calculation to produce a single, final position. The weighting of the individual solutions in the final position solution is based on relative standard deviation values entered by the user in the Select DGPS Reference Stations dialog box. This value is used as a scalar (multiplicative) factor, applied to the standard devications calculated for the latitude, longitude, and height for each reference station solution. The scaled standard deviations are then used as the weight for the respective unknown in the determination of a weighted mean value; the higher the standard deviation, the less accurate that value is deemed to be and, hence, the less weight that will be applied to that observation in relation to the others of the same type.

Multi-Ref solutions can also be obtained by adding multiple RTCM receivers to WinFrog. For example, adding 2 or 3 U.S. Coast Guard beacon receivers (each set to receive a different set of RTCM corrections) will allow for a Multi-Ref solution.

**Multi-Ref** solutions offer three distinct advantages over a single RTCM source solution:

| | |
|---|---|
| **Increased Reliability** | a DGPS solution is still available if one of the RTCM base stations fails. Independent solutions can be removed from the mean position calculations if they are unstable or of questionable quality. |
| **Increased Accuracy** | In remote areas, combining corrections from multiple surrounding base stations removes any local biases from the rover's DGPS position. |
| **Quality Control** | If the RTCM DGPS corrections being received are being generated by another WinFrog system located at the Base Station, WinFrog's **GPS Calcs Module** can utilize Reference Station Integrity Monitoring (RSIM) data to verify the quality of the DGPS position. |

# To Configure GPS Calculations

This section details the steps required to configure GPS Calculations in WinFrog, including the addition and configuration of all required devices. As per any device used in WinFrog, these devices must first be added to the WinFrog system (and "generically" configured), then added to the specific vehicle's device list and configured for that specific application.

## To Add a GPS Device to WinFrog

As mentioned briefly above, WinFrog's **GPS Calculations Extension Module** requires GPS pseudorange and ephemeris data to generate a position. Not all GPS receivers are capable of providing this information, nor is WinFrog currently capable of using the data from every GPS device that can generate this information. See the section named **Pseudorange Positioning** above for a list of those devices that are currently supported by WinFrog.

Some GPS receivers require more than one serial port to provide all of the required information to WinFrog. For example, **Trimble 4000** receivers pass the ephemeris data to WinFrog via the **RCI** option (the **Trimble RCI** device in WinFrog) and the pseudorange data via the **Cycle Printouts** option (the **Trimble Cyclic** device). Each of these data types is treated as a separate device by WinFrog and, as such, must be connected to an independent serial port and added to WinFrog as a separate device.

In many Fugro Pelagos WinFrog installations, **Novatel** PC card GPS receivers are also used to provide ephemeris and pseudorange data to WinFrog. This is typically added to WinFrog by adding the **NOVATEL CON** GPS device to the WinFrog system.

See the **Peripheral (I/O) Devices** chapter for more information about adding GPS devices to WinFrog. Since the Trimble 4000 and NovAtel GPS Card are the most commonly used devices (in Fugro Pelagos installations) for providing information to the **GPS Calculations Extension Module**, their specific details are shown below.

**1** Choose **Configure > I/O Devices > Add.**

**2** Click the "+" beside the GPS group.

**3** Double-click the appropriate device.

For the **Trimble 4000 DL** receiver, add the **Trimble RCI** and **Trimble CYCLIC** devices.

For a **NovAtel GPSPC card**, add the **NovAtel Con** device.

**4** Configure the appropriate parameters.

**5** Choose **OK**.

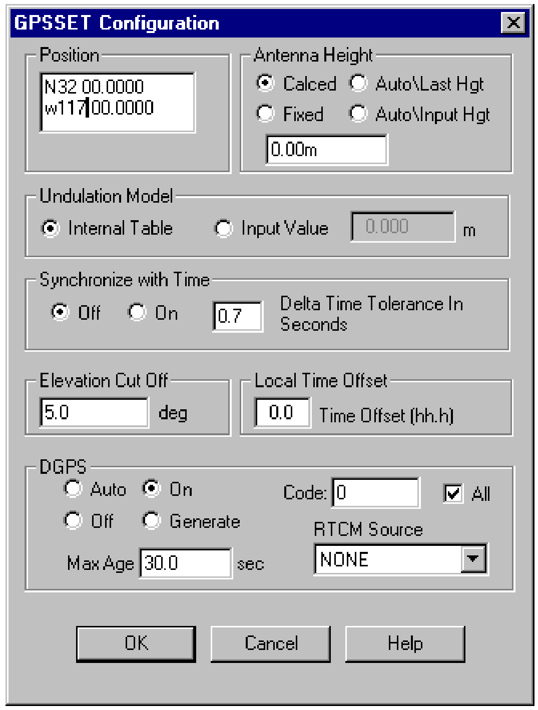
### To Generically Configure a GPS Device

With the required GPS device(s) now added to WinFrog, you must "generically" configure each device. **Note:** not all devices require this "generic" configuration, but it is best to attempt this configuration on **all** devices until you become familiar with the devices. The generic configuration of a device is accomplished easiest through the **I/O Devices** window.

**1** Select **View > I/O Devices**.

**2** Highlight the appropriate device then click the right mouse button and select **Configure Device**.

A dialog box opens for those devices requiring "generic" configuration, such as the NovAtel GPS Console device, as seen in the next figure.




### To Add a GPS Device's Data Items to a WinFrog Vehicle's Devices List

The addition of a peripheral I/O device's **Data Items** to a WinFrog vehicle is a straight-forward process and is detailed in the **Peripheral (I/O) Devices** chapter. The only additional concern when dealing with GPS devices to be used by the **GPS Calcs Module** is the fact that some of these GPS devices provide up to 3 separate **Data Items** that must be added to a vehicle; **Pseudorange**, **Ephemeris**, and **TimeDate.**

Since the **Trimble 4000** and **NovAtel GPS Card** are the most commonly used devices (in Fugro Pelagos installations) for providing information to the **GPS Calcs Module**, their specific details are found below.

When using a **Trimble 4000** GPS receiver:

- Add the **GPS**,**Trimble RCI, EPHEMERIS** and **GPS**,**Trimble Cyclic, PSEUDORANGE** data items.(The **GPS**,**Trimble Cyclic, TIMEDATE** device is optional and requires additional wiring.)

For a **NovAtel GPS PC** card:

- Add the **GPS,CONSOLE,PSEUDORANGE** and **GPS,CONSOLE,EPHEMERIS** data items. The **GPS,CONSOLE,POSITION** data item is the position as calculated internally by the NovAtel GPS Card. This can be added for use as a backup (redundant) positioning source, but is not required for **GPSCEM** purposes.

### To Configure a GPS Device for a Vehicle Using GPS Calcs Module

It is an absolute necessity that you edit the "specific" configuration of a GPS **Pseudorange** device that is to be used with the **GPS Calcs Module**. This "editing" provides access to many important configuration options that will affect the quality of the positioning as calculated by the **GPS Calcs Module**.

The steps required to configure a device for a specific vehicle are detailed in the **Peripheral (I/O) Devices** chapter. The following paragraphs detail the dialog boxes that display when you edit a **Trimble GPS Pseudorange** device added to a vehicle's device list.

**1** Open the **Vehicle Text** window (**View > Vehicle Text**). Place the mouse pointer within the boundaries of the **Vehicle Text** window, then click the right mouse button, and select **Configure Vehicle-Devices**.

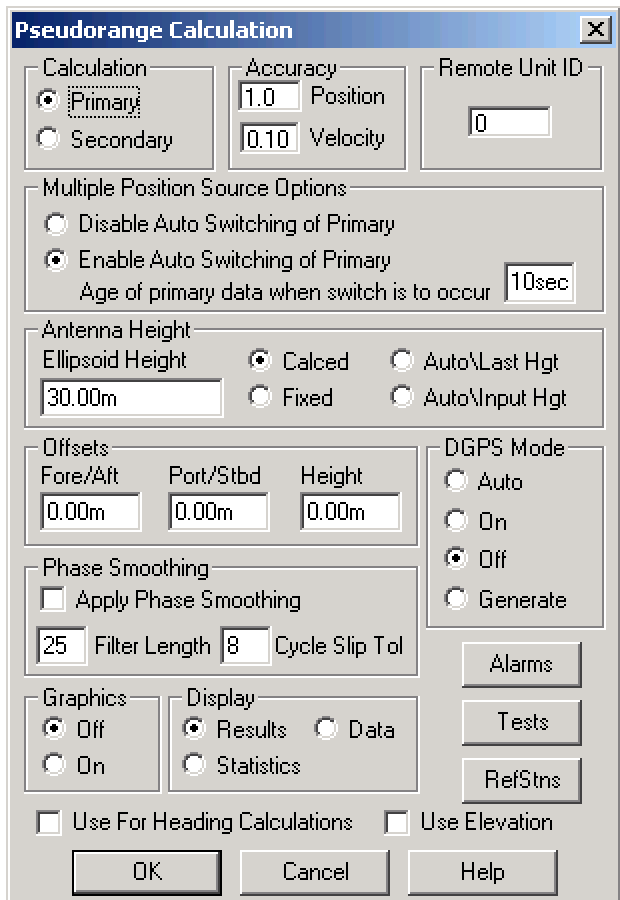
**2** Highlight the **GPSPSEUDORANGE** device.

If a **Trimble 4000** is used, this is the **GPS, Trimble CYCLIC, PSEUDORANGE** device.

If a **NovAtel GPS PC** card is used, select the **GPS, CONSOLE,PSEUDORANGE** device.

**3** Click the **Edit** button.

The **Pseudorange Calculation** dialog box opens, as seen below.




**4** In the **Calculation** area at the top of the **Pseudorange Calculation** dialog box, select either the **Primary** or **Secondary** radio button.

| | |
|---|---|
| **Primary** | If selected, the pseudorange-derived solution is used in the Kalman filter to produce a position solution. More than one positioning device can be |

| | |
|---|---|
| | configured as **Primary**. WinFrog will combine the positions from all **Primary** devices into a weighted solution based on the accuracy value of each device. The lower the accuracy number (the higher the accuracy), the more weight applied to that device. |
| **Secondary** | If selected, the pseudorange-derived position is simply monitored and is not utilized in the Kalman filter for real-time positioning. |

**5** In the **Accuracy** area, enter a value in the **Position** field.

This is the expected accuracy of the **Pseudorange** derived position and is used in the weighting of this device in the Kalman filter.

See the manufacturer's manual for the stated accuracy value.

**6** In the **Accuracy** area, enter a value in the **Velocity** field.

This is the maximum acceleration allowed in the Northing and Easting components of the pseudorange-derived position (in meters/second^2). This entry affects how dynamic the calculated GPS receiver's positioning can be.

See the manufacturer's manual for the stated accuracy value.

**7** Enter a value in the **Remote Unit ID** field.

This parameter is used when receiving pseudoranges from a remote GPS device, such as a **GPS Pod**. Typically, remote stations utilize radio telemetry networks to transfer their pseudoranges to WinFrog. This requires that each member of the network have a unique ID or code to be identifiable.

Unless the Pseudoranges are coming from a network source, the **Remote Unit ID** value should be left at 0.

**8 Multiple Position Source Options**

This group box allows you to enable automatic switching of a secondary to primary should the data from all POSITION and PSEUDORANGE data items set to primary timeout. The **Age** entered is the length of time that the secondary will wait in the absence of data from all primaries, before taking over as primary. This age is only entered for the secondary.

For example, if the POSITION or PSEUDORANGE data items associated with two GPS receivers were set to primary and the POSITION or PSEUDORANGE data item of a third GPS receiver was set to secondary, both primary GPS receivers must time out before the secondary will become the primary. Upon the recovery of either of the original primary data items, the original primary will be reset to primary and the original secondary will be reset to secondary.

Note for the auto switching feature to work, there must be at least one primary and one secondary enabled. For example, given two data items, one set to primary with the auto switching disabled and the other set to secondary with the auto switching enabled, if the primary fails the secondary is not set to primary and the vehicle positioning stops until the primary data item recovers.

**Disable Auto Switching of Primary:**

If this data item is not to be involved in the auto switching process, check this box. As stated above, this data item is then not involved in the auto switching process in any way.

**Enable Auto Switching of Primary:**

If this data item is to be involved in the auto switching process, either as a primary or a secondary, check this box. If set to secondary, enter the Age of data the primary data items must reach before this secondary is switched to act as the primary.

In order for this option to be effective you must have at least one primary and one secondary. If there are multiple secondary data items that are enabled for switching, the first one to receive data will become primary.

Note: This option is not available for USBL based POSITION data items.

**9** In the **Antenna Height** area, the following parameters are configured:

| | |
|---|---|
| **Ellipsoid Height** field | Enter the **Height** of the antenna with respect to the **WGS84 Ellipsoid**. |
| **Calced** radio button | WinFrog uses a pseudorange-derived **Elliposid Height** as the antenna's **Ellipsoid Height**. In this mode, WinFrog requires a minimum of **four** satellites in order to calculate a valid position and elevation. |
| **Fixed** radio button | Fixes the **Antenna Height** to the **Ellipsoid Height** entered in the **Ellipsoid Height** field. In this mode WinFrog is able to calculate valid positions using a minimum of **three** satellites. |
| **Auto\ Last Hgt** radio button | WinFrog calculates a valid **3D** position if four or more satellites are available. If only three satellites are available, the **Antenna Height** is fixed to that of the last **valid Calculated Ellipsoid Height** value. In this mode WinFrog is able to calculate valid positions using a minimum of **three** satellites. |
| **Auto\ Input Hgt** radio button | WinFrog calculates a valid **3D** position if four or more satellites are available. If only three satellites are available, the **Antenna Height** is fixed to the value entered in the **Ellipsoid Height** field. In this mode, WinFrog is able to calculate valid positions using a minimum of **three** satellites. |

**Note**: the **Antenna Height** entered in the **Pseudorange Calculation** dialog box is always referenced to the **WGS84 Ellipsoid**. In some other WinFrog dialog boxes, heights may be referenced to **MSL** (mean sea level) or the user-defined vertical reference point.

**10** In the **Offsets** area, enter the offsets of the GPS antenna from the CRP using the **Fore/Aft**, **Port/Stbd**, and **Height** entry fields.

These values are defined as the antenna position as measured from the **Common Reference Point**. Remember that forward and starboard positions are entered as positive numbers, while aft and port are entered as negative numbers. Ensure that the units of measure are entered correctly.

**11** Select the appropriate radio button in the **DGPS Mode** area.

There are four different **DGPS Modes**:

| | |
|---|---|
| **Auto** radio button | WinFrog will apply differential corrections to its GPS pseudorange-derived position calculations when those corrections are available to the vehicle. If no RTCM corrections are available, WinFrog computes a single point (+/- 100 meters) solution. |
| **On** radio button | WinFrog must receive RTCM differential corrections. If no DGPS corrections are available, WinFrog does not compute a position. |
| **Off** radio button | WinFrog does not use RTCM differential corrections in its pseudorange-derived position computations, even if they are available. Only a single point GPS position will be calculated in this mode. |
| **Generate** radio button | Reserved for future development. |

**12** Configure the parameters in the **Phase Smoothing** area.

If the **Apply Phase Smoothing box** is checked, set the **Filter Length** and **Cycle Slip Tolerance**.

WinFrog has the capability to use GPS Carrier Phase measurements to smooth GPS Code positioning.

The GPS system works by modulating the standard C/A code information onto two carrier frequencies identified as L1 and L2. These carrier frequencies have a wavelength of 19 and 24 centimeters, respectively, and carry no timing or navigation information. Some high precision, survey-grade GPS receivers can lock onto either L1, L2, or both L1 and L2 frequencies. Most GPS receivers typically utilize only the L1 frequency.

Since the carrier frequencies carry no timing information, there is no method of analyzing the time difference from signal transmission at the satellite to signal reception at the receiver and, hence, no way to use the signal by itself to solve for a position.

However, once the GPS receiver has locked onto the carrier frequency, it is able to count the change in the number of carrier phase wavelengths that has occurred since lock. This provides the basis for WinFrog's Carrier Phase Smoothing.

This technique works by using a weighted combination of Code and Carrier Phase observations in the final GPS position solution. The relative weights of the two measurements changes with time. When Phase Smoothing is initially turned on, WinFrog utilizes only the Code measurements in the position solution. Based on the calculated C/A Code position, WinFrog then calculates the number of L1 frequency wavelengths between the receiver and each of the satellites and attempts to calculate a position based on these new ranges. Because there are multiple satellites to consider, and the fact that the C/A code position is not usually better than plus or minus 1 meter, there are several possible solutions to each satellite's Carrier Phase count.

Numerous combinations are attempted, until a solution with the best fit of all ranges is obtained. As mentioned above, as long as the satellite's carrier frequency remains in lock, the GPS receiver can observe the incremental or decremental count in the Carrier Frequency wavelengths. This allows the Carrier solution to remain intact despite the fact that the satellites and the GPS receiver are both moving.

Over time, the smoothing filter begins weighting the Code measurements less and relying more on the Carrier Phase measurements. After a user-definable number of epochs (an epoch can be considered to be approximately equal to 1 second) WinFrog relies almost exclusively on the Carrier Phase measurements.

Because the Carrier Phase solution (i.e. the carrier wavelength counts) are determined only by the C/A Code position, no gain is made in terms of overall positional accuracy. However, because the individual pseudorange observations are now being made to greater accuracy (i.e. fractions of a 19 cm wavelength), positional stability is improved.

This state of improved stability remains intact as long as the GPS receiver is able to maintain lock on the satellites and therefore able to continue to utilize the initial Carrier Phase wavelength count changes. However, if the GPS receiver loses lock on a satellite's Carrier frequency (called a “Cycle Slip”), it must re-calculate the total number of wavelengths to that satellite. The GPS receiver provides this Cycle Slip information to WinFrog. If the number of Cycle Slips exceeds the user-specified tolerance, WinFrog returns to the C/A Code position and re-calculates the number of Carrier Phase wavelengths to each satellite.

### To Configure the Phase Smoothing Filter

- With the **Pseudorange Calculation** dialog box still open, select the **Apply Phase Smoothing** box in the **Phase Smoothing** area of the **Pseudorange Calculation** dialog box.

- Enter a value in the **Filter Length** field.

  The **Filter Length** value sets the number of epochs (approximately the same as seconds) over which WinFrog switches from a position based on Code measurements to a position based on the Carrier Phase measurements.

  For example, if the filter length is set to 25, it takes 25 epochs before the GPS Calcs Module position will rely almost exclusively on the Carrier Phase measurements.

- Enter a value in the **Cycle Slip Tol** field.

  The **Cycle Slip** tolerance parameter sets the sensitivity of the **Cycle Slip** detection routine. This routine works by using **Doppler Phase Rates** to predict phase measurements from epoch to epoch. This prediction is compared with the actual measurement. If the difference between the prediction and the actual measurement is greater than the **Cycle Slip tolerance**, then WinFrog assumes that a **Cycle Slip** has occurred and the smoothing filter is reset. WinFrog's ability to predict phase measurements depends heavily on the vehicle's dynamics. **Note:** in highly dynamic situations, it may be necessary to **increase** the **Cycle Slip Tolerance**.

**13** In the **Graphics** area of the **Pseudorange Calculation** dialog, select either the **On** radio button or the **Off** radio button.

If **Graphics** are turned **On**, a labeled cross representing the raw (unfiltered) location of the antenna (as calculated by the **GPS Calcs Module**) is plotted in the **Graphics** and **Bird's Eye** windows. This feature allows a comparison of raw versus filtered positions between different sources. This also provides a check of the offset values entered.

**14** In the **Display** area, select one of the three radio buttons.

This parameter sets which type of information is displayed in the pseudorange device's **Calculation** window. It can be set to one of the following modes:

| | |
|---|---|
| **Results** | Displays the Results of the GPS Calculations. |
| **Data** | Displays information about Carrier Phase Smoothing. |
| **Statistics** | Displays Statistical data.<br>See the **Monitoring of Statistical Tests** section below for more information. |

For more information about the different Pseudorange displays, see the **GPS Calculation Displays** section later in this chapter.

**15** The **Alarms** button is used to access the **GPS Alarms** configuration dialog box. More details are found in the **Alarms** section later in this chapter.

**16** The **Tests** button is used to configure statistical tests. More details are found in the **UKOOA Statistical Testing** section later in this chapter.

**17** The **Ref Stns** button is used to configure which DGPS Reference stations will be used to provide **RTCM** corrections to the vehicle's pseudorange position solution. The following sections will detail all steps required to configure WinFrog for DGPS pseudorange positioning.

**18** Enable the **Use for Heading Calculations** feature if the device is to be used in conjunction with another GPS device for determination of heading of the vessel. In most cases, only high accuracy receivers should be used for heading calculations as WinFrog simply inverses the individual sensors' raw positions to derive the azimuth between them.

**19** Enabling the **Use Elevation** feature affects the **Water Depth** value that is recorded in WinFrog's data files (i.e. the automatic and manual files).

Rather than record simply the water depth value received from the echo sounder (with applied offsets), WinFrog will derive the **Ellipsoidal Height** of the bottom. WinFrog will use the derived **GPS Antenna Ellipsoidal Height** and **subtract** the **GPS Antenna Height Offset**, the **Echo sounder Depth Offset**, and the **Observed Water Depth** values.

This option is required in those circumstances where there is no constant vertical reference to which depth measurements can be referred, such as is the case when surveying a river. This feature should only be used when a high accuracy (centimeter-level) RTK GPS system is used.

# Applying RTCM Corrections to WinFrog Pseudorange Position Calculations

WinFrog **Pseudorange Calculations (**i.e. the **GPS Calculations Extension Module)** can solve for a standalone (non-DGPS corrected) position, a single reference station DGPS solution, or a multiple reference station (**Multi-Ref**) DGPS solution.

The previous sections detail the addition and configuration of GPS Pseudorange devices for standalone positioning. The following sections explain how to apply DGPS corrections from a single RTCM source or multiple RTCM sources to WinFrog pseudorange calculations.

## To Add RTCM Device(s) to WinFrog

**1** From the **Configure** menu, choose **I/O Devices… > Add**.

**2** Choose **RTCM** from the devices list.

**3** Click **OK**.

**4** Configure the following serial port communication parameters in the **Comm Data** dialog box:

| | |
|---|---|
| **Name:** | should be a unique name for the RTCM correction to distinguish this device from other RTCM devices. |
| **Baud Rate** | enter the same value as the RTCM device |
| **Data Bits** | enter the same value as the RTCM device |
| **Parity** | enter the same value as the RTCM device |
| **Comm Port** | selects the operating system's communication port to which the device is connected, (**not** the Digiboard™ port number, although they may be the same in some cases). |

Consult the RTCM device's manual for more information on communication settings for the device.

**5** Once the communication parameters are set, click **OK**.

If multiple RTCM receivers are used, they must each be interfaced separately, and added to WinFrog individually with a unique identifier (i.e. RTCM1, RTCM2, etc.). In other words, repeat steps 1 through 6 above for each RTCM device.

If a Fugro **SkyFix** receiver is used, it is interfaced to the WinFrog computer as a **single** RTCM device, despite the fact that a single SkyFix receiver can provide RTCM corrections from up to 5 different reference stations in its data string. The individual RTCM **ID**'s are later added to the vehicle's position separately. This concept is explained below.

**6** From the WinFrog menu bar select **View > I/O Devices.**

**7** Highlight the appropriate **RTCM** device(s) and ensure that the **SV**, **PRC**, **RRC**, and **IOD** data are updating at regular intervals.

Most RTCM systems should be updating this information approximately every 3-5 seconds.

### To Add an RTCM Device to a Vehicle's Device List

The next step is to add the **RTCM** Device(s) to the vehicle's **GPS Calcs Module's** position calculations.

**1** Ensure that the appropriate vehicle **Name** is displayed in the **Vehicle Text** window. Place the mouse pointer in the **Vehicle Text** window (**View > Vehicle Text**), click on the right mouse button, and select **Configure Vehicle-Devices**.

**2** Click the **Add** button.

**3** Select the **RTCM,*,DGPS-COR's** device from the list of **Available Data Items**.

**4** Click **OK**.

The **RTCM, *,DGPS-COR's** device now appears in the vehicle's **Devices** window.

**5** Repeat steps 1-4 for each reference station to be used in the position calculations.

For example, Fugro's SkyFix system sends RTCM corrections for up to 5 reference stations on the same data string. Selecting **Use All** with a SkyFix device removes the ability to control (i.e. add or remove) the RTCM stations individually. It is better to add the SkyFix **RTCM** device to the vehicle's device list multiple times (once for each station used), and configure the **Station Id (Stn ID)** of each RTCM "device" to reference one of the **Codes** in the SkyFix data string. WinFrog allows a maximum number of five RTCM sources to be used in a vehicle's GPS Calcs Module position calculations.

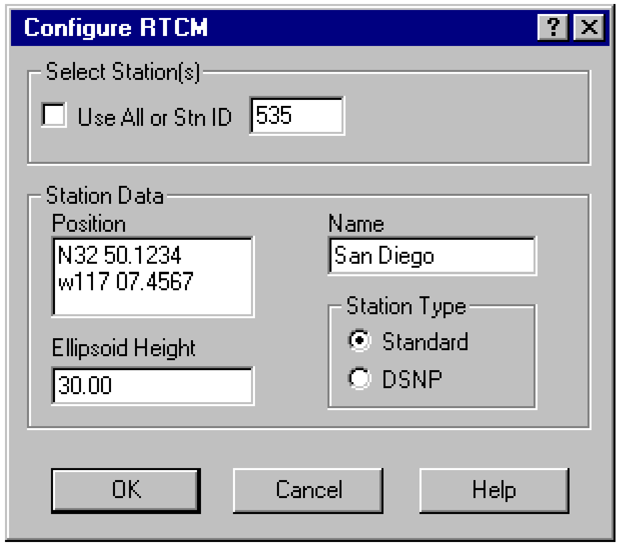
The next step is to configure the RTCM device for use with the **GPS Calculation Extension Module**.

### To Configure an RTCM Device in a Vehicle's Device List for use with the GPS Calcs Module

**1** Ensure that the appropriate vehicle name is displayed in the **Vehicle Text** window. Place the mouse pointer in the **Vehicle Text** window (**View > Vehicle Text**), click on the right mouse button, then select **Configure Vehicle-Devices**.

**2** Highlight the **RTCM,*,DGPS-COR's** device from the appropriate vehicle's **Devices** list and select the **Edit** button. The **Configure RTCM** dialog box displays, as seen below.

**3** Enter the appropriate values in the **Configure RTCM** dialog box:




## Select Station(s)

| | |
|---|---|
| **Use All** | As mentioned above, this setting is not preferred. If the **Use All** box is checked, WinFrog uses all of the reference stations data available with this **RTCM** device. |
| **Stn ID** | If the **Use All** box is not checked, WinFrog uses the specific reference station associated with the **ID** entered in this field. |

## Station Data

| | |
|---|---|
| **Position** | Enter the Reference Station's **WGS 84 latitude, longitude**, and **ellipsoid height**. This information is not used in the weighting of the reference stations in the Multi-Ref calculations. Although the distance to each reference station is, in fact, calculated and displayed in the Calculations window. This is for general information purposes only. |

**Note**: If the RTCM source includes a **Type 3** message (including the station's coordinates), WinFrog will "read" this information and update this entry window accordingly. SkyFix, for example provides this information for each reference station approximately every 2 minutes.

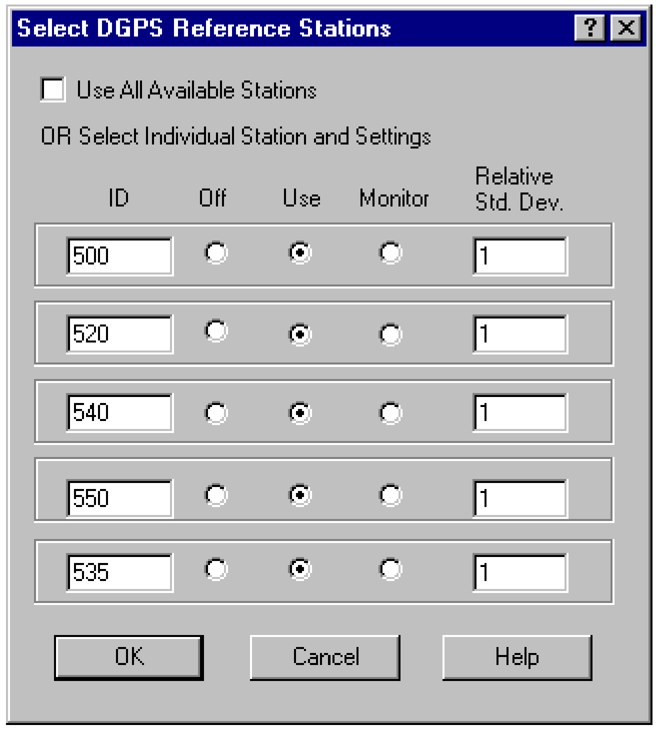
| | |
|---|---|
| **Name** | Enter the name of the **Reference Station** used. This will allow you to immediately identify the station if it fails, rather than have to reference the station's code to the location. |
| **Station Type** | These options are for future development and are not currently enabled. |

7 Click **OK** to close the **Configure RTCM** dialog box.

### To Enable/Remove an RTCM Source in WinFrog's Pseudorange Calculations

1. From the vehicle's **Configure Vehicle-Devices** menu, highlight the **GPS, name, PSEUDORANGE** device and select **Edit**.

2. Select the **RefStns** button in the lower right corner of the dialog box. The **Select DGPS Reference Stations** dialog box opens, as seen below.




3. There are two ways to enable the DGPS reference stations that have been added to the vehicle's device list.

**Use All Available Stations** — Select this option to instruct WinFrog to use all of the RTCM Sources that have been added. As mentioned above, this method does not provide you the control over the station selection that you have if you add the stations individually.

**Select Individual Stations and Settings** — Select this option to select and control which reference stations are used or simply monitored in the **GPS Calcs Module** position calculations.

- **ID** — Enter the individual reference stations' **ID** in the available windows.
- **Off** — Select this option to turn this station **Off** in the MultiRef Position calculations.
- **Use** — Select this option to **Use** this station in the MultiRef Position calculations.
- **Monitor** — Select this option to simply **Monitor** the position determined by using this Reference Station's RTCM corrections. This DGPS

position is not used in the Multi-Ref station solution.

Typically, a station's **ID** is set to **Use** unless that individual position solution becomes unstable and must be removed (i.e. set to **Off** or **Monitor**) from the overall Multi-Ref solution.

**Relative Std. Dev.** Enter the Relative Standard Deviation values in the entry windows at the right side of the dialog box (in meters).

By default, each DGPS position calculation is given a standard deviation value of 1 meter. This means that each of the individual positions calculated using the individual reference station corrections are treated equally when combined in the Multi-Ref solution. The weighting is inversely proportional to the number entered. In other words, entering a higher value in this window actually lessens the amount of weight that that position will have in the Multi-Ref solution. For example, entering a standard deviation of 2 will specify that that position will have a weight of ½ compared to the other stations.

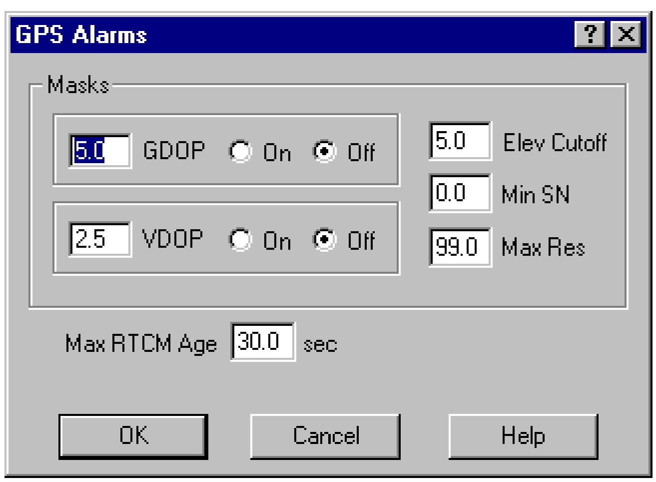
**4** Click **OK** to close the **Select DGPS Reference Stations** dialog box.

WinFrog should now be calculating a DGPS pseudorange solution. View the individual solutions and the weighted mean position information using the **View >Calculations** window. See the **GPS Calculations Displays** section later in this chapter for details about the data displayed in the **Calculations** window.

## Alarms

In addition to these standard configuration parameters, WinFrog can also be used to set various alarms to provide additional control over the GPS pseudorange calculations. Alarms are set to warn of the degradation in the accuracy of a solution.

Select the **Alarms** button in the **Pseudorange Calculation** dialog box. The **GPS Alarms** dialog box appears as seen below.



## Dilution of Precision (DOP)

**Dilution of Precision (DOP)** refers to the strength of the geometry of the visible GPS satellites with respect to the GPS receiver. Using satellites that are clustered together will typically produce a high **DOP** (i.e. a lower accuracy) value while using satellites that are found spread in all quadrants around the GPS receiver will provide a low **DOP** (i.e. high accuracy) value.

The **DOP** can be considered a multiplying factor of the sum of the other errors inherent in GPS positional calculations. An ideal geometry would provide a DOP value of 1. Since there are currently 24 satellites in use, and most GPS receivers are able to utilize between 6 and 12 channels simultaneously, an over-determined solution is sometimes available; in this case the **DOP** value can be less than 1.0.

DOP values are determined for all aspects of a GPS derived position: horizontal, vertical, and time components.

| | |
|---|---|
| **Geometric Dilution of Precision (GDOP)** | combines the horizontal, vertical, and time components |
| **Vertical Dilution of Precision (VDOP)** | this value refers only the dilution to the vertical component of the solution. |

### Masks

WinFrog can set masks to provide additional control over pseudorange calculations.

| | |
|---|---|
| **Elev (i.e. Elevation) Cutoff** | is used to limit the usage of satellite pseudoranges from satellites that are too close to the horizon. Signals sent from satellites near the horizon have longer travel times through the atmosphere, resulting in lower signal strength and increased (unpredictable) propagation delays. |
| **MinSN (Minimum Signal to Noise)** ratio | this value specifies what minimum signal strength value will be accepted. If the satellite's signal is not clearly received by the GPS receiver the coded information may be misinterpreted, resulting in ranging and, subsequently, positioning errors. |
| **Max Res (Maximum Residual)** | WinFrog uses the entry made here to decide if a satellite's pseudorange will be used in the position's solution. If the satellite range does not agree with the calculated position by less than the entered value, it will not be included. The **Max Res** value is always entered in meters. |

### To Configure Alarms

**1** With the **Pseudorange Calculations** dialog box still open, click the **Alarms** button. (To open the **Pseudorange Calculations** dialog box from the Vehicle's **Configure Vehicle-Devices** dialog box, highlight the **GPS, name, PSEUDORANGE** device and select **Edit**).

The following parameters are configured in the **GPS Alarms** dialog box:

| | |
|---|---|
| **GDOP (Geometric Dilution of Precision)** | This parameter is calculated from satellite geometry and gives an indication of the expected accuracy of the 3D position and time components of the final GPS solution. If you select the **On** radio button and the calculated **GDOP** exceeds the value entered in the **Masks** field, WinFrog displays the following warning in the **Calculations** window: **Rejected, GDOP Gating**. |
| **VDOP (Vertical Dilution of Precision)** | This parameter is calculated from satellite geometry and gives an indication of the expected accuracy of the vertical component of the GPS position solution. If the **On** radio button is selected and the calculated VDOP exceeds the value entered by the user in the **Masks** field, WinFrog displays the following warning in the **Calculations** window: **DGPS, VDOP Height Fixed**. |
| **Elev Cutoff (Elevation Angle Cutoff)** | In position computations, WinFrog will not use measurements from any satellites with elevation angles below the value entered by the user in the **Elev Cutoff** field. Any satellites that are below the value entered in the **Elev Cutoff** field are indicated by the text changing from black to magenta on the reference station page of the **Data Item Text** view in the **Calculations** window. |
| **Min SN (Minimum Signal to Noise)** ratio | Use this to set the minimum signal to noise ratio for the pseudorange calculations. If a satellite's signal to noise ratio falls below the entered value, it is not used in position computation by WinFrog. Satellites not used in the position computation are indicated by the text changing from black to magenta on the reference station page of the **Data Item Text** view in the **Calculations** window. |
| **Max Res (Maximum Measurement Residual)** | In its pseudorange position computations, WinFrog will not use any satellite measurement with a residual greater than the value entered in |

the **Max Res** field. Satellites not used in the position computation due to measurement residuals are indicated by the text changing from black to magenta on the reference station page of the **Data Item Text** view in the **Calculations** window.

**Max RTCM (Maximum RTCM Differential Correction Age)**

The value entered in the **Max RTCM** field sets the maximum age of real-time differential corrections. If the age of a satellite's corrections exceeds the entered value of the max RTCM age, the **STAT** light in the **Position** portion of the **Calculations** window turns yellow, indicating that the data are not used in the solution. Click the **ACK** button to acknowledge this alarm.

# UKOOA Statistical Testing

WinFrog pseudorange calculations include UKOAA statistical testing. This incorporates the basic GPS pseudorange position solution, QC (w-test, F-test), statistical analysis, and testing as detailed in the document, *Guidelines for the use of Differential GPS in Offshore Surveying*, September 1994, Issue #1, UKOOA.

**Note:** it is not recommended to use UKOAA statistical testing over long DGPS baselines. A DGPS baseline is the distance between the fixed, known DGPS reference station and the vehicle's position.

## w-Test

WinFrog's GPS pseudorange calculations combine pseudoranges from numerous satellites to calculate latitude, longitude, and height. In a perfect world, the distance from the calculated position to any of the satellites would be exactly the same as the measured pseudorange distance. However, in reality, a least-squares adjustment must be made to the observed distances to obtain the final position. This adjustment produces "residuals" in the pseudoranges. Residuals are the amount of error that remained after the pseudorange was adjusted to fit the mean solution.

The **w-test** entails normalizing the residuals of a GPS pseudorange solution and testing these against a 99% confidence limit for "outliers". An outlier is a pseudorange residual that falls beyond an acceptable limit. This limit is 2.576 times the standard deviation of the GPS device position. The standard deviation of most survey-grade GPS receivers can be approximated to be approximately 1 meter. If outliers are found, they are removed and the solution is re-executed, excluding that satellite data pertaining to the outlier. If more than one satellite is found to produce a residual outlier, only that satellite with the largest normalized residual is eliminated. This continues until no outliers are present or until the exclusion of any more data would result in insufficient data for a solution (four satellites for 3D and three for 2D). Since the normalized residuals tend towards being equal with reduced redundancy (as the number of satellites used in the solution approaches the minimum required), it is unlikely that WinFrog will ever have to stop the exclusion of data due to insufficient satellites. Nonetheless, WinFrog still checks for this condition.

# F-Test

The **F-test** is a check of the **Unit Variance** of the GPS pseudorange solution. This confirms the validity of the model used for the solution and the weighting of the observations used. **Note:** it is only a confirmation check; no data or solution results are "thrown out" based on the results of the test.

The unit variance should be unity. If the unit variance is consistently different from unity, it indicates that there may be a problem with the stochastic model used, or there is an unmodeled bias in the data.

## Calculation Notes for Statistical Testing

It is important to note that although WinFrog solves for position, clock, and velocities and drift, only the **Position** and **Clock** components of the solution are used for the **w-test** and the **F-test**.

The residuals pertaining to the position and clock unknowns are normalized and tested against the 2.576 limit. If any outliers occur, the maximum outlier is flagged and WinFrog then excludes the respective satellite data. This repeats until one of three conditions are met: no outliers are detected, further rejection of data would result in insufficient data for a solution, or five satellites have been excluded.

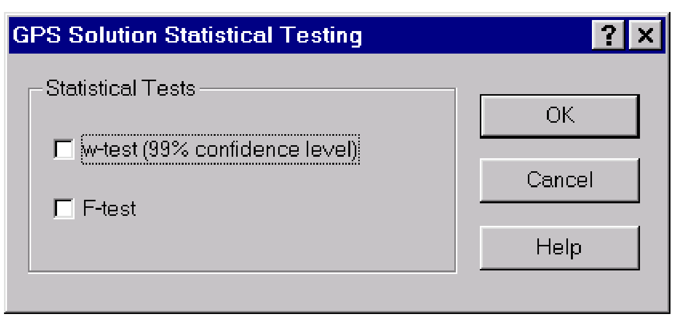
The normalization of the residuals, the determination of the maximum normalized residual, and the computation of the RMS are executed regardless of the w-test mode setting. However, outliers are only rejected if the w-test mode is on. Once the solution is finalized, the F-test is executed if the F-test mode is on.

WinFrog then proceeds with the calculation of the solution's standard deviations and error ellipses, both at the 95% confidence level.

### To Configure Statistical Tests

**1** With the **Pseudorange Calculation** dialog box still open, click the **Tests** button. (To open the **Pseudorange Calculations** dialog box from the **Vehicle's Configure Vehicle Devices** dialog box, highlight the **GPS, name, PSEUDORANGE** device and select **Edit.** See **To Configure a GPS Device for a Vehicle Using GPS Calcs Module** earlier in this chapter.)

The **GPS Solution Statistical Testing** dialog box appears.




By default both the **w-test** and the **F-test** are not enabled.

2 Click either the **w-test** (99% confidence level) checkbox, the **F-test** checkbox, both, or neither.

3 Click **OK**.

# Monitoring of Statistical Tests

### To Display the Results of the Statistical Testing

1 With the **Pseudorange Calculation** dialog box still open, select the **Statistics** radio button in the **Display** area.

The associated **Calculations** window displays statistical data in the Reference Station page. For more details, refer to the **GPS Calculation Displays** section earlier in this chapter.

# GPS Pod Positioning

WinFrog has the capability to track remote vehicles transmitting GPS pseudorange measurements through a UHF token ring telemetry link. This is done via the use of a Fugro Pelagos GPS “Pod”, which consists of a GPS receiver and a radio transmitter. Raw pseudorange measurements are transmitted from the remote GPS Pod to a radio receiver connected to the WinFrog computer. WinFrog then uses these pseudoranges to calculate a position for the pod in a manner similar to that described previously. RTCM corrections can also be applied to these pseudoranges to determine a DGPS position for the “Pod”.

All **Masks** and **Alarms** that can be used for a local GPS pseudorange device can also be used for a remote GPS Pod.

### To Track a GPS Pod in WinFrog

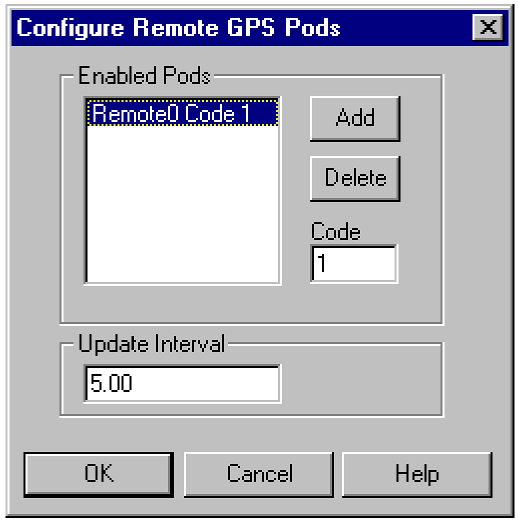
1 Select **View > I/O Devices.**

2 With the mouse pointer in the left (white) portion of the **I/O Devices** dialog box, right-click and choose **Add Device**.

3 Click the “+” symbol beside the **GPS** category and select **GPS Pod**.

4 Click **OK**.

5 Configure the Device I/O Parameters dialog box to suit the telemetry device’s current configuration. Be sure to include the GPS Pod’s Baud Rate, Data Bits, Stop Bits, Parity, and Communication Port Number, along with a Name for the pod.




6 Click **OK** to close this dialog box and save the changes.

7 In the **I/O Devices** window select the **GPS Pod** device, then right-click and select **Configure Device** from the options presented. The **Configure Remote GPS Pods** dialog box displays.

8 Select the **Add** button in the **Configure Remote GPS Pods** dialog box. A **Remote** is added to the **Enabled Pods** list.

9 The **Remote Unit Code** number must be entered. Each GPS Pod must have a unique **Remote Code** (also referred to as a **Remote Unit ID**) associated with it. This number must match the binary number configured on the GPS Pod's internal DIP switches.

**Note:** the **Code** cannot be zero as this is reserved for local (non-telemetry) GPS units.

10 Highlight the value in the **Code** entry window, then enter the **Code** as per above. Now click on the **Remote** (as found in the **Enabled Pods** portion of the window) to update the newly entered code value.

11 The **Update Interval** must be entered. This value should reflect realistic requirements and also the capabilities of the telemetry network. A value of **5.00** seconds is typically more than adequate.

12 Repeat steps **7-10** to add additional pods found in the **Token Ring Network**.

13 Click on **OK** to close this dialog box and save the changes.

14 Ensure that the data from the pod(s) are updating regularly in the **Decoded Data** portion of this dialog box. The **Decoded Data** window shows the time since the **Last Range Record**, **Last Ephemeris Record**, and **Last Almanac Record** were received. It is important to ensure that all three of these fields are updating. **Ephemeris** and **Almanac** data update intervals may extend to tens of minutes, whereas **Range** information should be updating with each telemetry update received.

15 Select the main menu item **View** > **Vehicle Text.** Ensure that the correct vehicle name is shown and, with the mouse pointer within the limits of the **Vehicle Text** window, click the right mouse button and select the **Configure Vehicle - Devices** option.

16 Click the **Add** button found beside this vehicle's device list.

17 Select the **GPS,*pod*,PSEUDORANGE** device from the list of **Available Data Items**.

18 Click **OK**. The GPS Pod is now added to the vehicle's calculations.

19 Select the just added **GPS,*pod*,PSEUDORANGE** device from the **Devices** list.

20 Click the **Edit** button to display the **Pseudorange Calculation** dialog box.

21 Enter the appropriate **Code** for the GPS Pod that will be used to position this vehicle.

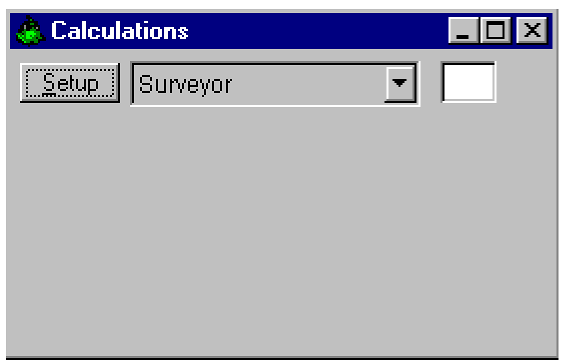
22 Configure the other **Pseudorange Calculation** dialog box options as per the previous section.

# GPS Calculation Displays

After a pseudorange device has been added to a vehicle's calculations, WinFrog can display information pertinent to the pseudorange positioning calculations. This information is displayed in the **Calculations** window.

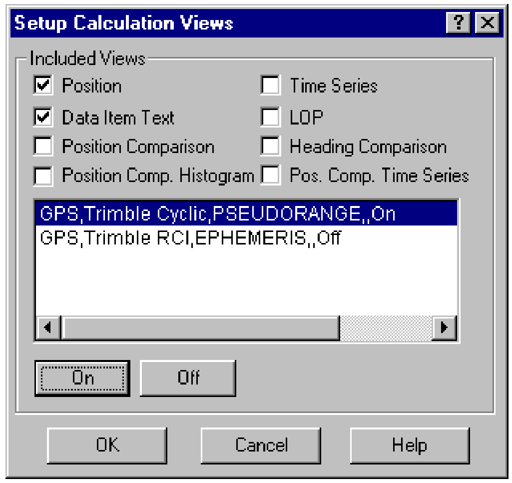
### To View Pseudorange Calculation Data

1 From the **View** menu, choose **Calculations**.




2 Select the desired vehicle from the dropdown list at the top of the **Calculations** window.

3 Click the **Setup** button. The **Setup Calculation Views** dialog box opens.



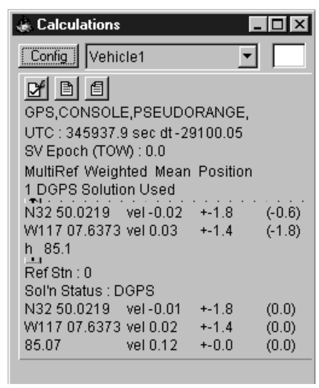

4 Select the **GPS,*,PSEUDORANGE** device.

5 Click the **On** button.

6 In the **Included Views** area, select **Data Item Text.** (You can also select **Position**, but this is optional.)

7 Click **OK**.

The **Calculations** window opens to display a summary of the Multi-Ref Position solution. (Shown below without the **Position** option enabled).




The **Calculations** window contains several pages of pseudorange calculations information; click the button (the third button of the three small buttons presented in this section of the **Calculations** window) to scroll between pages:

| | |
|---|---|
| **Multi-Ref Summary** page | This opening page displays a summary of this vehicle's Multi-Ref Pseudorange position solution. See the **Multi-Ref Summary** section immediately below for details. |
| **Reference Station** page(s) | These pages display information concerning a specific reference station. There is one page for each reference station used. In addition, three |

different types of information can be displayed in one of these windows, depending on the radio button selected in the **Display** area of the **Pseudorange Calculation** dialog box: **Results, Data,** or **Statistics.**

**Note**: if there are no RTCM Differential GPS corrections available, or the **Off** radio button is selected in the **DGPS Mode** area of the **Pseudorange Calculation** dialog box, there will be no reference station pages in the **Calculations** window, only the general page.

## Multi-Ref Summary Page

The **Multi-Ref Summary** page contains information pertaining to the individual solutions that are used to generate a Multi-Ref position. The following information is displayed:

- UTC
- Satellite Time of Week
- Status of the Multiple Reference Station solution.
  (See the section entitled Multiple RTCM Solutions for more information.)
- The number of DGPS solutions used in the Multi-Ref position calculations
- The Position and Velocities of the Multi-Ref solution
- Ellipsoid Height (in meters)
- If enabled, the results of the w-test and F-test are also displayed. (See the previous section entitled UKOAA Statistical Testing for more information.)

In addition, the following information is displayed for each Reference Station:

- Reference Station ID and Name.
- Status of the solution. (i.e. the status of the DGPS solution for the given Reference Station)
- Vehicle Position and Velocity as computed from the reference station.
- Difference between this individual solution and the combined (Multi-Ref) solution in meters. This value is given in the brackets ( ).

## Individual Reference Station Display Page(s)

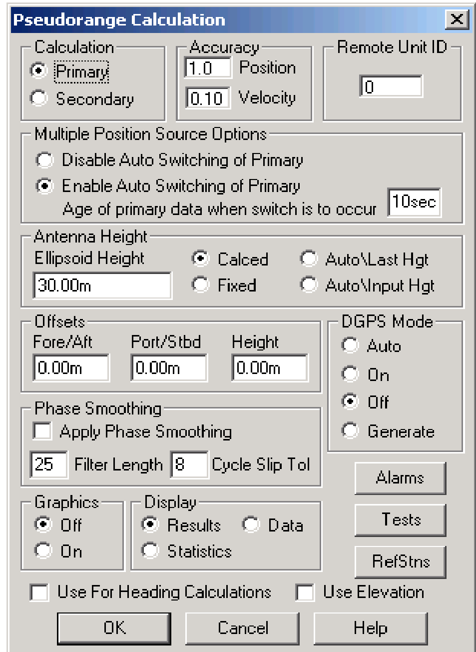
In addition to the Multi-Ref Summary page, WinFrog also provides a page of information for each individual DGPS Reference Station solution (to toggle through the available pages, click on the page button). This allows you to examine various details of each individual DGPS solution, depending on which option has been selected in the **Display** area of the **Pseudorange Calculation** dialog box: **Results**, **Data**, or **Statistics**.

**Pseudorange Calculation Results Page**

As the name implies, selecting the **Results** option will display information regarding the results of an individual station's pseudorange position calculations.

### To Display Pseudorange Calculation Results in the Calculations Window

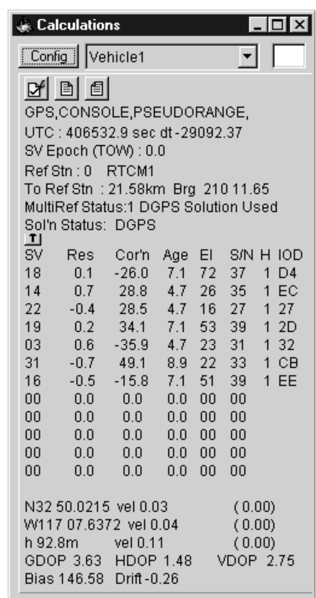
**1** In the **Calculations** window, click the left most of the three **Data Item Text** option buttons to shortcut to the vehicle's **Pseudorange Calculation** dialog box.




**2** Select the **Results** radio button in the **Display** area.

**3** Click **OK** to close this dialog box and save the selection.

**4** Click the right most “page” button of the three **Data Item Text** buttons in the **Calculations** window to scroll from the Multi-Ref Summary page. The **Results** data for an individual solution will show in the **Calculations** window similar to the display seen below. The top area repeats the **Summary** information mentioned above.




### Top Area

- Name of Pseudorange device.
- QC Results for w-test and F-test. (See the UKOAA Statistical Testing section

earlier in this chapter for more information).

- Satellite Time of Week.
- Reference Station ID Number and Name.
- Status of the Multiple Reference Station solution. See the section entitled Multiple RTCM Solutions for more information.
- The number of DGPS solutions used in the Multi-Ref solution.

## Column Area

| | |
|---|---|
| **SV** | Satellite PRN |
| **Res** | (Satellite Pseudorange Residual) If this value exceeds the maximum residual entered in the **GPS Alarms** dialog box, the text changes from black to magenta. |
| **Cor'n** | Correction to the raw pseudorange (as received from this DGPS reference station). If no RTCM corrections are available, then all values will be zero. |
| **Age** | Age of RTCM corrections. If the DGPS mode is set to **On** and the **Age** exceeds the **Maximum RTCM Correction Age** entered in the **GPS Alarms** dialog box, the text changes from black to magenta. |
| **El** | (Elevation angle of satellite) If the satellite drops below the **Elev Cutoff** angle entered in the **GPS Alarms** dialog box, the text changes from black to magenta. |
| **S/N** | (Signal to Noise ratio) If this value exceeds the **Minimum Signal** to **Noise** value entered in the **GPS Alarms** dialog box, the text changes from black to magenta. |
| **H** | (Satellite Health Status) |

| | |
|---|---|
| **1** | SV healthy, valid ephemeris, DGPS differential corrections available, DGPS solution. |
| **G** | SV healthy, valid ephemeris, no differential corrections available, single point GPS solution. |
| **N** | SV healthy, valid ephemeris, no differential corrections available, DGPS solution. |
| **E** | Valid ephemeris not available (usually displayed when the receiver has just locked onto a satellite). |
| **L** | Satellite is below elevation cutoff. |
| **H** | SV is unhealthy. |
| **S** | SV SNR is below the minimum limit. |

| | |
|---|---|
| **w** | satellite observation determined to be an outlier. (See the **UKOAA Statistical Testing** section earlier in this chapter for details.) |
| **IOD** | (Issue of Data) This is a hexadecimal representation of the code transmitted with the ephemeris to be used to match satellite data, i.e. differential corrections computed using the same ephemeris at the reference station as being used at the remote. If the IOD for a calculated range correction does not match that of the satellite at the remote site, the correction is not applied. Type 2 RTCM messages are employed to provide a transition when new ephemeris are downloaded (usually at the top of the even UTC hour). |

### Bottom Area

- Vehicle Position and Velocity as computed using this reference station data.
- Difference between the individual solution and the combined solution in meters. This value is given in the brackets ( ).
- GDOP, HDOP, and VDOP values.
- Clock Bias and Drift

## Pseudorange Calculation Data Page

When the **Data** option is selected in the **Display** area of the **Pseudorange Calculations** dialog box, the individual **Pseudorange Calculation** pages display information pertinent to **Phase Smoothing.** See the **Phase Smoothing of Pseudorange Measurements** section earlier in this chapter for more information on configuring **Phase Smoothing**.

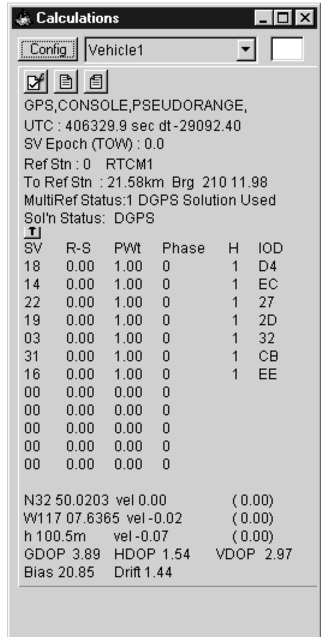
### To Display Pseudorange Calculation Data in the Calculations Window

**1** In the **Calculations** window, click the left most of the three **Data Item Text** option buttons to shortcut to the vehicle's **Pseudorange Calculation** dialog box.

**2** Select the **Data** radio button in the **Display** area.

**3** Click **OK**.

**4** Click the right most "page" button of the three **Data Item Text** buttons in the **Calculations** window to scroll from the Multi-Ref Summary page. The data for an individual solution will appear in the **Calculations** window similar to the display seen below. The top area repeats the **Summary** information mentioned above.




The following details the information displayed in the **Calculations** window when the Data option has been selected.

## Top Area

- Name of Pseudorange device.
- QC Results for w-test and F-test. See the section entitled UKOAA Statistical Testing for more information.
- Satellite Time of Week.
- Reference ID Number and Name.
- Status of the Multiple Reference Station solution. See the section entitled Multiple RTCM Solutions or more information.
- The number of differential solutions used.

## Column Area

**SV** — Satellite PRN

**R-S** — the difference between the **Raw** pseudorange and the **Smoothed** pseudorange in meters.

**PWt** — the **weighting** for the pseudorange measurements. When **Phase Smoothing** is turned on, as the number of sequential phase observations for a given satellite increases, the weight given to the phase observations increases, and the weight given to the raw pseudorange observations decreases. The value in this column is the weighting applied to the **Raw Pseudorange**. One minus this value gives the weight applied to the phase observation. The minimum weight that WinFrog will give to pseudoranges is 0.01.

**Note**: if there is loss of lock on a given satellite, the **PWt** value will reset to one and restart the **Phase Smoothing** for that satellite.

**Phase** number of epochs since last filter reset

**H** Satellite Health/Status:

| | |
|---|---|
| **1** | SV healthy, valid ephemeris, DGPS differential corrections available, DGPS solution. |
| **G** | SV healthy, valid ephemeris, no differential corrections available, single point GPS solution. |
| **N** | SV healthy, valid ephemeris, no differential corrections available, DGPS solution. |
| **E** | valid ephemeris not available (usually displayed when the receiver has just locked onto a satellite). |
| **L** | Satellite is below elevation cutoff. |
| **H** | SV is unhealthy. |
| **S** | SV SNR is below the minimum limit. |
| **w** | satellite observation determined to be an outlier. See the UKOOA Statistical Testing section earlier in this chapter for more information. |

**IOD** (Issue of Data) This is a hexadecimal representation of the code transmitted with the ephemeris to be used to match satellite data,(i.e. differential corrections computed using the same ephemeris at the reference station as being used at the remote). If the IOD for a correction does not match that of the satellite at the remote site, the correction is not applied. Type 2 RTCM messages are employed to provide a transition when new ephemeris are downloaded (usually at the top of the even UTC hour).

### Bottom Area

- Vehicle position and velocity as computed from the reference station.
- Difference between the individual solution and the combined Multi-Ref solution in meters. This value is given in the brackets ( ).
- GDOP, HDOP, and VDOP.
- Clock Bias and Drift.

## Pseudorange Calculation Statistics Page

When the **Statistics** option is selected in the **Display** area of the **Pseudorange Calculations** dialog box, the individual **Pseudorange Calculation** pages display information pertinent to the

**w-test** and the **F-test.** See the **w-test** and **F-test** sections earlier in this chapter for more information.

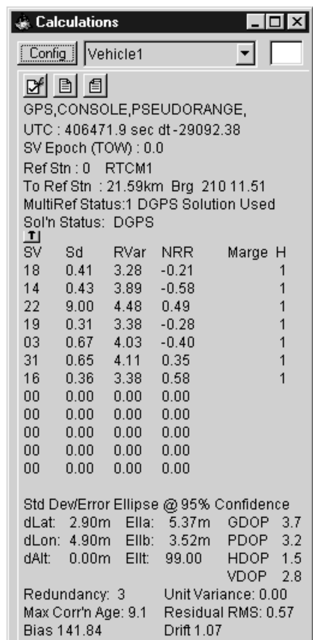
### To Display Pseudorange Calculation Statistics in the Calculations Window

**1** In the **Calculations** window, click the left most of the three **Data Item Text** option buttons to shortcut to the vehicle's **Pseudorange Calculation** dialog box.

**2** Select the **Statistics** radio button in the **Display** area.

**3** Click **OK**.

**4** Click the right most "page" button of the three **Data Item Text** buttons in the **Calculations** window to scroll from the Multi-Ref Summary page. The **Statistics** data for an individual solution will appear in the **Calculations** window similar to the display seen below. The top area repeats the **Summary** information mentioned above.




## Top Area

- Name of Pseudorange device.
- QC Results for w-Test and F-Test.
- (See the UKOAA Statistical Testing section above for more information.)
- Satellite Time of Week.
- Reference ID Number and Name.
- Status of the Multiple Reference Station solution. See the section entitled Multiple RTCM Solutions for more information.
- The number of Differential solutions used in the Multi_Ref position.

## Column Area

**SV** Satellite PRN

| | |
|---|---|
| **Sd** | Satellite pseudorange standard deviation (in meters) computed by WinFrog's pseudorange algorithms |
| **RVar** | Pseudorange variance (in meters) as determined by WinFrog calculations |
| **NRR** | Normalized Pseudorange Residuals |
| **Marge** | For future development, will display the **Marginally Detectable Errors** of the pseudorange. |
| **H** | Satellite Health/Status: |

| | |
|---|---|
| **1** | SV healthy, valid ephemeris, DGPS differential corrections available, DGPS solution |
| **G** | SV healthy, valid ephemeris, no dDifferential corrections available, single point GPS solution. |
| **N** | SV healthy, valid ephemeris, no differential corrections available, DGPS solution. |
| **E** | ephemeris not available (usually displayed when the receiver has just locked onto a satellite). |
| **L** | satellite is below elevation cutoff. |
| **H** | SV is unhealthy. |
| **S** | SV SNR is below the minimum limit. |
| **w** | satellite observation determined to be an outlier. See the **UKOOA Statistical Testing** section earlier in this chapter for more information. |

| | |
|---|---|
| **IOD** | (Issue of Data) This is a hexadecimal representation of the code transmitted with the ephemeris to be used to match satellite data, (i.e. differential corrections computed using the same ephemeris at the reference station as being used at the remote). If the IOD for a correction does not match that of the satellite at the remote site, the correction is not applied. Type 2 RTCM messages are employed to provide a transition when new ephemeris are downloaded (usually at the top of the even UTC hour). |

## Bottom Area

- Standard Deviations for Latitude (dLat), Longitude (dLon) and Height (dAlt) at the 68% confidence level
- 95% Confidence Error Ellipse semi-major axis (Ella), semi-minor axis (Ellb) and the orientation of the semi-major axis (Ellt)
- The GDOP, PDOP, HDOP and VDOP values, color-coded based on use of alarm limits as on previous displays
- Solution Redundancy = Number of Observations (Pseudorange Measurements) Used **-** Number of Unknowns (4 for 3D, 3 for 2D)
- Unit Variance computed from the Pseudorange residuals

- Maximum Age of all DGPS Corrections used in the solution
- Residual RMS for the solution
- Clock Bias and Drift

# Reference Station Integrity Monitoring (RSIM) Features

Most GPS companies manufacture hardware that can be used to generate RTCM format DGPS corrections from a reference station set up at a point of known coordinates. These corrections can then be applied to pseudorange measurements at mobile stations to produce accurate real-time DGPS positions. Unfortunately, most GPS differential hardware manufacturers include little or no quality assurance information with these corrections, which could potentially result in inaccurate results at the mobile stations. WinFrog features an innovative and efficient approach for QA of the pseudorange corrections that takes advantage of a dual reference station configuration. This is called **Reference Station Integrity Monitoring (RSIM)**.

WinFrog has the capability to provide **real-time RSIM**. When this feature is used, WinFrog takes RTCM corrections from a reference source and performs quality assurance calculations to produce a quantifiable error estimate as to the accuracy of the differential position. WinFrog then broadcasts the error estimate information along with the RTCM corrections. A mobile WinFrog system can then be configured to inform the user of a problem with the RTCM corrections if the error exceeds a set tolerance. With this additional integrity information, the mobile user can monitor the quality of the corrections, allowing for accurate real-time differential GPS with quality assurance.

WinFrog allows for a great deal of flexibility in RSIM setup and allows for various configurations of Reference Stations and Integrity Monitors. For example, WinFrog can be configured to operate as a DGPS Reference Station and as an RTCM Integrity Monitor station at the same time. This setup can be used to provide a redundant RSIM Base Station or provide a network of two or more RSIM Base Stations. (**Note:** the terms Base Station and Reference Station are used interchangeably in this document).

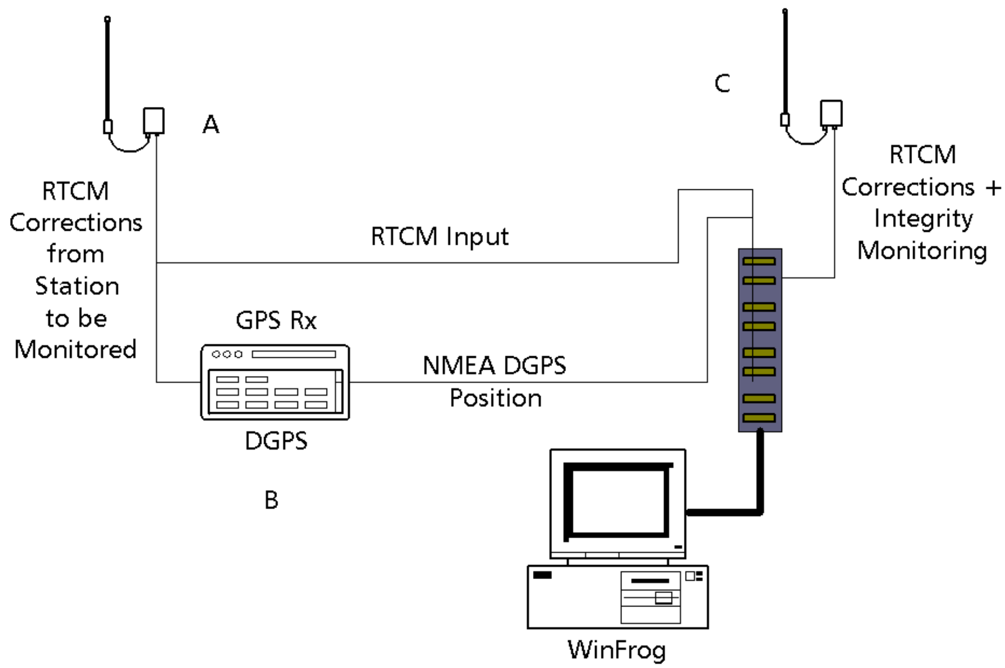
The next section discusses the features of WinFrog’s RSIM and is divided into two parts: the **Reference Station** and the **Remote Station.**

## Reference Station Configurations

Three types of **RSIM** setups will be discussed in this section: **Single**, **Redundant**, and **Multiple** Reference Stations.

### Single Reference Station

The graphic below is a schematic drawing of a **Single Reference Station** approach where one DGPS position source is used by WinFrog to develop RSIM message data.




As shown above, a single base station RSIM system requires three main components:

**A An RTCM Source**

There are three options for acquiring RTCM corrections:

**1)** Set up a survey grade GPS receiver over a known point and generate RTCM corrections using the factory configured algorithms. These corrections could be interfaced to WinFrog via a radio telemetry link, modems connected to dedicated phone lines, or even wired directly to WinFrog if the receiver is physically close enough.

**2)** Use RTCM corrections received from an external source, such as the U.S. Coast Guard, Fugro SkyFix, or any one of several commercially available sources.

**3)** Use a GPS receiver (with the antenna over a point of known coordinates) that is able to provide pseudorange and ephemeris data to WinFrog. WinFrog's GPS Calculations Extension Module could then be used to calculate positions, compare them to the known coordinates, and generate DGPS corrections which could then be re-inserted into another WinFrog I/O port as RTCM corrections.

**B A GPS Receiver set up over a known point**, near enough to the WinFrog RSIM computer to allow a direct connection between the two. This receiver must be configured to either:

**1)** Receive and apply the RTCM corrections to produce a DGPS corrected position, which is output to WinFrog.

**2)** Output raw pseudoranges and ephemeris data to WinFrog. In this case, WinFrog's GPS Calculations Extension Module would then add the RTCM correction from device **A** to internally calculate a DGPS-corrected position for monitoring purposes.

**C** **An RTCM Output Device** capable of transmitting the RTCM format corrections and the integrity message to the mobile receivers. This could be a radio telemetry system or perhaps modems connected to dedicated phone lines.

The **Single Base Station RSIM system** works as follows:

**1** RTCM corrections are received from source **A** (figure above).

**2** These are used by GPS receiver **B**, or internally by WinFrog's GPS Calcs Module to produce a corrected position.

**3** WinFrog compares this position to the known station position and calculates delta latitude, delta longitude, and delta height values.

**4** WinFrog formats and broadcasts the deltas as **Type 16 RTCM** messages. WinFrog also transmits **Type 1** RTCM pseudorange corrections at the same time.

**5** The **Type 1** data are received and applied at the mobile stations, be it to an external GPS receiver or to WinFrog using the GPS Calcs Module. The RTCM receiver must also be configured to provide at least the **Type 16** RTCM data to the mobile WinFrog system. This will provide the mobile WinFrog system with the delta position data required by the Integrity Monitoring routine.

## Single Reference Station Component Configuration

A single Reference Station RSIM requires configuring the three components **A**, **B**, and **C** outlined above. For the sake of simplicity, in the sections below **Component B** is an external GPS receiver configured to input RTCM corrections and output a DGPS position to WinFrog. (See the sections above for further details on setting up WinFrog's GPS Calcs Module if an internal GPS device is to be used.)

**Component A: RTCM Source**

The **RTCM** source must be able to provide correct data on a consistent basis. The data must be of a recognized **RTCM** format message type, specifically the RTCM **Type 1** (along with the required **Type 2**), or **Type 9**. Ensure that all communications parameters are set the same on both **Component A** and WinFrog.

## Component B: DGPS Positioning

The GPS receiver used for **RSIM** must be configured to input **RTCM** corrections from **A** and output a DGPS corrected position.

### To Configure a GPS Receiver for DGPS Positioning

**1** Use a serial **Y** cable to split the RTCM corrections from **Component A** so that it can be connected to both the GPS receiver input and to WinFrog at the same time.

If WinFrog's GPS Calculations Extension Module is being used to generate the Monitor Position (instead of an external GPS receiver), only a single RTCM output is required from the RTCM device.

**2** Configure the GPS receiver to input and apply the RTCM corrections and subsequently output a DGPS corrected position to WinFrog.

Consult the GPS receiver manual for more information on setting up for real-time DGPS operations.

**3** Connect the DGPS Position Output to a WinFrog communication port.

**4** Add the appropriate GPS device to WinFrog (From the **Configure** menu, choose **Devices > Add…** ).

**5** Select **GPS**.

**6** Click **OK**.

**7** Select the appropriate GPS device. Typically this would be the **NMEAGPS** device.

**8** Click **OK**.

**9** Configure the communications parameters in the **Device I/O Parameters.**

**10** View the data being received from the GPS device to ensure that the position being received is a DGPS position (i.e. its **Status** is **2**).

**Component C**

**Component C** is the RTCM Output device. As mentioned above, this could be a radio transmitter or perhaps a modem connected to a dedicated phone line. In order for output of RTCM/ RSIM data via the computer's serial port ensure that all communications parameters are set the same on both **Component C** and WinFrog.

**To Configure RTCM Output**

**1** From WinFrog's **Configure** menu, choose **I/O Devices > Add…**

**2** Click on the "**+**" beside **OUTPUT**.

**3** Highlight the option **RTCM-104.**

**4** Click **OK**.

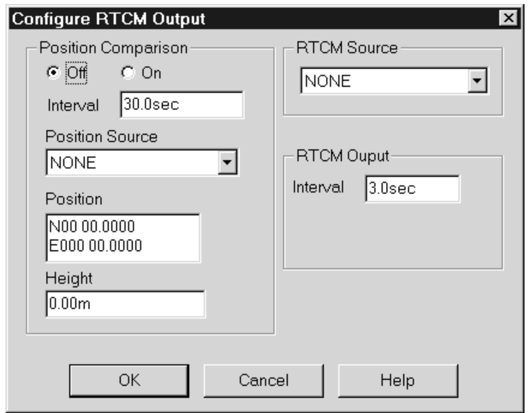
**5** Configure the communication parameters to match those of the device that will be used to transmit the RTCM data. Note which serial port is selected.

**6** Click **OK**.

**7** Connect the transmitting device to the above chosen serial port.

**8** In the **I/O Devices** window, highlight the **RTCM-104 Output** device.

**9** Click the right mouse button, then select the **Configure Device** option.




**10** In the **Position Comparison** area of the **Configure RTCM Output** dialog box, select the **On** radio button.

**11** Set the **Position Comparison Interval**.

This value determines how frequently WinFrog computes and outputs delta latitude, longitude, and height information. These delta values are formatted and output as a **Type 16 RTCM** message to form the **RSIM** message.

**Note:** the data transmitting device may encounter problems if this interval is made too small. It is suggested to leave the value at the default of 30 seconds.

**12** From the **Position Source** dropdown menu, select a source.

This will be the GPS device that provides the monitor station with its DGPS corrected position (i.e. Device **B**).

**13** Highlight and enter the known latitude and longitude in the **Position** entry field.

**Note:** the coordinates may be in either degrees-minutes-seconds (ddd mm ss.sss or degrees-minutes-decimal minutes (ddd mm.mmmm) format.

**14** Enter the ellipsoidal height in the **Height** field.

**Note:** this is ellipsoidal height, not mean sea level height. Also, this entry is for the ellipsoid height of the GPS antenna, not the control point over which the antenna is set up.

**15** From the **RTCM Source** dropdown menu, select a source. This is the name of the RTCM input device (i.e. Device **A**).

**16** Click **OK**.

At this point **RSIM** is enabled and is including integrity monitoring information in the RTCM messages output to Device **C**.

## Redundant Reference Stations

A single WinFrog system can be used as both a **Reference Station** and an **Integrity Monitoring Station** at the same time. This provides the mobile stations with the benefit of RSIM as well as redundancy in RTCM sources.

At this time, this configuration works only with a NovAtel GPS card installed in the WinFrog computer. The NovAtel GPS card console device can be configured to output both pseudorange and ephemeris information as well as self-generated RTCM corrections based on an entered reference position. A cable must be connected from the NovAtel GPS card comm port to the appropriate WinFrog (i.e. Digiboard™) comm port in order for WinFrog to be able to receive the RTCM corrections from the NovAtel card. The pseudorange and ephemeris information are transferred from the NovAtel card to WinFrog directly through the PC bus.

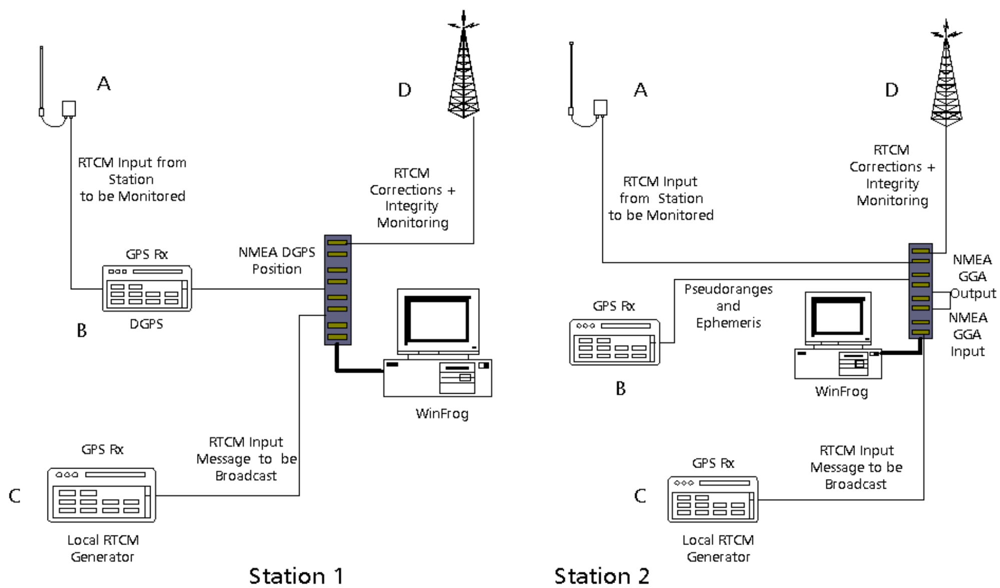
WinFrog's GPS Calcs Module applies these NovAtel-generated RTCM corrections (or the externally generated RTCM corrections) to the NovAtel provided pseudorange and ephemeris information to calculate a DGPS position.

The **RTCM Output** device can then be configured to use this DGPS NovAtel pseudorange position as the **Position** source, and either the NovAtel RTCM or the external RTCM source as the **RTCM** source.

## Multiple Reference Stations

With the proper equipment, you can setup a network of two or more Base Stations, each generating RTCM and RSIM information. This system also provides the RTCM redundancy mentioned in the previous section.

Below is a schematic drawing for two stations providing RSIM.




Station 1: DGPS position computed by GPS receiver
Station 2: Pseudorange position calculated by WinFrog

A multiple Base Station configuration requires five components at each site:

- Two GPS receivers set up over known points (both close enough to allow for direct interfacing to the WinFrog computer).

  **Note:** these are labeled as components **B** and **C** in the diagram.

- A WinFrog system

- A Transmitter for the transmission of the RTCM corrections and RSIM information. This communications link can be a direct cable connection or an RF link.

  **Note:** this is labeled as component **D** in the diagram.

- A Receiver for reception of RTCM corrections and RSIM information.

  **Note:** this is labeled as component A in the diagram.

The system works as follows:

**1** RTCM corrections are generated by GPS receiver **C** at **Station 1**.

**2** These corrections, along with RSIM data from GPS receiver **B** at **Station 1**, are transmitted via the communication link **D** at **Station 1** to **A** at **Station 2**.

**3** The RTCM messages are received by telemetry device **A** at **Station 2** and sent to **Station 2** WinFrog.

**4** The **Type 16** RSIM message is read by the **Station 2** WinFrog and an alarm is sounded, if required. The RTCM corrections are applied within WinFrog to the raw pseudorange measurements from the GPS receiver **B** at **Station 2** to calculate a corrected position at that site.

**5** WinFrog's **RSIM** compares this position with the station's known coordinates and computes delta latitude, longitude, and height.

**6** This RSIM information is formatted into a special case of the Type 16 RTCM message and output along with the RTCM corrections from local GPS receiver **C** at **Station 2**.

**7** This information is then broadcast by transmitter **D** at **Station 2**.

These processes are occurring simultaneously in the opposite direction. RTCM messages generated by the GPS receiver **C** at **Station 2** are received by telemetry device **A** at **Station 1** and input into WinFrog and the GPS receiver **B** at **Station 1**. The Type 16 RSIM message is read by the **Station 2** WinFrog and an alarm is sounded, if required. These RTCM corrections are applied to the raw pseudoranges from **Station 1** to calculate a corrected position. This position is then output to WinFrog at **Station 1** where the RSIM calculates Delta latitude, longitude, and height. **Station 1** WinFrog then outputs the RSIM message as a Type 16 RTCM message along with the RTCM corrections from the local RTCM generator **C** at **Station 1**. This information is then broadcast by transmitter **D** at **Station 1**.

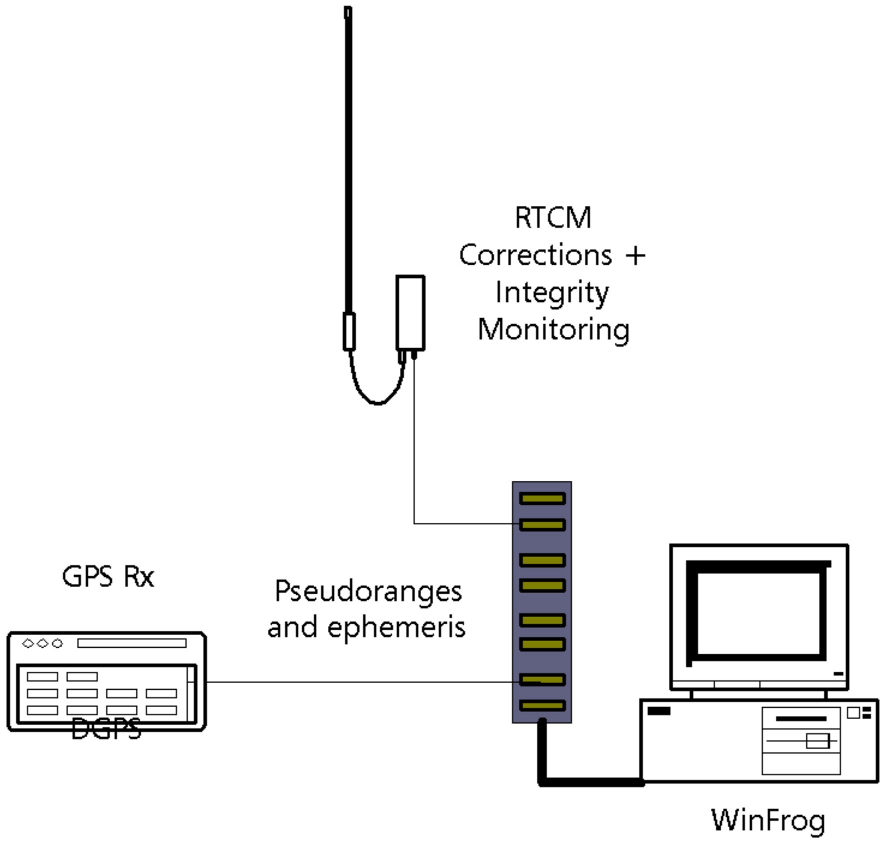
## Use of RSIM at the Remote Station

When WinFrog broadcasts RTCM format data containing RSIM and DGPS corrections data, all WinFrog Remote Stations capable of receiving the transmission will be able to access the integrity monitoring information. This provides the Remote Stations with a quantifiable error associated with the given corrections and the ability to sound an alarm to notify the user when the error exceeds a set tolerance. If multiple RTCM correction (and hence RSIM) sources are used, a tolerance can be configured for each source.

**Note:** it is not necessary for the **Remote Station** to be calculating its own position to be able to monitor the RSIM positional accuracy information. In other words, a computer could be set up to simply observe the RSIM information. However, typically, the **Remote Station** is applying the RTCM pseudorange corrections at the same time as it is monitoring the RSIM data.

The following section describes only those steps required to setup **Remote RSIM Monitoring**. See the paragraphs above for setting up a remote station for pseudorange calculations.

The physical setup for RSIM information at the **Remote Station** is shown in the schematic below.




The system works as follows:

The **Remote WinFrog** system receives RTCM corrections along with RSIM integrity information from the **Reference Station**. (This is typically accomplished via a radio telemetry link.) Simultaneously, GPS measurements in the form of raw pseudoranges and satellite ephemeris are being output from the Remote GPS receiver to WinFrog. WinFrog takes the raw pseudorange measurements and applies the RTCM corrections to calculate a DGPS-corrected position.

When the remote WinFrog system receives a RSIM message, the deltas are combined and compared with a configurable tolerance level. If the RSIM positional error exceeds the tolerance, WinFrog changes the status light in the **Calculations** window to red and sounds an alarm. (This occurs only if the **Calculations** window is open and correctly configured.) Click the **Ack** button in the **Calculations** window to silence the alarm.

### To Configure a Remote Station to Use RTCM/ RSIM Data

**1** Connect the RTCM radio input to a WinFrog communications port.

**2** Add an RTCM device to WinFrog.

**3** Configure the WinFrog communication parameters to correspond to those of the RTCM device.

The next step is to add an **RTCM Monitor** device to a **new** vehicle's device list.

**Note:** do not add the **RTCM Monitor** to an existing vehicle. The RSIM message contains the Reference Station's coordinates, which will be accepted as the Vehicle's position. If this device is added to a vehicle, that vehicle's position will jump to the Reference Station's position.

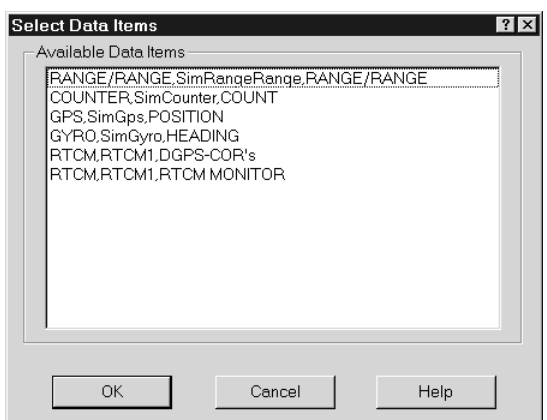
**4** With the mouse pointer in the limits of the **Vehicle Text** window, click the right mouse button then select the **Configure Vehicles** button.

**5** Click the **Add Vehicle** button along the right side of the **Configure Vehicles** dialog box.

**6** Configure the newly added vehicle, as described in **Vehicles** chapter. Specifically, enter a unique **name** to identify this as the RSIM "vehicle".

**7** With the new vehicle highlighted in the **Vehicle List** in the **Configure Vehicles** dialog box, click the **Configure Vehicle-Devices** button.

**8** Click the **Add** button to add a device to the vehicle's Devices list. This opens the **Select Data Items** dialog box.

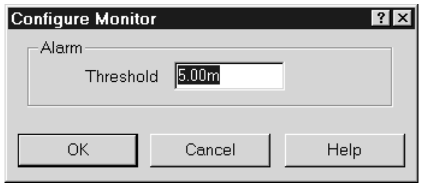



**9** Select the **RTCM,*,RTCM MONITOR** device.

**10** Click **OK**. The RSIM monitor now appears in the **Devices** box in the **Configure Vehicle-Devices** dialog box.

**11** In the devices list, highlight the **RTCM,*,RTCM MONITOR** device.

**12** Click the **Edit** button to open the **Configure Monitor** dialog box.




**13** Enter an **Alarm Threshold**.

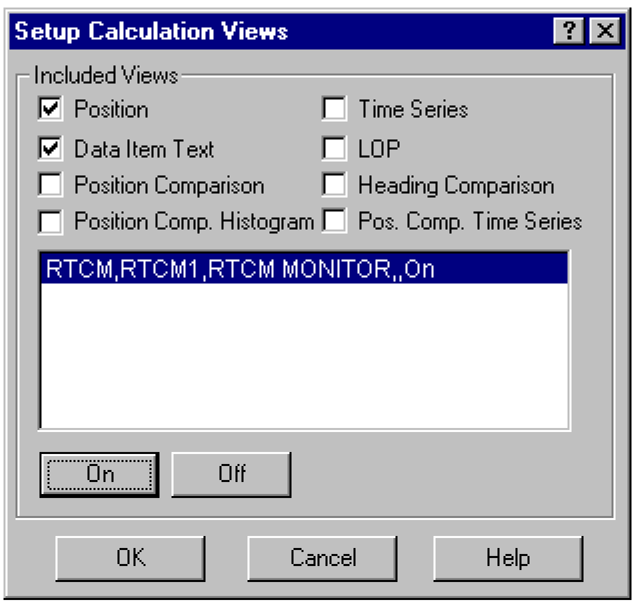
This parameter sets the threshold error for the delta latitude and delta longitude RSIM data. If the **combined** delta latitude, longitude, and height errors exceed the value entered in the **Threshold** field, WinFrog changes the vehicle **Status** in the **Calculations** window to **red** and sounds an alarm. Click the **Ack** button to silence the alarm. See the following section for more information on setting up the **Calculations** window.

### To Turn on the Audible and Visual Alarms

**1** From the **View** menu, choose **Calculations**.

**2** From the dropdown menu, select the vehicle with the **RTCM Monitor** device.

**3** Click the **Setup** button. The **Setup Calculation Views** dialog box appears as seen below.

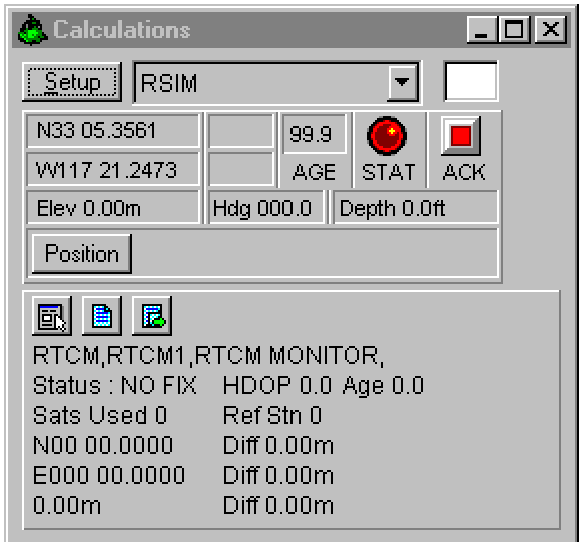



**4** In the **Included Views** area, check the **Position** box and the **Data Item Text** box.

**5** Select the **RTCM,*,RTCM MONITOR** device.

**6** Click the **On** button.

**7** Click **OK** to close the dialog box and save the changes.




The **Calculations** window displays the following information for a "vehicle" configured with the RSIM device:

| | | |
|---|---|---|
| **Vehicle Position** | | Latitude, longitude, height. (Heading, and depth of vehicle not relevant in this case.) |
| **AGE** | | Time since last position update. |
| **STAT** light | | Shows current status of the position solution: |
| | **Green** | Valid position. |
| | **Yellow** | Potentially invalid position (more than 20 seconds since last position update). |
| | **Red** | Invalid position. If the Reference Station positional difference exceeds the value set in **Alarm Threshold** in the **Configure Monitor** dialog box, the position is invalid. |
| **ACK** button | | Press this button to silence alarms. |

**Data Item Text**

| | | |
|---|---|---|
| **Status** | | Solution Status at Base Station. This can have the following values: |
| | **DGPS** | Valid Differential GPS position |
| | **SP GPS** | Single Point position (no DGPS) |
| | **NO FIX** | No position calculated. |
| | **UNKN** | Unknown Status. |
| **HDOP** | | Horizontal Dilution of Precision at the Base Station. |

| | |
|---|---|
| **Age** | Age of DGPS corrections from the Base Station. |
| **Sats Used** | Number of satellites used in the DGPS solution at the Base Station. |
| **Ref Stn** | Base Station ID number. |
| **Base Station Position** | The calculated latitude, longitude, and ellipsoidal height of the Base Station |
| **Base Station Differences** | Delta latitude, longitude, and height in meters. If the square root of the sum of the squares of these position differences exceeds the value set in **Alarm Threshold** in the **Configure Monitor** dialog box, the **STAT** light turns red and an audible alarm sounds. |
| **Time Series Option** | This **Calculations** window option can be used to display the positional delta values relative to time. Enable this display by clicking the **Calculations** window's **Setup** button, then check the **Time Series** box. Click **OK** to return to the **Calculations** window. You can change the vertical scale (which shows the positional differences in meters) and the horizontal scale (which shows Time) by clicking on the provided arrows. |

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