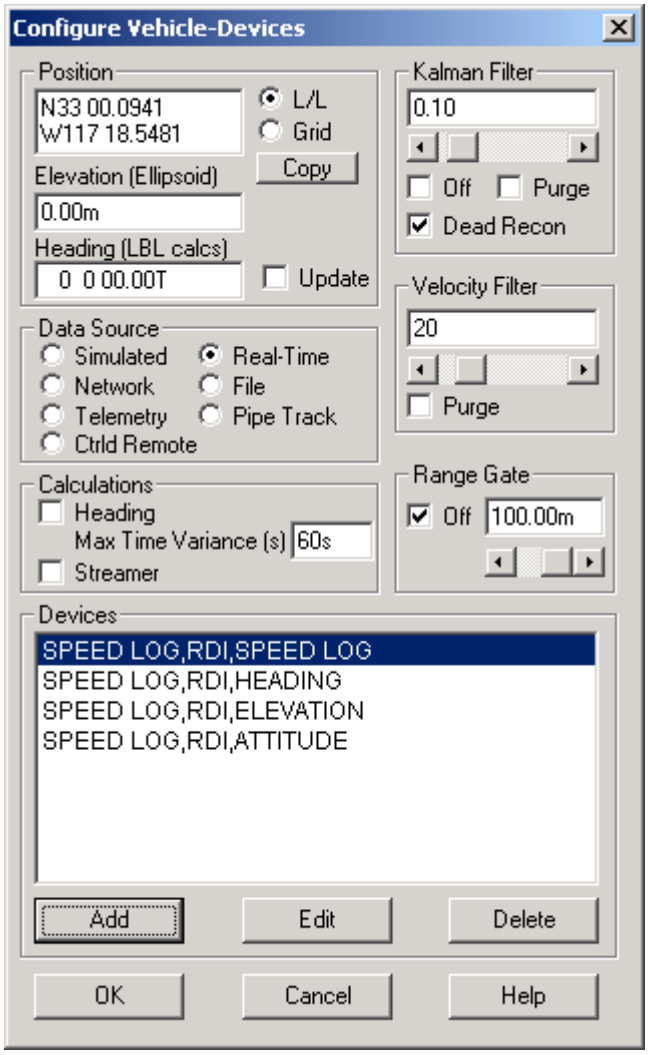
WinFrog Device Group:	**Speed Log**
Device Name/Model:	**RDI**
Device Manufacturer:	RD Instruments 9855 Businesspark Avenue San Diego Ca USA 92131-1101 858 693 1178
Device Data String(s) Output to WinFrog:	:BS :SA or nPART
WinFrog Data String(s) Output to Device:	None
WinFrog Data Item(s) and their RAW record:	SPEED LOG 402 HEADING 910 ELEVATION 372 ATTITUDE 413

DEVICE DESCRIPTION:
The RDI is a doppler velocity log (DVL). If placed on a fish, the data can be used to enhance the performance of USBL positioning of the fish. The DVL must be bottom tracking for the data to be used for USBL position enhancement.

The primary message WinFrog expects is the :BS message containing the velocity data. The SPEED LOG data item is associated with this data. The :SA message is also decoded and contains attitude and heading data. The HEADING and ATTITUDE data items are associated with this message.

A third undocumented message can also be decoded. It begins with nPART, data item, …check sum<CR><LF>
Where:
n can be any letter.
This message has two formats (each beginning as stated) but contain either the velocity data or heading and elevation data. Thus the SPEED LOG, HEADING and ELEVATION data items are associated with this message.

WinFrog is able to utilize the data from Doppler speed log in the position Kalman Filter to enhance results, specifically for positioning an ROV with USBL. It is critical that the device is set up correctly, and monitored, in order to ensure correct application of the data. It is also important to note that only the *Speed over Ground* data is used in the Kalman Filter. The Kalman Filter is under the Vehicle Text Window/Configure Vehicle Devices for each vehicle. See the Configure Vehicle-Devices dialog box below.



The application and monitoring of the Doppler speed log is detailed in the following sections. **It is important to note that the values and limits stated here for any of the configurations discussed are guidelines. You must evaluate the actual performance and make adjustments accordingly.**

Background on Filtering and Gyro Input

General Kalman Filtering:

The Kalman Filtering performed by WinFrog allows the direct input (to the filter) of position and velocity data. The application of this data within the filter is a balance between:

- the accuracy attributed to each individual data type, and,
- the Kalman Filter setting itself.

The former is the accuracy entered by the operator for each data item when configuring its use as attached to a vehicle. The latter is the Kalman Filter setting controlled with the slider bar in the Configure Vehicle-Devices dialog box.

It is important to realize that the correct application of the Kalman Filter requires careful consideration of the actual accuracy of each data item and the relative accuracy between data items utilized. If the accuracy relationship is unbalanced, the Kalman Filter will be biased towards the data item with the overly optimistic accuracy setting.

The Kalman Filter setting itself controls how reactive to new data the filter will be. The default setting of 0.1 is applicable for many situations. The impact that the new data has in the filter is also affected by the accuracy setting for that data item. Note that the lower the value, the more smoothing that is applied.

If the Kalman Filter is set to OFF, the Velocity Filter is used. The Velocity Filter is a 'central tendency' filter, which seeks the median of the input values. The Velocity Filter does not affect position (i.e. the position of the vehicle will be the resultant of the raw data from the positioning sensors). The velocity filter will 'smooth' the velocity only. This is good for use when minor changes in velocity need to be monitored (e.g. Cable Lay Vessels and Vessel Tows where estimated time of arrival is important).

Gyro Requirements:
A Doppler speed log unit provides WinFrog with fore/aft and port/starboard (and in some cases, up/down) velocities. For use in the Kalman Filter, these are converted to Northing and Easting velocity vectors. Therefore, it is necessary to have a reasonably accurate and calibrated vehicle heading source to enable the transformation of the velocities from a vehicle based X/Y reference frame to an absolute North/East reference. The heading data used is that which is configured for the vehicle, including any offsets applied in the associated HEADING data item configuration.

At present, the vertical velocities are not utilized within WinFrog.

DEVICE CONFIGURATION INSTRUCTIONS

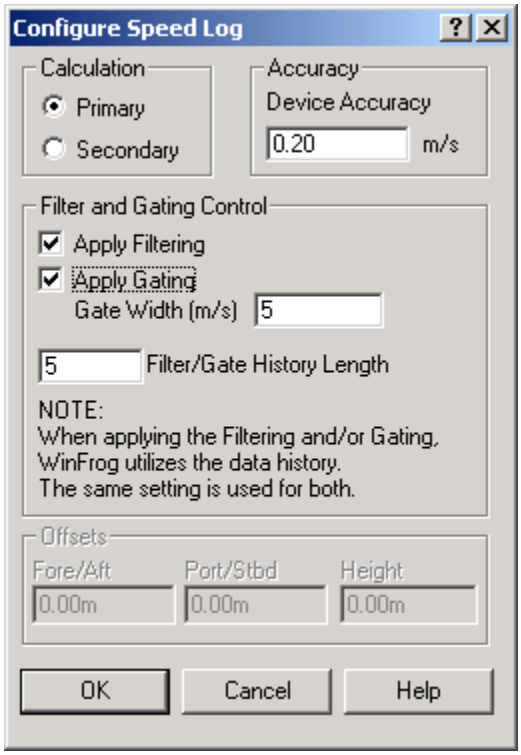
WINFROG I/O DEVICES > EDIT I/O:
Serial
Configurable Parameters

WINFROG I/O DEVICES > CONFIGURE DEVICE:
No configuration is required at the I/O Device window level.

WINFROG VEHICLE > CONFIGURE VEHICLE DEVICES > DEVICE DATA ITEM > EDIT:
Adding the RDI device creates four data items: SPEED LOG, HEADING, ELEVATION and ATTITUDE. Once the data items have been added to the vehicle, they must be edited to suit the application.

Data item: SPEED LOG, RDI, SPEED LOG

The SPEED LOG data item must also be edited once it is added to a vehicle's device list. Highlight the SPEED LOG data item in the vehicle's device list and click the Edit button. The Configure Speed Log dialog box appears as seen below.



Calculation:
Set to Primary if you wish the Doppler data to be used to assist the position of the vehicle.

Accuracy:
Accuracy of the Doppler speed logs in m/s. The default is 0.2. Change this only with caution and knowledge of the results.

Apply Filtering:
Controls the filtering of the raw Doppler data prior to its use in the Kalman Filter. If selected, a central tendency filter (which seeks the median of the input values) is applied to the data using the number of samples defined in the *Filter/Gate History Length*, the result of which is used for input to the Kalman Filter.

Apply Gating:
Controls the gating of the raw data prior to its use in the Kalman Filter. If selected, the new data is tested against the data history based upon the number of samples defined in the *Filter/Gate History Length*. If it exceeds the gate limits, the data is rejected.

Gate Width:
Defines the gating limits in m/s, the value must be determined by monitoring the data.

Filter/Gate History Length:
Defines the number of samples (minimum 3, maximum 30) to be used for both the central tendency filtering and the gating. This setting must reflect the application, environment and the Doppler performance. It depends upon balancing the need to smooth the data and the required responsiveness to real changes in the data. The longer the filter, the smoother the result, however, the result will be less responsive to the actual dynamics of the vehicle. The shorter the filter, the less smooth the results, and the more responsive to the actual dynamics of the vehicle.

It should be noted that if the *Apply Filtering* option is selected, but not the *Apply Gating* option, a default gating value of 10m/s is used for the purpose of utilizing the filtering function.

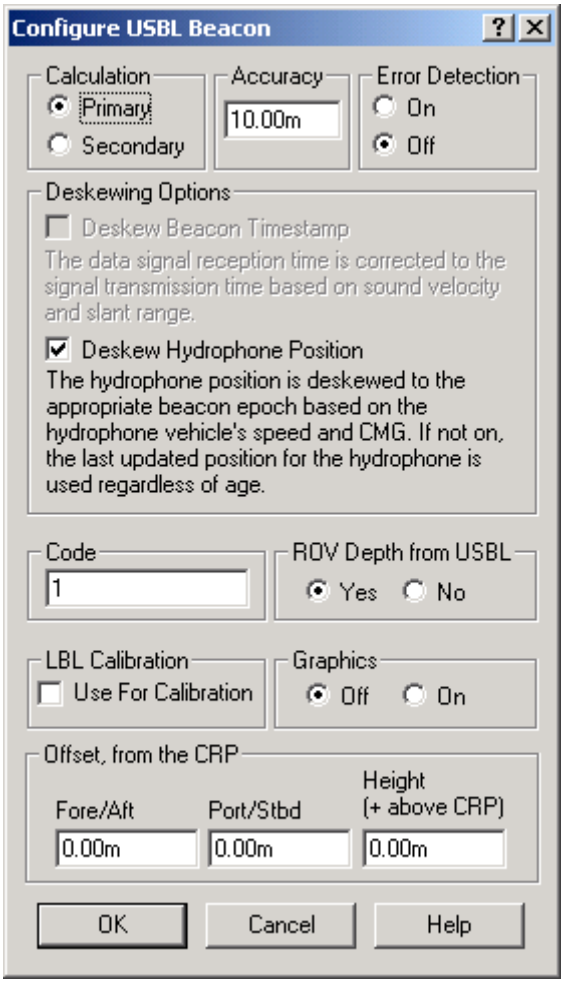
Offsets:
Not applicable for this operation.

CONFIGURATION DETAILS:

Under this section we will attempt to provide further information of the devices that may benefit from the Speed Log input.

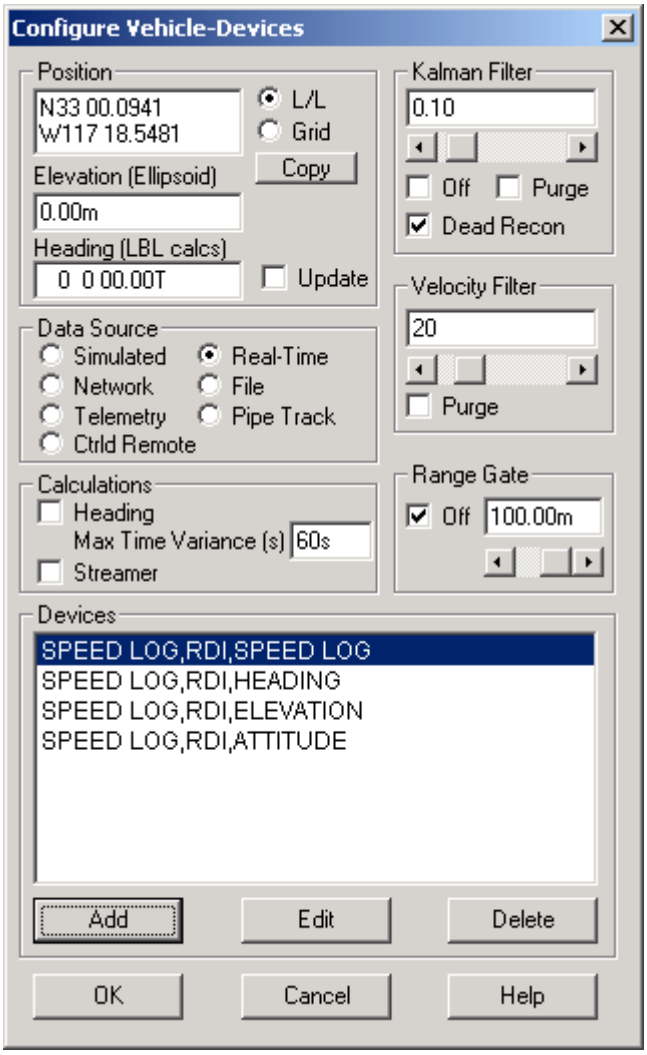
The correct use of the SPEED LOG data item is dependent upon the correct use of associated data items and the configuration of the associated vehicle Position Calculations. In a typical situation, the Doppler speed log is mounted on an ROV being positioned with USBL, so this is the setup that will be examined here.

USBL BEACON Data Type Configuration:
The ROV will be positioned using a USBL BEACON data item.



The *Accuracy* is the critical setting. This is generally between 7-15m, depending upon the performance of the USBL system. The lower the value, the greater the influence of the USBL data in the Kalman Filter. The higher the value, the less the influence of the USBL data in the Kalman Filter.

Vehicle Calculations Configuration - Kalman Filter:
Use the Configure Vehicle-Devices dialog box to configure the Kalman Filter and the Position Gating.



In order to utilize the SPEED LOG data in the determination of the vehicle position, the Kalman Filter must be on, i.e. not checked *Off*.

The responsiveness of the filter to new data is controlled with the untitled numerical entry in the *Kalman Filter* panel. This value can be entered directly in this box, or controlled with the slider. The smaller the number, the less responsive to new data the filter is. Again, the default is 0.10 and this is appropriate for the majority of applications. In noisy environments on a vehicle with a low dynamics, this can be reduced. Similarily, with good data on a vehicle with high dynamics, this can be increased. However, changes to this value should be made and monitored carefully to ensure that an inappropriate filter is not used. In general, this value will not be less than 0.05, or greater than 0.4. For ROV operations, a range of 0.10 to 0.30 is reasonable.

Vehicle Calculations Configuration: Range Gate:
The *Range Gate* setting is used not just for gating ranges, but position data also. It is an invaluable tool when positioning with USBL. This should be set to a value in keeping with the performance of the USBL system. The default of 100m is much too large to be of any use with the USBL. A value of 20m is a reasonable initial setting to use.

Resetting of the Vehicle's Position:
Based upon the monitoring of *ghost vehicles* (see below), you will be able to determine if the actual ROV position has been overly and incorrectly biased by either the doppler or the USBL to the point where it requires correction. This can be accomplished in several ways.

Purging the Kalman Filter:
From the Configure Vehicle-Devices dialog box, select the Purge checkbox in the Kalman Filter panel and exit this dialog with OK. This will reset the Kalman Filter and purge the *history*. The positioning will start afresh with the input of new data of any type currently configured to *Primary* for that vehicle.

Update the Vehicle Position:
Enter or copy a new initial position in the Configure Vehicle-Devices dialog box and select the Update checkbox. This will force the vehicle to this position and the Kalman Filter will take over.

Disabling a Data Source:
Either the SPEED LOG or USBL BEACON data item can be removed from the solution by setting them to *Secondary*. The affect of the data will remain for a short period due to the fact that the Kalman Filter uses history to predict the future.

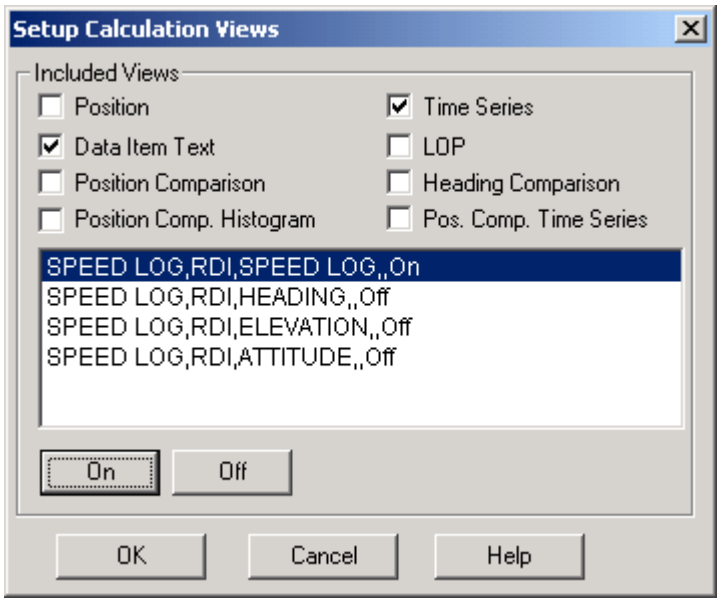
Monitoring the Application of the Speed Log:
The monitoring of the speed log device falls into three categories:

1. Input of data.
2. Filtering and gating of the speed log data, prior to use in the Kalman Filter.
3. Affect of the speed log data on the position.

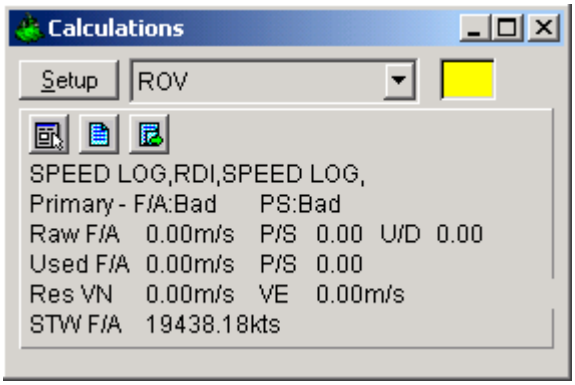
Monitoring Device Input:
WinFrog does not provide alarms when a device stops updating. Therefore, the device input should be checked at the I/O Device Window / Decoded Data tab regularly. The time of data displayed for every device will indicate if data is being received.

Monitoring the Filtering and Gating of the SPEED LOG Data Item

To monitor the actual use of the speed log data as attached to the vehicle, a Calculation window should be opened. In this window, select the appropriate vehicle from the dropdown list. Then using the Config button to the left of the vehicle dropdown list, access the configuration dialog box shown below.



Select the *Data Item Text* checkbox, highlight the SPEED LOG item and then click the *On* button. Exit with *OK*. The speed log data can then be monitored in this Calculation window, as shown below.



The information provided in this window is as follows:

- Data item and device name
- Calculation setting (Primary/Secondary) and the status of the F/A and P/S velocity data. The status can be *OK*, *Gate* or *Bad*. OK indicates that the data is valid and used. Gate indicates that the data has been gated and is not used. Bad indicates that the data as received from the speed log was either invalid, or not an *Over Ground Speed*.

- The raw F/A, P/S and Up/Down Over Ground velocities in m/s.
- The F/A and P/S velocities used in the Kalman Filter. If the speed log data filtering is turned on, these will be the results of the filter. If not, these will be the raw data repeated.
- The Northing and Easting velocity vector residuals in m/s. The residuals are the Kalman Filter results minus the used data.
- The *Speed Through Water*, if the device also provides (or only provides) this value

This window provides you with the means to observe the results of the gating and filtering. Changes to the SPEED LOG data item configuration are required if excessive gating occurs or the filtered data does not reasonably represent the raw data.

It should also be noted that a time series plot of the *used* fore/aft velocity (and *Speed Through Water* if available) can be displayed by selecting the *Time Series* checkbox in the Calculation window configuration dialog box.

Monitoring the Impact of the SPEED LOG Data Item:
The monitoring of the impact of the SPEED LOG data item on the positioning of the vehicle requires the setting up of *ghost* vehicles.

To monitor the performance of the SPEED LOG data only, add a vehicle to WinFrog, add the appropriate HEADING and SPEED LOG data items. Make sure to configure the vehicle's positioning parameters (i.e. Kalman Filter and Range Gating) and the data items, exactly as configured on the actual ROV Vehicle. When running with only a SPEED LOG data item as a source of positioning data, the vehicle must be given a starting positioning. Do this by copying the current ROV vehicle's position into the appropriate edit box in the *Configure Vehicle-Devices* dialog box and select the *Update* checkbox. Though the vehicle's position will always appear as yellow in the Vehicle Window, it will position based upon the Doppler speed log data.

To monitor the performance of the USBL BEACON data only, add a vehicle to WinFrog, add the appropriate HEADING and USBL BEACON data items. Make sure to configure the vehicle's positioning parameters (i.e. Kalman Filter and Range Gating) and the data items exactly as configured on the actual ROV Vehicle.

To minimize the distraction of the *ghost vehicles* on actual navigation and tracking, you may wish to do the following. From the *Vehicle Presentation* configuration option for the ghost vehicles, turn *Vehicle Window Data to* ***off*** to prevent the display of the vehicle data in the Vehicle window(s). You may also wish to limit the vehicle shape to a simple cross in a different color to make graphical comparison easier.

The difference in positioning between these vehicles and the actual vehicle will illustrate the affect the use of the SPEED LOG data is having in the Kalman Filter.

Resetting of the Vehicle's Position:
Based upon the monitoring of the aforementioned *ghost vehicles*, you will be able to determine if the actual ROV position has been overly and incorrectly biased by either the doppler or the USBL (to the point where it requires corrective actions). This can be accomplished in the following ways:

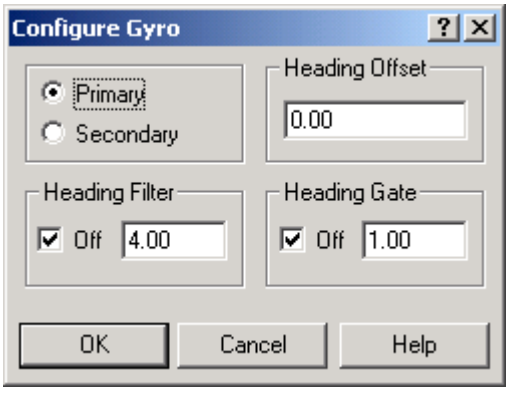
Purging the Kalman Filter
From the *Configure Vehicle-Devices* dialog box, select the *Purge* checkbox in the Kalman Filter panel and exit this dialog with *OK*. This will reset the Kalman Filter and purge the *history*. The positioning will start afresh with the input of new data of any type currently configured to *Primary* for that vehicle.

Update the Vehicle Position
Enter or copy a new initial position in the *Configure Vehicle-Devices* dialog box and select the *Update* checkbox. This will force the vehicle to this position and the Kalman Filter will take over.

Disabling a Data Source
Either the SPEED LOG or USBL BEACON data item can be removed from the solution by setting them to *Secondary*. The affect of the data will remain for a short period due to the fact that the Kalman Filter uses history to predict the future.

Data item: SPEED LOG, RDI, HEADING

The Heading data item must also be edited once it is added to a vehicle's device list. Highlight the HEADING data item in the vehicle's device list and click the Edit button. The Configure Gyro dialog box appears as seen below.



Calculation (Primary/Secondary):
Set the type of calculation to Primary or Secondary by selecting the appropriate radio button. Devices set to Primary are used to provide the vehicle with heading information. However unlike the Position data items, WinFrog does not calculate a weighted mean solution for multiple Heading data items. If more than one Heading data item is set to primary, the vessels heading, in WinFrog, will jump back and forth between the two. Devices set to Secondary are simply monitored, and are not used in the vehicle's calculations.

In the case of Primary device failure, WinFrog will not automatically use the Secondary device(s). You must manually change a Secondary device to Primary status in order for it to be used in the vehicle's calculations.

Heading Offset:
A correction value (as determined from a gyro calibration) can be input in the Heading Offset box. This value is added to the heading value from the Device to provide a corrected heading for the vehicle. Note that positive or negative values can be entered.

Heading Filter/Heading Gate:
The Heading Filter is used to "smooth" heading values used by the vehicle. The value entered in the Heading Filter indicates the number of headings that will be used to predict the next heading value. The larger the value entered, the "heavier" the filter will be – i.e. the slower the vehicle's heading will respond to changes.

The heading gate defines a tolerance value to limit the use of anomalies in gyro readings. If the next observed gyro value received falls outside the specified range of predicted values (i.e. plus or minus the entered value), the value will not be used.

Data item: SPEED LOG, RDI, ELEVATION

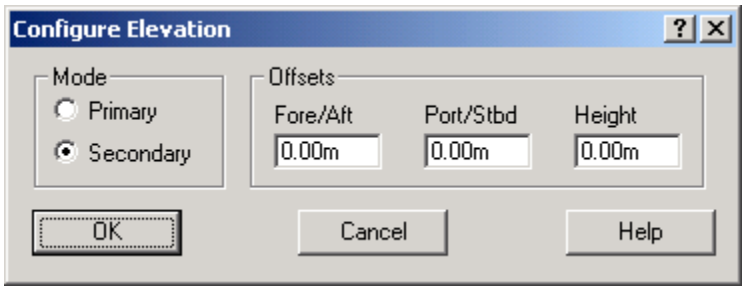
The elevation device does not provide an absolute elevation. If there is data being received from the elevation device, a flag is passed to the assigned vehicle. This flag is checked and will prevent the use of the data for vehicle elevation. It also prevents the operator from setting the data item to *Primary*. The elevation device is used as a data source for barometric relative heighting, and this is performed at the device level. The device therefore does not need to be added to a vehicle.

The **only** reason for adding the elevation data item to a vehicle is the resulting logging of the data to the raw file as a 372 record. The format for this record is as follows:

372, name, time, elevation, status, center elevation, raw data, temperature, relative humidity *where:*

- *372* is the raw data record identifier for an ELEVATION data type
- *name* is the operator assigned device name
- *time* is the computer time for the data
- *elevation* is the elevation in metres, which in some cases is always 0
- *status* is the status flag for the data, 1 = OK, 0 = Bad
- *center elevation* is the elevation reduced to the CRP, which in some cases is always 0
- *raw data* is the raw elevation data
- *temperature* is the temperature in Celsius
- *relative humidity* is the relative humidity in units of 0-1.0 (i.e. % * 100)

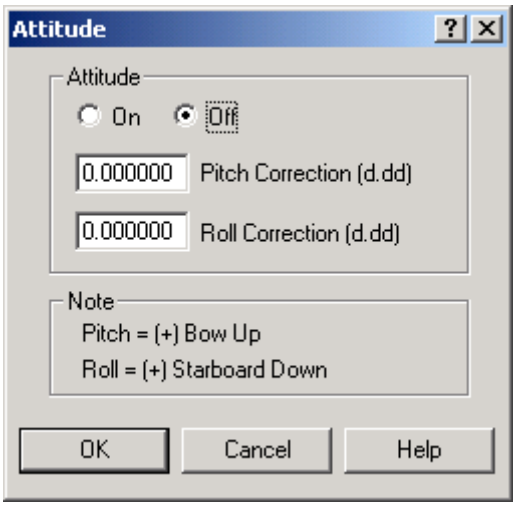
If the device is added to a vehicle, the following configuration dialog is available under the **CONFIGURE VEHICLE DEVICES > EDIT**:



As mentioned previously, the Mode can only be set to Secondary (unless no data is being received). Sensor offsets can be applied for the unit similar to other devices.

Data item: SPEED LOG, RDI, ATTITUDE

The Attitude data item must also be edited once it is added to a vehicle's device list. Highlight the Attitude data item in the vehicle's device list and click the Edit button. The Attitude dialog box appears as seen below.



By default, the sensor mode is off, meaning that data from the Attitude device will not be used in the vehicle's calculations. To turn the sensor on, and begin using the inclination corrections in the position output, click the **'On'** radio button.

Correction values can also be added in this section of the dialog. The correction values (entered in units of degrees-decimal degrees) are added to the raw pitch and roll values received from the Attitude device before the data is applied to the vehicle's calculations.

Ensure that entered values adhere to the sign convention used by WinFrog. You can verify that the corrections are entered properly by viewing the pitch and roll values in the I/O Device window and the Vehicle Text window.