Chapter 16: USBL Calibration

USBL systems utilize multiple-transducers located very close together within a single transceiver head to measure to beacons. They measure a single range to a transponder and by using the very short baselines formed between the multiple transducers, the horizontal and vertical angle can also be determined. The term **Ultra Short Baseline Acoustics** is derived from the fact that the baselines between the transceivers located on the transducer head are very short. USBL acoustics can be used to position surface and subsurface vehicles.

In order to be used to their full capabilities, USBL systems require calibration. This chapter details the calibration processes required and how WinFrog performs them. **Note:** the actual addition of USBL devices to WinFrog and their association and use with vehicles is covered in the **USBL Acoustics** chapter earlier in this manual.

WinFrog's calibration functions use a rigorous **least squares** approach, utilizing all available data. This is an important point to remember when collecting and processing the data and will be covered in detail in the following sections.

USBL Calibration

The purpose of the USBL calibration is to determine the errors associated with the mounting orientation of the USBL hydrophone with respect to pitch, roll, and heading and the velocity errors associated with the velocity of sound data used in the USBL system. This is required in order to eliminate these sources of errors when using the USBL system to either position a remote vehicle with a beacon attached or the vehicle with the hydrophone attached from a fixed beacon.

The USBL calibration, as performed by WinFrog, uses a rigorous least squares adjustment to first determine the position of the beacon used for the calibration, and then to simultaneously solve for the four unknowns, pitch correction, roll correction, heading correction, and velocity (scale) correction.

When WinFrog performs the least squares adjustments it uses the USBL observations as ranges from the hydrophone to the beacon. If the data is collected in a symmetric pattern about the beacon, the use of ranges in the least squares adjustment will eliminate most of the effects of ray bending. This is because the ray bending mostly affects the direction of the ray with only a small effect on its length. And the length effect will mostly be eliminated with symmetrically collected data. WinFrog also allows you to calculate the effect of ray bending. This requires that the data come from a Sonardyne USBL system outputting the CSV Surveyor's Acoustic message.

This section details the steps to follow to perform the USBL calibration, including the following:

- Preparation of WinFrog for performing the calibration data collection and processing.
- Vessel track for data collection.
- Collecting the data.
- Reviewing and editing the data.

- Processing the calibration.
- Application of the results.
- Troubleshooting the process.

Reviewing and editing of the data and the processing is an iterative process.

Note: You can also use this technique to simply calculate the position of USBL beacons. In this case, the differences between what is discussed in the remaining part of this chapter and what would be required are the data collection pattern, and the processing, which would stop once the beacon positions were determined.

USBL Calibration Preparation

In preparation for performing a USBL Calibration, WinFrog must be properly configured. Although WinFrog provides recourse during processing to correct for omissions and errors in the setup for the calibration, it is always better (and easier) to perform the setup correctly and eliminate the need to use these features.

Key Points to Review Prior to USBL Calibration

1 It is important that the correct **Working Transponder** file is loaded and available prior to the configuration for data collection. Check that there is a working file and it is the correct one.

When performing the calibration and when operating the USBL for positioning (if fixed beacons are being used), configure the **Vehicle** window to display the name of the **Working Transponder** file.

2 The **Transponder** file must contain, at a minimum, the beacon that is to be used for the calibration, the initial approximate position and depth for this beacon, and if the Sonardyne CSV acoustic message is used then the beacon turn around time must be entered. The depth is important because it is involved in the reduction of the observations to the map grid. Depths for the beacon can be determined using depth interrogations, if it is equipped with a depth sensor. Alternatively, the ship can pass directly over the deployment position while ranging to the beacon and the shortest range can be used for the depth. Other options include using a sounder or from a chart.

Note: A working velocity file is only required if the travel time from the USBL system is to be used, such as the Sonardyne CSV acoustic message or Simrad $---SSB telegrams. Otherwise, the velocity is entered into the USBL system itself.

3 Ensure that all positioning and related devices are correctly configured, including operational settings and sensor offsets. These devices must be active and receiving data. If new data are not present for any POSITION or USBL device that is attached to the calibration vehicle, no calibration data will be collected. The USBL HYDROPHONE data item must be attached to the vehicle being used for the calibration.

If an attitude sensor is present it must be injected directly into the USBL system. WinFrog does not currently support application of attitude data to USBL data or sensor offsets. Note that this is the only device for which this is true, all other devices and offsets support application of attitude data.

There may be offsets entered into the USBL system; you must check to see if these are present. If they are present they must be entered into the USBL HYDROPHONE data item configuration dialog (>Configure Transducer 1>USBL System internal offsets). Note that the signs must be correct. This is done so that the leaver arm from the USBL's offset point to the transceiver is corrected for attitude. i.e., WinFrog requires the beacon data relative to the transceiver not an arbitrary point on the vessel.

NOTE: The USBL system must not be configured to operate in **Fixed Beacon Depth** or **Telemetered Beacon Depth** mode, or similar. The Z component as determined from the analysis of the return signal at the hydrophone head is critical for the USBL Corrections Calibration process, in particular for the resolution for pitch and roll correction determinations. The use of an operating mode that uses some other means of determining the Z component will result in un-usable calibration data. It should be noted that once observed and recorded, the data cannot be re-engineered to make it usable.

4. It is strongly recommended that the USBL HYDROPHONE data item always be configured to **Positioning - Secondary**. While it can, in most cases, be configured to **Positioning - Primary** without affecting the data collection and subsequent processing, there are situations (discussed later) that require it be set to **Secondary**. Another consideration is that when set to **Positioning – Primary,** WinFrog will use the USBL to compute the position of the vessel. Since this determination will be based upon an estimated position for the fixed beacon, and USBL is less accurate then the DGPS likely used, it will result in a jump in the vehicle's position. This situation may cause alarm among personnel, such as the helmsman, who are using the WinFrog screens.

5. The computer directories should be setup such that the calibration data have a specific location to which they are saved. The saving and archival process for the files should be decided upon to ensure that the necessary steps are followed to ensure safe file saving and archiving.

6. The USBL beacon used for the calibration should be deployed in an area that will permit adequate maneuverability to perform the data collection pattern.

The Acoustic Calibration Dialog for Data Collection

The **Acoustic Calibration** dialog, from which all data collection, saving, loading, editing, processing, and reporting is performed, can be accessed in several ways.

To Access the Acoustic Calibration Dialog

1. Set the **Vehicle Text** window to display the information for the vehicle to which the USBL Hydrophone is attached.

2. With the cursor in the **Vehicle Text** window, right-click to access the pop-up menu.

3. Select **Acoustic Calibration**.

Or

4. From the Main Menu, select **Configure** > **Vehicles**.

5. Highlight the vehicle to which the USBL Hydrophone is attached, and click the **Acoustic Calibration** button.

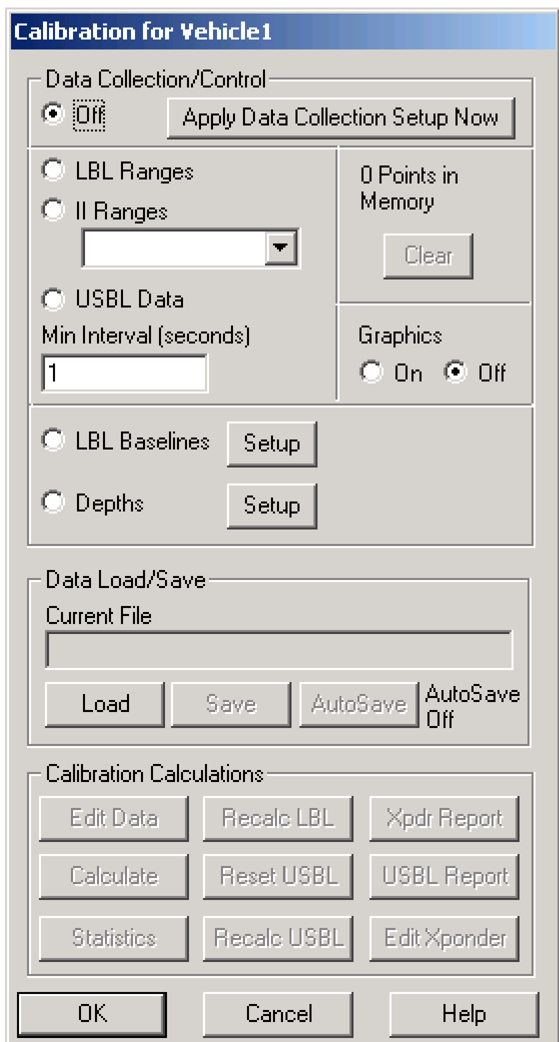
Or

6 From the **Acoustic Window**, click on **Configure > Select Vehicle for Calibration**, then click on the vehicle to which the USBL Hydrophone is attached.

7 Then click on **Configure > Calibration**.

Note: WinFrog is a multi-vehicle system. Ensure the vehicle that has the **USBL HYDROPHONE** data item added to it is the one selected/displayed before clicking the **Cal** button or using the right mouse button to access the pop-up menu. Normally this is not a problem as the button is disabled or the menu item isn't available, however, it may be enabled if another acoustic data item is present, such as LBL HYDROPHONE. If the incorrect vehicle is selected and the **Calibration** dialog is accessed, you will still be permitted to setup the calibration data collection, but no data will be collected because no USBL data items are associated with that vehicle. If it appears that no data are being collected, check for this problem.

The **Calibration** dialog box is shown in the next figure. This dialog box is modeless and does not restrict access to other WinFrog windows while open. It is recommended that this be left open during the data collection process.



The following details those controls associated with the USBL Calibration data collection process.

Note: The first time this dialog is opened for a vehicle, it creates a calibration data set including a copy of the information from the working transponder file. Each subsequent time the Calibration dialog is opened, WinFrog compares the current Working Transponder file against the transponder station information contained in the Calibration data set and informs you of differences between the Working Transponder file and the Calibration Transponder station data (coordinate variations and discrepancies in stations). You can then decide whether to overwrite the Calibration data set station information with that from the Working Transponder file, or ignore the differences and keep the Calibration data set station information untouched.

Data Collection Control

You control the type of data to collect with the controls in this section. Once selected, the **Apply…** button will change to reflect the changes that will be applied if it is clicked. Alternatively, selecting the data collection type and exiting the dialog with **OK** will also apply the settings.

Off	Stops data collection
LBL Ranges	Not applicable to USBL.
II Ranges	Not applicable to USBL.
USBL Data	Turns on the collection of USBL data. This is applicable for all USBL systems.
Min Interval	This controls the minimum data collection interval, in seconds, for the USBL data. During data collection, WinFrog checks for the presence of new data from the associated devices and then checks to see if the minimum interval has been reached or exceeded, and if so, logs the data. If either of the preceding checks fails, no data are logged.
LBL Baselines	Not applicable to USBL.
Depths	Not applicable to USBL.
Apply… button	The text of this button displays the collection setup that will be applied when clicked. Click this button to cause the current **Data Collection** setting(s) to be applied without having to close the dialog.
Points In Memory	The total number of points currently loaded/present in WinFrog memory. It is very important to note that when collecting calibration data, WinFrog logs the data to memory and not directly to disk. It is only written to disk when specifically directed by the operator.
Clear	This will clear the current calibration data in memory. **Note:** if these data have not been saved to disk, they are not recoverable after this is

executed. A confirmation prompt appears when the **Clear** button is clicked.

Graphics On/Off

Controls the display of the data collection positions in the **Graphics** and **Bird's Eye** windows. Thus, the **Graphics** display provides both a means for monitoring the progress of the data collection and clear illustration of the geometry. After setting this option, the **Apply…** button must be clicked or the dialog exited with **OK** in order for the changes to take affect. You may also have to refresh the graphics window by resizing.

Data Load/Save

Current File

This is a read only control giving the path and name of the currently loaded calibration file or the last one that had been in WinFrog memory.

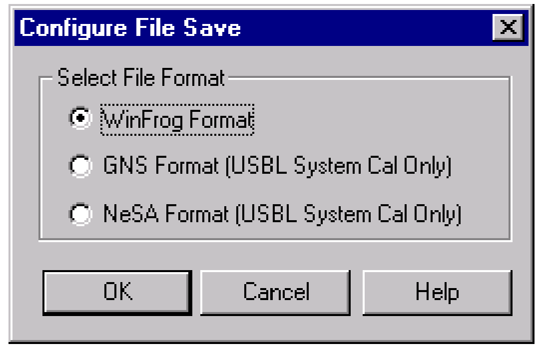
Load

Enables the browsing of available storage media to select a calibration file (*.cal) and load it into memory. **Note:** this action automatically clears all calibration data currently in memory. You are warned of this and are given the option to cancel the action. You are also prompted as to whether or not you wish to purge the current Calibration data set transponder information. If there is a difference between the station information of the Calibration data being loaded and the current Working Transponder file, you are informed of this and given the option to overwrite the Calibration data set station information from the Working Transponder file or ignore the difference.

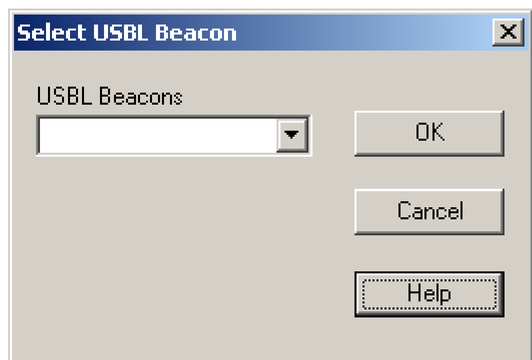
Save

This is only available if there are calibration data in memory.

Enables browsing of available storage media to select an existing file or enter a new file name to save all the data currently in memory to disk. **Note:** when data are saved to an existing file, that file's contents are replaced with the contents of the memory. When this option is accessed and USBL data is present, you are prompted for the file format to use. The next figure shows the available options.



The WinFrog format supports both LBL and USBL calibration data; the GNS and NeSA formats support only USBL calibration data. In all cases, the data should first be saved using the WinFrog format and if desired, resaved in the other formats. If only saved in either GNS or NeSA formats, some data will be un-recoverable and the file will not be able to be processed by WinFrog to the fullest capability of the software. If the radio button for either the GNS or NeSA format is clicked, you will immediately be prompted to select the USBL beacon whose data you want to save.



Select the beacon from the drop down list and click OK to exit. Upon exiting the **Configure File Save** dialog box with OK, you are then able to browse the directories.

If there are no USBL data present, the WinFrog format is defaulted to and WinFrog goes directly to the browse.

AutoSave Future development.

USBL Calibration Data Collection

This section addresses the preparation for data collection and the data collection and saving itself. It includes the design of the pattern the vessel will take to collect the data and the configuring of WinFrog to collect and log the data.

There is no limit to the number of data points collected and used for the calibration, other than the constraints placed by the available RAM and disk space.

USBL Calibration Vessel Track for Data Collection

The objective of the vessel track, or data collection pattern, for the calibration data collection process is to present all sides of the ship to the beacon in a uniform and controlled manner. To be more specific, the objective is to collect data while orienting the USBL hydrophone relative to the deployed beacon such that the direction from the hydrophone to the beacon is (at a minimum) as follows:

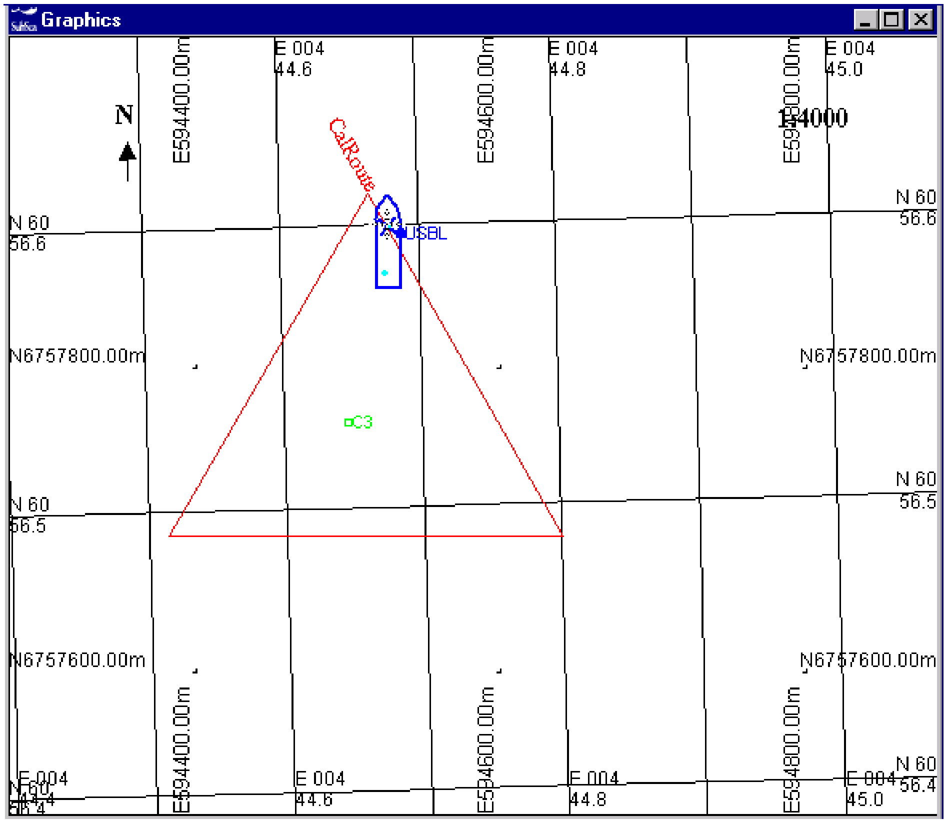
- Along the fore/aft alignment with presentation to the beacon in both the forward and aft direction.
- Along the port/starboard alignment with presentation to the beacon in both the port and starboard direction.

Though the WinFrog calibration processing will process data collected in any manner, there are industry-standard patterns that are recommended. These are the **triangle** and **cardinal points** patterns.

Note: It is important that the manufacturer's specifications, recommendations and guidelines are followed to ensure the optimum performance of the USBL system is achieved, both for calibrating and real time operations. Of particular importance is the horizontal distance from the beacon that the vessel should use when designing the collection pattern. The following documentation states 1.5 times the water depth, but this should be adjusted as required in order to achieve the optimum performance from the USBL system.

Triangle Pattern

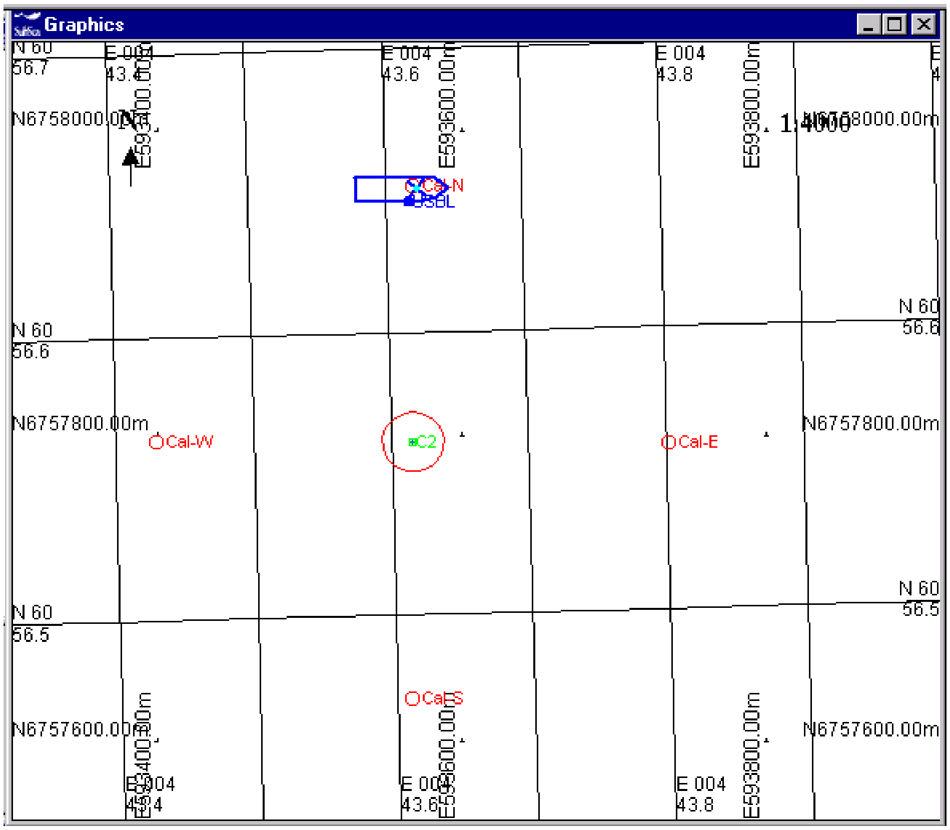
The triangle pattern consists of an equilateral triangle with apices approximately 1.5 times the water depth from the beacon (horizontally distant). The vessel travels along the track maintaining a constant heading, the heading being determined as perpendicular to one of the sides of the triangle. Data collection is continuous while traveling along the route. The next figure is an example of a triangle pattern vessel track. Data should also be collected directly over the beacon.



Cardinal Points

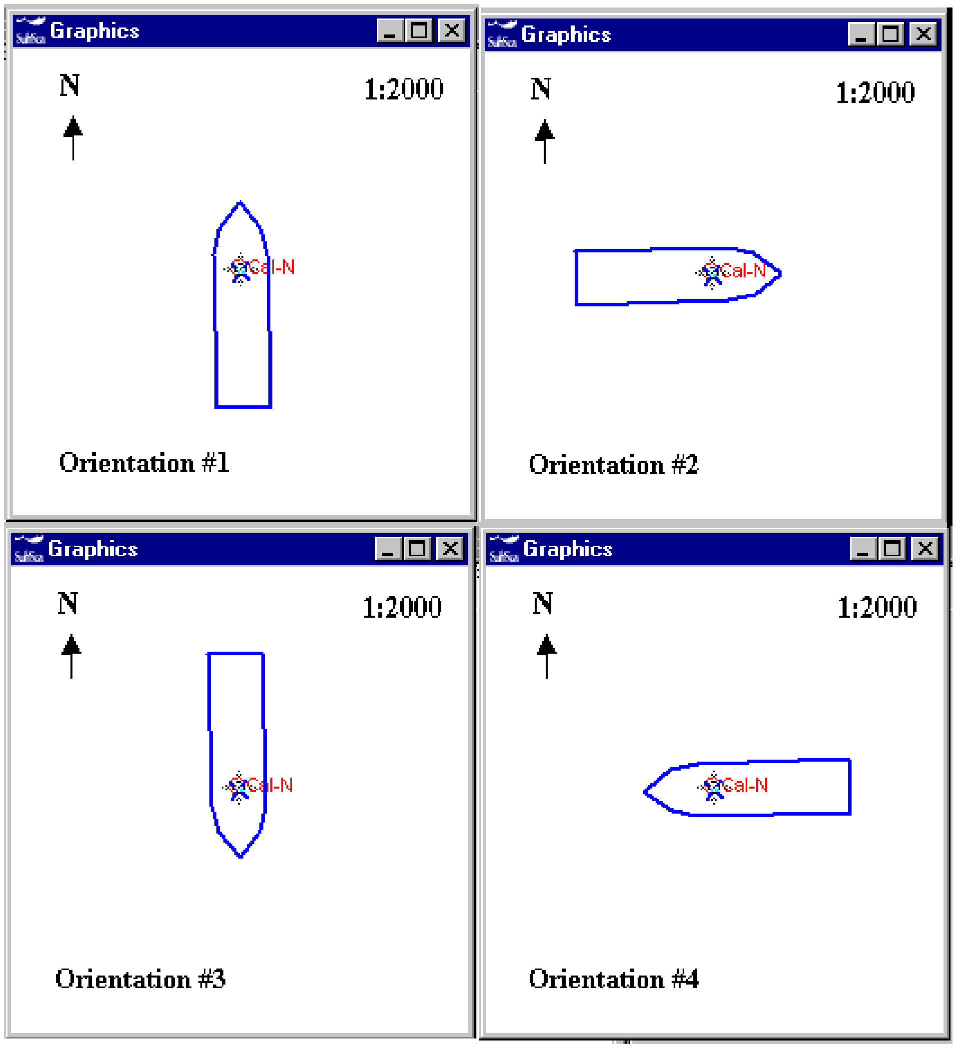
The term **Cardinal Points** pattern comes from the four main points of the compass. Designing the pattern involves assessing the current environmental conditions and determining the optimum heading that the vessel can maintain while holding station. Then using this heading as a reference, determine four points that are at a distance of approximately 1.5 times the water depth of the beacon from the beacon (horizontally distant) such that the azimuth from the beacon to the first point is equal to the aforementioned vessel heading, the azimuth to the second point is this same vessel heading plus 90°, the azimuth to the third is this heading same vessel heading plus 180° and the azimuth to the fourth is this same vessel heading plus 270°. A fifth point directly over the beacon is also usually included.

The following figure illustrates the location of the four **cardinal** points determined for a vessel heading of 0°. Note that the same points would be used if the vessel heading was determined to be 90°, 180° or 270°. They are labeled Cal-N (where the vessel is shown to be), Cal-E, Cal-S and Cal-W respectively. The beacon is shown as C2.



At each of the four cardinal points and the point directly over the beacon, the vessel collects data while holding station at four different headings. These headings are equal to the azimuths from the beacon to the four cardinal points as described above. In the above example, these headings would therefore be 0°, 90°, 180° and 270°.

The following figures illustrate the orientation of the vessel for the five data collection positions (each cardinal point and one over the beacon) based upon the above example.



The data collection is not continuous, but is started and stopped such that data is only collected when the vessel is at a cardinal point and is maintaining one of the four required headings. It is stopped while the vessel changes from one heading to the next and while transiting between the cardinal points.

Alternatives

The first pattern is only suited to vessels equipped with a dynamic positioning (DP) system. WinFrog employs a least squares adjustment to simultaneously solve for the four unknowns of the USBL calibration or the beacon coordinates that is not constrained by the pattern employed. Therefore, alternatives to these patterns are possible. To eliminate biases the pattern should have observation on opposite sides of the beacon.

Note: it is very important to note that the use of an alternative data collection pattern may influence the calibration setup, processing and results. (See the **WinFrog Setup for USBL Calibration Data Collection** and the **Transponder Position Calibration** sections for more details.)

General

It should be noted that in the case of the triangle and cardinal points patterns, it is the relative relationship and orientation between the vessel and the beacon that is important, not the absolute. Thus, in the case of the triangle pattern, the triangle can be rotated to any orientation as long as the vessel maintains the same heading (perpendicular to one leg of the triangle). Similarly, in the case of the cardinal points pattern, the actual pattern could be rotated to any orientation as long as the vessel's headings at each collection point matched the azimuths from the beacon to each of the points. This would hold true for an alternative pattern too.

WinFrog Setup for USBL Calibration Data Collection

This section explains the setup of WinFrog for the purpose of collecting data for a USBL calibration. The assumption is made that the USBL device and other required devices have been added to WinFrog and that the associated data items (USBL HYDROPHONE, POSITION, HEADING, etc.) have been attached to the calibration vehicle.

USBL Hardware

The setup of the USBL system is important in order to obtain optimum results from the calibration. The following steps must be followed.

1 If an attitude sensor is present, it must be injected directly into the USBL system. WinFrog does not currently support application of attitude data to USBL data or USBL sensor offsets. **Note:** this is the only device for which this is true, all other devices and offsets support application of attitude data.

2 Offsets from the USBL system's hydrophone to a reference point on the vessel must be entered into the USBL system. In most cases, these are already present because they are required to reference the data to the **Center of Gravity (COG)** of the vessel for output to a **Dynamic Positioning (DP)** system. If this is not the case, offsets to the same **Common Reference Point (CRP)** that will be used by WinFrog are to be entered, making sure that the vertical reference is the waterline. This is done so that the leaver arm to the transceiver is corrected for attitude, as well as the observations from the transceiver to the beacon.

3 The USBL system must not be configured to operate in **Fixed Beacon Depth** or **Telemetered Beacon Depth** mode, or similar. The Z component as determined from the analysis of the return signal at the hydrophone head is critical for the USBL Corrections Calibration process, in particular for the resolution for pitch and roll correction determinations. The use of an operating mode that uses some other means of determining the Z component will result in un-usable calibration data. It should be noted that the data cannot be re-engineered to make it usable.

4 The USBL systems may support the direct entry of USBL corrections. Since these are used to correct the data prior to output to peripheral hardware, they can be left in the system and the WinFrog calibration is then used to refine the corrections. This is particularly true for corrections entered to correct for gross USBL installation errors, such as the mis-alignment of the transducer head by 180°. WinFrog applies a rigorous least squares adjustment and makes no assumptions that the corrections are small angles. However, it is unable to resolve a heading error of 180°.

Note: due to the possibility of confusing sign conventions, it is recommended that the results of the WinFrog USBL Calibration not be entered directly into a USBL system.

Rather, they should be entered and applied within WinFrog. The sign conventions used by WinFrog and presented to you are provided in such a manner that the sign conventions are easily followed. The WinFrog results of the calibration are entered into the WinFrog USBL hydrophone configuration exactly as shown and printed.

Vehicle Configuration

The vehicle configuration consists of editing the data item's associated with the calibration vehicle. This is accomplished using that vehicle's **Configure Vehicle-Devices** dialog.

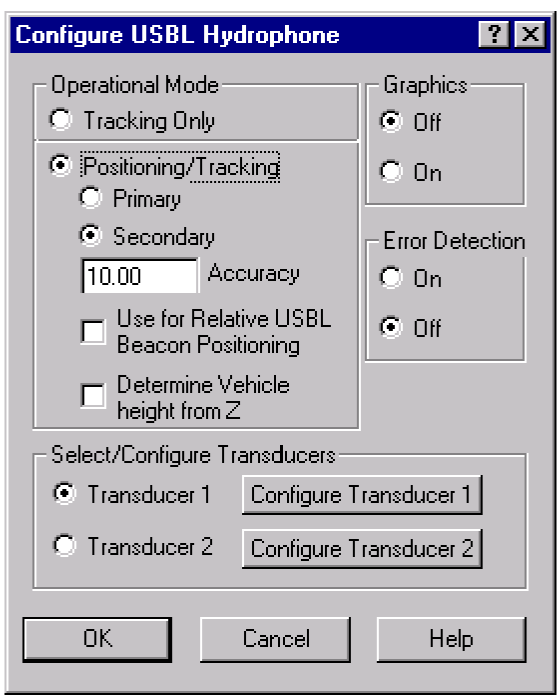
It is recommended that the **Kalman Filter** be turned on **and Dead Reckoning** enabled for the USBL Hydrophone vehicle.

Note: all POSITION and USBL HYDROPHONE data associated with the calibration vehicle will be logged to the calibration file, along with general vehicle data. In addition, a standard deviation is logged for each data item. This is used to determine the initial weighting for that data item in the calibration processing (inverse of the standard deviation squared).

If a **POSITION** data item is configured as **Primary** its standard deviation is logged in the calibration file. If a **POSITION** data item is configured as **Secondary**, the standard deviation logged for that data item is 0 or Off. The standard deviation logged for the USBL HYDROPHONE is the accuracy entered for this data item.

Note: it is recommended that the accuracy settings be "pessimistic" and relative with respect to the different systems involved. Reasonable settings for a DGPS are 3 to 5 meters and 7 to 10 meters for a USBL system (HYDROPHONE and BEACON). The same relative relationship should be maintained in real-time and calibration processing.

The following figure illustrates a typical USBL HYDROPHONE configuration as attached to a vehicle.



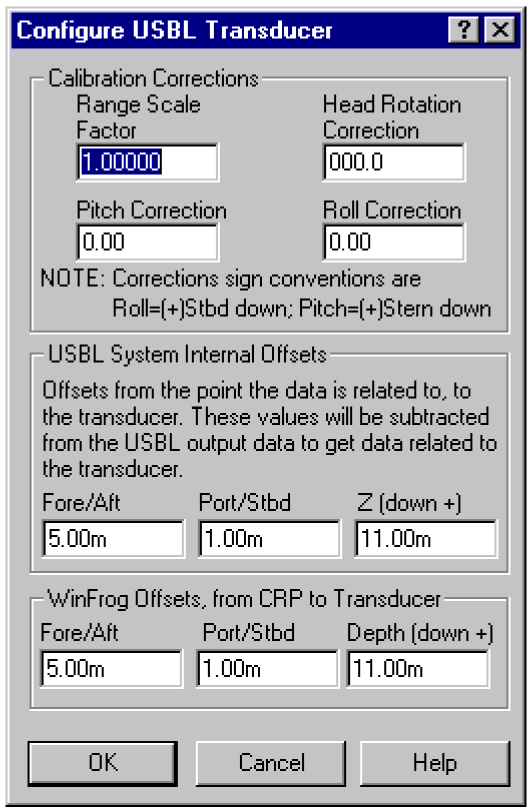
Note: it is set to **Secondary**. As previously mentioned, while setting this to **Primary** may not affect the calibration processing (see note below), it will affect the real-time positioning. If set to **Primary** WinFrog will use the fixed beacon and USBL data to position the vessel. This will likely produce inaccurate positioning with respect to DGPS and thus position jumps that may result.

Note: a general procedural recommendation is that the USBL HYDROPHONE data item always be set to **Positioning - Secondary**. If an alternative data collection pattern is used, it is critical that the USBL HYDROPHONE data item be set to **Secondary**. If set to Secondary, you are not constrained during the processing by an incorrect decision made at the data collection.

Though it will not affect the data collection, it is recommended that the **Use for Relative USBL Beacon Positioning** and **Determine Vehicle height from Z** check boxes be **unchecked**.

To Configure the Transducer Settings

1 Click the **Configure Transducer** button associated with the Transducer selected for use. The Configure USBL Transducer dialog is shown in the next figure.



Is the calibration a confirmation or initial calibration? If it is a confirmation calibration, the settings for the **Calibration Corrections** will probably already reflect the results of a previous calibration and should be left as they are. If the calibration is the initial determination of the correction values, the settings for the corrections must be reset to the following:

Range Scale Factor	1.
Head Rotation Correction	0.
Pitch Correction	0.
Roll Correction	0.

Note: during the calibration process you have recourse to reset the process, i.e., to revert to the original raw data unaffected by any calibration corrections applied either at the time of data collection or during the processing to that point. Therefore, an incorrect decision at this point is not irreversible.

The offsets must also be confirmed to be correct. There are two sets of offsets to enter for a USBL system. The first are the offsets currently entered into the USBL system itself to reference the data to a specified vessel reference point (i.e. COG). Note the sign convention of these offsets; the values are entered as measured from the said reference point to the transducer. A vertical offset is positive if the transducer is below the reference point.

The second set of offsets are the standard WinFrog sensor offsets with the respective sign convention, i.e. values are as measured from the CRP to the sensor and a vertical offset is positive if the sensor is below the CRP. Remember, the WinFrog CRP must be at water level and thus, the vertical offset is actually the draft of the transducer.

Note: there is no recourse to the entry of incorrect USBL system offsets within WinFrog once the data is logged, i.e. if the offsets from the USBL reference point back to the transducer (as entered directly into the USBL system) are incorrectly entered into WinFrog, the data can not be used for the calibration. If this happens, the calibration data file can only be recovered through manipulation using a spreadsheet program. There is however, recourse for the incorrect entry of the WinFrog sensor offsets.

The previous figure is an example of the WinFrog CRP and the USBL system's reference point being, in fact, the same point.

To Collect USBL Calibration Data

The collection of the calibration data is controlled directly from the **Acoustic Calibration** dialog.

1 Set the minimum data logging interval.

Since the only limit on the amount of data logged is the available computer memory and available storage media space, it is better to set this interval fairly small. If too long, any problems (i.e. acoustic noise) during the data collection may result in unacceptable gaps in the designed collection track. It is easier to edit out data than wish there was more data present.

2 Toggle the **USBL Data** radio button.

3 Click the **Apply** button.

As points are collected, the **Points in Memory** text will update and, if the **Graphics On** is selected, the data collection points will be displayed in the **Graphics** windows.

New data will not be collected until the minimum time has elapsed and then only when the next new data are received for all USBL HYDROPHONE and POSITION devices attached to the vehicle.

When the data collection is complete, or at any time the collection is to be suspended, toggle the **Off** radio button and click the **Apply** button. It is important to note that the data collection can be suspended and resumed at any time. This is particularly relevant when using the **cardinal points** pattern.

WinFrog does not support the writing of the calibration data directly to disk as it is collected. The saving of the calibration data to file is an operator-initiated action.

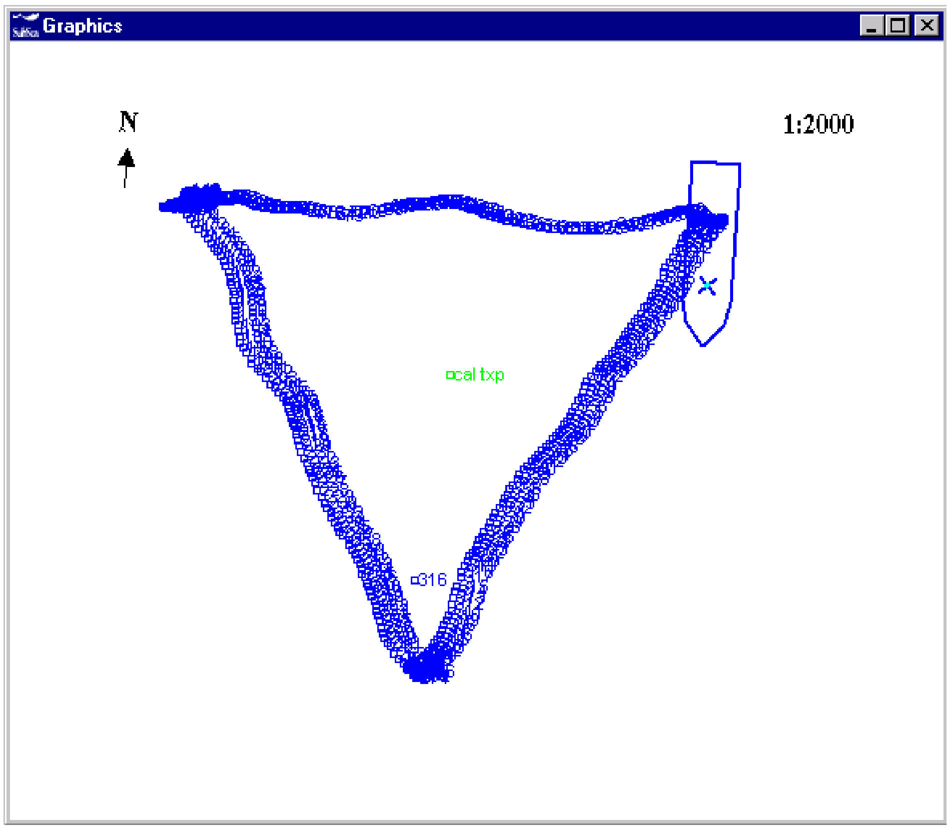
To Save Calibration Data to File

1 From the **Acoustic Calibration** dialog, click the **Save** button.

This can be performed at any time there are data present in memory. It is very strongly recommended that the data be saved regularly to a file during the collection process. Remember, as mentioned previously, when data are saved to an existing file, the contents of that file are replaced with the complete data currently in memory. Thus, though this provides an easy technique for repeatedly saving the data to the same file during the data collection process, care must be exercised to ensure that the correct file is selected.

In addition, an existing data file can be loaded and data collection turned **on** to add more calibration data.

The following figure illustrates a completed calibration collection based upon the **Triangle** pattern.



The calibration files (*.cal) are written to disk using ASCII text and as such are easily accessible and readable. The format for these files is given in the **WinFrog File Formats** appendix of this manual.

Note: once the data collection is complete, the original calibration data file should be archived and set to **read only**. Then, make a copy for actual use in WinFrog. In this way, you can always revert to the original data file if necessary.

USBL Data Collection - Monitoring

The number of points collected are displayed in the Calibration configuration dialog box. However, the data collection process is best monitored with the **Calibration Status** window in the **Acoustic Window** (see the **Operator Display Windows** chapter).

USBL Calibration Data Editing

The data editing can be performed any time there are data available in WinFrog memory, though it is generally done once the data collection process is complete.

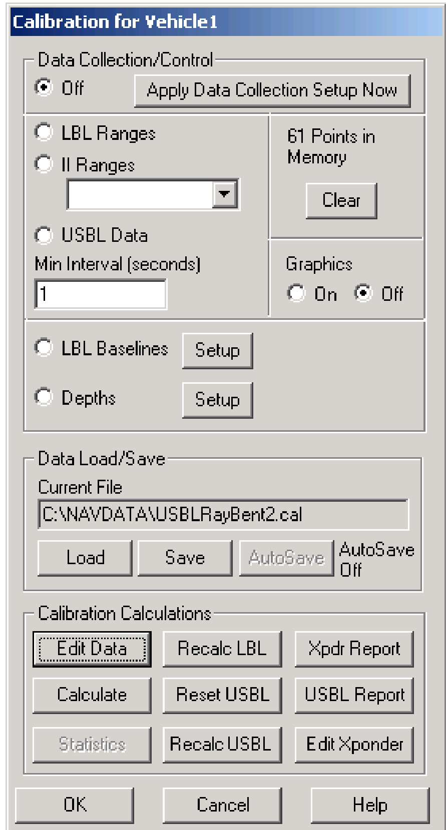
The purpose of viewing and editing the data is to locate and remove those data that are considered to be invalid. WinFrog provides you with graphical editors that enable easy inspection of the data, detection of any trends, and direct editing capabilities. The graphical editors allow you to view the LOP data directly and the LOP residuals. The former is best used for investigating trends and visually detecting outliers, usually visible due to the associated break in a trend, and thus, is a very important pre-processing tool. The latter is valuable for refining the editing in subsequent iterations.

Note: the term editing the data consists of setting the weighting value for any given LOP and changing data item offsets. You do not have access to the actual data for the purpose of altering values.

An initial review of the data should be made prior to any calibration calculations. The purpose of this review is to find obvious flyers and bad data and remove them from the solution immediately. Then, after each calibration solution, the data should be viewed again for analysis and any further required editing.

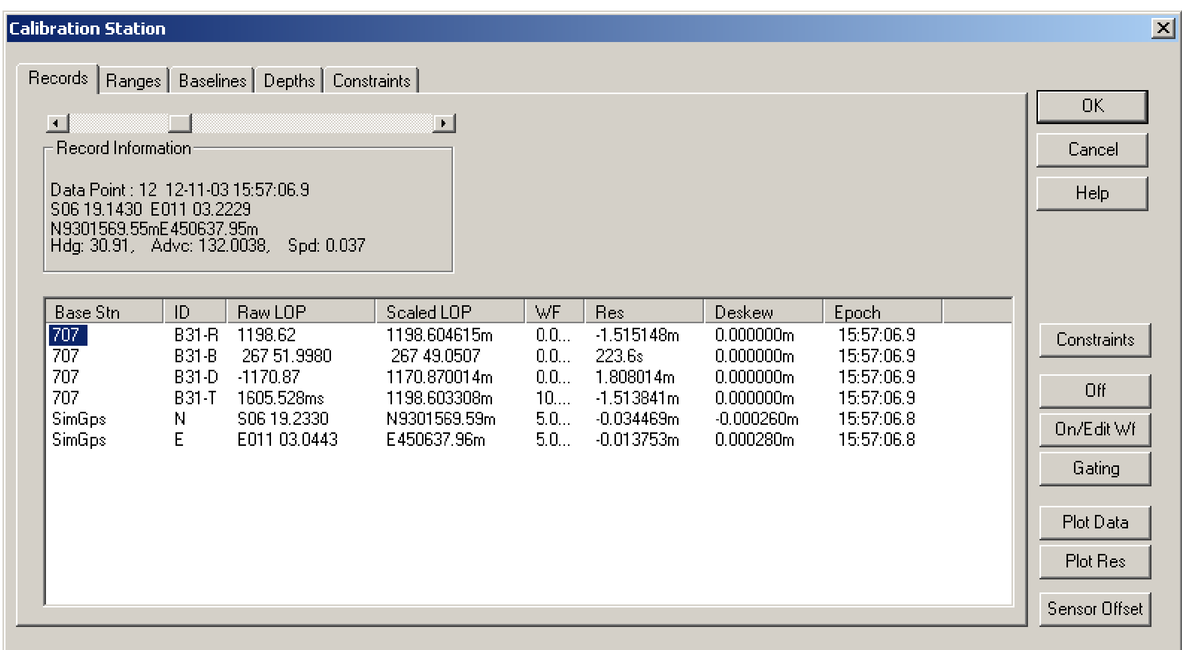
To View USBL Calibration Data for Editing

1 From the **Calibration** dialog box, click the **Edit Data** button.



(The **Edit Data** button is only accessible if there are data present in memory.)

WinFrog opens a **Calibration Station** dialog box, as shown in the next figure, which displays the vessel position, GPS position LOPs and USBL range, bearing, depth (and if available TWTT) LOPs.



Note: the example shown above includes four USBL based LOPs, R, B, D and T. The T LOP is two-way-travel-time and is not available for all USBL devices. If it is not supported by the respective USBL driver in WinFrog, this LOP is not displayed.

The Calibration Station dialog box presents you with several options for viewing the calibration data. For a USBL Corrections calibration, generally only the **Records** and **Ranges** tab are relevant. The available editing options accessed via the buttons located on the right side of the dialog depend on the tab selected, and in the case of the **Records** tab, the type of LOP selected.

To edit an LOP, simply select it and click the appropriate button on the right. Make the editing changes as required and exit the editing dialog with **OK** to save the editing changes or **Cancel** to discard any changes made.

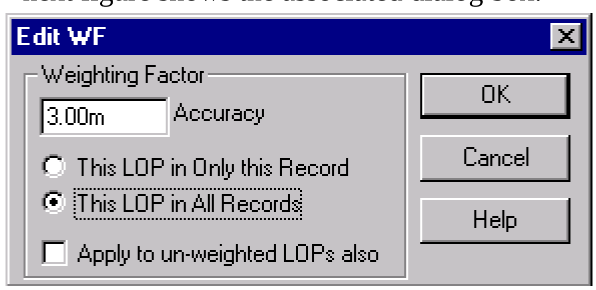
The following details the options available and the associated dialog boxes.

Off

This simply sets the weighting factor for the selected LOP to 0, which de-weights it from the solution. This option is only available with the **Records** and **Constraints** tabs. When associated with a constraint, this toggles it between applied and not applied.

On/Edit Wf

This enables you to edit the actual weighting factor for the selected LOP. This control extends to applying the new weighting factor to the selected LOP in the displayed epoch only, or in all epochs in which this LOP is present. You can also control if the new weighting factor is to be applied to those LOPs already de-weighted. The next figure shows the associated dialog box.



Note: When a tab other than the **Records** is selected, the **This LOP in Only this Record** option is not applicable and is disabled.

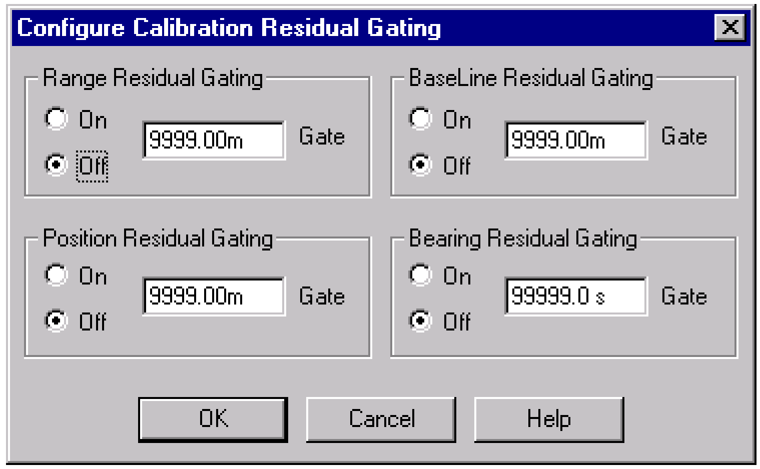
Gating

This enables you to apply **residual gating** to the **complete** data set based upon the current results. This is a powerful tool for quickly editing out flyers, but it can also edit out good data and leave in bad if applied incorrectly. It is important to note the following points:

- The gating is only applied when this option is accessed and exited with **OK**.
- The gating is applied based upon the current residuals. If the gating is applied before any

editing or any processing of solutions, the residuals will be based upon approximate transponder coordinates and as a result, the gating may have unexpected and erroneous results.

- If the gating is turned off for any LOP type and the dialog is exited with **OK**, all LOPs of that type will be re-weighted into the solution if they contain a non-zero value.The next figure shows the **Residual Gating** options.



This option is only available with the **Records** tab.

Plot Data button

Click this button to access a graphical editor for all of the instances of the selected LOP in the Calibration data set. See **Using the Plot Panel: LOPs** section later in this chapter for details on this editing window.

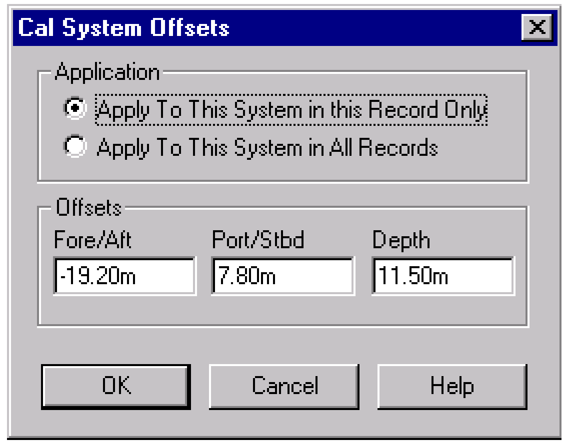
Plot Res(iduals) button

Click this button to access a graphical editor for the residuals for all instances of the selected LOP in the Calibration data set. See **Using the Plot Panel: Residuals** later in this section for details on this editing window.

Sensor Offset button

This button is only available for those data records involving sensor offsets, specifically Positionand USBL Surface Range. It allows you to change the offsets for any sensor involved in the calibration. This provides for corrections in the case of incorrect configuration of the system prior to data collection. You can enter the new offsets and then select whether to apply them to the associated system for the current epoch only or for all epochs. This option is only available with the **Records** and **Ranges** tabs.

The following shows the **Cal System Offsets** dialog for those LOPs associated with surface observations, i.e. ranges and position LOPs.



Note: In the case of USBL observations, this only affects the WinFrog offsets. The USBL system offsets entered as part of the **USBL HYDROPHONE** data item configuration cannot be edited. In addition, offsets applied when a USBL slant range LOP is selected are appropriately applied to all LOPs associated with the selected LOP' s system.

After each major stage of data editing, it is recommended that you save the calibration file to disk. You should give each calibration file a unique name (i.e., the name can have a lettering or numbering code or even a short descriptive message appended indicating the processing stage represented by the file) so that it does not write over a preceding copy of the same calibration set. When given a unique name, at any point in the processing you wish to return to a known point or state in the editing and calculation process, you can reload the appropriate file and resume the processing from that point.

The following detail the **Records** and **Ranges** tabs.

Records Tab

This tab is in two sections. A slider bar located in the top left allows the operator to go scroll through the complete data set essentially in chronological order. As you move the slider, the data for the respective calibration record displays. Also in the top left panel is the summary of the data record. This information varies depending upon the data item being viewed.

The second section is the data panel itself. The List View window presents the LOPs contained in the currently selected record.

Data Point Selection

This section is the top left panel and provides you with the option of scrolling through the complete data set using the slider bar. The position information for the vehicle used to collect the data for the selected epoch is displayed in this panel.

Line 1	The calibration point number and the date and time for the selected point.
Line 2	The geographic coordinate for vehicle's CRP on the working ellipsoid.
Line 3	The map grid coordinate for the vehicle's CRP.
Line 4	The vehicle's heading, CMG, and speed in knots.

Data Point Summary

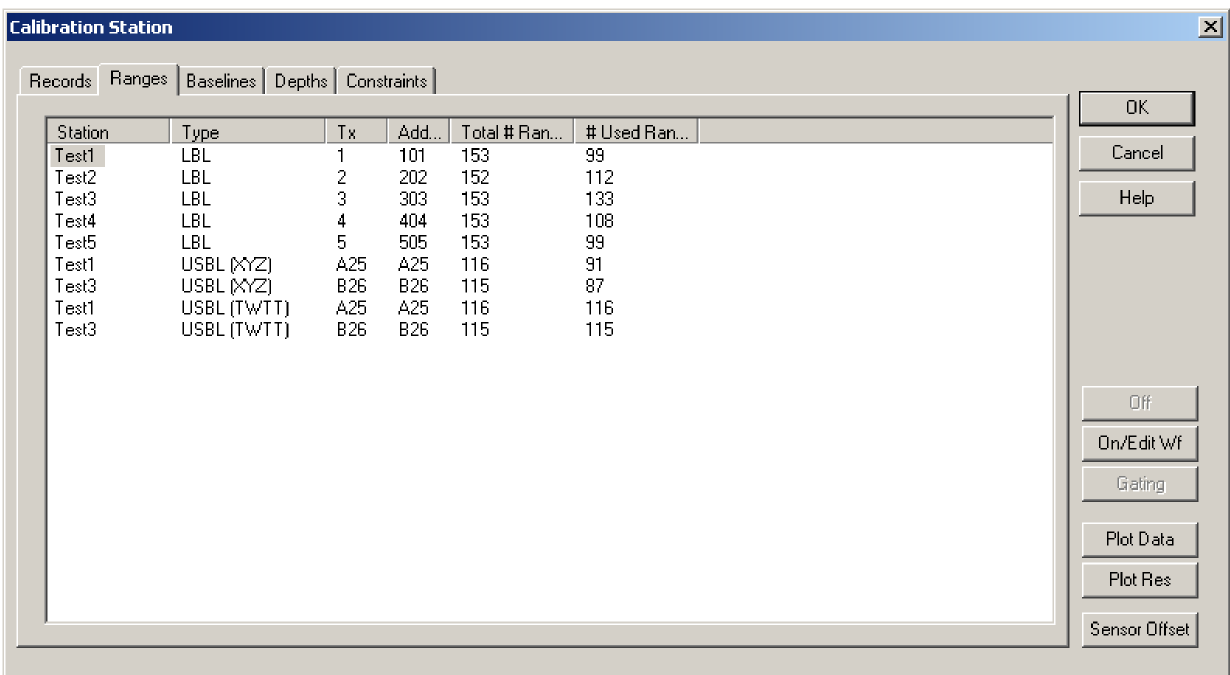
This section is the lower, larger panel and presents the data (LOPs) collected at the selected epoch in a list window. **Note:** there are no sort capabilities available, the data are displayed in the order that the data items are added to the associated vehicle. It is also important to note that the selection of an LOP is only possible from the first column. The order does not affect the calibration processing. A single position data item provides two LOPs: a latitude and a longitude. A USBL data item provides three LOPs: slope range, bearing, and depth.

Base Stn	This lists the LOP's name. In the case of a position LOP, the name of the associated device is shown, in the case of the USBL LOPs, the name of the station is given.
ID	This lists the associated ID of the LOP. In the case of a position LOP, it is the denotation of either N(orthing) or E(asting). In the case of a USBL range LOP, it is the beacon ID with a code identifying the LOP type: R = Range, B = Bearing, D = Depth and T = TWTT.
Raw LOP	This is the raw LOP, or actual data, logged for the LOP. For a position LOP it is the WGS 84 latitude and/or longitude. For USBL LOPs, they are the raw slope range, bearing, depth and TWTT as obtained from the USBL system (corrected for the USBL system offsets).
Scaled LOP	This is the scaled LOP, or data reduced to the map projection. In the case of a position data item, the WGS 84 position is transformed to the working ellipsoid and then projected onto the working map projection. For the USBL LOPs, the data are projected onto the map grid and corrected with the current USBL calibration corrections, either as they were applied in real-time (during data collection) or determined and applied as part of the current calibration processing.
WF	This is the weighting factor used for the LOP in the solution. **Note:** the lower the value, the greater affect the LOP will have on the solution.
Res	This is the residual for the LOP for the selected epoch.

Deskew	The individual LOPs collected for a given calibration epoch are actually valid for different times. The calibration point epoch is defined by the vessel position epoch. Position LOPs are deskewed to the vessel epoch using velocity vectors generated as part of the standard real-time positioning and processing and logged with the calibration data. In the case of USBL LOPs, the vessel position is dekewed to the USBL epoch and as a result the deskew value for USBL data is shown as 0 in this window. In fact, the data capture and logging is driven by the reception of the USBL data and as a result, if the vehicle positioning is set to use Kalman Filter and Dead Reckoning (recommended settings) the vessel epoch and USBL data epoch will be virtually the same.
Epoch	This is the time stamp for the LOP data.

Ranges Tab

This tab allows you to view a summary of all surface ranges observed and contained in the calibration file. The information presented is detailed here.



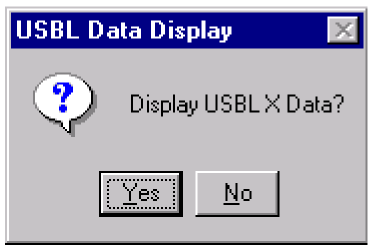
Station	The name of the **Xponder** station observed to.
Type	The surface range may be a standard LBL TWTT (**LBL**) observation, a USBL XYZ based observation (**USBL (XYZ)**) or a USBL travel time observation (**USBL (TWTT)**).

Tx	The transmit channel (or frequency) or beacon ID of the **Xponder** station observed to.
Address	The address of the **Xponder** station observed to, which in the case of a USBL beacon duplicates the ID.
Total # Ranges	The total number of observations made to the **Xponder** station.
# Used Ranges	The total number of observations made to the **Xponder** station that are weighted into the solution.

Using the Plot Panel: USBL LOPS

When you click the **Plot Data** button in the **Calibration Station** window with a Position or USBL LOP selected, the following graphical editor is opened.

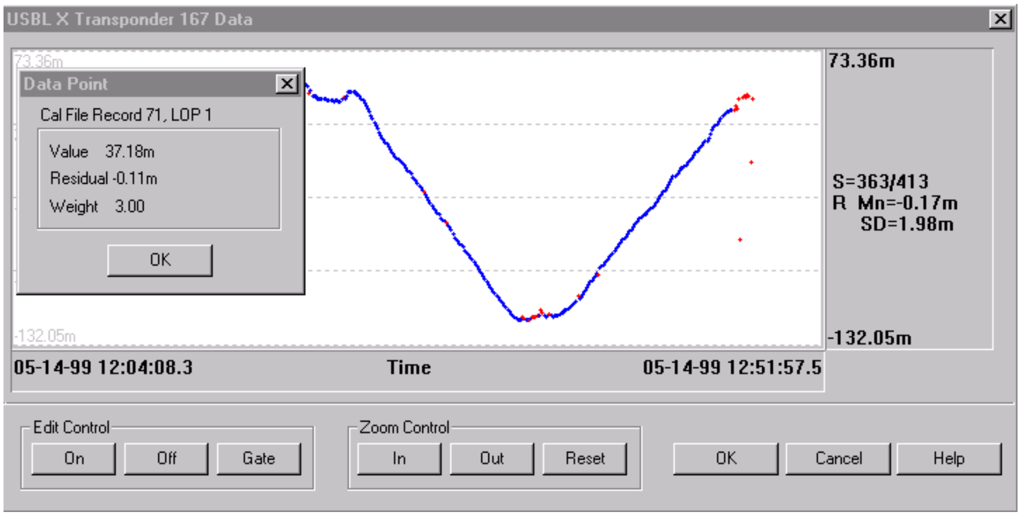
In the case of a USBL range or bearing LOP, a prompt pops up asking if you wish to plot **X** or **Y** data respectively.



Answering **Yes** to either of these prompts results in the graphical editor plotting the scaled X or Y data used to produce the scaled range and bearing LOPs. Answering **No** to results in the graphical editor plotting the scaled range and bearing LOPs respectively. The viewing of the X and Y data is representative of viewing the components of the bearing LOP in greater detail. This provides for comprehensive data viewing and editing options.

Note: it is recommended that for the initial viewing looking for trends and outliers, the actual range and bearing LOPs be viewed.

The LOP data are plotted as LOP (Y axis) versus epoch time (X axis). This provides a valuable visual editing tool as the data trends are clearly evident and breaks in trends indicating problems can easily be seen and examined. Outliers are also easily detected. Data which are weighted in the solution are drawn in blue, those which are de-weighted are drawn in red.



Time Axis — The time axis (horizontal) is labeled with the time/date for the left and right most extents of the window. When the panel is originally drawn and on a **Reset** (see below) this axis is extended 10% of the total time span before and after the actual data time span.

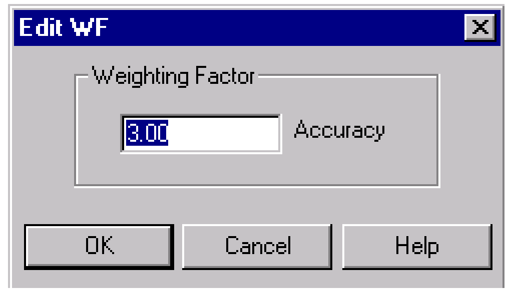
LOP Axis — The LOP axis (vertical) is labeled with the LOP value for the top and bottom, along with the summary of the LOPs. This summary includes the number of LOPs weighted in the solution and the total number of LOPs in the data set, and the mean residual and its standard deviation based upon those LOPs currently weighted in the solution. When the panel is originally drawn and on a **Reset** (see below) this axis is extended 10% of the total LOP values span at top and bottom.

Point Exam — Double-click the left mouse button in the plot panel to cause WinFrog to locate the closest data point and display the information for that point in a message dialog box, as shown in the above figure.

Windowing — Using the left mouse button (click and drag) you can draw a window in the plot panel. This provides WinFrog with the outline of the area in which to perform subsequent actions, as detailed below.

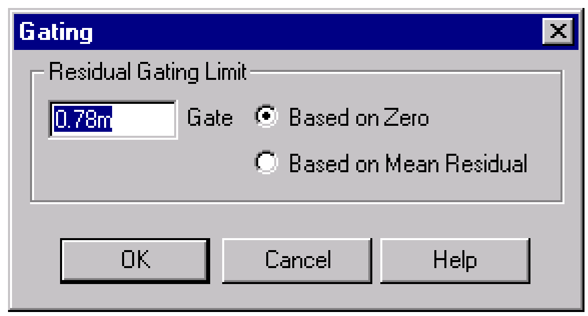
Edit Control

On — If an area of the plot panel has been selected, you are presented with the option to enter a weighting factor to be applied to all points in the selected area. The next figure shows the associated dialog box.



Off If an area has been selected in the plot panel, all LOPs in that area will be de-weighted (weighting factor set to 0).

Gate This allows you to apply gating to a specific LOP. This is preferred over blindly applying gating to the complete data set, as described above. The gating is applied to the data in a selected area or if an area in the plot panel has not been selected, to the complete LOP set. The next figure shows the options available for the gating.



You can enter the gating value and then select the application of the gate value. If **Based on Zero** is selected, any LOP whose residual is outside ± gate is de-weighted. If the **Based on Mean Residual** option is selected, any LOP whose residual is outside the mean residual ±gate is deweighted. The default gate is the standard deviation for the residuals for the respective weighted LOPs.

Zoom Control

In If an area has been selected in the plot panel, this area is drawn to the extents of the display. Otherwise the plot panel is zoomed in by a factor of 2 vertically. The horizontal time span remains the same.

Out Regardless of whether an area is selected in the plot panel, this causes a zoom out of 10% vertically. The horizontal time span remains unchanged.

Reset Re-draws the plot panel to the original coverage.

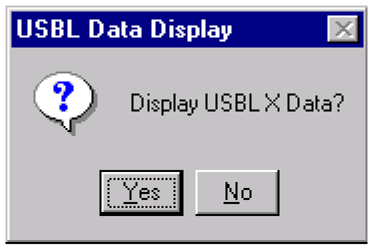
To close the window and apply all changes made with this editor, click **OK**. Clicking **Cancel** closes the window, discarding all changes made.

Note: If the data being viewed is a USBL XYZ based LOP (i.e., a calculated slant range, X, bearing, Y or depth LOP but not the TWTT LOP), and LOPs are de-weighted in the above process, the associated XYZ based LOPs are automatically de-weighted. This does not apply to the weighting in of LOPs.

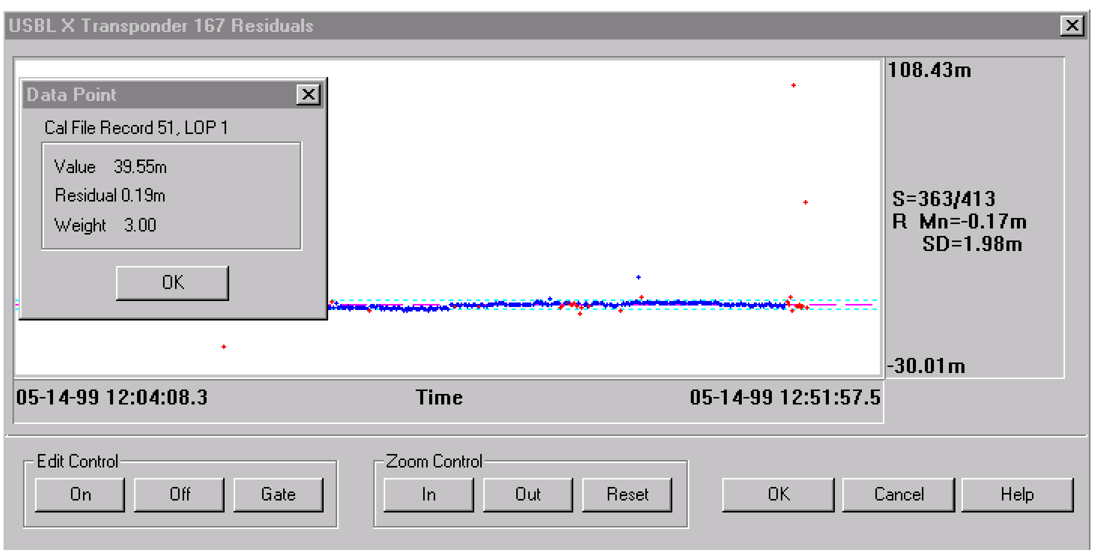
Using the Plot Panel: USBL Residuals

When you click the **Plot Res** button in the **Calibration Station** window with any LOP selected, the following window is presented.

In the case of a USBL range or bearing LOP, a prompt pops up asking if you wish to plot **X** or **Y** data respectively.



Answering **Yes** to either of these prompts results in the graphical editor plotting the residuals based upon the scaled X or Y data. Answering **No** to results in the graphical editor plotting the residuals based upon the scaled range and bearing data.



The window title gives the LOP type and the name of the specific LOP. The capabilities and options are the same in this window as detailed in **Using the Plot Panel: USBL LOPS**.

The horizontal lines represent the following:

- Long dashed magenta line is 0.
- Short dashed magenta line is the mean of all the residuals.
- Short dashed light blue line is the mean residual ± standard deviation.

The residuals are plotted against time, that is the time stamp for the data reception. Data weighted in the solution is plotted in blue, that de-weighted is plotted in red.

Note: Though the graphically editing of Residuals is useful, it must be done carefully and always after the initial calibration processing. It is important to be aware that the least squares technique minimizes the residuals of all observations. Consequently, it distributes any errors throughout the whole array. The error from a single observation will appear in the residuals of all the observations. The amount that appears in each observation depends upon the geometry, number of observations, and the weight assigned to each observation. One cannot assume that the observation with the largest residual is necessarily the observation with the error (although this is where one generally begins to investigate). Consequently, do not eliminate large blocks of observations all at one time. Remove only a few of the largest then solve again.

Note: If the residuals being viewed are based upon a USBL XYZ based LOP (i.e., a calculated slant range, X, bearing, Y or depth LOP but not the TWTT LOP), and LOPs are de-weighted in the above process, the associated XYZ based LOPs are automatically de-weighted. This does not apply to the weighting in of LOPs.

USBL Calibration Processing

The solution of the USBL calibration is a two-step process. The first step is to determine the position of the beacon used. The second step is to use this known beacon to determine the USBL calibration correction values. This process can be repeated to confirm the results. However, it is recommended that the cycle not be repeated more than twice as this has a tendency to bias the results and the solution of the calibration corrections may diverge from the correct results.

Each step of the process has different data requirements and, as a result, the editing of the data is approached differently for each.

The following sections detail the two steps.

Transponder Position Calibration

As mentioned, the USBL calibration requires that the position of the beacon used be determined.

Note: the USBL range and USBL Angles (bearing LOPs) can both be used for the determination of the beacon position (at present, the depth LOP is available only as an editing tool, not an observable for the solution of the beacon position). However, it is recommended that only the range LOPs be used. Experience has shown that the slope range, as extracted from the XYZ data, is more reliable than the range and bearing for many USBL systems. More importantly, with the use of the range LOPs only, the effects of any unapplied USBL corrections are minimal and appear to the least squares solution as noise. If a good data collection pattern has been employed (i.e. either the triangle or cardinal points patterns), this noise has a minimal affect on the solution of the position as it tends to be cancelled out.

Note: the USBL range data used to calibrate a beacon position can either be that calculated from the XYZ data or that calculated from the travel time, but not both. In the case of the latter, a **Working Velocity** file must be present.

Data Editing

The editing of the data requires an initial editing prior to performing any position calculations. This is followed by a review of the data once the first position solution has been successfully performed, to refine the selection of valid data.

Pre-Position Solution Editing

Using the **Plot Data** option, as detailed previously in the **USBL Calibration Data Editing** section, the POSITION and USBL range LOPs collected for the calibration should be reviewed specifically for those points that appear to break a trend or are obvious outliers. These changes may be exaggerated, as in the case of a bad hit on the beacon, resulting in a jump in the range to the beacon of many meters. They may also be subtle, as in the case of the GPS losing the differential corrections and beginning to drift from a DGPS solution.

It is equally important to re-weight into the solution those points that for one reason or another were automatically de-weighted during the data collection process, but in review appear to be valid.

It is important to remember that at this point, the USBL corrections are "unaccounted for." This may cause good data to appear to break a trend, especially in the case of the bearing and depth LOPs. It is for this reason that these LOPs are not examined at this stage in the processing.

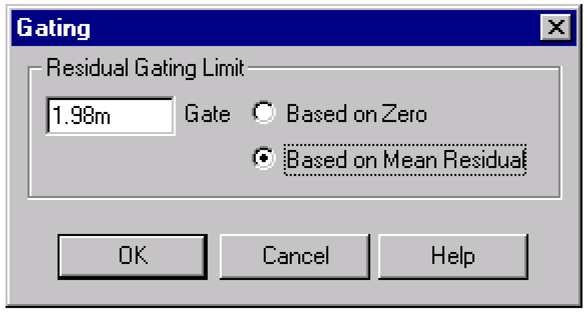
The graphical editor should be used to its full capability to zoom in on questionable areas of the data. If there is doubt as to whether the data are indeed breaking a trend, do not de-weight it at this stage.

Post-Position Solution Editing

Once a position has been solved for, the data should be reviewed again. The graphical editors are the best editing tools to use.

It is important to remember that, at this point, the USBL corrections are still "unaccounted for."

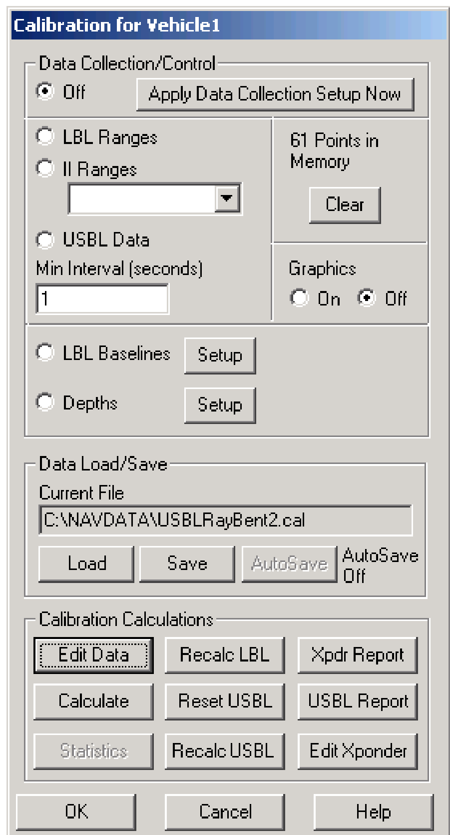
Review the data using the **Plot Data** to ensure no outliers or trend breakers were missed. Then use the **Plot Residual** option to view the residuals for the POSITION and range LOPs. At this stage, the residuals should be fairly consistent, in that they are not excessive, though in the case of the USBL LOPs, they will probably be offset from zero. The standard deviation will generally indicate the range of the errors due to the unaccounted for USBL corrections. Remove those points with large residuals. Depending upon the quality of the data, the gating feature may be used to apply further editing of the data, although very carefully. If used, it should be applied to the Mean Residual, **not** Zero, as illustrated in the following figure.



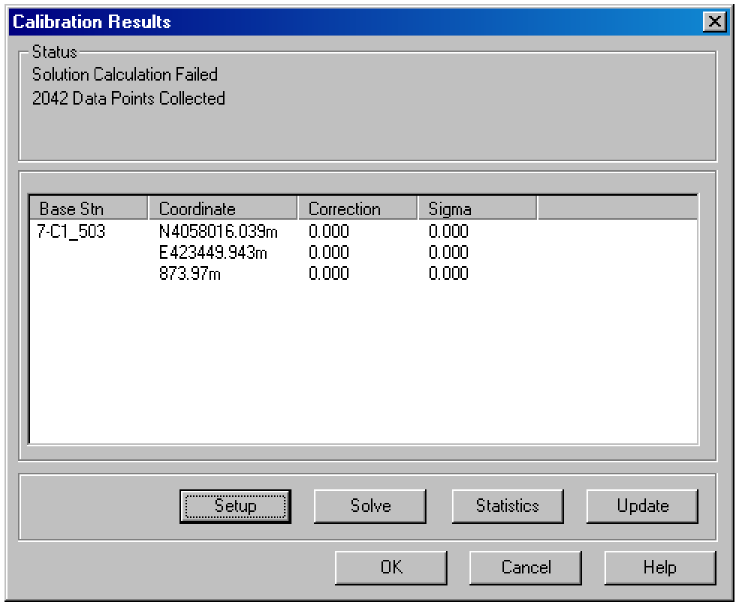
Setup

To Setup for the Determination of the Beacon Position

1 In the Calibration dialog, click the **Calculate** button.

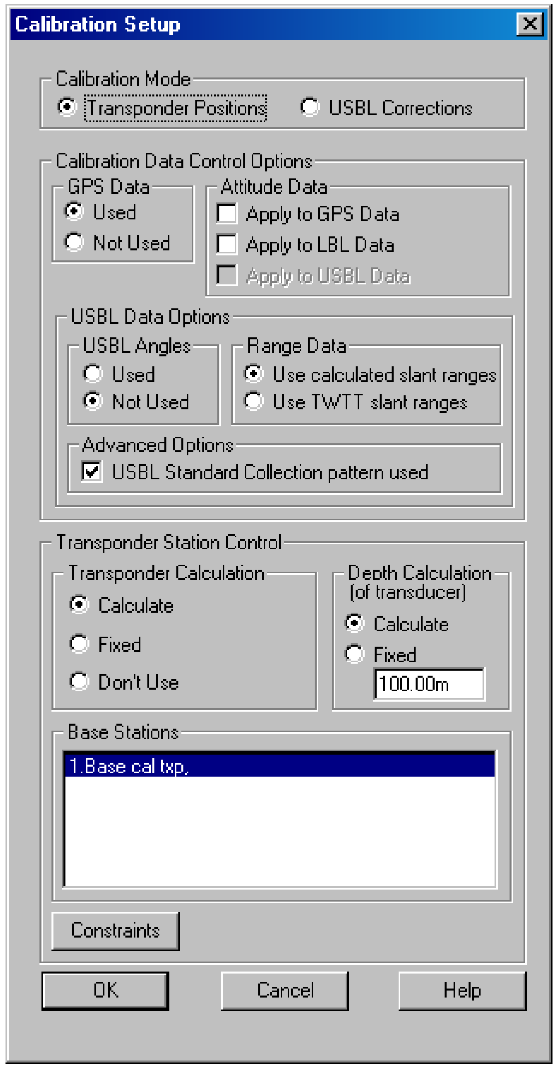


The **Calibration Results** dialog box opens.



2 Click the **Setup** button to configure the solution type and parameters.

This opens the **Calibration Setup** dialog, shown in the next figure. The sample shown reflects typical settings.



The calculation options are as follows:

Calibration Mode

Transponder Positions	WinFrog will solve for the positions of the transponders/beacons as configured. Select this option for this phase of the processing.
USBL Corrections	WinFrog will solve the USBL calibration corrections as configured.

Calibration Data Control Options

GPS Data	Controls the use of the logged GPS data.
Used	The GPS position data are used in the calibration solution. This must be selected for a USBL beacon position solution.
Not Used	The GPS position data are not used in the calibration solution. This is not applicable for a USBL beacon position solution.

Attitude Data

Apply to GPS Data — If available during the data collection, the pitch and roll data logged with the GPS LOPs are applied to the GPS sensor offsets in the solution.

Apply to LBL Data — Not applicable to a USBL beacon position solution.

Apply to USBL Data — If available during the data collection, the pitch and roll data logged with the USBL TWTT LOP are applied to the USBL sensor offsets in the solution. **Note** that this is applicable to the transponder position portion of the calibration process when TWTT data is used and never for the actual USBL correction portion of the calibration process.

USBL Angles — This allows the use of USBL bearing LOPs to be used in the solution of a USBL beacon position. For the determination of a USBL beacon position for the purpose of then solving the USBL corrections, this is not to be used. However, it is a useful tool if the position of a beacon is required and data from a calibrated USBL system are used to collect data without actually circling the beacon.

Range Data — **Note:** The radio button labels change depending upon the data recorded.

Use calculated slant ranges — Select this option if the slant range data to be used for the transponder beacon position determination is derived from the XYZ data (typical).

Use TWTT slant ranges — Select this option if the slant range data to be used for the transponder beacon position determination is derived from the observed signal travel time. Note that if this option is selected, the **Attitude Data** option **Use Apply to USBL Data** becomes available. This is because the travel time data is not corrected to a vertical datum and therefore the application of pitch and roll to the application of the sensor offsets can improve the solution. This will be disabled if the data does not contain two way travel time.

Use Travel Time — This radio button will be present if the data contains two way travel time with no XYZ data. This is the case with Sonardyne's surveyor's acoustic CSV telegram. When this button is present the other two will not be present.

Advanced Options

USBL Xponder Standard Cal

This is an important setting. A standard calibration is considered to be one that specifically meets the objective of the design of the data collection pattern.

To summarize the objective here, this is a collection pattern that evenly distributes the collection points about the beacon while presenting the hydrophone to the beacon such that observations fore and aft, port and starboard are equal. If the triangle or cardinal points pattern is used, this should be checked (default setting). If any other pattern is used, this should be unchecked in order to ensure that any non-symmetry of the pattern does not bias the results.

In a **Standard Cal**, the vessel's position is considered an observation and is adjusted using the data collected during the least squares adjustment. In a **non-Standard Cal**, the vessel's position is considered a known and is held unaltered during the processing from the original position logged during the data collection.

Note: If processed as **Standard Cal**, in order to revert back to the original data to try processing as a **non-Standard Cal**, use the **Reset USBL** option in the main Calibration dialog (see **Using the Reset USBL Option**) Alternatively, reload the original data and repeat the processing as a **non-Standard Cal**.

Note: if the data were collected with the USBL HYDROPHONE data item configuration set to **Positioning-Primary**, it is recommended that the data be processed as a standard calibration. This is due to the real-time positioning of the vessel having been affected by the positioning from an uncalibrated beacon and, therefore, must be adjusted during the processing.

Transponder Station Control

Transponder Calculation

This controls the horizontal position solution for the beacon selected in the **Base Stations** list box.

Calculate

Solves for the Northing and Easting of the beacon.

Fixed

The beacon is held fixed (known) in the solution. This is not applicable in the processing of a USBL beacon for the purpose of performing a USBL calibration.

Don’t Use	The beacon is not used at all in the solution. It is important that if a transponder appears in the list, but there are no data for it in the calibration data, this option is selected for that transponder. Otherwise, the solution will fail.

Depth Calculation

This is an important setting in any calibration, but especially in the case of a USBL calibration. The errors solved for in the USBL calibration include a scale factor, which (even if excessive) is largely accounted for in the least squares solution with respect to the horizontal position determination. It can however, influence the determination of the depth, which will subsequently greatly impact the solution of the USBL corrections. If at all possible, the depth of the beacon should be determined using a depth sensor in the actual beacon and then held fixed **for processing**. As a check, once calibrated, the same data can be used to solve for the depth to confirm the validity of the solution.

Note: Do not confuse the term **Fixed** as discussed here in the context of the data processing with the term **Fixed** in the configuration the actual USBL system itself. They are completely different aspects of the calibration process. You are reminded here that the USBL system itself **must not** be configured to use Fixed Depth or Telemetered Depth or similar during the collection of calibration data.

Calculate	Solves for the depth of the beacon.
Fixed	The depth for the beacon is held fixed in the solution. You may enter a value here to use as the fixed depth. The default is the value present in the **Working Xponder** file when the calibration is first started or the depth solved in subsequent processing.

Base Stations

This lists all the stations available for the calibration solution (set to **USBL Fixed** in the **Xponder** file at the start of the calibration setup process or edited with the **Calibration Edit Xponder** option) by station name and, if it has been entered at some point (e.g. if the beacon is a dual purpose Sonardyne Compatt), the transponder’s address. It is important to note that when the **Calibration** dialog is first opened, the current **Working Xponder** file is copied to a calibration local copy of that file. It is this copy that is used throughout the calibration process, not the actual **Working Xponder** file. It is for this reason that it is very important to ensure that the **Xponder** file contains all transponders involved in the calibration and has their approximate starting coordinates entered prior to starting the calibration data collection, editing, and calculation process. If there are problems, the calibration data set station information can be edited using the **Edit Xponder** feature.

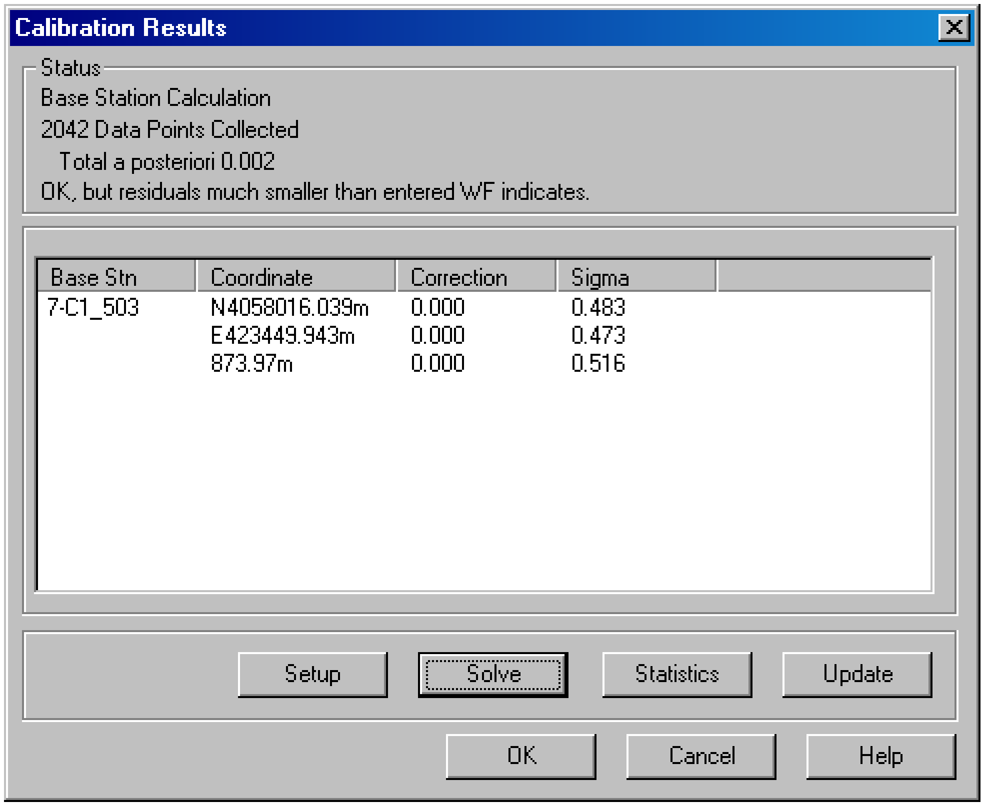
Select each transponder and configure appropriately using the options available in this panel. Once the configuration is complete, use the **OK** button to exit this dialog.

Additional Controls

Constraints	Click this button to configure constraints for the Least Squares Adjustment (see **To Enter Constraints for the Least Squares Adjustment**).

Solving

Once the solution is configured, you can perform the iterative calibration calculation directly from the **Calibration Results** dialog box. Continue clicking the **Solve** button until the solution has converged.



The Calibration Results Dialog Box

The **Calibration Results** dialog box is shown in the previous figure. The following details the components.

Status Panel

Displays the current status of the solution (first line) and the number of points used in the solution (second line). The following are possible status messages:

No Calibration Solution Defined	The **Setup** has not been performed for the calibration. A solution is not possible.
Solution Re-Defined, should Re-Process	The **Setup** has been re-accessed and exited with the **OK** button. Therefore, the solution should be re-calculated.
Solution Must be Recalculated	The solution has been reset and it must be re-calculated.
Base Station Calculation	Solution for transponders was successful.

Solution Calculation Failed	Solution failed. There are major problems with the data that must be investigated.
Processing…	WinFrog is executing the calibration processing.

Data Panel

Base Stn	The USBL beacon name of the station.
Coordinates	The Northing, Easting, and depth for the station. **Note:** the Units/Coordinates/Grid Coordinate Order controls the order of the Northing or Easting.
Corrections	The corrections determined and applied in the last adjustment iteration. If the associated coordinate component has been held **Fixed**, instead of the correction value, the term **Fixed** is displayed in brackets. **Note:** the term **corrections** here refers to the adjustments to the unknowns determined by the least squares adjustment, not the USBL corrections. The unknowns in this processing are the beacon coordinates and depth, if it is to be solved.
Sigmas	The sigma of the associated coordinate component as determined from the last adjustment iteration.

To Perform the Adjustment

As mentioned previously, the least squares solution is an iterative one.

1 Click the **Solve** button to perform one adjustment. If the solution is successful (converges), the results of the adjustment are displayed.

2 Continue to click the **Solve** button until the value no longer changes with each click.

The correction values continue to converge (get smaller), eventually reaching a value that remains unchanged on subsequent clicks of the **Solve** button. This indicates that the calibration adjustment is complete based upon the currently weighted data.

Note: in a "perfect" solution, the correction values would converge to zero. However, in the actual calibration, they should converge to values consistent with the accuracy of the acoustic system being used.

Problems with the calibration data are indicated by the following:

The solution fails. Probable causes are:

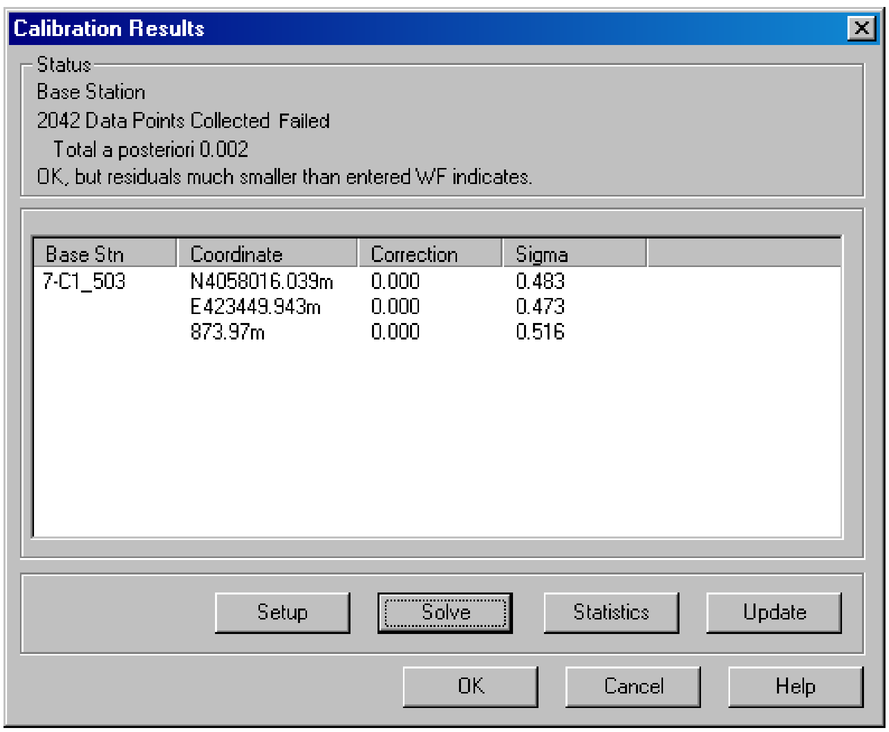
- A transponder has no data associated with it, but is not set to **Don't Use**.
- The initial transponder coordinates and/or depths are not sufficiently close to the actual locations. Also, check that the correct transponder was dropped or located at the correct location.
- There are flyers that have not been de-weighted from the solution.
- Incorrect beacons in file. To correct:
  A - Exit the calibration process

B - Confirm the validity and completeness of the Working Xponder file
C - Start a new calibration
D - Save to a dummy file.
E - Use a text editor to replace the 901 records in the real calibration file with those in the just created dummy file.

- GPS Data is set to Not Used
- The correction values converge, but not to a value consistent with the accuracy capabilities of the acoustic system being calibrated. This indicates that there are probably still bad data weighted in the solution. The LOPs should be re-examined using the graphical editor.
- The correction values jump about without converging, or appear to converge, but before reaching a static result start to increase again. This again indicates that there are probably still bad data weighted in the solution. The LOPs should be re-examined using the graphical editor.

Analyzing the Results: the Chi Squared Test and A Posteriori Variance factor

Once you click the **Solve** button, at least once, two more status lines display.



A **posteriori** values display on the first new line and, on the second new line, the results of a statistical test performed on the total **a posteriori**. Before the **a posteriori** values can be used, the solution must reach convergence or it is no longer productive to click the **Solve** button.

The **a posteriori** is a variance and is the sum of the square of each residual multiplied by its weight all divided by the number of observations less the number of unknowns. This value can be used as an aid in assessing the quality of the least squares adjustment.

The **a posteriori** is compared statistically to the **a priori variance** using the statistical test termed the **Chi squared test**. This test is performed at a 95% confidence interval. The value of the **a priori variance** is 1 because the standard deviation of each observation is known and set by the operator.

Why could the Chi Squared Test Fail?

If the test fails and the a posteriori variance is large, the adjustment and consequently the calculated coordinates of the transponders are unreliable. A failure of this statistical test can occur for three reasons:

- bad mathematical model
- unmodeled biases in the data (some bad observations)
- incorrect initial weighting (wrong Weighting Factor)

The first possible cause of the failure can be discounted as the mathematical model has been proven sound by several authors over many years.

The second cause of the failure, **unmodeled biases in the data,** is usually the cause that requires investigation. This can be due to the following:

- There is one or more bad observation: a baseline, surface-to-transponder range, depth or GPS fix.
- Excessive pitch and roll of the vessel during recording of the transceiver-to-transponder ranges without an attitude sensor input to WinFrog and enabled for use in the Vehicle positioning. This could effect all surface-to-transponder ranges and GPS positions. In this case, the unmodeled bias in the data is the un-calculated change in range due to pitch and roll. (Actually the ship rocks so the offset between the GPS antenna and the transponder is not correct so the transponder coordinates are calculated incorrectly at the time the observation is made.) WinFrog can be configured to use an attitude sensor in realtime and log the data to the calibration data for use in the calibration processing, if an attitude sensor is available when the data is observed.

  If an attitude sensor is not available and there is excessive ship pitch and roll the residuals will show a marked sinusoid pattern. The crests and troughs will usually straddle the mean, but not always evenly as the ship may roll to one side more than the other. If there are a large number of observations and all the larger outliers are removed, the pitch or roll to one side will cancel the pitch or roll to the other and the adjustment should be good. However in this situation one should multiply the geometric error ellipses by the square root of the **total a posteriori variance** to obtain the actual absolute error ellipses. This will then reflect the uncertainty in the absolute accuracy of the transponders due to the un-modeled pitch and roll.
- Invalid velocity profile.

The size of the **a posteriori** is a qualitative indicator of how many bad observations there are. It usually only requires one bad observation to cause the failure. However, when this happens the **a posteriori** variance is usually smaller (say less than 10). The more bad observations there are, the larger the **a posteriori variance** can become. If it is greater than 999, it indicates that there are several bad observations. **Note:** one large error is roughly equivalent to a few smaller errors.

The third possible reason that the test on the **a posteriori variance** factor can fail is **incorrect**

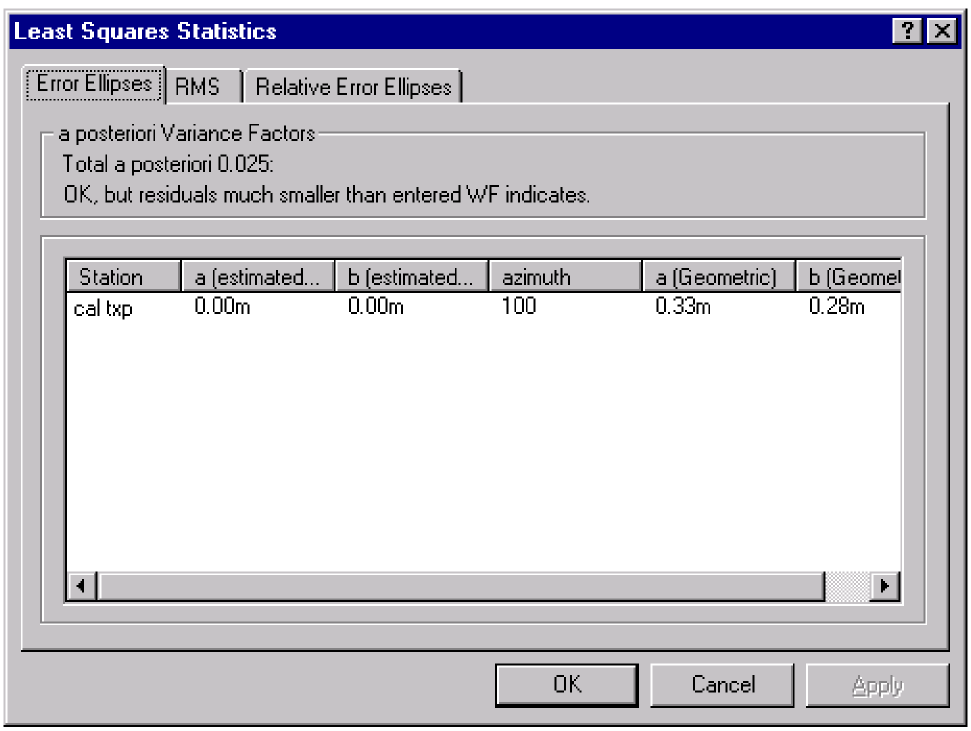
initial weighting. The initial weighting is the weighting factor value assigned to each observation. The status line may display the message, **OK, but residuals much smaller than initial WF indicates.** This means that the statistical test failed, but not due to bad data. This is caused by assigning weighting factor values that were too pessimistic to the observations, i.e. the standard error of each observation is better than that entered, as determined by the least squares adjustment. In this case, the solution is still good and the coordinates are reliable.

The weighting factors can be reduced and the solution re-processed to determine if this improves the a posteriori variances. However, it is important not to reduce them to unreasonably small values simply to achieve satisfactory **a posteriori variances**. If the weighting factors are reasonable, accept the results and use the geometric error ellipses for the absolute error ellipses and the error ellipses estimated from the Baseline a posteriori as the bottom relative error ellipses.

It should also be noted that there is a phenomenon with electronic instruments in that they produce precise results over short periods of time under steady environmental conditions. This can lead to the **a posteriori variances** indicating that the weighting factors are too pessimistic for the observations. Data collected over a short period of time when the seas are very calm and the water column has no discontinuity in velocity.

Analyzing the Results: the Error Ellipse and RMS

Clicking on the **Statistics** button in the **Calibration Results** dialog accesses the **Least Squares Statistics** dialog.



You can view the Station Error Ellipse, the Relative Error Ellipse and the solution RMS values.

For details, see **Viewing the USBL Solution Statistics** section later in this chapter.

Examining the Results and Repeating the Process

The process of reviewing and editing the data and then performing an adjustment should be repeated several times. The actual number of cycles depends upon the quality of the data. The objective is to achieve a reliable solution while using most of the data.

When editing the data by looking at the residuals, be aware that the least squares technique minimizes the residuals of all of the observations. Consequently, it distributes any errors throughout the whole array. The error from a single observation will appear in the residuals of all observations. The amount that appears in each observation depends upon the geometry, number of observations, and the weight assigned to each observation. One cannot assume that the observation with the largest residual is necessarily the observation with the error (although this is where one generally begins to investigate). Therefore, do not eliminate large blocks of observations all at one time. Remove only a few of the largest, then solve again.

In addition, the USBL corrections are still un-accounted for and the residuals may not be centered around 0 as one might expect. In this stage, only those LOPs whose residuals are extreme and are obviously outside of the main grouping should be de-weighted.

Note: as previously mentioned, it is recommended that the calibration be saved after each cycle. In this way, you can return to a known point or resume processing at a later time, if required. Once the calibration is considered complete and the final calibration file is saved to a new file, the intermediate files can be removed, leaving the original untouched file and the final result file. By loading the final result file, the calibration can be reviewed and/or printed at any time without having to perform any step other than loading the file.

Note: when a calibration file is saved, all configuration settings are also saved.

Note: if the USBL calibration is being performed only to calibrate the position of USBL beacons, then the processing is completed after repeating the process as detailed above. A report can then be generated.

USBL Calibration

With a known beacon position, the USBL system corrections can be determined. This process requires the same steps as followed for determining the beacon position.

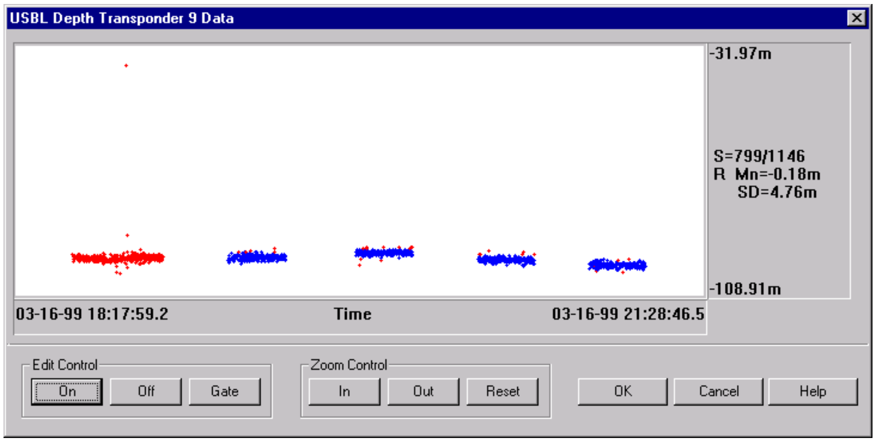
Data Editing

Similar to the editing of the data for the position determination, the editing of the data for the actual USBL corrections determination has a pre-first solution and post-first solution aspect to it.

In both cases, the data editing now focuses on the USBL data, specifically the bearing and depth LOPs. Whereas the range LOP is the least affected of the USBL LOPs by the corrections to be solved for (and thus the LOP to examine and use for the beacon position solution), the bearing and depth LOPs are greatly affected. Therefore, they are better indicators of the validity of the USBL data for use in the determination of the corrections and the results of subsequent correction determinations. The bearing can also be examined as the X and Y data (see **Using the Plot Panel: USBL LOPs**).

Pre-First Solution Editing

Once again, using first the **Plot Data** graphical editor, view the bearing (or X and Y) and depth LOPs for breaks in trends. **Note:** in this case, the trends may be dependent upon the orientation of the vessel at the time of the data collection and grouped as such. The following figure illustrates this point.



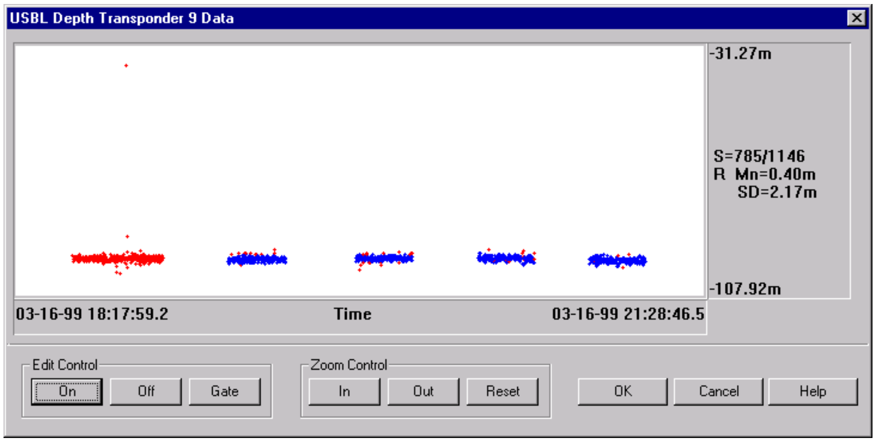
It shows the uncorrected depth LOP for a cardinal point collection pattern with five distinct groupings, all at slightly different values. Within each grouping there is very good agreement of the data. In this example, outliers and breaks in trends are illustrated by the two red points way above the first grouping and the red points in the subsequent four groupings, respectively.

The **Plot Residual** graphical editor can also be used for editing at this point, as long as you can focus on the trends and not the actual residual values.

Note: experience has shown that if the cardinal points pattern is used, at this point, all data collected while directly over the beacon (or nearly so) should be edited out of the solution. While it is valuable data for the determination of the beacon position, it degrades (rather than enhances) the determination of the USBL corrections themselves as processed with WinFrog.

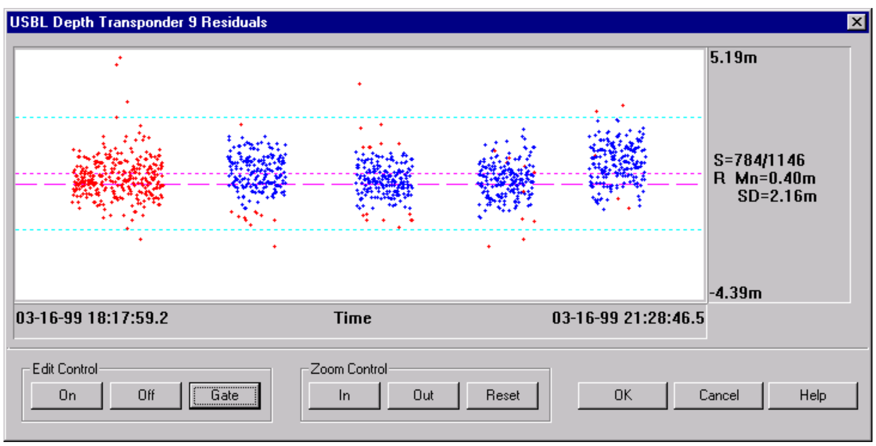
Post-First Solution Editing

After the first solution, the editing can focus on the **Plot Residual** editor and analyze the actual residual values. At this point, the initial USBL corrections have been determined and applied. As a result, the data should be more uniform. The following figure shows the same data as shown in the previous figure, but after an initial USBL correction solution/application.



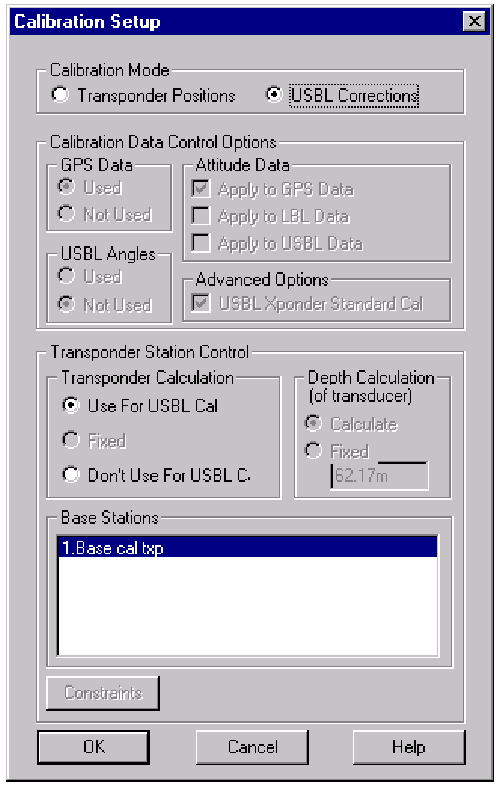
Notice that the groupings are now more consistent with each other and that the standard deviation of the residuals has dropped from 4.76 to 2.17 even though the mean has actually shifted from -0.18 to 0.40.

The **Plot Residual** editor provides a good means to both view the data and edit out data at this point. The following figure shows the same data, but with the **Plot Residual** editor, after applying the **Gate** option using the default **Residual Gate Limit** and applying the gate based on the **Mean Residual**.



Setup

The setup for the USBL corrections determination is accomplished using the **Calibration Setup** dialog, as used for the beacon position configuration.

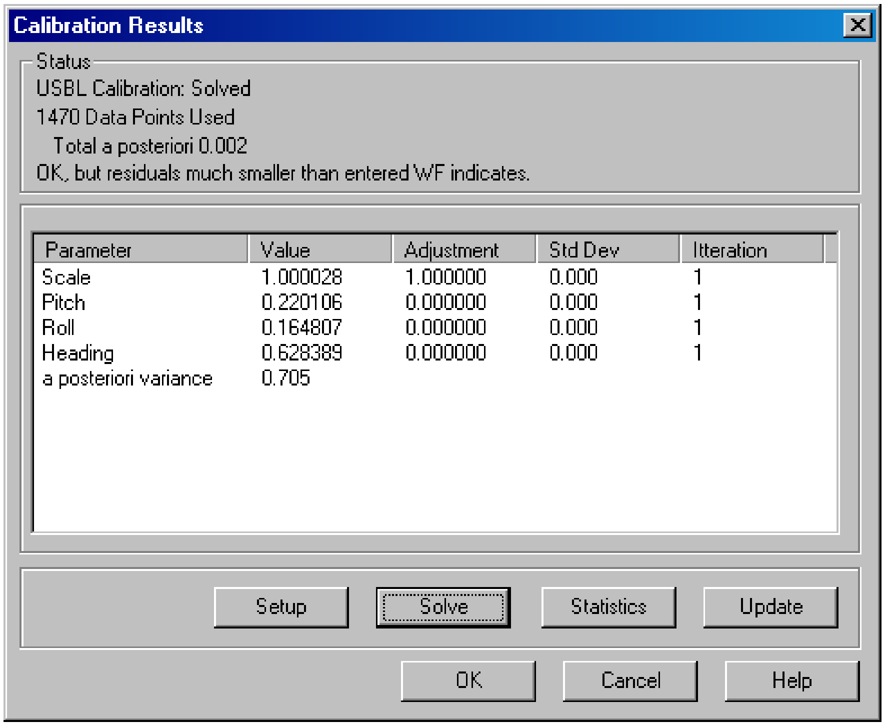


Note: by toggling the **USBL Corrections** option, all non-relevant options are disabled. In addition, the options for configuring the **Transponder Station Control** are altered to disable the **Fixed** option in the **Transponder Calculation** panel and all the **Depth Calculation** panel as non-relevant.

The only options available to you are the selection of the appropriate beacon and the **Transponder Calculation** settings of **Use For USBL Cal** and **Don't Use For USBL Cal**. Once you have chosen a beacon, set it to **Use for USBL Cal** and set all others to **Don't Use for USBL Cal**.

Solving

The process for the solving of this calibration varies somewhat from that of solving for the beacon position, with the exception that the process is still executed from the **Calibration Results** dialog by clicking the **Solve** button as shown in the next figure. The information displayed is also different.



For the sake of clarity, in this section and this section only, the USBL corrections will be referred to as the **unknowns** and the results of the least squares adjustment will be referred to as the **corrections**.

First, an explanation of the bottom panel as the top remains unchanged in content and information displayed.

First Column	This lists the current values for the unknowns, these being scale factor (S), pitch correction (P), roll correction (R), and heading correction (H). The scale factor has no units and the remaining parameters are displayed in decimal of degrees.
Second Column	This displays the corrections to the unknowns determined by the least squares adjustment.
Third Column	This displays the standard deviation of the corrections determined by the least squares adjustment.
Fourth Column	This displays the number of iterations the least squares adjustment took to converge.
a posteriori variance factor	Shown below the last row.

The solution process is an iterative one, as was the beacon position solution. First, click the **Solve** button to execute the least sSquares adjustment that will determine the corrections to be applied to the unknowns. These corrections are then applied to the unknowns by clicking the **Update** button. This process is repeated until the corrections reach zero (which in the case of the scale factor is indicated by a correction of 1.000000).

If the solution does not converge to zero, there is either insufficient data or there are bad points present in the weighted-in data. If this occurs, the data must be reviewed using the editors to determine the cause of the problem.

Analysis of the Results and Repeating

The results themselves are the primary tools for analysis. These provide a graphic presentation of the result of the determination of not just the beacon position, but of the data after determination and application of the USBL corrections. The **a posteriori variance** factor is also an indication of the quality of the data and the results. (Another important tool is the **USBL Calibration Report**, which will be discussed in a subsequent section.)

After completing a Solve/Update cycle, the data should be reviewed using the **Plot Residual** editor. Now that the USBL corrections have been determined and applied, the residuals should be reduced and match the expected accuracy of the systems involved. In addition, they should now be centered about or close to zero rather than offset, as is the case prior to this step. The **Gate** option can now be used to refine the data to be included in the calibration.

Unfortunately, there are no specific quantitative measures to compare the data against, to decide what data are acceptable and what data are to be removed. The data must be viewed by comparing any one LOP to the whole data set.

The prevailing environmental conditions at the time the data were collected have a very large impact on the results.

Another, but less reliable, analysis tool is the **a posteriori variance** factor. This should be equal to one (1.0). A value (much) lower than one is possible when a large quantity of data of high quality has been collected and/or the weights used are relatively high and pessimistic. A value greater than one does not necessarily indicate a bad solution, though if this value is greater than 10 the data should be reviewed for outliers.

It is recommended that the data be reviewed and edited once and then the Solve/Update cycle repeated again afterwards.

As a **confirmation**, the beacon position can be resolved for using the now corrected data. If the editing and processing have been correctly performed, the change in the position will be in the centimeter to decimeter range. If the change is greater, the solution must be suspect and restarted with greater attention paid to editing the data.

Note: it is recommended that the process of solving the beacon position after the determination of the USBL corrections be performed for the purpose of confirming the results of the whole USBL Calibration process only. Repeating the solution of the USBL corrections after resolving the beacon position can lead to a never-ending cycle that can actually cause the results to diverge from the correct results.

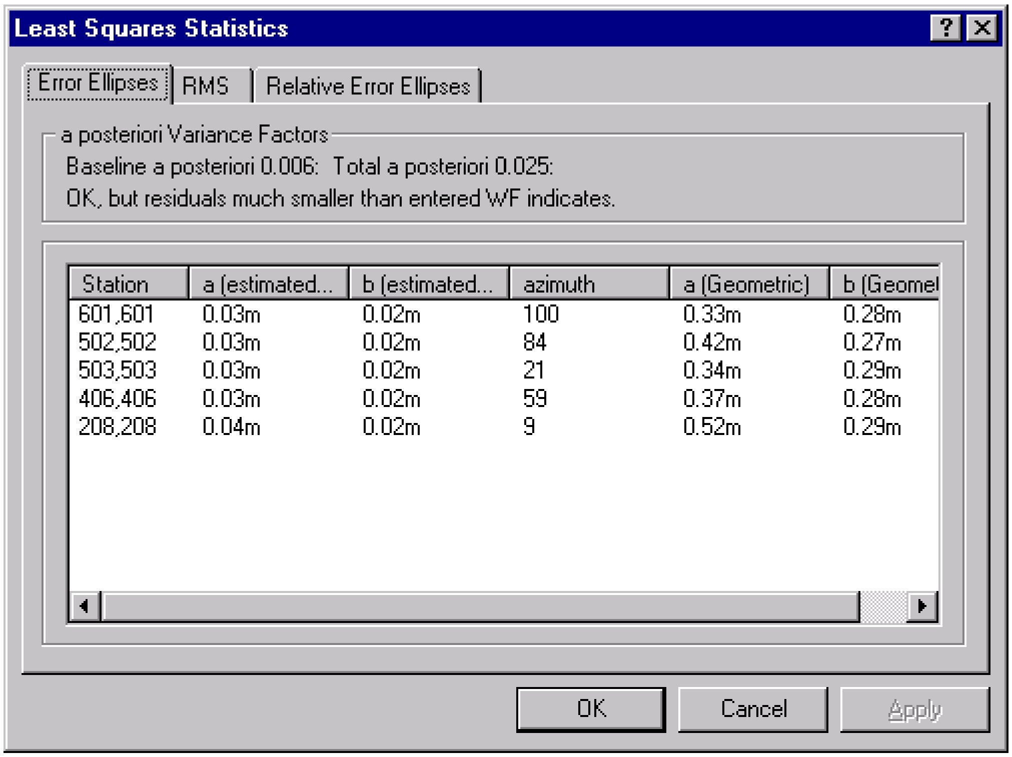
Viewing the USBL Solution Statistics

When a least squares adjustment of the station coordinates is performed the variance co-variance matrix of all the stations is also computed. These values are independent of the observations. They are dependent upon geometry and the weighting factors assigned to each observation.

WinFrog uses the variance co-variance matrix to produce basic statistic analysis tools, specifically **Error Ellipse**, **RMS** and **Relative Error Ellipse**.

To view the statistics for the USBL solution, click on the **Statistics** button in either the **Calibration** dialog or the **Calibration Results** dialog. This will access the **Least Squares Statistics** dialog. This dialog has three tabs to view the information in, **Error Ellipse**, **RMS** and **Relative Error Ellipse**.

Error Ellipse Tab



This tab presents the station error ellipse.

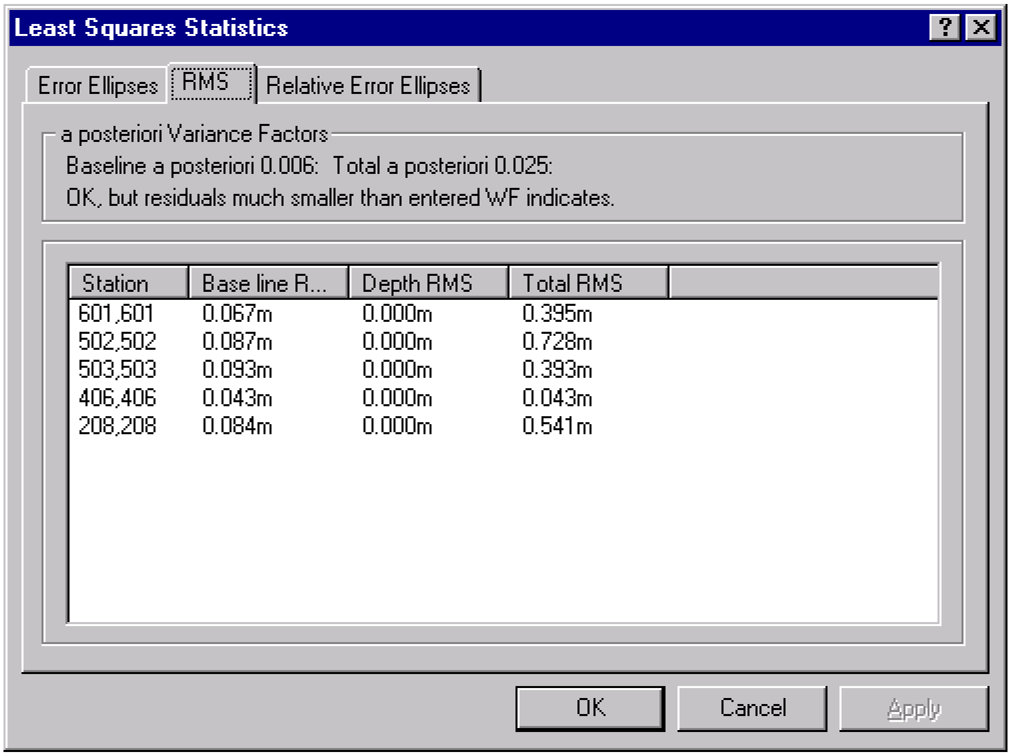
The first column gives the station name and the associated transponder address. If a station is occupied by more than one transponder, only the first transponder found is displayed.

The values **a Geometric** and **b Geometric** are the semi-major and semi-minor axes of the error ellipse determined directly from the variance co-variance matrix.

The values **a (Estimated using baseline a posteriori)** and **b (Estimated using baseline a posteriori)** are the **a Geometric** and **b Geometric** values scaled by the root of the baseline **a posteriori variance** factor. This is the estimate of the error ellipse of each transponder as if it were calculated using baselines only. It still involves the geometry of the whole system but reflects the more accurate baseline measurement.

The **azimuth** is the azimuth of the semi-major a axis.

RMS Tab



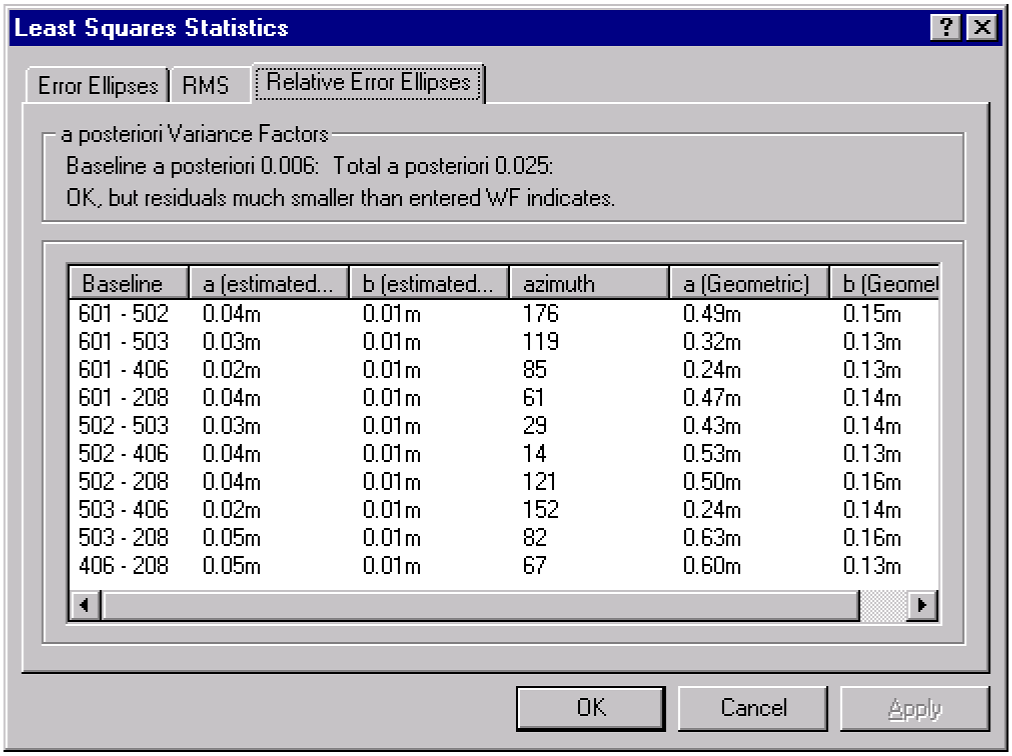
This tab presents the solution RMS values.

The first column gives the station name and the associated transponder address. If a station is occupied by more than one transponder, only the first transponder found is displayed.

The **Total RMS** values are the square root of the mean of the sum of squares of all residuals associated with the indicated station. The **Base line RMS** involves only baseline observation residuals. The **Depth RMS** only pertains only to the depth observations.

These values are a good indicator to the quality of the data used. They can also assist detecting where a bad observation may be.

Relative Error Ellipse Tab



This tab presents the relative error ellipse. A relative error ellipse calculated from the variance and co-variance of two stations. It involves the geometry and correlation between the two stations. If one had measured the base line between two stations then the correlation between these two would be some finite positive number. If the baseline had not been measured the correlation would most likely be smaller. But the proximity of the surrounding stations and number of other measured baselines also plays a factor.

If the baseline between two stations is measured the resulting relative error ellipse would be smaller than if the baseline was not measured. However the relative error ellipse still may be larger than either of the original station error ellipses. The relative error ellipses are a good indicator of the geometric strength or weakness between two stations. Smaller ellipse indicate strong geometry, larger ellipse indicate weaker geometry.

The first column gives the station name and the associated transponder address. If a station is occupied by more than one transponder, only the first transponder found is displayed.

The values **a Geometric** and **b Geometric** are the semi-major and semi-minor axes of the error ellipse determined directly from the variance co-variance matrix.

The values **a (Estimated using baseline a posteriori)** and **b (Estimated using baseline a posteriori)** are the **a Geometric** and **b Geometric** values scaled by the root of the baseline **a posteriori variance** factor. This is the estimate of the error ellipse of each transponder as if it were calculated using baselines only. It still involves the geometry of the whole system but reflects the more accurate baseline measurement.

The **azimuth** is the azimuth of the semi-major a axis.

USBL Calibration Reporting

Reporting for the USBL Calibration is accessed from the **Acoustic Calibration** dialog by clicking the **USBL Report** button. The results of the calibration are printed along with some statistical values and graphs described below.

The data presented in the USBL calibration report is described below and is essentially derived by comparison of raw USBL data to the mean position derived from that raw data and comparison of corrected USBL data to the mean position derived from that corrected data.

The maximum and minimum values of each set are displayed along with a mean, standard deviation and root mean square (RMS). The main values to consider when assessing the calibration are the Range C-O of the corrected data, specifically the mean. This is because it's the range that is used as the observation for the calibration.

The other C-O quantities are derived, but their RMS should provide a better evaluation number than the standard deviation. See below for a description of each.

Transponder Coordinates

Summary of the results of the position determination of the beacon used for the calibration, specifically:

- the beacon code;
- Northing c/w standard deviation;
- Easting c/w standard deviation; and
- Depth c/w standard deviation (if solved for).

Calibration Results

Summary of the results of the determination of the USBL Corrections, specifically:

- the Scale Factor (no units),
- Pitch Correction (decimal of degrees);
- Roll Correction (decimal of degrees);
- Heading Correction (decimal of degrees);
- the a posteriori variance factor; and
- the total number of data available and used in the calibration.

Data Summary Table

The summary table presents the minimum, maximum, mean, and standard deviation based upon Calculated-Observed (C-O) for un-corrected and corrected USBL data. In addition, the RMS for the respective C-O data sets is given for the corrected data. **Note:** to produce these values, the components of each calibration data record (XYZ) are subtracted from the corresponding calculated values derived from the calibrated beacon position and the USBL hydrophone position. In the case of the beacon position, range, and azimuth comparisons, these are derived from the XYZ data for each calibration data record. Note that only that data weighted in the USBL calibration solution are used.

Psns C-O	The distance between the mean beacon position and the position derived from each observation set (raw and corrected) is calculated. The statistical values of these two sets are calculated and displayed. **NOTE:** This data set is not *normally* distributed. In a *normally* distributed data set, whose expected mean is zero, adding more data should cause the mean to approach zero since some values will be positive and some negative. However, the distance between two points is always positive, thus the expected mean is not zero. Consequently, the mean and standard deviation should only be looked at as an indication of the noise in the data. Larger values indicate noisier data. The RMS is the better quantity to look at here.
X, Y and Z C-O	This is related to the vessel, X port/starboard, Y fore/aft and Z up/down. The known transceiver position is compared to the mean beacon position (raw and corrected) to produce the computed X, Y or Z value. The difference between this value and each observed X, Y and Z value is determined to produce the data sets. One set for raw data and one for corrected data for each item. This data should be normally distributed and does give an indication of the error in these directions.
Range C-O	Similarly to above, the slant range between the known transceiver position and the mean beacon positions (raw and corrected) are calculated. From that is subtracted the slant range (derived from each USBL observation set) to produce the data sets, one for raw and one for corrected. This data should be normally distributed and does give an indication of the range error. This is the observation that is used to calculate the beacon position. **Note:** Of all the USBL corrections the only one that affects the slant range is the scalar. Since the scalar is small there will be very little difference between the uncorrected and corrected data.
Bearing C-O	The azimuths from the USBL transceiver to the mean beacon positions (raw and corrected) are calculated. From these are subtracted the azimuth from the USBL transceiver to each observed beacon position (raw and corrected). This data should be normally distributed. Perhaps somewhat abstract, these values usually experience the greatest change between the raw and corrected data sets.

Plots and Histograms

The histograms based upon the data calculated to produce the **Data Summary Table**. Note that only that data weighted in the USBL calibration solution are used. The histograms include the mean value drawn as a vertical line at the appropriate position complete with annotation. The standard deviations are also drawn as vertical lines in the appropriate position.

Vehicle Position	This is a plot of the vehicle positions during the data collection, centered about the calculated beacon position.
Beacon Position, Uncorrected USBL	This is a scatter plot of the USBL beacon position calculated for each epoch using un-corrected USBL data, centered about the calculated beacon position. Note this is always uncorrected data. If the data was gathered with calibration corrections already in the Hydrophone Data Item configuration dialog they are not applied in this plot.
Beacon Position, Corrected USBL	This is a scatter plot of the USBL beacon position calculated for each epoch using corrected USBL data, centered about the calculated beacon position. Look for a tighter group about the center than the uncorrected.
Coor. Position C-O	Histogram of the distance from the solved for USBL beacon position to the position calculated for each epoch using corrected USBL data for each epoch. Since the values are distances they are always positive. This graph indicates how noisy the data is. The more spread out the graph, the noisier the data.

In the following histograms look for an improvement in the shape of the corrected data histograms. The shape should represent a normal distribution.

Raw Range Res, C-O	Histogram of the uncorrected USBL range residuals.
Corr'd Range Res, C-O	Histogram of the corrected USBL range residuals.
Raw Bearing Res, C-O	Histogram of the uncorrected USBL bearing residuals.
Corr'd Bearing Res, C-O	Histogram of the corrected USBL bearing residuals.
Raw X Res, C-O	Histogram of the uncorrected USBL X component residuals.
Corr'd X Res, C-O	Histogram of the corrected USBL X component residuals.

Raw Y Res, C-O	Histogram of the uncorrected USBL Y component residuals.
Corr’d Y Res, C-O	Histogram of the corrected USBL Y component residuals.
Raw Z Res, C-O	Histogram of the uncorrected USBL Z component residuals.
Corr’d Z Res, C-O	Histogram of the corrected USBL Z component residuals.

This window is a valuable analysis tool for the USBL calibration. The scatter plots clearly illustrate the quality of the data collected and the processing, supported by the histograms. As an analysis tool, this report provides you with the best summary of all aspects of calibration one place and should be utilized as such.

Clicking the right mouse button with the cursor in this window gives a pop-up menu with the following options:

Save to a metafile

This allows you to save the window as an enhanced metafile, which can, subsequently, be inserted into a document. The example in this manual has been created and inserted in this way. This provides a report quality presentation of the USBL calibration suitable for presentation to clients.

Save to CSV file

Saves the data to a file using comma-delimited fields to enable easy loading into another software package.

Change Vehicle Pos. Scale

Allows you to manipulate the scale of the panel containing the plot of the calibration data collection points.

Change USBL data Scale

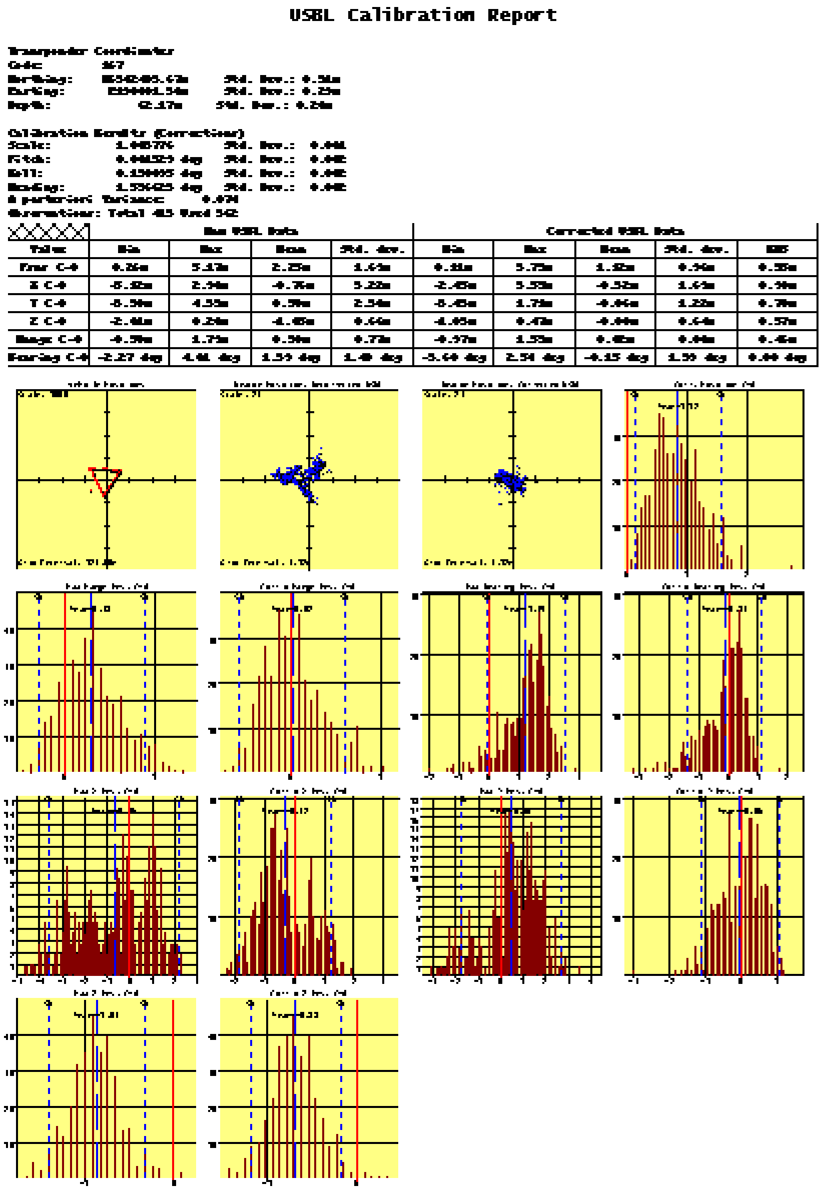
Allows you to manipulate the scale of the panels containing the calculated beacon positions based upon the raw and corrected USBL data. Note that both panels are plotted with the same scale.

Change color Graphics

Allows you to manipulate the background color of all panels.

Change color Data

Allows you to manipulate the color used to plot the histogram data.

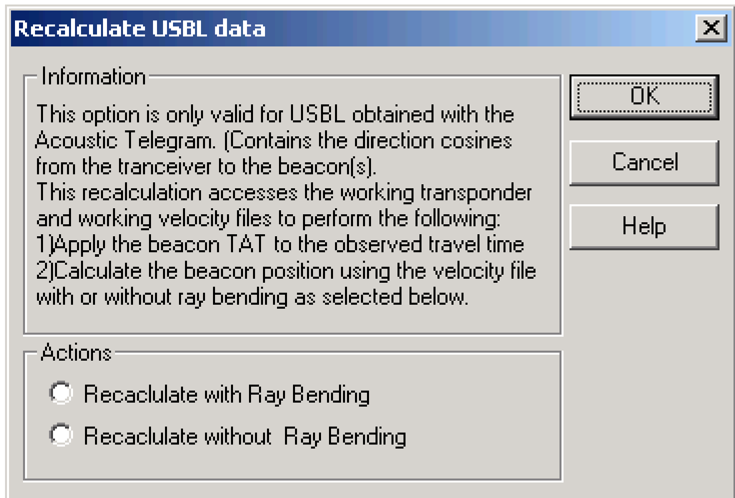


Recalculation of the USBL Data

This option is only applicable for data from the Sonardyne CSV Surveyor’s Acoustic telegram and the TWTT component of the Simrad HPR400 telegram with travel time included. It does not apply to standard X, Y, Z USBL data, even that included in the Simrad HPR400 telegram. For those cases where it is applicable, the data can be reprocessed with a new transponder file and/or a new velocity file to correct errors in the initial settings for turnaround time and estimates of transponder depths and changes to the velocity profile. As well, in the case of the Sonardyne data, the data can be recomputed with or without ray bending. If the Sonardyne data is loaded from a file and it isn’t known if ray bending was applied when collected, use this button to recompute it. After recomputing the data, you must reset the USBL calibration values using the button described below.

The application of ray bending uses the direction cosines, travel time, and the velocity profile to compute a new X, Y, Z and a reduced range of the beacon for display and eventual use in the calculation of the beacon coordinates and USBL calibration values.

If any USBL data from the Sonardyne telegram is detected in the calibration data, the following dialog opens when this button is clicked. Select the Ray Bending option desired and click OK to re-process. It should be noted that in the case of the calibration data containing both Sonardyne and Simrad-based data, ray bending is only applied to the Sonardyne data.



If only USBL data from the HPR400 telegram is detected, the processing launches upon clicking the Recalc USBL button.

Reset the USBL Calibration Data

At any time during the USBL processing, you have the option to reset the USBL data to its uncorrected state with respect to the USBL calibration corrections. This is sometimes required when during the processing you feel incorrect editing has biased the solution and that the best action is to start over. In addition, the reset can also be used to correct for the situation of logging the data with the wrong map projection settings.

Note: For any resetting of the USBL data and/or map projection, it is **critical** that the current WinFrog geodetic and map projection configuration is the correct one to use for the USBL calibration.

To execute this option, click the **Reset USBL** button from the main **Calibration** dialog.

When the button is clicked, you are prompted with a message box informing you of the reset options. These are as follows:

- Change the Map Projection and reset the USBL Calibration Corrections (click Yes); or
- Reset the USBL Calibration Corrections only (click No); or
- Abort the process (click Cancel).

Click the appropriate option. If Yes or No were selected, when the change and/or resetting process is completed, you are informed with an appropriate message box. For both of these options, any travel time data will be reprocessed using the current velocity profile. If none exists, then a default sound velocity of 1485 m/s is used.

The Transformation to a new Map Projection

The change of the map projection involves the following:

- Transforms the geographic coordinates for all base stations in the calibration data set to the current Working Map Projection.
- Transforms the geographic vessel positions to the current Working Map Projection.
- Transforms the raw position LOPs (WGS84 ellipsoid latitude and longitude) to the current Working Ellipsoid and then to the current Working Map Projection. **Note:** If the working ellipsoid is NAD83, SPCS 83, SPCS 27 using the NADCON transformation or NAD 27 using the NADCON transformation, and the calibration data has been loaded from a file, the ITRF/NAD83 transformation parameters are calculated for each calibration data epoch. This applies to the case of calibration data loaded from a file and then added to before this action is executed.

The Resetting of the USBL Data

The resetting of the USBL data involves the following:

- The current USBL corrections are reset to default values, that is scale = 1, pitch = 0, roll = 0 and heading = 0.
- The raw XYZ data are reprocessed with the reset calibration corrections and are projected to the current Working Map Projection to derive new scaled LOPs.
- If TWTT data are available, the current Working Velocity file is accessed and the raw TWTT LOP are reprocessed to determine new Reduced LOPs, i.e., slant ranges relative to the potentially new map projection.
- If direction cosine data are available, they are reprocessed with the current Working Xponder and Velocity files and the reset calibration corrections and projected to the current Working Map Projection.

This step also removes the affect of the USBL corrections that were present in WinFrog and applied during the data collection process.

Note: This option is the only method available for correcting the projection of standard USBL X, Y, Z data to the map projection if a bad depth was entered in the **Working Xponder** file prior to setting up for the calibration.

Updating the USBL Calibration

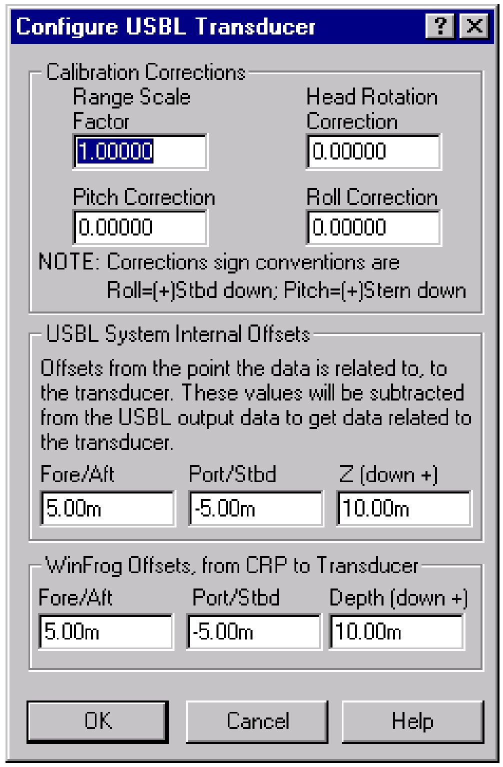
Once the USBL corrections have been determined, WinFrog must be updated in order for them to be applied. At present, this is not an automated process. After the final iteration of the USBL corrections processing is complete, the results, as displayed in the **Calibration Results** dialog box and printed in the **USBL Report**, must be manually entered in the appropriate USBL HYDROPHONE data item transducer configuration.

To Update the USBL Calibration Data in WinFrog

1 Access the calibration vehicle’s **Configure Vehicle-Devices** dialog.

2 Highlight the **USBL HYDROPHONE** data item and click **Edit** or double-click on it.

3 Click the appropriate **Configure Transducer** button to display the dialog shown below.



4 Enter the USBL corrections **exactly** as presented in any of the calibration displays and reports, including the same sign convention.

Confirmation Tests

The results printed in the **USBL Calibration Report** are, in themselves, a confirmation of the success and validity of the correction values determined. However, this is seldom accepted as the only confirmation.

To Confirm the USBL Calibration Results

Confirmation of the USBL calibration results generally requires that the calibration vehicle perform a specific action after changing the WinFrog configuration to track the deployed beacon as if it were a remote vehicle.

1 To change to tracking mode, first add a vehicle to WinFrog.

2 Attach the USBL BEACON data item to it and set the ID code to that of the deployed beacon.

3 Change the USBL HYDROPHONE data item attached to the calibration vehicle to **Tracking** mode.

The calibration vehicle will then execute a perform a predesigned maneuver and monitor the position of the tracked beacon. The objective of the this maneuver is similar to that for the design of the calibration data collection pattern itself, i.e. to orient the hydrophone with respect to the beacon such that observations to the beacon are made from all sides of the hydrophone in a controlled and uniform manner. The major difference is that the effect of the changes in the orientation is used to determine if the USBL corrections are valid, rather than to actually determine the corrections themselves. Typical maneuvers are the spin test, where the vehicle maintains station near the beacon while rotating its heading 360°, and simply steaming a line towards, over and away form the beacon.

If the results and application of the USBL corrections are correct, the beacon position will remain static within a specified tolerance.

If the corrections are incorrect, the beacon's position will appear to shift as the calibration vehicle performs its maneuver. This shift will be correlated to the orientation of the calibration vehicle with respect to the beacon.

Summary of the USBL Calibration Process

1 Ensure that all devices involved are operating properly and are correctly configured. These include the USBL, GPS, gyro and attitude sensor.

2 Ensure that all devices and their associated data items are added to WinFrog and the calibration vehicle, respectively. Confirm the configurations.

3 Ensure a valid **Working Xponder** file is opened.

4 Design the appropriate directory structure and file naming standard to ensure the data will be saved in manner that is easy to understand and manage.

5 Determine the data collection pattern to use.

6 Deploy a **Beacon** in the calibration area, taking a fix with the surface navigation to determine the estimated deployment location. Alternatively, if the beacon is deployed with an ROV (standard for deep water calibrations) take several fixes using the uncalibrated USBL system to determine an estimate for the deployment location.

7 Determine the depth of the beacon as precisely as possible.

8 Edit the **Working Xponder** file and ensure that a **USBL Fixed** beacon is present for the deployed beacon. Enter the beacon name, estimated deployment coordinates, the best determination of the depth (as is possible), and the beacon's code.

9 Setup the calibration data collection in WinFrog and following the pattern, collect the data, saving regularly to disk during the process.

10 Upon completion of the data collection. Copy the calibration file and set the copy's attributes to **Read Only**.

11 Process the data:

- Beacon position determination.
  - Review the data (position and range LOPs) and remove obvious bad data based upon trends. not residuals.
  - Setup and solve for the beacon position.
  - Review the same data again, this time refining the editing using examination of both the LOPs and their residuals.
  - Resolve the beacon position.
  - Repeat until satisfied with the results.
- USBL Corrections determination
  - Review the data (bearing and depth LOPs) and remove obvious bad data.

- Setup and solve for the USBL corrections.
- Review the data and refine the editing. Include the USBL report in the examination and analysis of the results to assist the editing.
- Resolve the USBL corrections.
- Repeat until satisfied with the results.

- Save the final calibration file.
- Save the report to an enhanced metafile for subsequent inclusion in a document/report.

12 Apply the results, entering the corrections in the appropriate USBL HYDROPHONE transducer configuration, being careful to enter the data exactly as produced in the calibration.

13 Perform a confirmation as required.

14 Perform any necessary file management and cleanup of intermediate files.

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