Chapter EM3b: LBL Calibration

LBL systems utilize a network of transponders located at known positions throughout the work area to which ranges are measured, either directly or in-directly, from a transducer attached to the vehicle to be positioned. These ranges enable a range/range solution for that vehicle's position. A single transducer element within a transceiver is used, either to perform the ranging directly, initiate a sequence of ranging, or send instructions to another transducer system to perform the ranging. The term **Long Baseline Acoustics** is derived from the fact that baselines between the known transponders can be up to several kilometers. LBL acoustics can be used to position surface and subsurface vehicles.

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

LBL Calibration

The purpose of an LBL calibration is to determine the position of the transponders deployed in the work area. These transponders may be deployed precisely mounted on an underwater structure, deployed using a Remotely Operated Vehicle (ROV), positioned using USBL, or simply dropped from a surface vehicle at the approximate desired location. Regardless of the deployment method, a network, or array, of transponders is placed and the accurate positions for the transponders are required. Until their positions are known, they cannot be used to position another vehicle.

The determination of the positions for newly placed transponders requires range measurements from known points. The reason for stating it in this way is that these known points could be other transponders already deployed and calibrated, a vehicle positioned by alternative means, or a combination of both. In the case of a surface vehicle, the vehicle's position will probably be determined using DGPS. In the case of a subsurface vehicle, its position will probably be determined using DGPS and a calibrated USBL from a surface vehicle. Regardless of the type of known points, the data are processed using a rigorous least squares algorithm to produce either 2D or 3D (depending upon operator selection) position solutions.

The calibration process requires the following steps:

1. transponder array design;
2. transponder deployment;
3. estimation of initial approximate transponder positions;
4. preparation for data collection;
5. data collection;
6. data review and editing;
7. data processing; and
8. application of the results.

The data review and processing is an iterative process.

These topics are covered in detail in the following sections.

Important Notes:

It is critical that a valid **Working Velocity** file be loaded into WinFrog before any LBL operation is undertaken. If an error is made and an invalid velocity file is present at the time of the calibration data collection (or none at all), WinFrog provides you with an option to apply a new velocity file during the processing.

It is important that a correct **Working Transponder** file is loaded and available prior to the configuration for data collection. If an error is made in the **Working Xponders** file, a station left out or incorrectly entered, WinFrog provides full editing options within the Calibration Editing process. It is still however, better to ensure the correctness and completeness of the **Working Xponders** file prior to the Calibration data collection.

LBL Transponder Array Design

While the intricacies of network design are beyond the scope of this manual, the following must be kept in mind.

Like any network of control stations, the array must be designed to provide strong geometry in the required area. If the vertical component of the vehicle position is to be solved for using the acoustic ranges, the array design must include vertical separation.

The reader should refer to Survey textbooks on this subject for more information.

Other considerations for the array design are as follows:

- structures in the area that may cause blockage or reflection of the acoustic signals;
- operations in the area that may result in damage to transponders, such as anchoring operations resulting in anchor chains being dragged through an array; and
- other acoustic operations in the area and the impact they will have on the LBL acoustics, such as frequency interference.

LBL Transponder Deployment

The deployment of transponders in the array will depend upon the resources available and the tolerance of the array design to variances from design location to actual location.

In the case where the allowable variance from the design position to actual position is very small, the transponders are often positioned in tripods using an ROV tracked from the surface with a calibrated USBL system. Alternatively, they may be lowered using a surface crane, again tracking the transponder using a USBL transponder co-located with the LBL transponder and a calibrated USBL system. If the transponder is being placed within an existing calibrated array, it can be tracked using the existing array.

Where tolerances are less tight, or the resources are not available for the above methods of deployment, the transponders are simply deployed from the surface vessel. In this situation the vessel is positioned such that the transponder deployment point is over the design location and the transponder is released to free fall to the bottom. In this case the transponder is attached to an anchor with a short rope. Since the transponder is free to move with the currents it is inherently less accurate than using tripods.

In either case, it is important to obtain a reasonable approximate position of the transponder deployment location. In the former, the design location will likely be fairly accurate, depending upon the success of the deployment. In the latter, the position of the transponder deployment point at the time of release is used.

LBL Calibration Preparation

Before performing the LBL calibration, WinFrog must be prepared. Although WinFrog provides recourse during the 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. The following covers the points to check for prior to calibration.

1 Ensure that there is a valid **Working Velocity** and **Working Xponder** file opened in WinFrog. When performing the calibration, and when operating the LBL for positioning, it is advised that the option to display the names of the **Working Velocity** and **Xponder** files in the **Vehicle** window be exercised.

2 The **Xponder** file must contain, at a minimum, all transponders that are to be calibrated. The initial approximate positions and depths for the transponders must also be entered accordingly. The depth is important because it is involved in the reduction of the observations to the map grid. Depths for the transponders can be determined using depth interrogations if they are equipped with a depth sensor. Alternatively, the ship can pass directly over the deployment position while ranging to the transponder and the shortest time travel converted to a distance and used for a depth. Other options include passing over the transponder with a calibrated sounder and using this information and the known height above the water bottom of the transponder to determine the depth. One may also obtain the approximate depth from a chart. Issues of **Double Occupancy** (see the section **Xponder Files, Special Case: Double Occupancy** in the **Working Files** chapter) must be addressed. These are applicable when a USBL system is used to observe surface ranges and an LBL system is used to observe baselines or if multiple transponders are required at locations to support accurate baseline observations (EHF) and deep water surface ranges (MF).

3 Ensure that all positioning and related devices are correctly configured, including operational settings and sensor offsets. The **LBL TRANSCEIVER** data item must be attached to the vehicle being used for the calibration and, while it is recommended that it be configured to Positioning **-** Secondary, it can be configured to Positioning **-** Primary without affecting the data collection and subsequent processing. However, during the data collection process WinFrog will perform a position determination using the LBL data collected. Since this determination will be based upon estimated positions for the array transponders, it may not agree with the other positioning systems, resulting in a jump in the vehicle's position. This may cause comments and even alarm among those personnel using the WinFrog screens, such as the helmsman. If a USBL system is to be used to collect surface ranges, the **USBL HYDROPHONE** data item must be attached to the vehicle and configured. The same issues as applied to the **LBL TRANSCEIVER** configuration with respect to Primary and Secondary, apply to this data item.

4 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 at the beginning of the project to ensure that the necessary steps are followed for safe file saving and archiving.

LBL Calibration Data Collection

The calibration data collection process involves setting up WinFrog to collect and log the data and the design of the path the vessel will take to collect the data. WinFrog provides the capability to perform a rigorous least squares solution using all available data in a single solution. This data includes surface navigation (DGPS positions), subsurface ranges (surface to transponder ranges), baselines (inter-transponder ranges) and depth observations. The collection process should reflect this.

Note: if the calibration is for the purpose of extending an existing array, it is probably not necessary to collect the surface to array data. Therefore, in these circumstances the data collection process can proceed as detailed in the **WinFrog Setup for LBL Calibration Baseline Data Collection** section later in this chapter.

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

Overview of 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 several ways.

To Access the Acoustic Calibration Dialog

1 Set the **Vehicle Text** window to display the information for the vehicle to which the LBL Transceiver 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 LBL Transceiver is attached, and click the **Acoustic Calibration** button.

Or

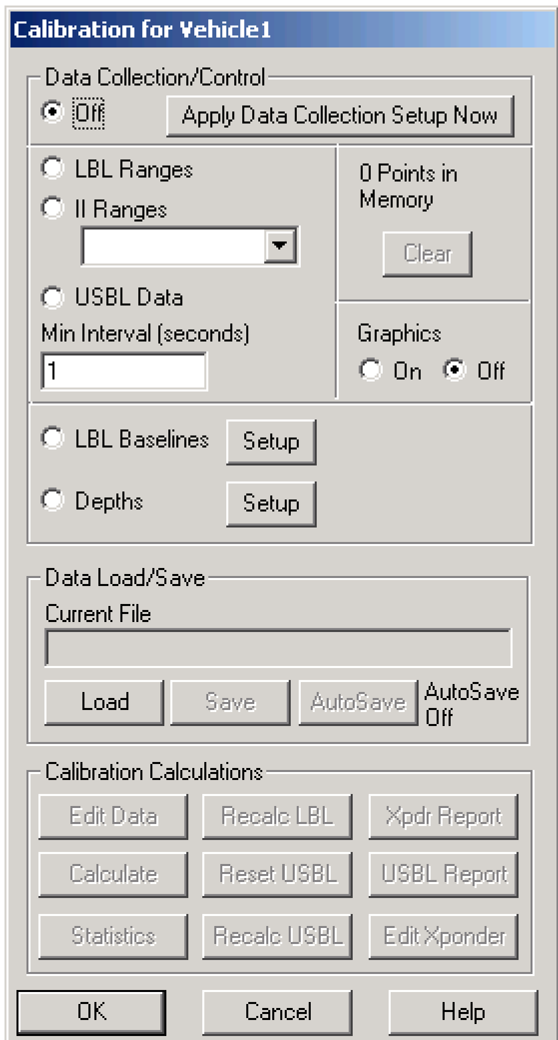
6 From the **Acoustic Window**, click on **Configure > Select Vehicle for Calibration**, then click on the vehicle to which the LBL Transceiver is attached.

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

Note: WinFrog is a multi-vehicle system. Ensure the vehicle that has the **LBL TRANSCEIVER** 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. 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 calibration will take place because no LBL data items are associated with that vehicle. If it appears that no data are being collected, check for this problem.

This problem is minimized accessing the dialog via the Acoustic Window. Only those vehicles with LBL data items attached are listed and available for selection, and the Calibration dialog cannot be opened until a vehicle is selected.

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 LBL Calibration data collection process.

Note: A Calibration data set for a given vehicle is initiated as soon as the Calibration dialog is opened for that vehicle.

Note: Whenever the Calibration dialog is opened, WinFrog checks the current Working Xponders file against the Xponder station information contained in the Calibration data set. If no Xponder station information exists in this set, for example, when the Calibration dialog is first opened, WinFrog automatically copies the complete Working Xponders file into the Calibration data set. On subsequent openings of this dialog, WinFrog performs a check and informs you of differences between the Working Xponder file and the Calibration Xponder station data (coordinate variations and discrepancies in stations present). You can then decide whether to update or over write the Calibration data set station information with that from the Working Xponders 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	Turns on the collection of LBL range data. This is applicable to all LBL devices.
II Ranges	This allows you to specify the transponder to interrogate using the Individual Interrogation Frequency (IIF) for that transponder. You then use the dropdown list box to select the transponder to range to with this command. **Note:** This is specific to Sonardyne LBL Compatts. Only those transponders in the Working Xponder file set to LBL Mode Fixed and Model LBL MK-II or MK-IV are available for selection. **Note:** Regardless of the **Transmit Code** configured in the associated **TRANSCEIVER** data item prior to using this mode, the **Transmit Code** will be set to **None** when this mode is stopped.
USBL Data	Turns on the collection of USBL data.
Min Interval	This controls the minimum data collection interval for the above three data collection options. The value entered is in seconds. 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	Turns on the collection of baseline measurements between transponders. This is not available to all LBL units. This is setup via the associated **Setup** button and is discussed later in this chapter. In addition, there is a text display to

	the right of the **Setup** button that presents the status of the baseline collection process with respect to completed or aborted.
Depths	Turns on the collection of depth observations by transponders. This is not available to all LBL units. This is setup via the associated **Setup** button and is discussed later in this chapter. In addition, there is a text display to the right of the **Setup** button that presents the status of the depth collection process with respect to completed or aborted.
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 exiting the dialog box with **OK**.
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. **Note:** baseline data does constitute a data collection point and they will be displayed if present. 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 to the dialog exited with **OK** in order for the changes to take affect. There are additional graphic features available directly within the **Graphics Window** configuration options. (see the **Operator Display Windows** chapter).

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

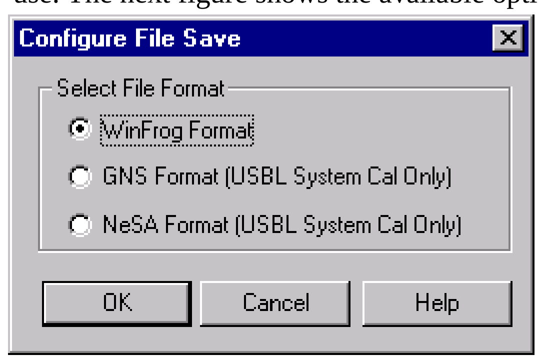
all data calibration observation data currently in memory. You are warned of this and given the option to cancel the action. You are also prompted as to whether or not you wish to purge the current Calibration data set station information. If there is a difference between the station information of the Calibration data being loaded and the current Working Xponders file, you are informed of the difference detected and given the option to either update or over write the Calibration data set station information from the Working Xponder file or ignore the Working Xponder file.

Note: When loading a calibration file pre-version 13, the data is scanned to generate data summary records (see **LBL Calibration Data Editing** section). These generated records are not as complete as those generated and saved with the calibration file post version 12.

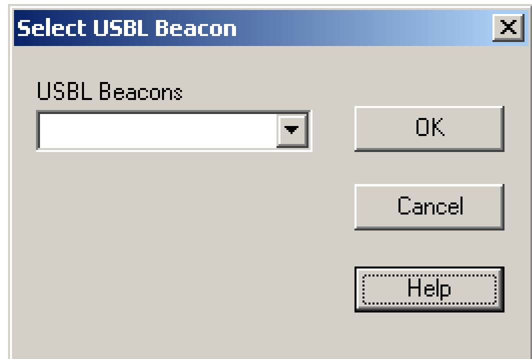
Save

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, WinFrog scans the calibration data in memory to determine if there are any USBL data present. If there are, 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. It can subsequently be re-saved in either of the other formats. However, 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 for which to save the data on the **Select USBL Beacon** dialog box.



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.

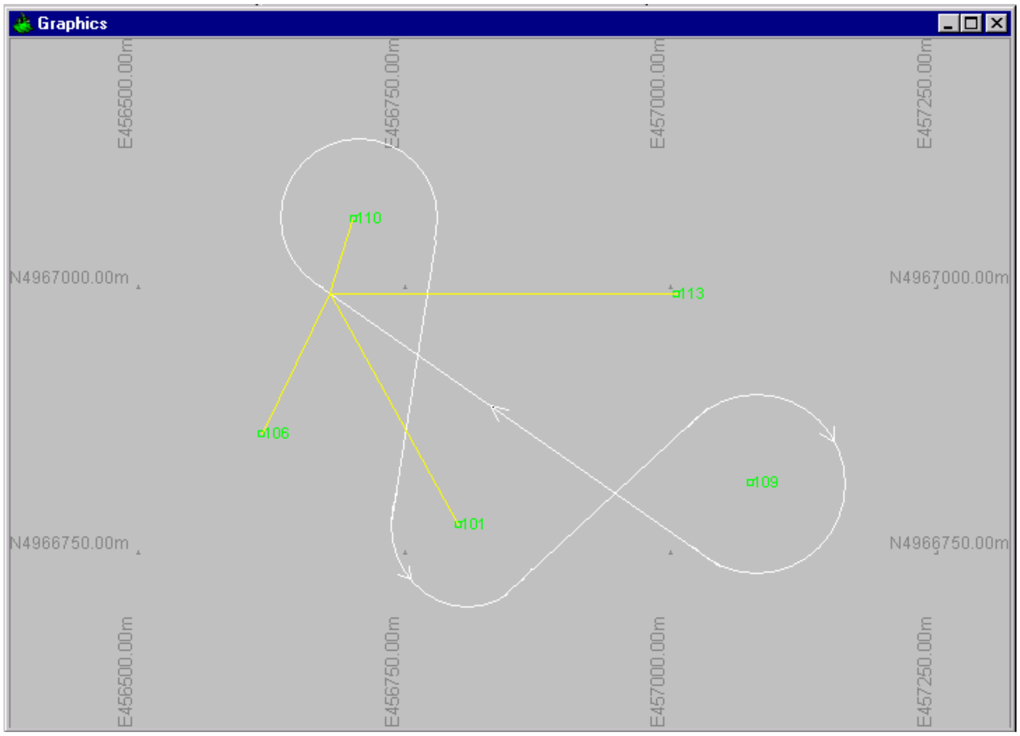
If there are no USBL data present, the WinFrog format is defaulted to and WinFrog goes directly to the browse.

AutoSave Future development.

LBL Calibration Range Data Collection Vessel Track

The ideal data collection scenario would have the surface vessel circle each transponder in the array, at a distance of approximately 1.5 times the water depth, while collecting range data to all the transponders. However, due to local restrictions, such as other vessels and structures in the area and the expense of ship time to perform this, it is not always possible, nor feasible, particularly with arrays of more than 6 transponders.

Another consideration is the ability to measure baselines between the transponders. If this is an option, as is the case with Sonardyne COMPATTs, the requirement to circle each transponder is lessened.



Be cautioned that collecting ranges to a transponder from only one side without supplemental data, such as baselines, may bias the results of the solution. Range data should be collected at opposing points around a transponder. Collecting data in this manner will reduce the affect of error sources such as sound velocity errors.

The collection track should therefore be designed with the idea of circling as many transponders as is reasonably possible, including those transponders at the extreme reaches of the array. The figure above illustrates a possible vessel track for a 5-transponder array with baseline measurement capabilities.

The lines drawn from a point on the track to transponders 101, 106, 110, and 113 represent the ranges to those transponders, all of which are logged. Transponder 109 is considered out of range at this point for this example and, therefore, a range to it is not available from this point on the track. It is not required that the data for any one specific transponder be logged sequentially. The track (illustrated above) circles or “boxes in” transponders 101, 109, and 110 and also provides additional ranges to transponders 106 and 113 from all points along the track.

WinFrog Setup for LBL Calibration Range Data Collection

This section covers the collection of range data between the LBL transceiver affixed to the data collection vehicle and the array transponders.

This section assumes that the LBL device has been added to WinFrog and the associated **LBL TRANSCEIVER** data item, along with all other required data items (i.e. POSITION, HEADING), have been added to the appropriate vehicle.

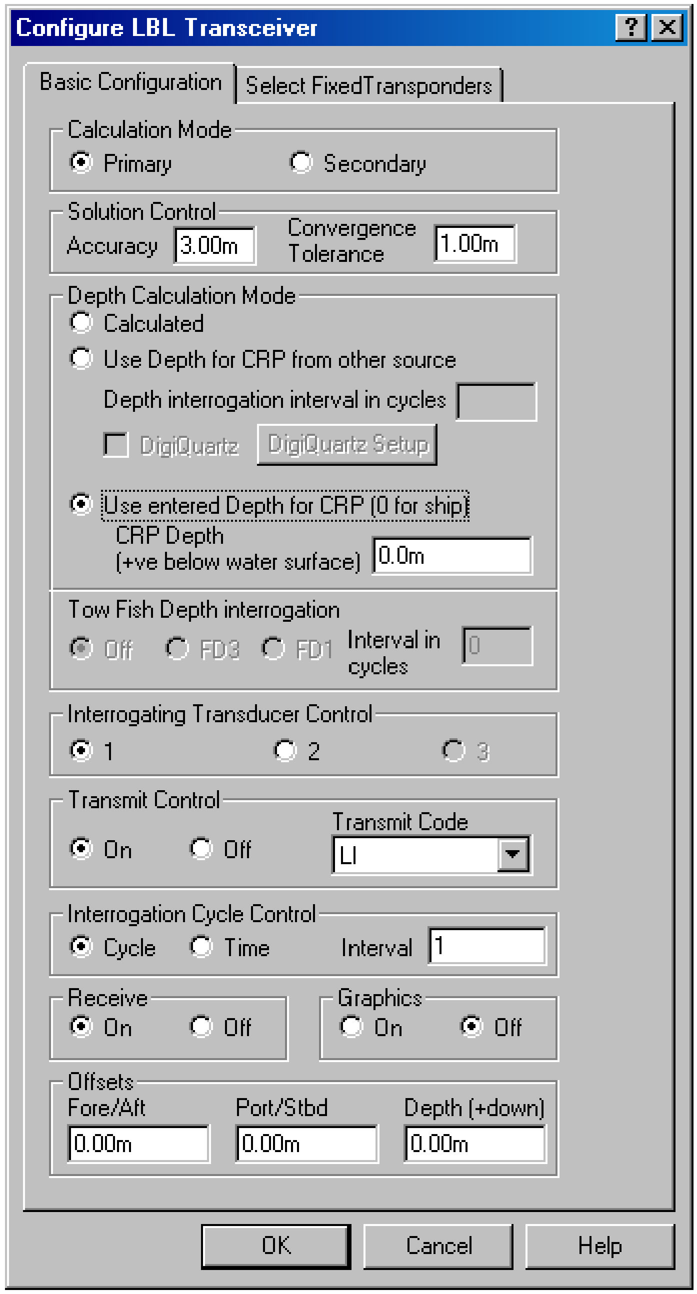
Vehicle Configuration

The vehicle configuration consists of editing the data items associated with the calibration vehicle. This is accomplished using that vehicle’s **Configure Vehicle Calculations** dialog.

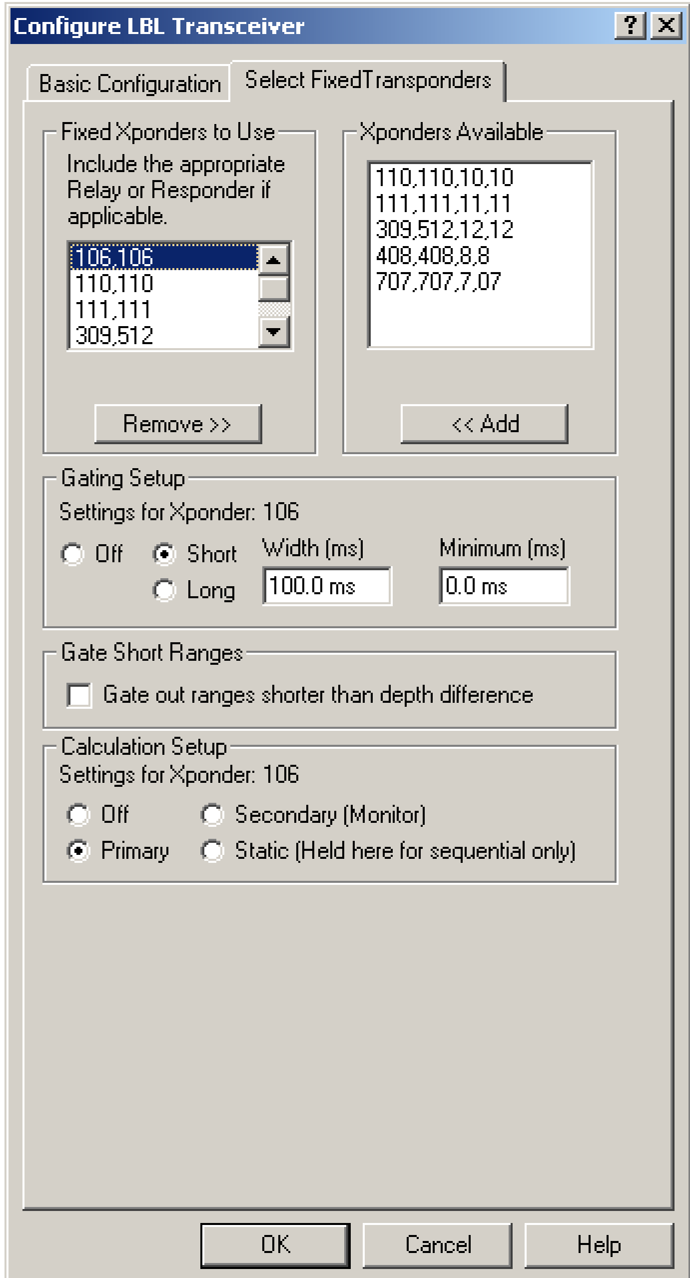
Note: all **POSITION**, **LBL TRANSCEIVER** and **USBL HYDROPHONE** (and **PSEUDORANGE** if used) data associated with the calibration vehicle are logged to the calibration file, along with general vehicle data. In addition, a standard deviation is logged for each data item. This is used to determine the initial weighting for that data item in the calibration processing (inverse of standard deviation squared). If a **POSITION** data item is configured as **Primary**, the standard deviation logged for that data item is the associated accuracy as entered. 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 **LBL TRANSCEIVER** and **USBL HYDROPHONE** is the accuracy entered for the respective data item. If the LBL equipment has baseline capability, the standard deviation is based upon the frequency used.

The next figure illustrates a typical **LBL TRANSCEIVER** configuration as attached to a vehicle. The Calculation should be changed to **Secondary**. As previously mentioned, while setting this to **Primary** will not affect the calibration processing, it will affect the real-time positioning. If set to **Primary**, WinFrog will attempt to use the range data to the uncalibrated transponder array to position the vehicle. This will likely produce incorrect positioning and thus position jumps that may result in the mistrust of the navigation by those using it.

Note: In the case of Sonardyne hardware, do not set the **Transmit Code to II**. If it is desirable to use the **II** command for Calibration data collection, select the respective option from the Calibration dialog.



The transponders that are to be ranged to must also be configured. This includes those transponders to be ranged to using the **II** command. The next figure illustrates an example of selected transponders. This is covered in greater detail in the LBL Acoustics chapter. If the transponders are not selected, the associated data will not be collected for the calibration data.



In the case of the **USBL HYDROPHONE** data item, the specific transponders to observe are not selected directly. WinFrog logs all USBL data output by the USBL system that corresponds to Fixed USBL transponders in the **Working Xponder File**.

Calibration Data Collection Configuration

The calibration data collection configuration is accomplished using the **Calibration** dialog.

To Initiate Data Collection of Surface Range Data

1 Set the minimum data logging interval.

Make sure this interval is not too long or any problems (i.e. acoustic noise) during the data collection may result in unacceptable gaps in the data.

2 Toggle the **LBL** radio button to interrogate all enabled transponders and click the **Apply** button.

Or

3 Toggle the **II Ranges** radio button and select the transponder to interrogate from the associated drop down list to interrogate only a specific transponder and click the **Apply** button.

Or

4 Toggle the **USBL** radio button to interrogate all enabled transponders and 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 display in the **Graphics** windows.

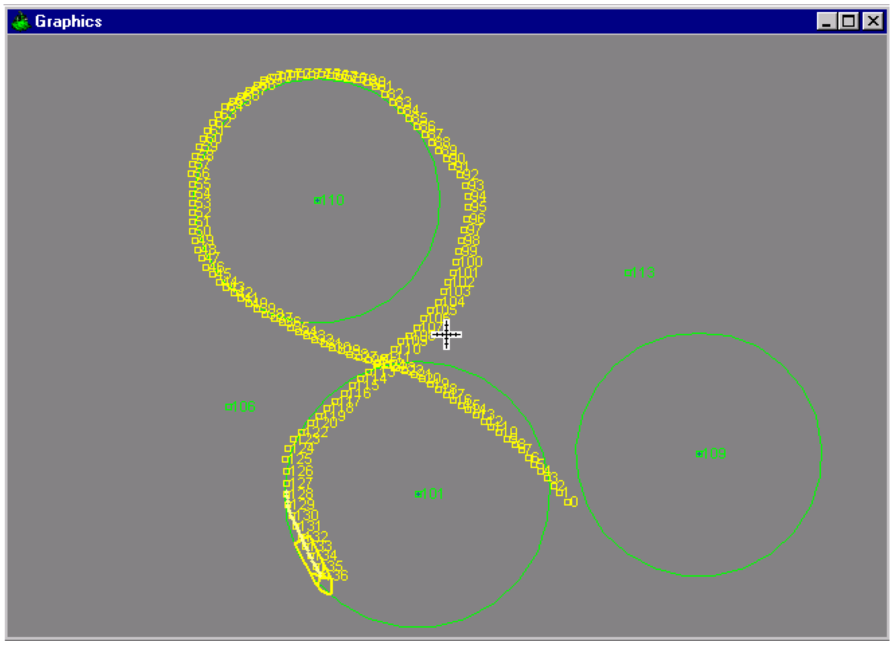
New data will not be collected until the minimum time has elapsed and then only when the next data set is received.

5 When 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 data collection can be suspended and resumed at any time. In addition, an existing data file can be loaded and data collection turned on to add more calibration data.

Note: Because WinFrog does not write the calibration data directly to disk as it is collected, it is very strongly recommended that the data be regularly saved to a file during the collection process. As mentioned above, 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.

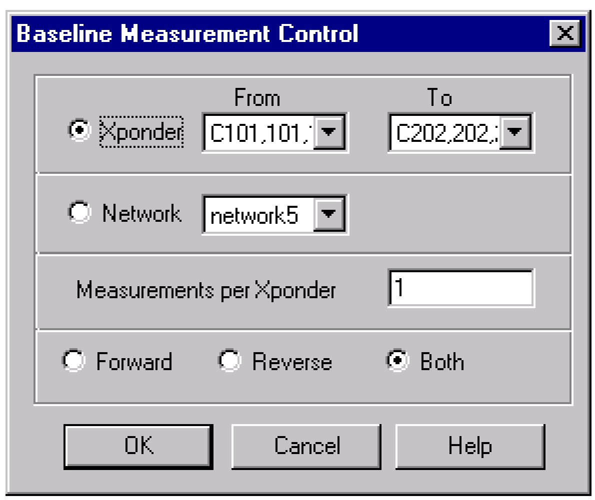
The next figure illustrates a calibration collection in progress based upon the track plan shown previously. Note the rings around the transponder locations to assist the vessel in maintaining the required distance from the transponders.



WinFrog Setup for LBL Calibration Baseline Data Collection

If the LBL system being used is capable of measuring baselines between transponders (for example, Sonardyne's PAN with their COMPATTs), you can configure WinFrog to initiate the measurement of these baselines and log them with the rest of the calibration data.

In the **Calibration** dialog box, turn off current data collection. Click on the **Setup** button associated with LBL Baselines. The next figure shows the baseline configuration options.



WinFrog provides the option to select between a manually controlled baseline measurement process or an automated baseline measurement process. Although the automated option is the simplest to implement, it is recommended that it only be used in a good acoustical environment.

Xponder	Selection of this option enables you to manually select the transponder stations to measure between (from/to). The associated **From** and **To** dropdown lists present those transponders in the

	Xponder file that are available for baseline measurements, i.e. set to **LBL Fixed**. WinFrog initiates the measurement of this baseline and stops when this is completed. You must then re-enter this dialog box to setup for the next baseline measurement.
Network	Selection of this option allows you to select the network within which baselines will be measured. WinFrog then automatically steps through this network measuring all possible baselines. When all of the possible baselines have been measured, the process is completed and stops. **Note:** in a poor acoustic environment, this approach can produce a lot of non-measurements resulting in potentially more operator intervention than if the baselines were configured manually.
Measurements per Xponder	Enter the number of times the baseline configured is to be measured.
Forward	The selected baseline is measured **Forward** only, i.e. only from the **From** to the **To** transponder.
Reverse	The selected baseline is measured in **Reverse** only, i.e. only from the **To** to the **From** transponder.
Both	The selected baseline is measured first **Forward** and then in **Reverse**.

Once the baseline setup is complete, exit this dialog using **OK**. In the **Calibration** dialog box, make sure to toggle the **LBL Baselines** option and click the **Apply…** button. At this time, the **Apply** button will display **Pause Baseline Collection**. If you wish to pause the process, click this button. If the baseline measurement process has been paused, this button will display **Restart Baseline Collection** until it is pushed again to resume collecting baselines. To halt the baseline collection before the set is complete, select the **Off** radio button and click **Apply**.

You are informed of the completion or abortion of the baseline measurement cycle with a message to the right of the Setup button.

Note When collecting baselines, WinFrog performs the following automated editing:

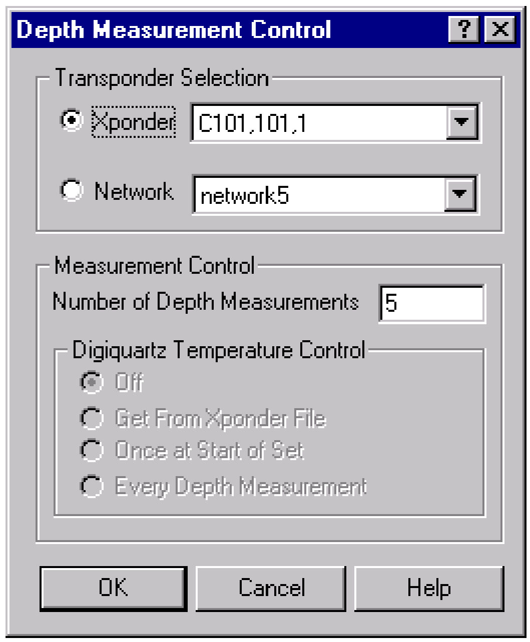
- The standard deviation (weight) assigned to a baseline is based upon the acoustic frequency in use
    - LF, 0.5m
    - MF, 0.15m
    - HF, 0.04m
    - EHF, 0.02m
- If a baseline observation is flagged with an error, it is de-weighted.

- If a zero baseline is detected, it is considered a failed observation and de-weighted
- If a baseline that is not with +/- 50% of the expected baseline distance it is considered a failed observation and de-weighted.

WinFrog Setup for LBL Calibration Depth Data Collection

If the LBL system being used is capable of measuring the depths of the transponders (for example, Sonardyne's PAN with their Compatts), you can configure WinFrog to initiate the measurement of the depths and log them with the rest of the calibration data.

In the **Calibration** dialog box, turn off current data collection. Click on the **Setup** button associated with Depths. The next figure shows the depth configuration options.



WinFrog provides the option to select between a manually controlled depth measurement process or an automated depth measurement process. Like the case of baseline observations, although the automated option is the simplest to implement, it is recommended that it only be used in a good acoustical environment.

Transponder Selection

Xponder

Selection of this option enables you to manually select the transponder stations to measure depths for. The associated dropdown list presents those transponders in the **Xponder** file that are available for depth measurements, i.e. set to **LBL Fixed**. WinFrog initiates the measurement of this depth and stops when it is completed. You must then re-enter this dialog box to setup for the next depth measurement.

Network	Selection of this option allows you to select the network within which depths will be measured. WinFrog then automatically steps through this network measuring all depths. When all the possible depths have been measured, the process is completed and stops.

Measurement Control

Number of Depth Measurements	Enter the number of times the depths configured are to be measured.
Digiquartz Temperature Control	If the selected transponder is configured for a digiquartz depth sensor, or if any of the transponders in the selected network are configured for a digiquartz depth sensor, the following options are available to configure the collection of the required Temperature count data.
Off	The Temperature Count query is never issued for the transponder.
Get From Xponder File	Future development.
Once at the Start of Set	The Temperature Count query is sent once at the start of each depth measurement set. If set to interrogate the network, each transponder is queried before proceeding with the depth queries.
Every Depth Measurement	Each depth query is accompanied by a Temperature Count query. This is very time consuming and should only be used if deemed to be necessary.

Once the depth setup is complete, exit this dialog using **OK**. In the **Calibration** dialog box, make sure to toggle the **Depth** option and click the **Apply…** button. At this time, the **Apply** button will display **Pause Depth Collection**. If you wish to pause the process, click this button. If the depth measurement process has been paused, this button will display **Restart Depth Collection** until it is pushed again to resume collecting depths. To halt the depth collection before the set is complete, select the **Off** radio button and click **Apply**.

You are informed of the completion or abortion of the depth measurement cycle with a message to the right of the Setup button.

LBL 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** section). Alternatively, the calibration summary data can also be viewed via the **Calibration** dialog box by clicking the **Edit Data** button (see **LBL Calibration Data Editing**).LBL Data Collection - General Issues

It is important to stress the versatility of the WinFrog calibration process, both the data collection and the processing. It is not necessary to perform the data collection in a set sequence, be this all data for a specific transponder uninterrupted by data associated with another transponder, or all the ranges and then all the baselines.

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 found in the **WinFrog File Formats** appendix.

Note: once the data collection is completed, the original calibration data file should be archived and set to read only. A copy is then made for actual use in WinFrog. In this way, you always have recourse to the original data file if necessary.

LBL Calibration Data Editing

The editing of the data can be performed at any stage when data are present in WinFrog memory, whether loaded from an existing file or logged during a data collection process.

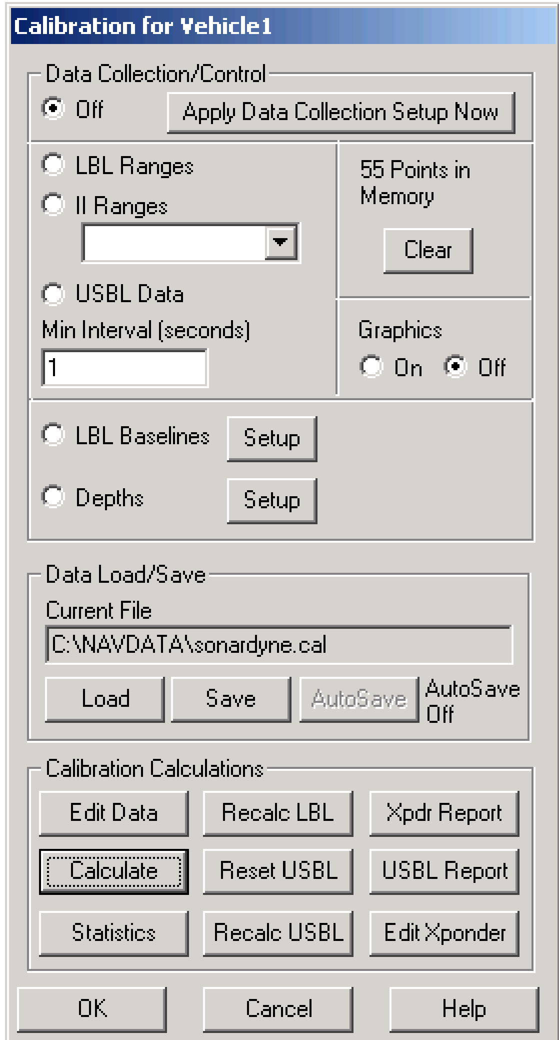
The purpose of viewing and editing the data is to locate and remove those data that are considered to be invalid. WinFrog provides graphical editors that enable easy inspection of the data, detection of any trends, and direct editing capabilities. The graphical editors allow you to view the LOP data directly and the LOP residuals. The former is best used for investigating trends and visually detecting outliers, usually visible due to the break in the trend, especially prior to any calibration calculations. 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. The only exception to this is the Temperature Count value used for reducing digiquartz data to a depth.

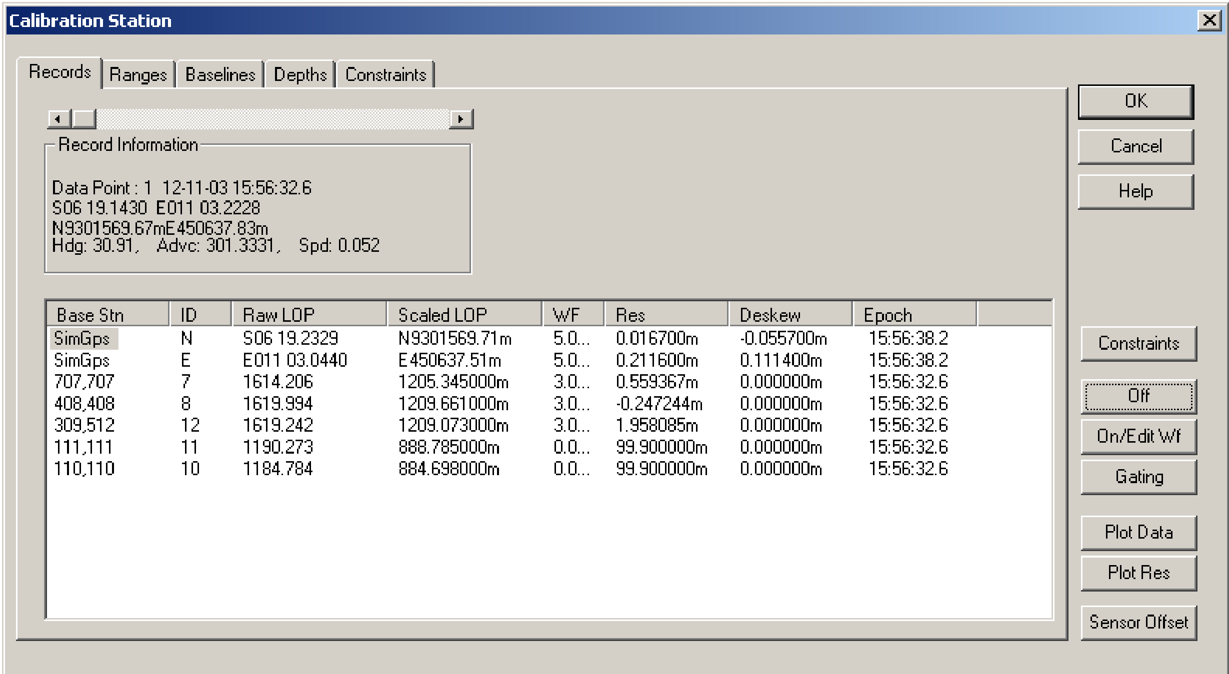
An initial review of the data should be made prior to any calibration calculations. The purpose of this review is to find obvious flyers and bad data and to remove them from the solution immediately. Then, after each calibration solution, the data should be viewed again for analysis and any further required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

Viewing and Editing the Data – The Calibration Station Window

From the **Calibration** dialog box, click the **Edit Data** button. (This button is only available if there are data present in memory).



WinFrog opens a **Calibration Station** dialog box as shown in the next figure. You can view all LOPs in the Calibration data set alphanumerically from this dialog. The example here shows the display of vessel position and LBL ranges or Lines of Position (LOPs).



The Calibration Station dialog box presents you with several options for viewing the calibration data. 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 windows and dialog boxes.

Constraints

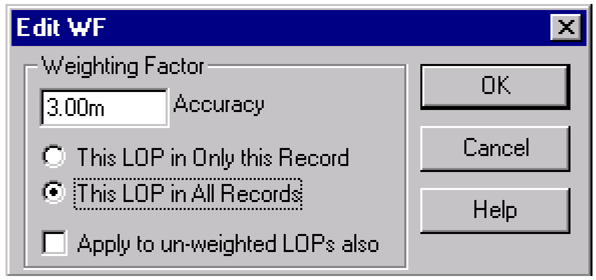
If constraints have been added to the calibration, clicking this button will automatically find the Constraint data and display it in this dialog. This button is present only if constraints have been added to the data set. This option is only available with the **Records** tab.

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.

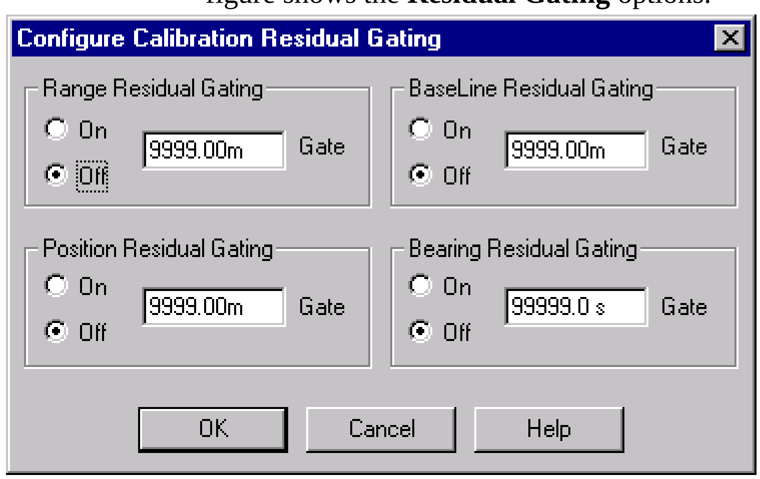


Note: When a tab other than **Records** is selected, the **This LOP in Only this Record** option is not applicable and is disabled.

Gating

This enables you to apply **residual gating** to the **complete** data set based on 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.

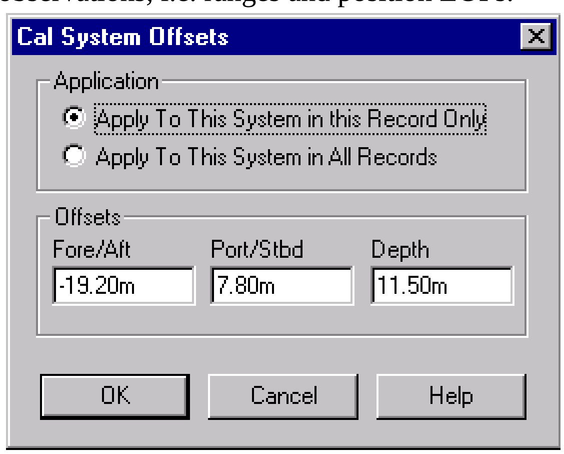
Plot Res(iduals) button

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

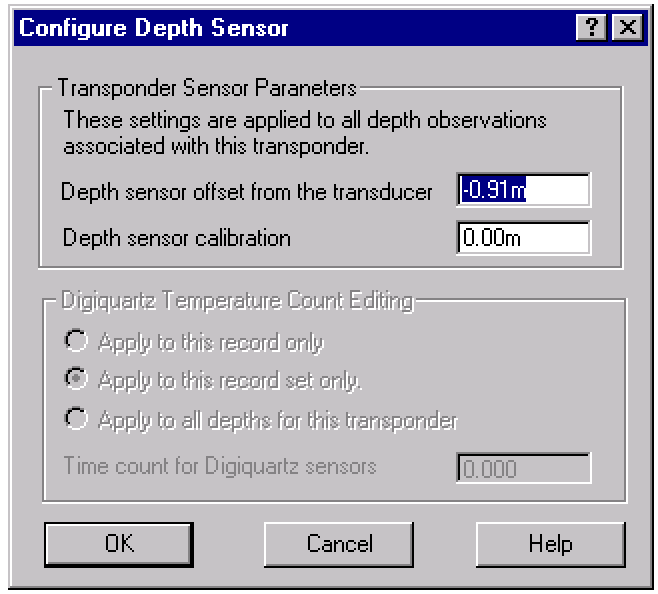
This button is only available for those data records involving sensor offsets, specifically Position, LBL and USBL Surface Range and Transponder Depth LOPs. It allows you to change the offsets for any sensor involved in the LBL calibration. This provides for corrections in the case of incorrect configuration 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.

The following shows the **Configure Depth Sensor** dialog for the depth LOPs.



For all depth sensors, you can modify the offset used to associate the sensor location with the transponder's transducer. In addition, a calibration value can be entered. For details on these settings, refer to the **Working Xponders** sections in the **Working Files** chapter. These changes are applied to all depth LOPs associated with this station and transponder.

If the depth sensor is a digiquartz sensor, you have the additional option of entering a new temperature count value and selecting whether to apply it to the reduction of the raw depth observation for the selected depth LOP only, or to all the depths LOPs in the associated record, or to all depths associated with this station and transponder.

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.

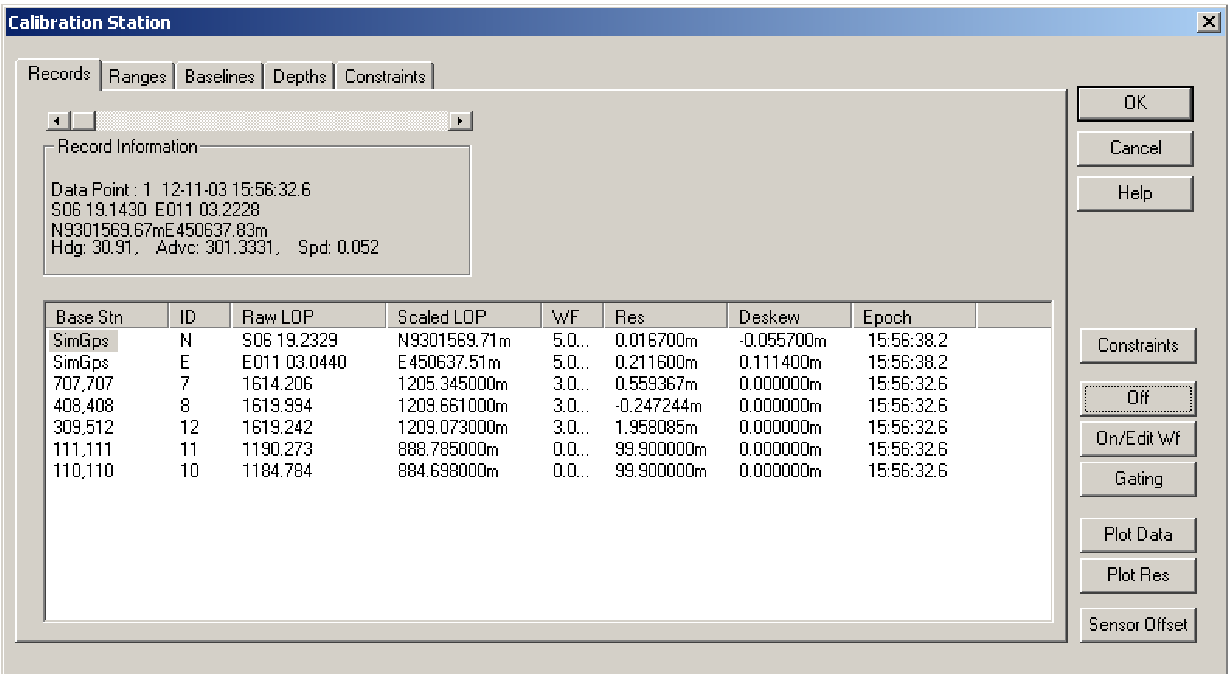
Records Tab

This tab is in two sections. A slider bar located in the top left allows you 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. Again, this varies depending upon the data item of the selected record.

LBL Calibration Data Editing – LBL Position and Range LOPs

The components of the Calibration Station window when viewing a Position and LBL Range record are as follows:



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:** the list window does not support sorting; the data are displayed in the order that the data items are added to the calibration file. 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.

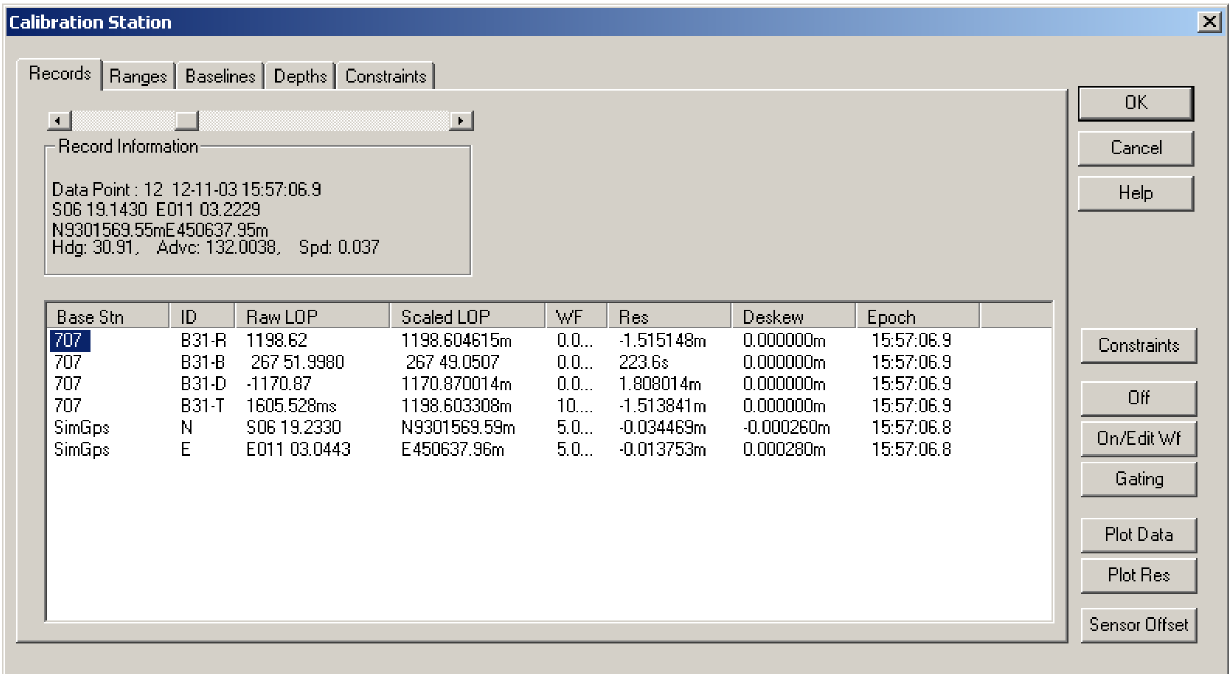
An LBL data item provides as many LOPs as there were transponders that were logged at a given epoch.

Base Stn	This lists the name of the LOP. In the case of a position LOP, the name of the associated device is shown, in the case of a range LOP (transponder), the name of the station and address of the transponder are listed.
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 an LBL range LOP, it is the transmit channel or frequency of the transponder.
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 an LBL range LOP, it is the two way travel time in milliseconds.
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 an LBL range LOP, the data are corrected for any time delays, reduced to a one way travel time, converted to a distance using a calculated sound velocity, and then projected onto the map grid.
WF	This is the weighting factor used for the LOP in the solution.
Res	This is the residual of 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 LBL data epoch and, therefore, the deskew time for an LBL range LOP is always 0. Other LOPs are then deskewed to that epoch, using velocity vectors generated as part of the standard real-time positioning, and processed and logged with the calibration data.

Epoch	This is the time stamp for the LOP.

LBL Calibration Data Editing – USBL Position and Range LOPs

LBL calibrations can include surface ranges from a USBL system. The following shows the **Records Tab** for this data item.



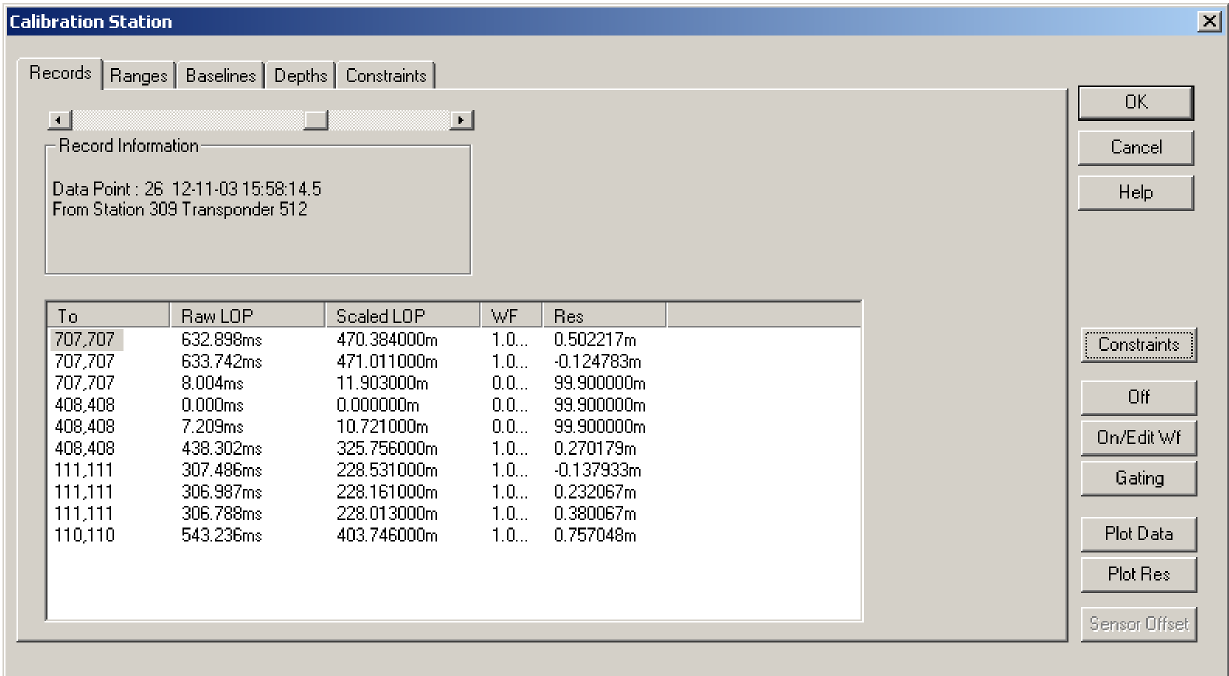
The display and editing of the USBL epoch is the same as that for the LBL epoch. The exception to this is the display of the USBL data itself. The USBL data recorded by WinFrog consists of the XYZ data directly from the USBL device, corrected for the USBL system offsets as entered into WinFrog for the respective **USBL HYDROPHONE** data item. The data is listed as 3 LOPs in this dialog, the calculated **slant range**, calculated **bearing**, and the **depth**. If the USBL system used supports the output of travel time data, this is presented as a 4^{th} LOP similarly to the LBL surface range travel time. The LOP type is indicated in the **ID** column where the character appended to the beacon code describes the LOP as follows:

R = Range, B = Bearing, D = Depth and T = TWTT.

Note: Even if the travel time data is provided by the USBL system as a one-way travel time, WinFrog converts this to a two-way travel time (TWTT) value in milliseconds to conform to the process already in place for standard LBL observations.

LBL Calibration Data Editing - Baseline LOPs

The components of the **Calibration Station** window when a baseline record is being viewed are as follows:



Data Point Selection

This section, within the top left panel, provides you with the option of scrolling through the complete data set using the slider. In addition, the basic record information is displayed in this panel.

Line 1	The calibration point number and the date and time for the first baseline logged in the selected record.
Line 2	The name of the **From** Station and the address of the transponder.

Data Point Summary

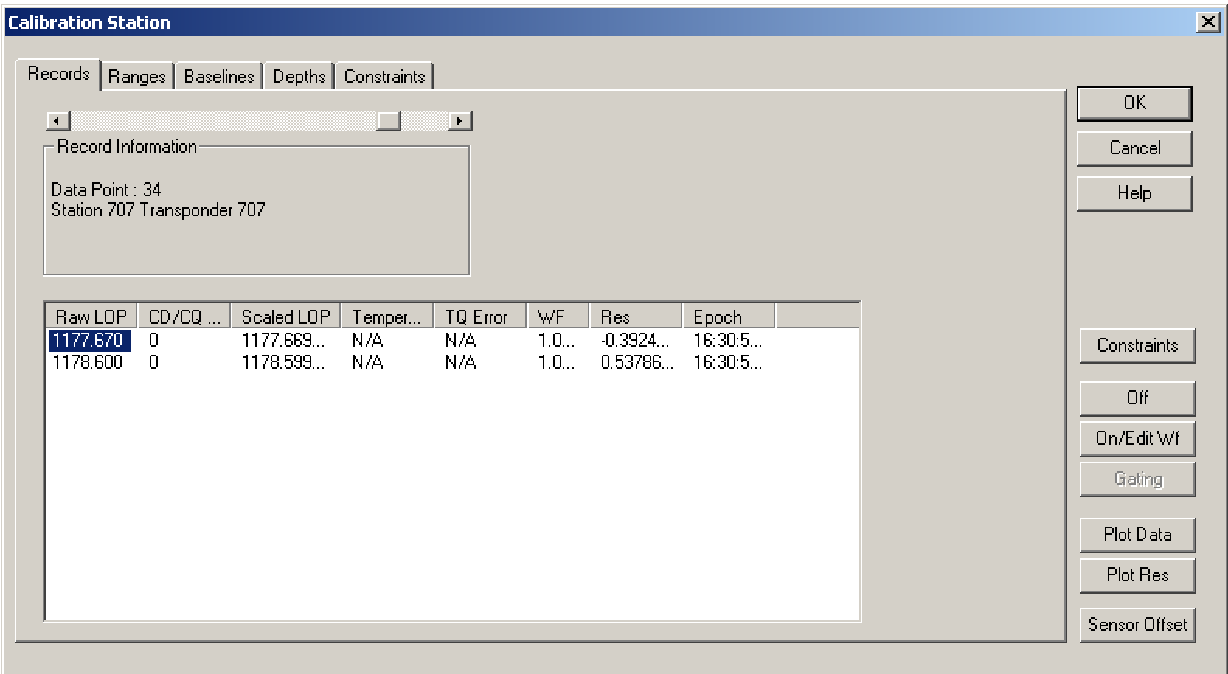
This section is the lower, larger panel and presents the data (LOPs) that make up this record in a list window. **Note:** the list window does not support sorting; the data are displayed in the order that the data items are added to the calibration file. It is also important to note selection of an LOP is only possible from the first column.

To	This lists the name of the **To** station and the address of the transponder.
Raw LOP	This is the raw LOP (the observed two way travel time in milliseconds) logged for the LOP.
Scaled LOP	This is the scaled LOP, the observed LOP corrected for turn-around-time, reduced to a one way travel time, converted to a distance using a calculated sound velocity and then projected onto the map projection.

WF	This is the weighting factor used for the LOP in the solution.
Res	This is the residual for the LOP.

LBL Calibration Data Editing - Depth LOPs

The components of the **Calibration Station** window when a depth record is being viewed are as follows:



Data Point Selection

This section, within the top left panel, provides you with the option of scrolling through the complete data set using the slider. In addition, the basic record information is displayed in this panel.

Line 1	The calibration point number.
Line 2	The name of the Station and the address of the transponder.

Data Point Summary

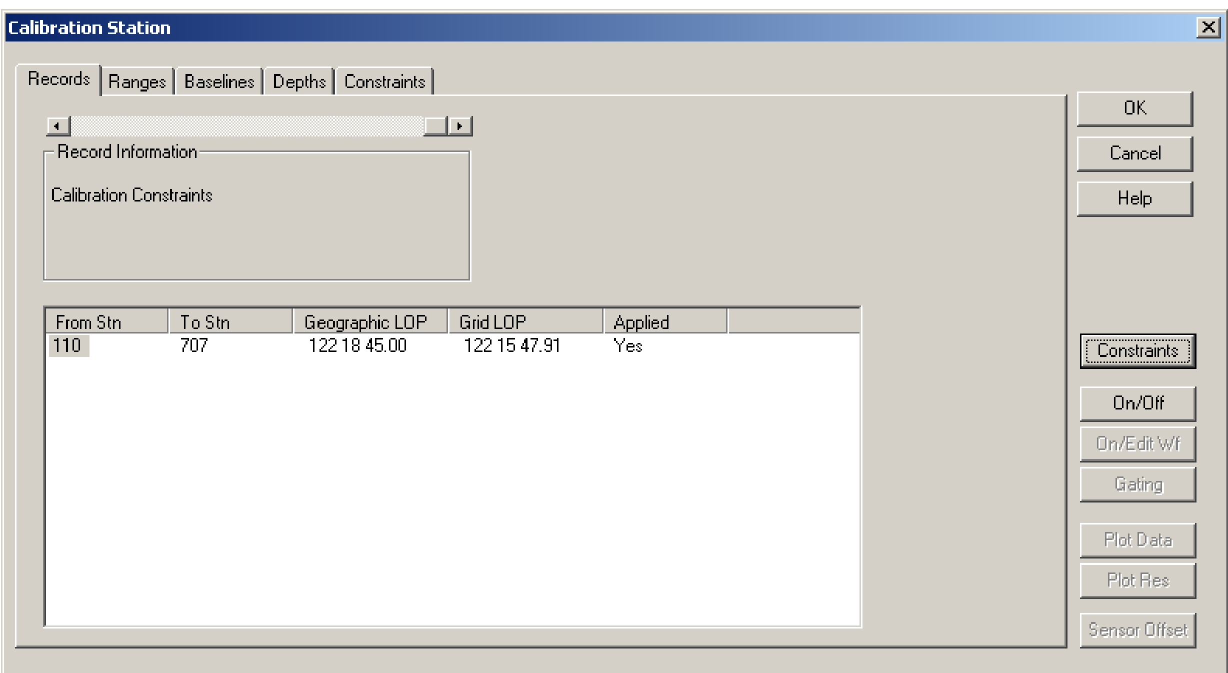
This section is the lower, larger panel and presents the data (LOPs) that make up this record in a list window. **Note:** the list window does not support sorting; the data are displayed in the order that the data items are added to the calibration file. It is also important to note selection of an LOP is only possible from the first column.

Raw LOP	This is the raw LOP. If the sensor is a strain gauge depth sensor, this is the observed depth value in metres. If the sensor is a digiquartz depth sensor, this is the count of

	the frequency output of the sensor.
CD/CQ Error	This is the error state of the associated query, 0 indicates no error.
Scaled LOP	This is the scaled LOP, the observed data reduced to represent the depth of the station monument (see the **Working Xponders** section in the **Working Files** chapter).
Temperature Count	This is the temperature count value associated with the digiquartz observation. If the sensor is a strain gauge, N/A is displayed.
TQ Error	This is the error state of the query for the temperature count, 0 indicates no error. If the sensor is a strain gauge, N/A is displayed.
WF	This is the weighting factor used for the LOP in the solution.
Res	This is the residual for the LOP.
Epoch	This is the time stamp for the depth query.

LBL Calibration Data Editing - Constraints

The components of the **Calibration Station** window when a constraint record is being viewed are as follows:



Data Point Selection

This section, within the top left panel, provides you with the option of scrolling through the complete data set using the slider. In addition, the basic record information is displayed in this panel.

Line 1	Calibration Constraints
Line 2	Blank
Line 3	Blank
Line 4	Blank

Data Point Summary

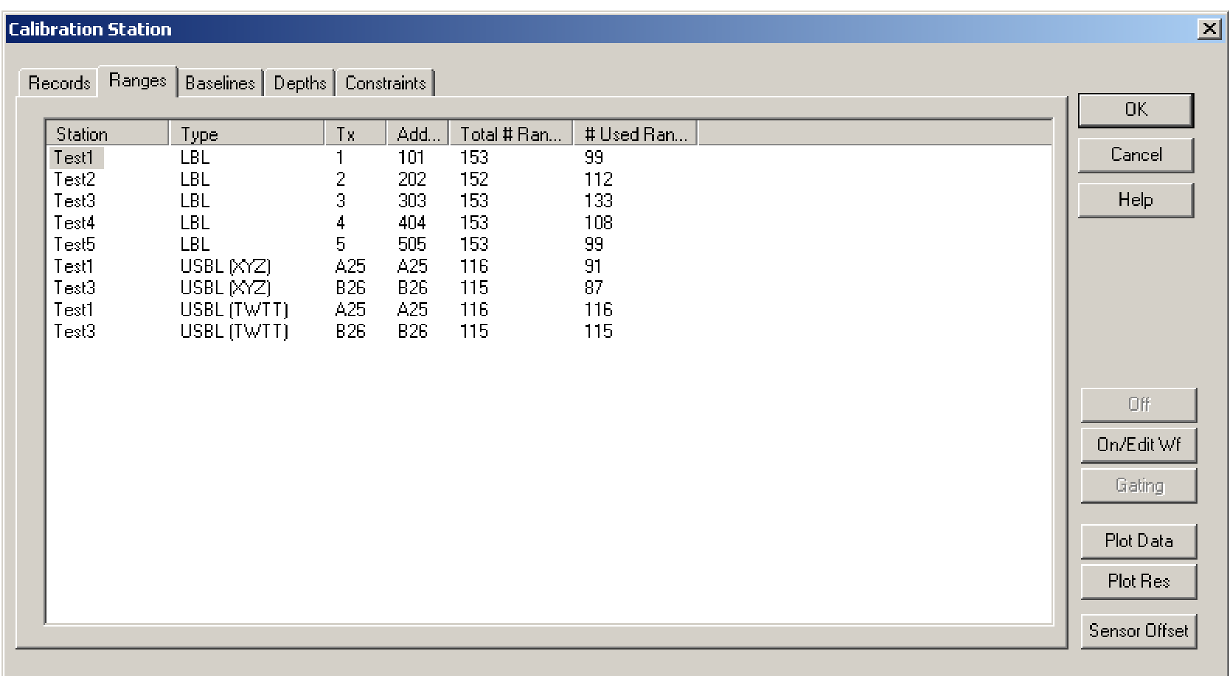
This section is the lower, larger panel and presents the data (LOPs) that make up this record in a list window. **Note:** there are no sort capabilities available, the data are displayed in the order that they were collected. It is also important to note selection of an LOP is only possible from the first column.

From Station	This lists the name of the **From** station.
To Station	This lists the name of the **To** station.
Geographic LOP	This is the constraint on the working ellipsoid.
Grid LOP	This is the constraint on the Map Projection.
Applied	This is the Applied status, either **Yes** or **No**.

The only editing options associated with a Constraint LOP from this window is to toggle the **Applied** status between **Yes** and **No**. This is accomplished by selecting the appropriate constraint LOP and clicking the **On/Off** button.

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.

The range data summaries are sorted by type (LBL, USBL derived from XYZ and USBL TWTT). Within each of these subsets, the summaries are sorted by station name and, for cases of double occupancy, then by address or beacon code depending upon the data item. Thus, the order they are displayed in will remain constant for a given calibration file.

Baselines Tab

This tab allows the operator to view a summary of all the baselines observed and contained in the calibration file. The data for each baseline pair is given in two lines in the window, one line for forward and one line for reverse. This provides a more complete review of the data for analysis. The baseline summaries are generated from the baseline data. To provide consistency in the presentation, thus facilitate evaluation, the summaries are created and sorted as follows:

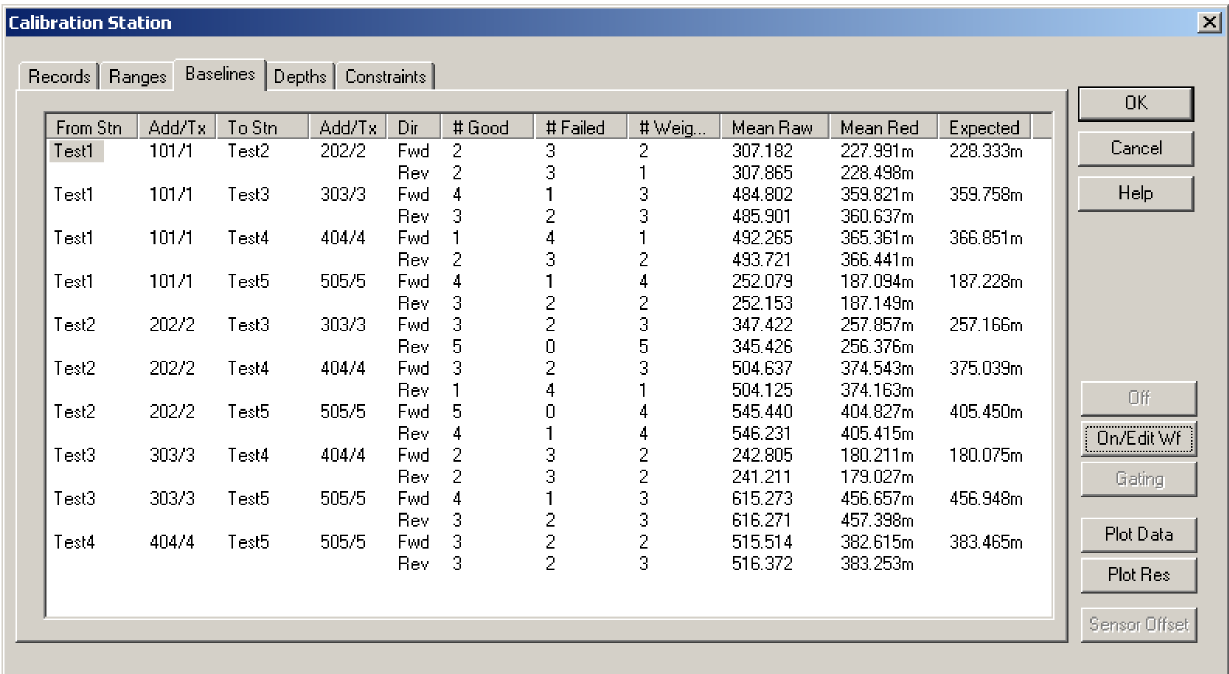
- For a given baseline pair, regardless of the direction any of the observations are actually made, the **FORWARD** direction is always from the station whose name is alphanumerically less than the other. For example, given a baseline pair with the stations *Transponder 1* and *Transponder 2*, **FORWARD** is from *Transponder 1* to *Transponder 2*.
- The primary sorting of baseline pairs is based on the **FROM** station name. In the case of stations with the same name (double occupancy), these are further sorted based on the **FROM transponder's** address.
- The secondary sorting of baseline pairs is based on the **To** station name. In the case of stations with the same name (double occupancy), these are further sorted based on the **TO transponder's** address.

This results in the display of the baseline summary data for a given calibration file to always be in the same order with the same convention for forward and reverse, regardless of the order or direction the data is collected in or subsequent editing actions. This is also true for the display of this summary information in the **CALIBRATION STATUS** window (see **ACOUSTIC**

WINDOW section in the **OPERATOR DISPLAY WINDOWS** chapter).

The information presented is detailed here.

Note: The summary includes baselines of zero length if any were observed. These are considered to be failed observations.



From Stn	Add/Tx	To Stn	Add/Tx	Dir	# Good	# Failed	# Weig...	Mean Raw	Mean Red	Expected
Test1	101/1	Test2	202/2	Fwd	2	3	2	307.182	227.991m	228.333m
				Rev	2	3	1	307.865	228.498m	
Test1	101/1	Test3	303/3	Fwd	4	1	3	484.802	359.821m	359.758m
				Rev	3	2	3	485.901	360.637m	
Test1	101/1	Test4	404/4	Fwd	1	4	1	492.265	365.361m	366.851m
				Rev	2	3	2	493.721	366.441m	
Test1	101/1	Test5	505/5	Fwd	4	1	4	252.079	187.094m	187.228m
				Rev	3	2	2	252.153	187.149m	
Test2	202/2	Test3	303/3	Fwd	3	2	3	347.422	257.857m	257.166m
				Rev	5	0	5	345.426	256.376m	
Test2	202/2	Test4	404/4	Fwd	3	2	3	504.637	374.543m	375.039m
				Rev	1	4	1	504.125	374.163m	
Test2	202/2	Test5	505/5	Fwd	5	0	4	545.440	404.827m	405.450m
				Rev	4	1	4	546.231	405.415m	
Test3	303/3	Test4	404/4	Fwd	2	3	2	242.805	180.211m	180.075m
				Rev	2	3	2	241.211	179.027m	
Test3	303/3	Test5	505/5	Fwd	4	1	3	615.273	456.657m	456.948m
				Rev	3	2	3	616.271	457.398m	
Test4	404/4	Test5	505/5	Fwd	3	2	2	515.514	382.615m	383.465m
				Rev	3	2	3	516.372	383.253m	

From Stn The name of the **From Xponder** station in the baseline pair.

Add/Tx The address and transmit channel (or frequency) of the **From Stn**.

To Stn The name of the **To Xponder** station in the baseline pair.

Add/Tx The address and transmit channel (or frequency) of the **To Stn**.

Dir Describes the observation direction for that line of data in the window for the given baseline pair, either forward (**Fwd**) or reverse (**Rev**).

 # Good The total number of successful baseline observations. Note that being successful does necessarily mean that the observations themselves were good or valid.

 # Failed The total number of failed baseline observations.

 # Weighted The total number of baseline observations currently weighted in the solution.

Mean Raw The mean raw observation (TWTT) of those baselines weighted into the solution.

Mean Red — The mean reduced baseline (slant range) of those baselines weighted into the solution.

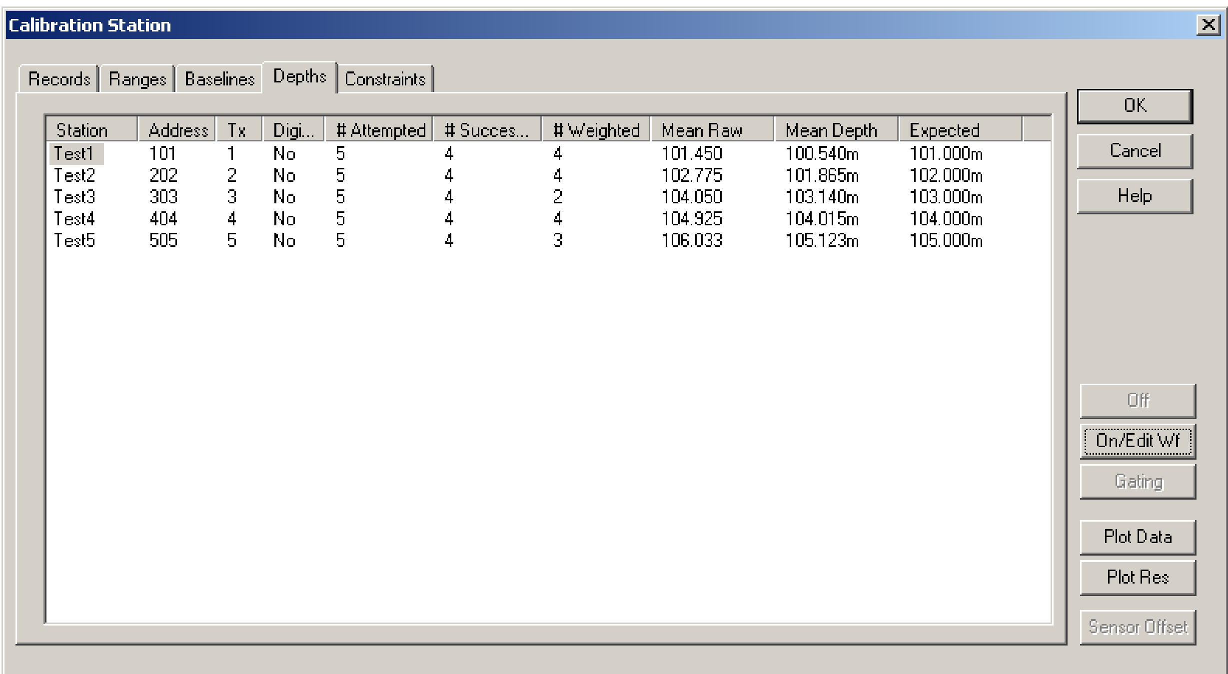
Expected — The calculated baseline (slant range) length.

Depths Tab

This tab allows the operator to view a summary of all the depths observed and contained in the calibration file.

The depth summaries are sorted by station name. In the case of stations with the same name (double occupancy), a secondary sorting based on the station's transponder address is done. This normalizes the presentation of the data to facilitate evaluation, both in this tab and the **CALIBRATION STATUS** window (see **ACOUSTIC WINDOW section in the OPERATOR DISPLAY WINDOWS** chapter).

The information presented is detailed here.



Station — The name of the **Xponder** station.

Address — The address of the transponder.

Tx — The transmit channel (or frequency) of the transponder.

Digiquartz — Indicates if the depth sensor is a digiquartz.

 # Attempted — The total number of attempts made to observe a depth.

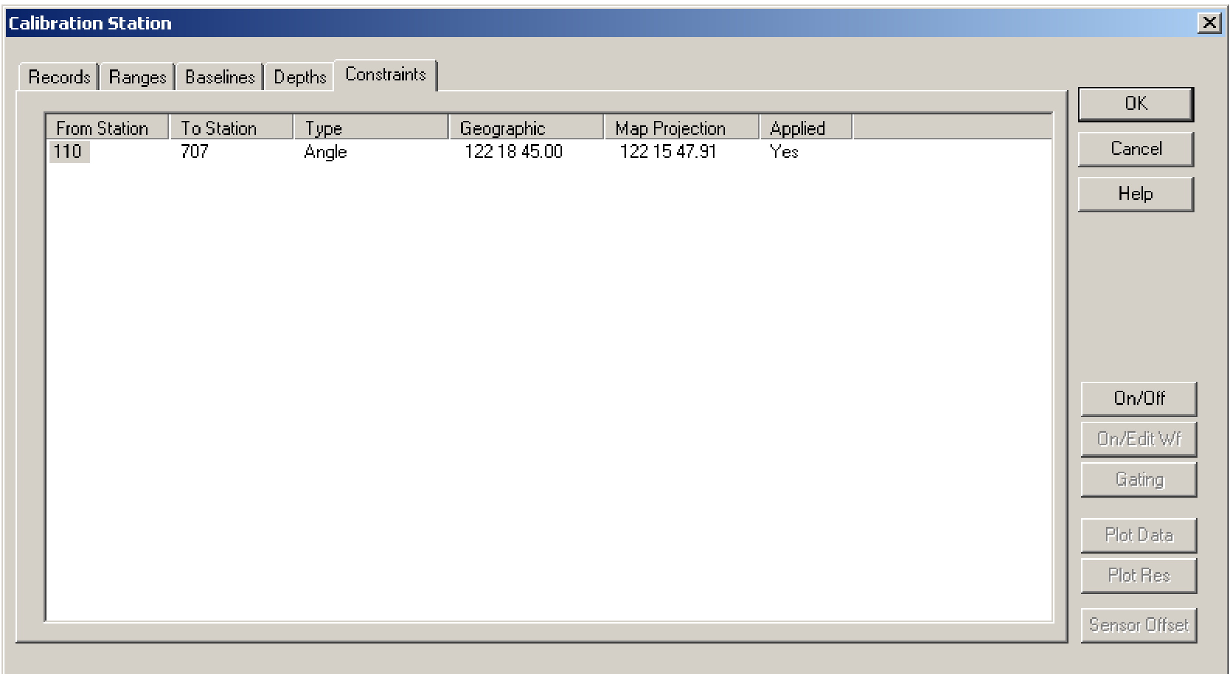
 # Successful — The total number of successful depth observations. Note that being successful does necessarily mean that the observations themselves were good or valid.

 # Weighted — The total number of depth observations currently weighted in the solution.

Mean Raw	The mean raw observation of those depths weighted into the solution.
Mean Red	The mean reduced depth of those weighted into the solution.
Expected	The calculated depth.

Constraints Tab

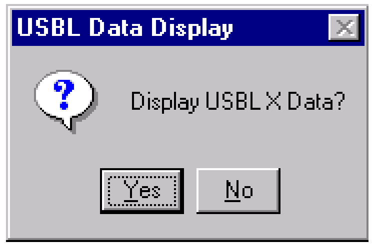
This tab allows the operator to view a summary of all the constraints added to the calibration file. The information presented is detailed here.



From Station	The name of the **From Xponder** station in the constraint pair.
To Station	The name of the **To Xponder** station in the constraint pair.
Type	The type of constraint, either **Angle** (azimuth) or **Distance**.
Geographic	The constraint on the working ellipsoid.
Map Projection	The constraint projected onto the Working Map Projection.
Applied	Shows whether or not the constraint is enabled (**Yes**) or not (**No**).

Using the Plot Panel: LOPS - Position and Surface Ranges

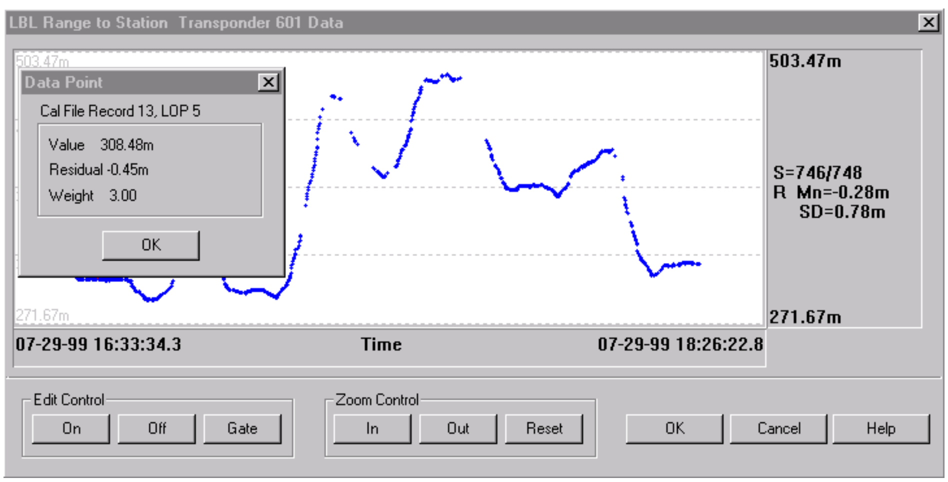
When the **Plot Data** button in the **Calibration Station** window is clicked with a Position or LBL range LOP selected, the following graphical editor is opened. In the case of a USBL range or bearing LOP, a prompt pops up asking if you wish to plot **X** or **Y** data respectively.



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** 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 you view the slant range or TWTT residuals when editing USBL data for the determination of a beacon position.

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 that are weighted in the solution are drawn in blue; those that 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.

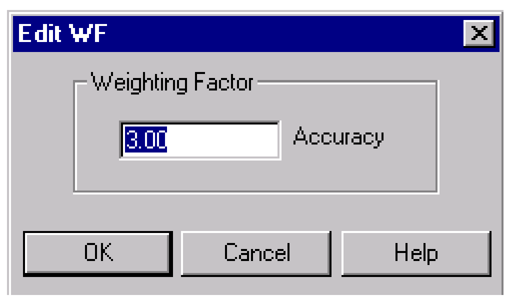
Windowing

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.

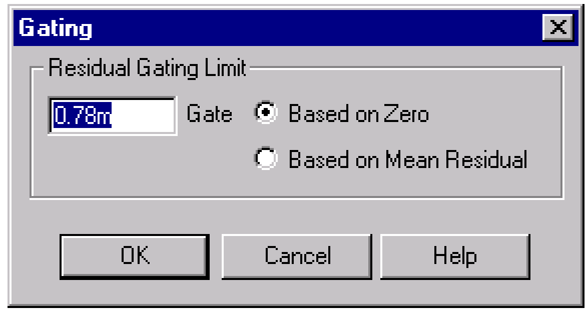


Off

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.

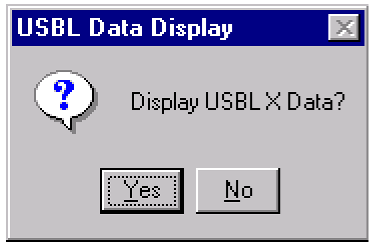
Reset — Re-draws the plot panel to the original coverage.

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.

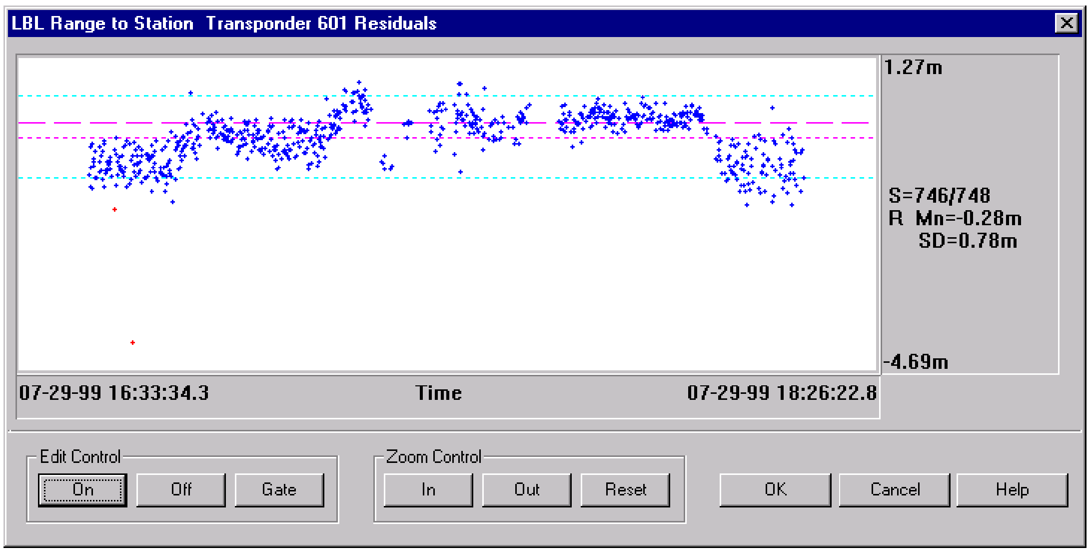
Using the Plot Panel: Residuals

When the **Plot Res** button in the **Calibration Station** window is clicked 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 scaled X or Y residuals. Answering **No** results in the graphical editor plotting the scaled range and bearing residuals respectively.

Note: It is recommended that you view the slant range or TWTT residuals when editing USBL data for the determination of a beacon position.



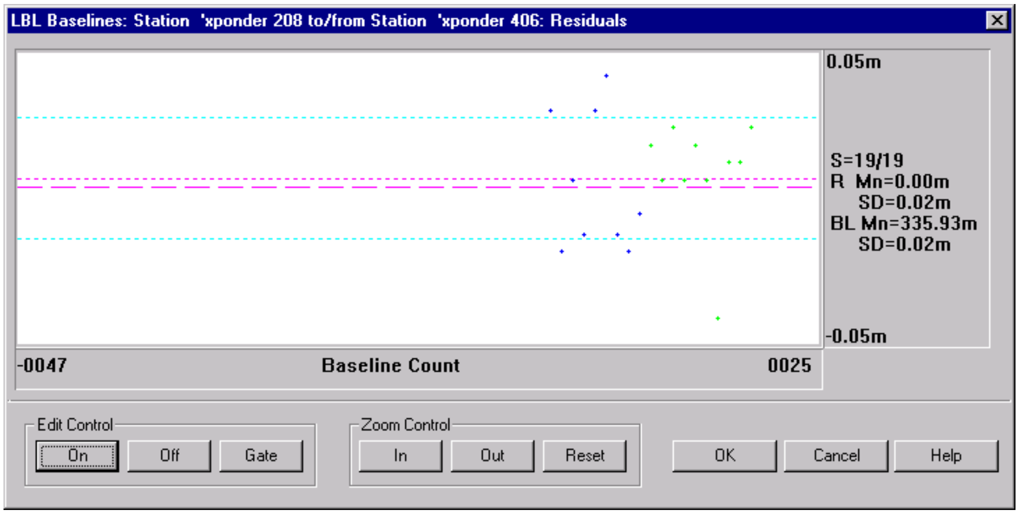
The window title gives the LOP type and the name of the specific LOP. The capabilities and options are the same in this window as detailed in **Using the Plot Panel: LOPS - Position and LBL Ranges**.

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.

If the LOP being viewed is a Position, LBL range or Depth LOP, 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. The above figure is an example of an LBL range LOP.

If the LOP being viewed is a Baseline LOP, the residuals are plotted against a baseline count. Forward baselines weighted in the solution are plotted in blue, reverse baselines weighted in the solution are plotted in green. Any points representing data that is deweighted from the solution are 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 for 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.

To evaluate the residuals to detect bad data

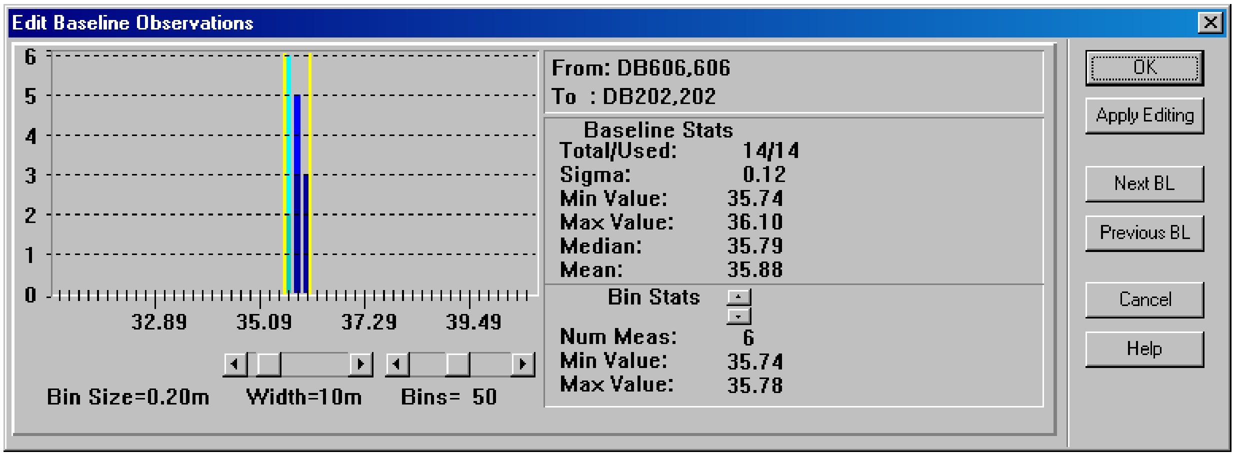
1. First ensure all the obvious bad data has been removed by looking at the LOP (see **Using the Plot Panel: LOPS**).

2. **Next**, examine all the residuals. Then select only one observation at a time to be turned off. This can be the largest but also consider what was happening during the data collection phase. If the ship rolled sharply at some point or hit a wave that caused it to shudder, one may want to select the observation(s) that occurred at this time. One may see some residuals that do not part from the trend by very much but combined with knowledge of a large ship roll may indicate the offending observations. After turning off the bad observation re-solve, if the statistical test still fails turn this observation back on and select another then repeat the procedure. One can shorten the process by selecting a few observations to turn off then re-solve and if the test passes turn back on, one observation at a time, re-solving after each, until the bad observation is found. One should also consider the number of observations there are. Given a large data set if a few good ones are turned off along with a bad one there will not be much accomplished by spending time finding the good ones to turn them back on.

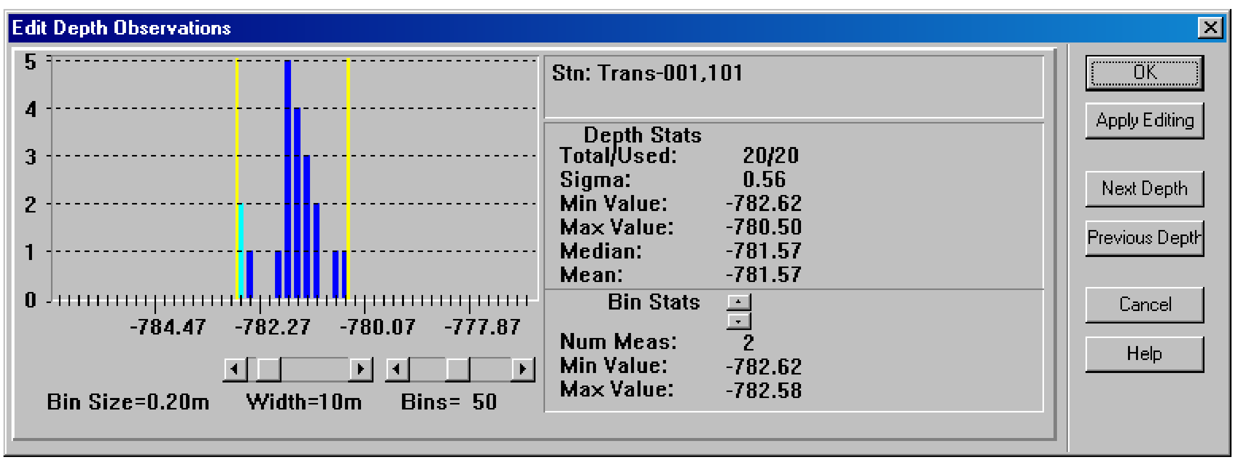
Using the Plot Panel: Baseline and Depth LOPs

When the **Plot Data** button in the **Calibration Station** window is clicked with a baseline or a depth LOP selected, the graphical editor opened plots the data in histogram format.

If the LOP selected is a baseline, the data set is searched for all baselines with the same **From** and **To** transponders as the one selected. It then searches for all the reverse baselines. These are displayed in the histogram. This is a powerful editing tool in that, in general, the correct baseline is the shortest observed baseline, which is easily visible using a histogram.



If the LOP is a depth, the data set is searched for all depths associated with the selected station and transponder.



How WinFrog Bins the Data

1 Determines the central value of the set and calculates the bin size.

2 Using the following formula, calculates the difference between the central value and the individual baseline values.

(((baseline-centralBaselineValue)+width/2) / binSize)

3 With this information, determines which bin to place the baseline.

Using the Histogram Panel

The histogram display itself consists of the individual bins drawn with the top of the panel representing the maximum number of baselines in the most populated bin.

What the colors mean:

- Bins containing data that are weighted in the solution are drawn in blue.
- Bins containing data that are de-weighted in the solution are drawn in red.
- The portion of the bin representing the forward baselines (if applicable) is lighter in color than that portion representing the reverse baselines. If a bin has both forward and reverse baselines in it, the forward are on top.
- The bin that is currently selected for the display of its statistics is drawn in light blue.

The Controls and Panels:

Edit Bars	The edit bars represent the limits of the data that are weighted in the solution and are drawn in yellow, from the top to the bottom of the panel. These can be moved to graphically edit the data. Click and drag either bar. When these are moved, the previous position is drawn in dark blue until the mouse releases the bar, at which time the old position marker disappears. Any bin outside the new edit bar position is de-weighted from the solution, any bin inside the new position is weighted in the solution. All statistics are updated immediately in the window, but the actual editing is not applied until the Apply Editing button is clicked.
Histogram Controls	Control of the width of the whole panel and the number of bins in the panel. The actual bin size is a derivative of these settings and is displayed.
Width	The width the histogram panel represents.
Bins	The total number of bins to be used to represent the panel width.
Bin Size	Width divided by number of bins.
Station Information	In the case of baselines, the names and addresses of the **From** and **To** transponders are given. In the case of Depths, the station name and transponder are given.

Baseline/Depth Stats

Total/Used	The total number of measurements made versus the total number weighted in the solution. **Note:** Zero length baselines are not included in the histogram nor are they considered when determining the total number of baselines as displayed here. As a result, the total displayed here may not match that derived from the Baseline Summary tab (see **Baseline Tab**).

Sigma	The standard deviation of the variance.
Min Value	The minimum value.
Max Value	The maximum value.
Median	The median of this data set.
Mean	The mean of this data set.

Bin Stats

Num Meas	Number of data in the selected bin.
Min Value	Minimum value in the selected bin.
Max Value	Maximum value in the selected bin.
up/down arrows	Scrolls up and down the bins selecting the bin for which to display the Bin Specs.

Button Controls

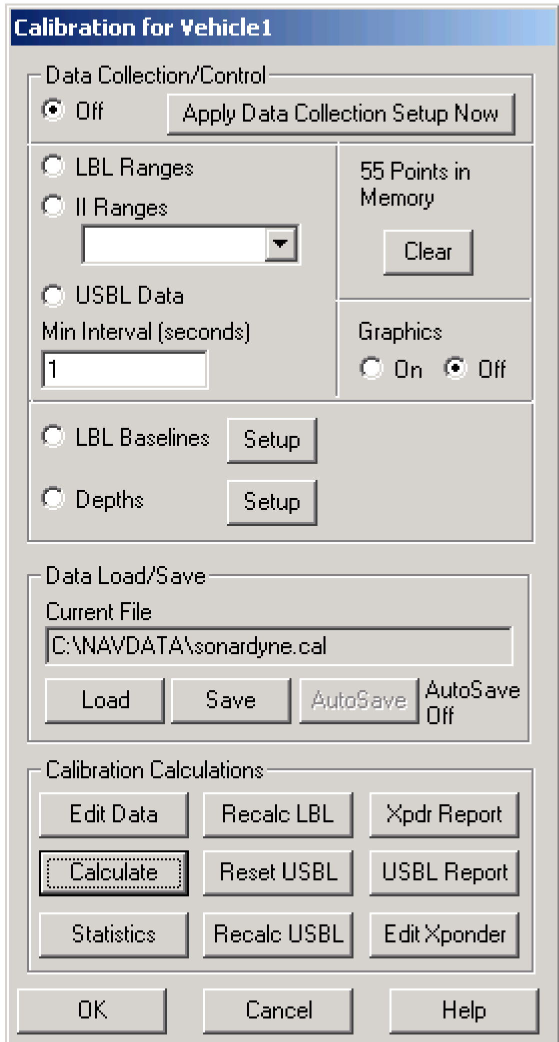
Apply Editing button	Applies editing performed with the histogram. Note that closing the window with **OK** does not accomplish this.
Next BL/Depth button	Looks for the next baseline or depth in the calibration data set and displays the histogram for it. Note that the changes made to the histogram before clicking this button are not applied unless the **Apply Editing** button is clicked first.
Previous BL/Depth button	Looks for the previous baseline or depth in the calibration data set and displays the histogram for it. Note that the changes made to the histogram before clicking this button are not applied unless the **Apply Editing** button is clicked first.

Note: WinFrog bases the display of the number of observations used and the color-coding of the histogram's bins on the left and right most bins with weighted in observations. Thus, if a de-weighted baseline/depth lies in a bin that includes weighted in observations (this can be a result of an observation that agrees with other good observations but is flagged with an error when decoded), it is included in the count of used baselines/depths and is included in a bin colored as weighted in. This can result in an apparent discrepancy between the baseline and/or depth summary display and the associated histogram.

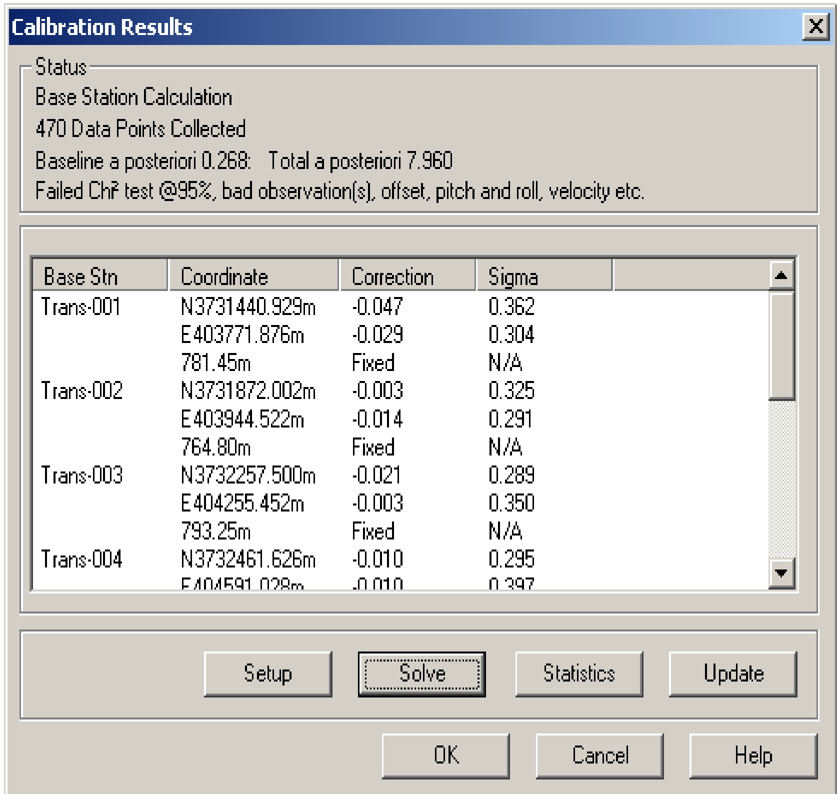
LBL Calibration Calculations

WinFrog applies a rigorous least squares technique to the calibration calculations, processing all of the data in a single adjustment. As this approach is quite new, some users tend to wish to employ older techniques. These older process includes: independently processing areas of several key transponders, performing a second calculation where these transponder's coordinates are held fixed, and then computing the remaining transponders coordinates using baseline observations. The flexibility of WinFrog allows you to perform the calibration the "old way," but you are losing the benefit (and speed) of combining all the data to perform a more rigorous and complete solution.

From the **Calibration** dialog, click the **Calculate** button.



The **Calibration Results** dialog opens.

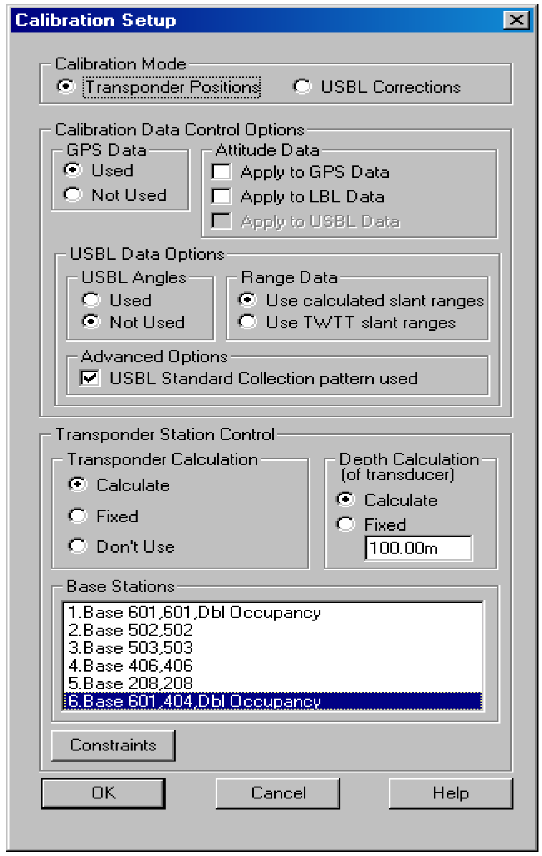


Note: the calibration edit settings are saved to the calibration file. Therefore, if the data being processed are from a loaded file that was already processed, this dialog box will present the options that have already been set. In addition, the statistical results will also be available and displayed.

From this dialog you can configure the calculations (**Setup**), process the data (**Solve**) and update the **Working Xponder** file (**Update**). At any stage, this dialog displays the current solution results.

To Setup the LBL Calibration Solution

1 Click the **Setup** button to display the **Calibration Setup** dialog shown in the next figure.



You now have the following options:

Calibration Mode

Transponder Positions — WinFrog will solve for the positions of the transponders as configured. This must be selected for LBL Calibrations.

USBL Corrections — WinFrog will solve the USBL calibration corrections.

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 option must be selected if you are performing a calibration using the LOPs from the LBL transceiver to the transponders.
- **Not Used** — The GPS position data are not used in the calibration solution. Choosing this option results in all LOPs from the transceiver to the transponders to be not used, as they require the GPS coordinates. Only baseline LOPs will remain unaffected and will be used in the solution.

Attitude Data

Apply to GPS Data — The pitch and roll data logged with the GPS LOPs are applied to the GPS sensor offsets in the solution.

Apply to LBL Data — The pitch and roll data logged with the LBL range LOPs are applied to the LBL sensor offsets in the solution.

Apply to USBL Data — This is only available if the option to use **Use TWTT slant ranges** has been selected, in which case the pitch and roll data logged with the USBL TWTT LOPs are applied to the USBL sensor offsets in the solution.

USBL Angles — This applies to the application of USBL data. For more information refer to the **USBL Calibration** chapter.

Range Data

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.

Advanced Options

USBL Xponder Standard Cal — This applies to the processing of a transponder position for a USBL corrections calibration. See the **USBL Calibration** chapter.

Transponder Station Control

Transponder Calculation — This controls the horizontal position solution for the station currently selected in the **Base Stations** list box (see below).

Calculate — Solves for the Northing and Easting of the station.

Fixed — The station is held fixed (known) in the solution.

Don't Use — The station is not used at all in the solution.

Note: it is important that if a transponder appears in the list, but there are no data for it in the calibration data set, this option must be selected for that transponder. Otherwise, the solution will fail.

Depth Calculation

Calculate — Solves for the depth of the station. If depth observations are available and weighted in the solution, they will be used.

Fixed — Constrains the depth of the station in the solution. You may enter a value here to use as the fixed depth. The default is the last depth value for this station, either originally from the **Working Xponder** file when the calibration was first started, or from the last solution.

Base Stations — This lists all stations available for the calibration solution by station name and transponder address Note that if a station is entered twice with different transponders assigned to it, it is considered a single station and cannot be set to **Calculate** for one instance and **Fixed** for the other. If the data for one transponder but not the other is to be used, this must be done in the appropriate weighting of the respective data. All data associated with a given station, regardless of how many transponders are located on that station, is used as weighted and the station is solved for only once.

It is important to note that when the **Calibration** dialog is first opened, the current **Working Xponder** file is copied to the calibration data set station information. It is this information that is used throughout the calibration process, not the actual **Working Xponder** file.

Note: 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.

Additional Controls

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

2. Set the appropriate configuration settings.
3. Select each transponder and configure appropriately using the options available in this panel.
4. If constraints are to be applied, click the **Constraints** button and configure the constraints.
5. Click **OK** to exit and use the configuration, or **Cancel** to exit this dialog and discard the settings.

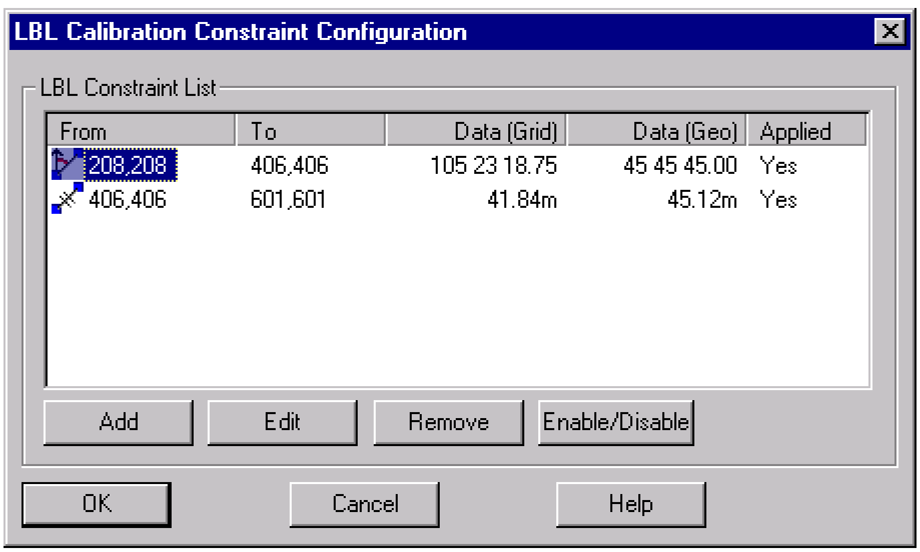
To Enter Constraints for the Least Squares Adjustment

The LBL calibration solution supports azimuth and baseline constraints. The azimuth constraint allows the solution of an LBL array to be oriented as set by the constraint. The baseline constraint allows for the entry of known distances between stations that may not have been observed, for example between transponders mounted on opposite sides of a structure that is being positioned.

The constraints are saved and loaded with the Calibration data set.

There is a limit of 10 constraints.

1. In the **Calibration Setup** dialog, click the **Constraints** button.

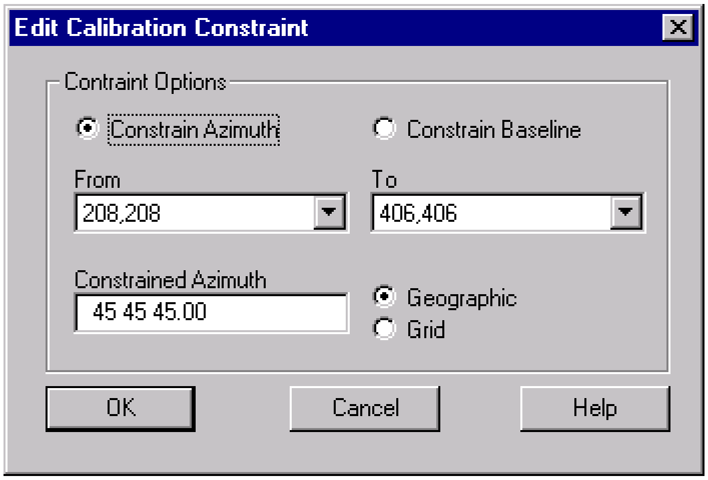


2. The overview window presents all the currently configured constraints. The information presented is as follows:
   - An icon indicating if the constraint is an azimuth or a baseline.
   - The name and transponder address for the **From Station**
   - The name and transponder address for the **To Station**.
   - The constraint, **Data (Grid),** projected onto the Map Projection grid
   - The constraint, **Data (Geo)**, on the Working Ellipsoid.
   - The status, **Applied**, of the constraint, **Yes** indicating that it is or will be used in the solution, **No** indicating that it will not be used in the solution. This enables you to enter a constraint and turn it off and on without having to actually re-enter the constraint each time. This can also be controlled from the Calibration Station dialog.

The options available from this dialog are as follows:

- **Add**, allows you to enter a new constraint.
- **Edit**, allows you to edit the constraint currently highlighted in the list view. Double clicking on the constraint in the list view also allows editing of the constraint.
- **Remove**, allows you to remove the constraint from the list. Note that once a constraint is removed, it must be added again if it is to be used.
- **Enable/Disable**, toggles the **Applied Yes/No** setting for the currently highlighted constraint.

3 Clicking **Add** or highlight an existing constraint and clicking **Edit**, or double clicking an existing constraint accesses the **Edit Calibration Constraint** dialog.

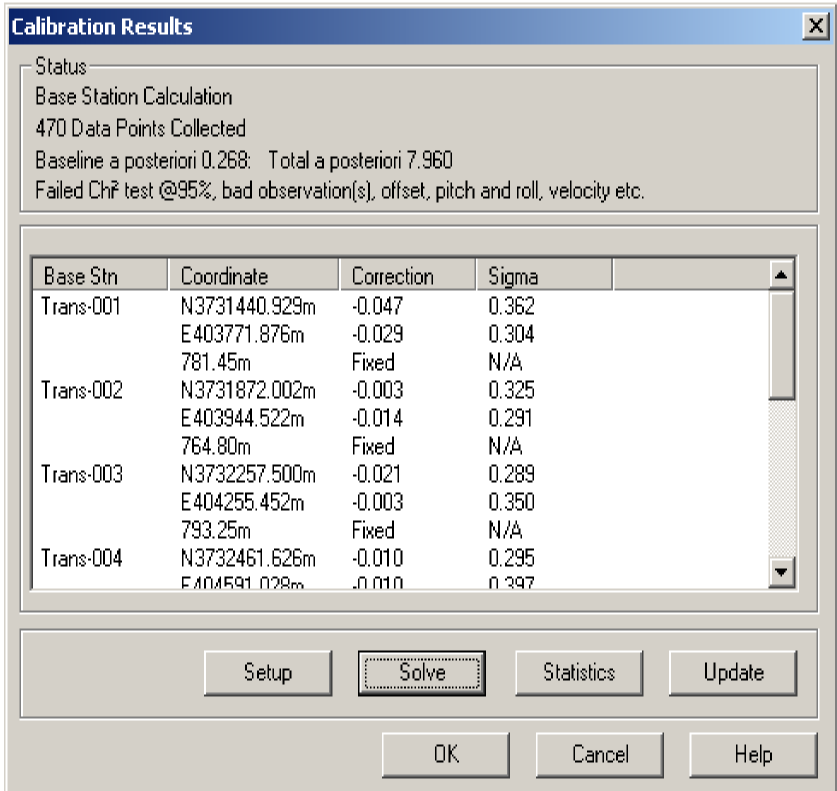


- Select the Constraint type, either **Azimuth** or **Baseline**. Note that the data entry controls will change slightly to reflect the different data entries, angle or distance.
- Select a **From** and **To** station from the respective drop down lists. The stations are listed by name and transponder address. If a station is occupied by more than one transponder, only the first instance is listed.
- Enter the **Constraint**. This can be entered as either a geographic or a grid value by selecting the appropriate radio button, **Geographic** or **Grid** respectively.
- Exit with **OK** to keep the constraints added/edited, or **Cancel** to discard the addition or editing of the constraint. Note that the default **Applied** setting is **Yes**.

4 Click **OK** to exit and apply the constraints added/edited, or **Cancel** to discard the changes.

To Calculate the LBL Calibration Solution

Once the solution is configured, you perform the iterative calibration calculation directly from the **Calibration Results** dialog box.



The following details the components.

Status Panel

Displays the current status of the solution on the first line and the number of points used in the solution on the second line. A third and fourth line are used to present statistical information and are discussed later in this chapter (see **Analyzing the Results**). 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-executed and 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	The solution for transponders was successful.
Solution Calculation Failed	The solution failed. There are major problems with the data that must be investigated.
Processing…	Calibration processing is occurring.

Data Panel

Station	The name of the station. If a station is occupied by more than one transponder, each instance is listed but only the first lists the following data. Subsequent listings simply state **Double Occupancy**.
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.
Sigmas	The sigma of the associated coordinate component as determined from the last adjustment iteration.

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) with each click 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 an 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:

- Once the data appear to have converged, the value oscillates back and forth between two values with each click of the **Solve** button.
- 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.
- **GPS Data** is set to **Not Used** and there are no transponders held fixed and/or there are insufficient baseline LOPs

- The solution fails. Probable causes are:

  A A transponder has no data associated with it but is not set to **Don't Use**.

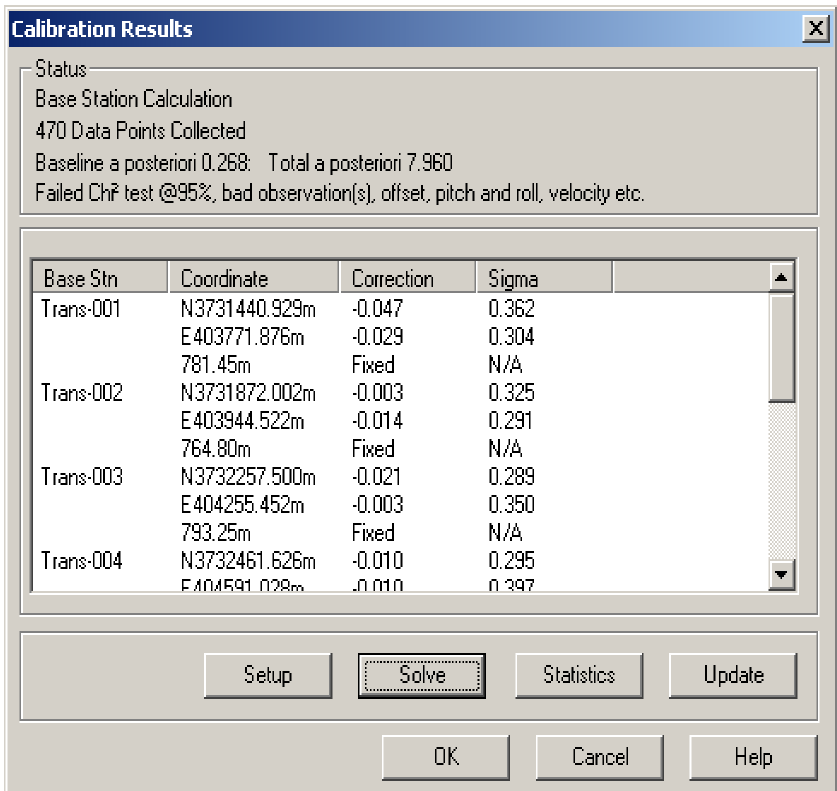
B The initial transponder coordinates and/or depths are not sufficiently close to the actual locations. Also check that the correct transponder was dropped or located at the correct location, **see Editing Calibration Station Information**.

C There are flyers that have not been de-weighted from the solution, see **LBL Calibration Data Editing**.

D Incorrect transponders in the file, **see Editing Calibration Station Information**.

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.



Two **a posteriori** values (**baseline** and **total**) 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. The **baseline a posteriori** is calculated just using baseline residuals. These values can be used as an aid in assessing the quality of the least squares adjustment.

Unless indicated, a reference to **a posteriori** refers to the **Total a posteriori** not the **Baseline a posteriori**. 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
- un-modeled 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, **un-modeled 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 un-modeled 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.) If an attitude sensor is available when the data is observed, WinFrog can be configured to use it and log the data to the calibration file for use during the calibration process.

  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 should cancel the pitch or roll to the other and the adjustment should be good. However, you should change the weight factor on the observations to reflect this error. If this is not done you 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.
- Certain inter-transponder baselines may be subject to excessive ray bending causing the range to be short or long yet appearing consistent. Generally this is more likely to happen with the longer baselines than the shorter or otherwise the error is likely to be larger with the longer rather than the shorter. Should this happen the residuals and the a posteriori will be large. Redesigning the array is the best solution, however, you can improve the adjustment by increasing the standard deviation of those baselines that are suffering from the ray bending while leaving the others as they are. Conversely, all of them may be changed as a function of distance. Excepting obvious bad measurements, judging the poorest measurement based upon the residual is not valid as the errors get

pushed into the baselines with the poorest geometry.

- 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.

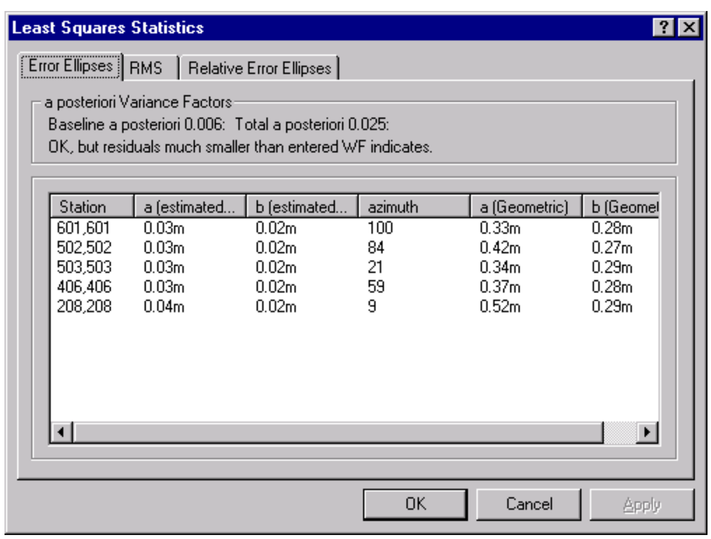
The third possible reason that the test on the **a posteriori variance** factor can fail is **incorrect initial weighting**. The initial weighting is the weighting factor value assigned to each observation. The status line may display the message, **OK, but residuals much smaller than initial WF indicates.** 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 **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 LBL 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 with acceptable statistics while using most of the data.

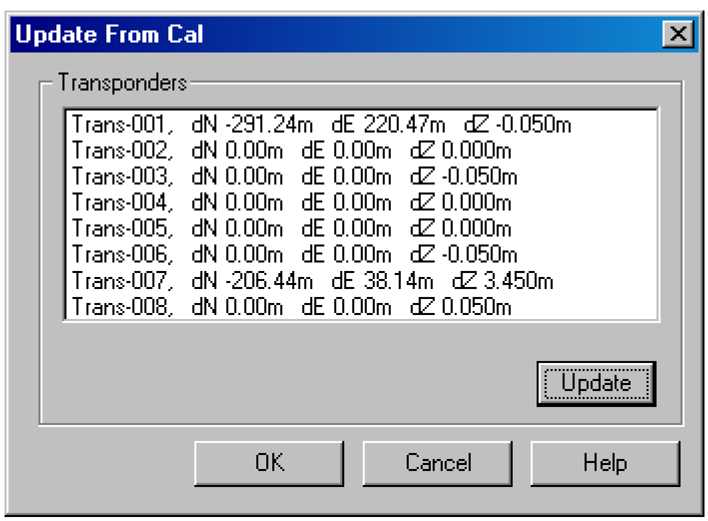
When editing the data by looking at the residuals, be aware that the least squares technique minimizes the residuals of all of the observations. Consequently, it distributes any errors throughout the whole array. The error from a single observation will appear in the residuals of all the observations. 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). Consequently, do not eliminate large blocks of observations all at one time. Remove only a few of the largest and then solve again.

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, 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. At that time, the remaining files are 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.

Updating the Xponder File with the Calibration Results

Once you consider the calibration complete, the **Working Xponder** file can be updated directly from the **Calibration Results** dialog.

1 Click the **Update** button to display the dialog box shown in the next figure.



Each transponder present in the calibration copy of the Xponder file is listed by name, along with the corrections to be added to the respective Northing, Easting, and depth values in the **Working Xponder** file.

2 If a transponder is present in the calibration transponder list, but not in the **Working Xponder** file, instead of corrections "**(Not in Working File)**" is displayed opposite the respective transponder. To update the transponder, highlight the desired transponder, and click **Update**.

Once updated, the corrections for that transponder will change to 0 in the list.

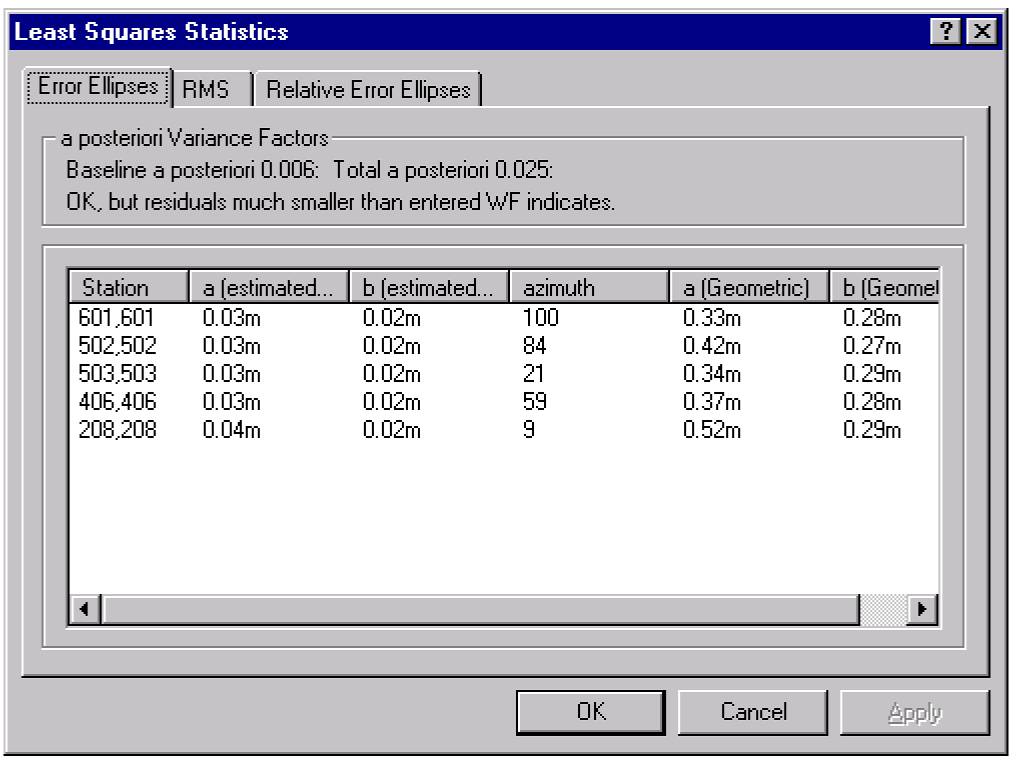
Viewing the LBL Solution Statistics

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 LBL 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.

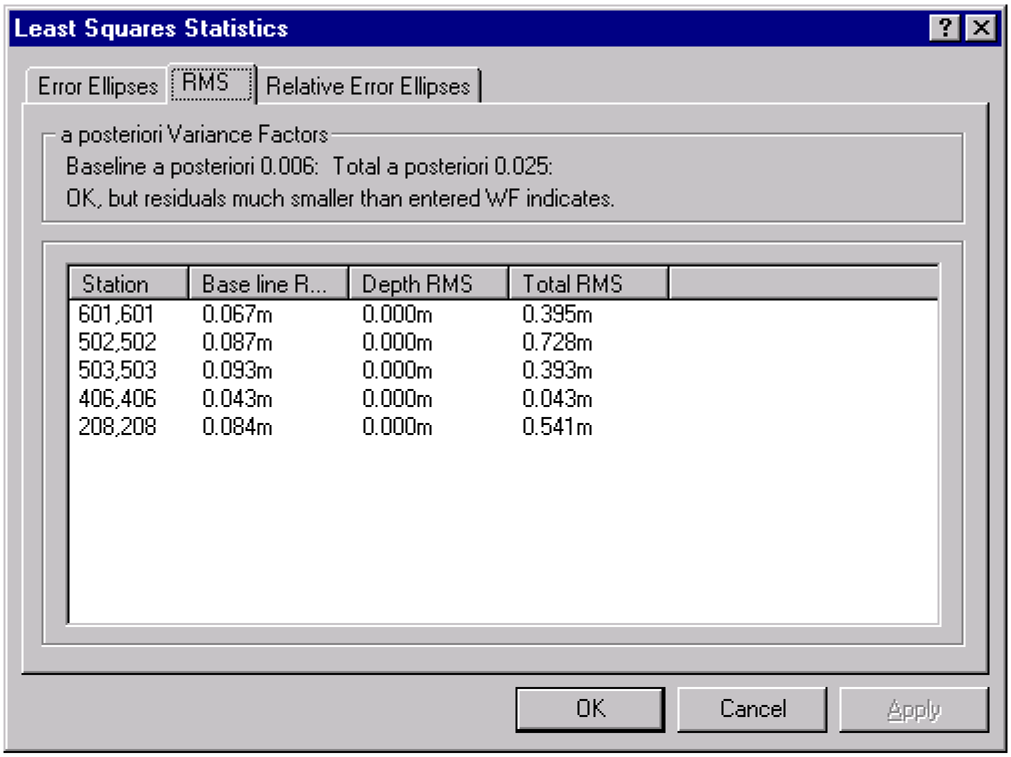
The first column gives the station name and the associated transponder address. If a station is occupied by more than one transponder, only the first transponder found is displayed.

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



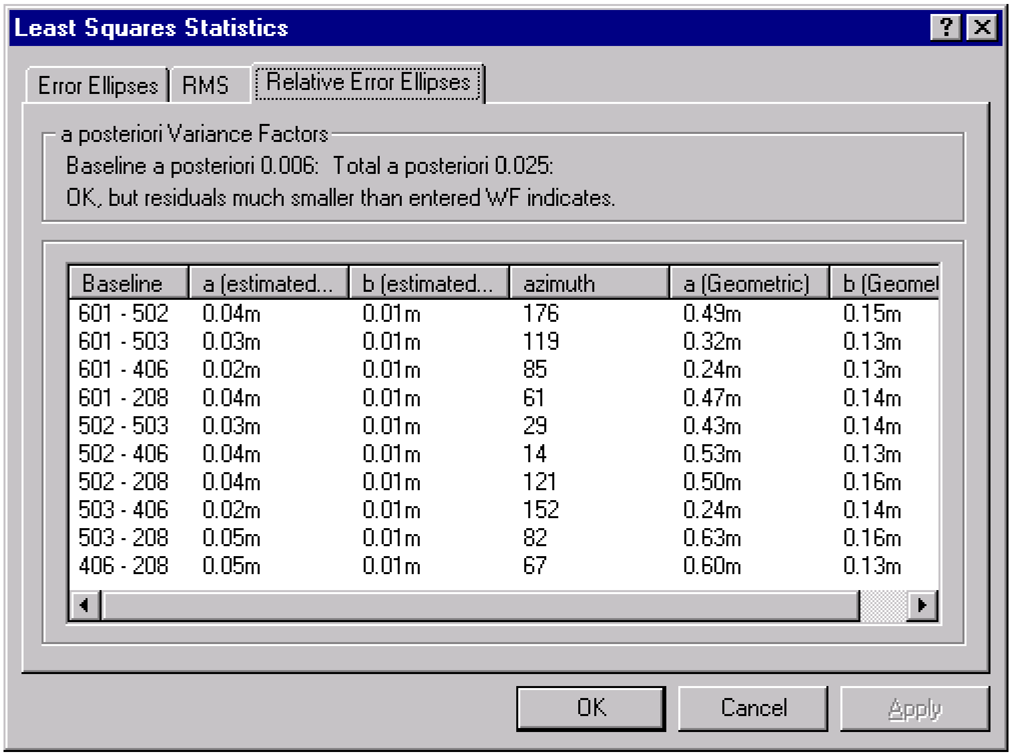
This tab presents the solution RMS values.

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.

Editing Calibration Station Information

The station information contained in the Calibration data set is essentially a copy of the **Working Xponders** file that was active when the calibration dialog was first opened to start a calibration data collection.

This Calibration data set station information is checked against the current **Working Xponders** file every time the Calibration dialog is re-opened or a Calibration data file is loaded. At these times you are informed of differences detected between the coordinates for the same station in both the **Working Xponders** file and the Calibration data set. In addition, stations that are in the **Working Xponders** file but not in the Calibration data set are detected and you are so informed of the discrepancy. You can choose to update the Calibration data set from the **Working Xponders** file or ignore the **Working Xponders** file and continue only with the station information in the Calibration data set.

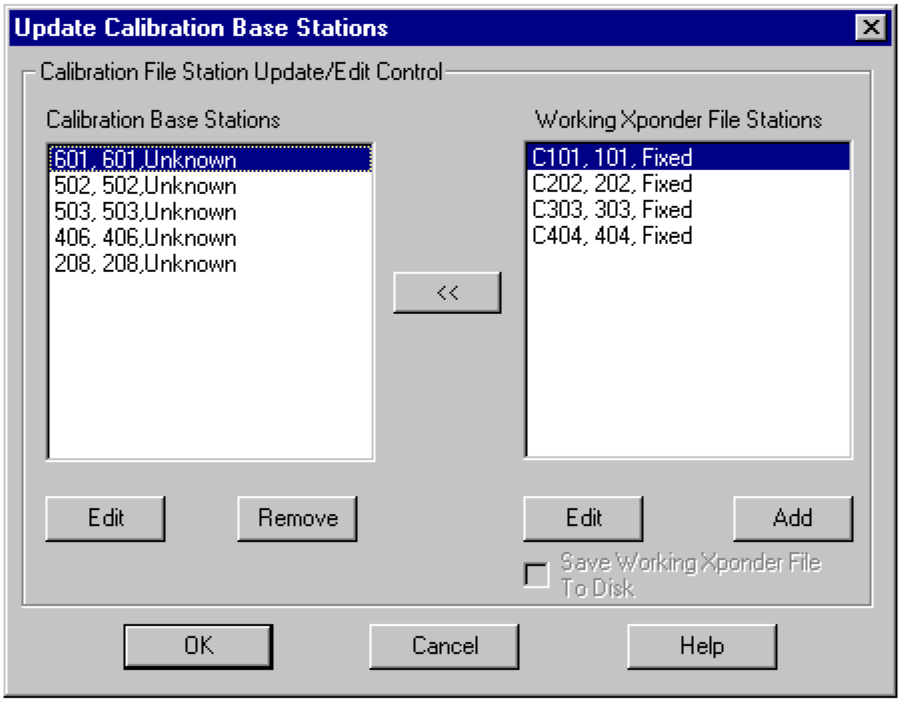
In addition to the aforementioned checks and options, when loading a Calibration file, you are prompted to either purge the existing Calibration data set station information before loading in new information or leave it and add the station data from the new Calibration data set to it.

Ultimately, the chance exists that the station information contained in the Calibration data set requires editing and/or cleaning out.

The editing of the Calibration data set station information may also be required to configure settings not supported in previous WinFrog versions and therefore not optimally configured when an old Calibration file is loaded for review or re-processing.

And finally, the editing of the Calibration data set station information may be required due to a calibration processing that due to bad data that was not edited out first, corrupting the solution to the point where the coordinates for the stations are in error to the magnitude that a solution with properly edited data is not possible without re-initializing the starting station coordinates.

To edit the Calibration data set station information, click the **Edit Xponder** button in the **Calibration** dialog. This accesses the **Update Calibration Base Stations** dialog.



The **Calibration Base Station** list box lists the stations currently in the Calibration data set by station name, transponder address and type. Note that if a station is occupied by more than one transponder, all instances are listed here. You must take care not to corrupt the coordinates. They are all available because the **Height Above Monument** setting can be configured from here. If the coordinate for one changes, you must also change the other from here.

The **Working Xponder File Stations** list box lists the stations contained in the current **Working Xponder** file. Note that if there is currently no **Working Xponder** file, this list box states this and no editing or adding of **Working Xponder** file stations can be performed.

The options available are as follows:

- Edit a Calibration Base station
- Remove a Calibration Base station
- Copy a new station from the **Working Xponder** file to the Calibration data
- Update an existing station in the Calibration data from the **Working Xponder** file
- Edit a **Working Xponder** file station
- Add a **Working Xponder** file station
- Force the **Working Xponder** file to write out to the disk when exiting this dialog.

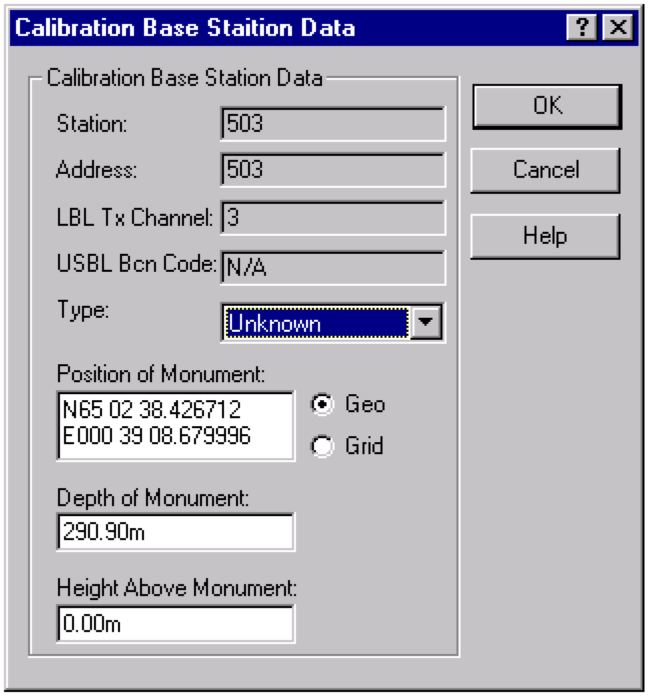
To Edit a Calibration Base Station

1 Highlight a station in the **Calibration Base Station** list.

2 Click the **Edit** button directly below this list box.

Or

3 Double-click on the station in the **Calibration Base Station** list that is to be edited.



4 This dialog displays the station name, address of an LBL transponder, the transmit channel or frequency of an LBL transponder and the beacon code of a USBL transponder. These are not configurable from this dialog. To change any of these settings, the same station in the **Working Xponder** file must be edited (see **To Edit a Working Xponder File Transponder**) and then used to update the Calibration data set version (see **To Update the Calibration Data Set Station Information**).

You can edit the following items:

- **Type**
- **Position of Monument**
- **Depth of Monument**
- **Height Above Monument**

5 Edit the station information as required.

6 Click **OK** to exit and apply the station information changes, or **Cancel** to exit and discard any changes made.

To Remove a Calibration Base Station

1 Highlight a station in the **Calibration Base Station** list.

2 Click the **Remove** button directly below this list box.

3 Respond to the confirmation prompt accordingly, **Yes** to continue with the remove process or **No** to cancel the operation.

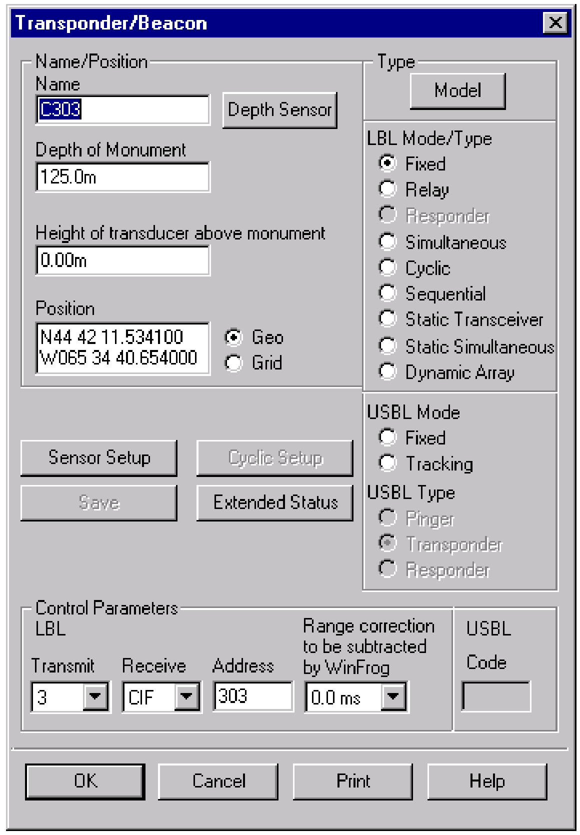
To Edit a Working Xponder File Station

1 Highlight a station in the **Working Xponder File Stations** list.

2 Click the **Edit** button directly below this list box.

Or

3 Double-click on the station in the **Working Xponder File Stations** list that is to be edited.

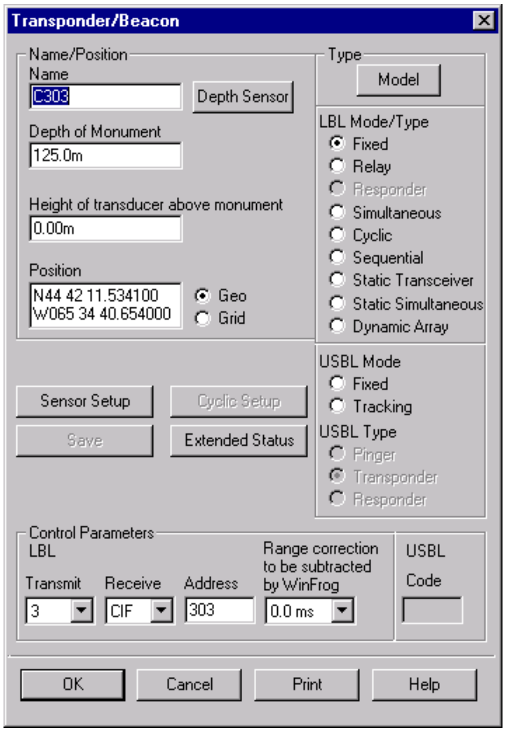


4 See the **Working Xponders File** section in the **Working Files** chapter for information on editing the Xponder station. Edit the station information as required.

5 Click **OK** to exit and apply the xponder station changes, or **Cancel** to exit and discard any changes made.

To Add a Working Xponder File Station

1 Click the **Add** button directly below the **Working Xponder File Stations** list.



2 See the **Working Xponders File** section in the **Working Files** chapter for information on editing the Xponder station. Edit the station information as required.

3 Click **OK** to exit and add the new xponder station, or **Cancel** to exit and discard the new Xponder.

To Update a Calibration Base Station

1 Highlight a station in the **Working Xponder File Stations** list.

2 Click the arrow button located between the two list boxes.

3 The calibration data set station information is checked for the existence of a selected station. The match is based first on matching the Station name. Then, in the case of the calibration data set station being an LBL transponder, a match of the address is checked for, or in the case of those transponders that do not use addresses, the transmit code. If the calibration data set station is a USBL beacon, the beacon code is checked for a match. If a match is found, the Calibration copy is updated with the **Working Xponder** file version.

4 If the station does not already exist in the Calibration data set station information, the station is added.

Note: If a calibration data set station requires an update of the address, transmit code or beacon code, you must first remove the calibration data set copy, then select the required **Xponder File** station and then follow the steps above.

To Complete the Base Station Editing

1 If any changes to the **Working Xponder** file have been detected, the **Save Working Xponder File to Disk** checkbox is activated. If the modified **Working Xponder** file is to be immediately saved to disk, check this box.

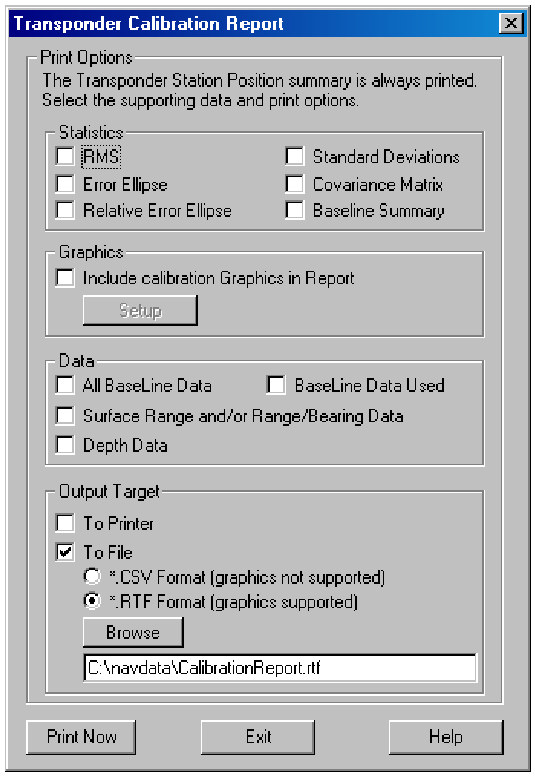
2 Click **OK** to exit the **Update Calibration Base Stations** dialog and apply the changes made, or click **Cancel** to exit discarding all changes made.

LBL Calibration Report

You can print an **LBL Calibration Report** at any time during the LBL calibration processing. The report can be printed directly to the default Windows printer or to an rtf format file.

To Print an LBL Calibration Report

1 From the **Calibration** dialog box, click the **Xpdr Report** button to access the **Transponder Calibration Report** dialog.



2 The report always includes the following items:

- Calibration Overview
  - Date report printed
  - Date/time calibration data collection was started
  - Date/time calibration data collection was completed
  - Total number of surface ranges observed/used (percentage)
  - Total number of baselines observed/used (percentage)
  - Total number of depths observed/used (percentage)
- Files
  - Name of current calibration file and dated/time saved
  - Current Working Xponder file (not necessarily the one used for the calibration)

- Current Working Velocities file (not necessarily the one used for the calibration)
- Geodetics
  - Datum name
  - Ellipsoid name
  - Map Projection
- Calibration Configuration and Constraints
  - Station solution configuration (what was solved for, what was held fixed, what was not used)
  - Constraints used
- Basic Statistical Analysis
  - a posteriori variance factor for complete adjustment
  - a posteriori variance factor for baselines only
  - Chi Squared test results
- Transponder Station Position Summary Table
  - Station name
  - Geographic coordinates
  - Map Projection coordinates
  - Depth

3 The supporting data options to include with the report are selected. The options are as follows:

- Statistics
  - RMS for each station
    - Based upon baselines only
    - Based upon depths only
    - All associated observations
  - Absolute error ellipse for each station
    - Semi-major and minor axis scaled by the a posteriori variance factor (for the baseline component only) representing both the geometry and the quality of the baselines.
    - Orientation of the semi-major axis
    - Semi-major and minor axis not scaled by the any a posteriori variance factor and therefore representing the geometry only
  - Relative error ellipse for all stations
    - Semi-major and minor axis scaled by the a posteriori variance factor (for the baseline component only) representing both the geometry and the quality of the baselines.
    - Orientation of the semi-major axis
    - Semi-major and minor axis not scaled by the any a posteriori variance factor and therefore representing the geometry only
  - Standard Deviations
  - Covariance Matrix
  - Baseline Summary
    - For every baseline pair the following information is presented for all observations made *Forward* and *Reverse* (note that observations are

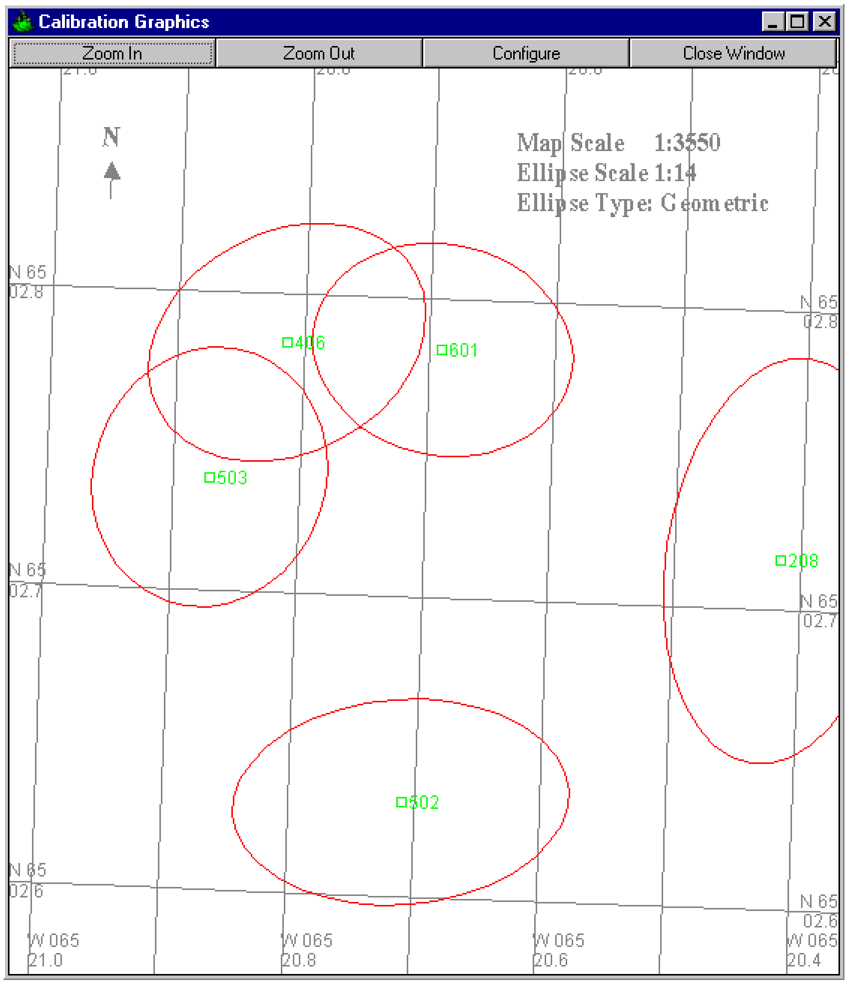
displayed as slant ranges reduced to the Map Grid):

- Number of observations made
- Number of observations weighted in the solution (used)
- Percentage of observations weighted in the solution (used)
- Mean of the weighted observation
- Standard deviation of the weighted observations.
- Minimum weighted observation
- Maximum weighted observation
- RMS of residuals of the weighted observations

- Graphics
  - Graphic representation of the transponder array and supporting data (see step 4)
- Data
  - All Baseline Data
    - The data set is searched and all baseline observations are grouped by their to/from stations and presented in separate tables, with each pair being presented in two tables – one each for observations in each direction.
    - The data includes the raw TWTT observations, scaled LOPs (slant range distances reduced to the Map Grid), weighting factor and residuals.
    - The mean raw baseline (TWTT in ms), mean reduced baseline (grid slope range) and the RMS for the residuals are included in the table, though it should be noted that the mean values are not used directly in the calibration solution and are included for evaluation only.
    - The data is presented in tabular form.
  - Baseline Data Used
    - Same as the All Baseline Data option except only those baseline observations weighted in the solution are presented.
  - Depth Data
    - The data set is searched and all depths for each station are grouped and presented in separate tables.
    - The data includes the raw data, scaled data, weighting factor and residuals.
    - The mean raw data, mean scaled data and the RMS for the residuals are included in the table, though it should be noted that the mean values are not used directly in the calibration solution and are included for evaluation only.
  - Surface Range or Range/Bearing Data
    - For each data collection epoch the following is printed:
      - The data point number, epoch date/time and data item
      - Vehicle geographic and grid position at this epoch
      - Vehicle heading, course made good and speed at this epoch
      - The LOP data is then presented in a table listing the following:
        - LOP ID
        - Base Stn Name
        - Raw LOP
        - Reduced LOP
        - Weight Factor
        - Residual
        - Deskew value

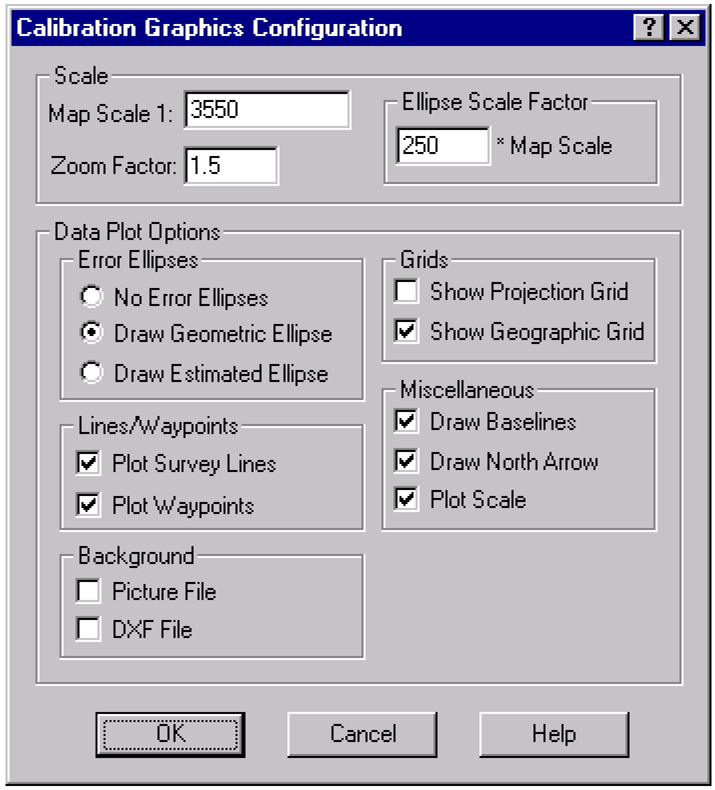
4 If selected to include in the report, configure Graphic options. Click the Setup button in the Graphics panel.

- The **Calibration Graphics** window pops up.



The Zoom In and Out buttons can be used to examine the graphics window in detail. However, the printing of the graphics has been normalized to always plot the same size on paper.

- Click the **Configure** button.



- Select the options:
  - Scale
    - Map Scale
    - Zoom Factor (only affects viewing the Calibration Graphics window, the print out is normalized to always print the same size and area.
  - Ellipse Scale Factor
    - In order to better see the error ellipse, they can be scaled relative to the map scale used to draw the rest of the graphics.
  - Data Plot Options
    - Error Ellipses
      - No error ellipses drawn
      - Draw the Geometric ellipse (non-scaled ellipse)
      - Draw the Estimated Ellipse (scaled by the baseline a posteriori variance factor)
    - Lines/Waypoints
      - Plot current Survey Lines file
      - Plot current Waypoint file
    - Background
      - Plot current Picture file
      - Plot current DXF file
    - Grids
      - Plot the Map Projection grid
      - Plot the Geographic grid
    - Miscellaneous
      - Draw the baselines observed

- Draw a North Arrow
- Draw the scale used

- Click the **OK** button to exit and apply the settings or **Cancel** to exit discarding the settings.

5 Select the output options from the following:

- To Printer
  The data is formatted and printed directly to the printer in a report ready format utilizing *.rtf file formatting features using a temporary rtf file.
- To File
  The report is written to the selected file.
- *.csv Format

The data mimics the printed report except that all data is comma delimited, including the tables. It ports directly into Excel. This format does not support graphics and therefore, even if selected, are not printed to this file.

- *.rtf Format
  This file report is the same as the printed report. The temporary rtf file used to generate the printed report is copied to the selected file. This format supports the graphics option.
- Browse to select/set destination file
  - Enables you to browse and select/set the destination file
- Display/edit destination file directly
  - Displays the name and path of the destination file as well as allowing for direct entry of the destination file.

6 Click **Print Now** to exit the dialog and generate the printout or file as set. When printing the report to a file, WinFrog checks for duplicate file names. If a duplicate file name is found, you are asked if you wish to select a new file, in which case you can browse to select/set the new destination file. If this option is refused, you are asked if you wish to over-write the existing file or not. If it is decided not to over-write the file, the output to the file is aborted.

Or

7 Click **Exit** to exit without generating a report.

Recalculate LBL Data

Due to the configuration of WinFrog at the time of observation, it may be necessary to recalculate the reduced LOPs.

Examples of such situations are as follows:

- Invalid Working Velocities file used or a better one is now available.
- Incorrect turn-around-time (TAT) used for a transponder(s).
- Initial depth values used for the stations in error by tens of meters or more and thus potentially impacting the real-time projection of the observed range and

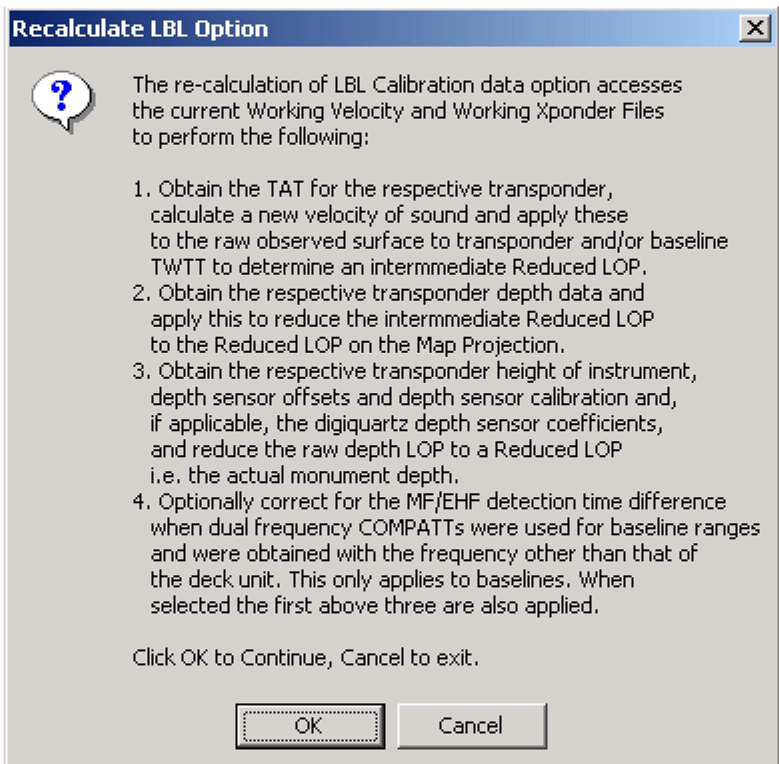
baseline data to the map projection.

- Incorrect HI used for a transponder(s), depth sensor offset or calibration value.
- Incorrect digiquartz depth sensor coefficients used.
- Dual frequency COMPATT detection time correction was not applied when data was collected. (Sonardyne COMPATTs only)

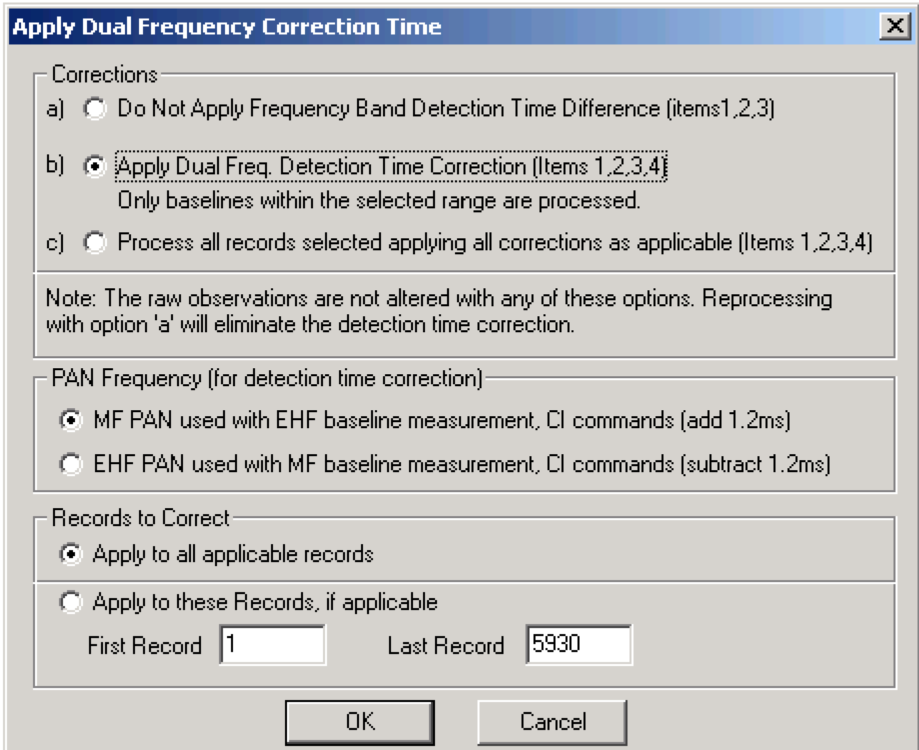
WinFrog allows for the recalculation of the reduced data from the raw data provided that correct Working Velocities and Working Xponders files are present when this is executed.

Note: The calibration file base station data is not automatically updated from the Working Xponder file data when the recalculate option is executed. The exception is any base station that has a depth observation associated with it. You must use the **Edit Xponder** feature to do this (see **Editing Calibration Station Information).**

Click the **Recalc LBL** button in the Calibration dialog. The following message box appears to inform you of exactly which recalculations will be performed.



Click **OK** to continue with the recalculation process or **Cancel** to abort. Clicking **OK** results in the display of the **Apply Dual Frequency Correction Time** dialog box.



Corrections

The top choice 'a' is for all but Sonardyne transponders. It is also the choice if the Sonardyne transponders were not dual frequency.

The second choice 'b' will allow one to correct baseline measurements if dual frequency Sonardyne transponders were used to collect the baselines and the frequency correction was not applied. This situation arises when the PAN or MK5 RovNav is one frequency, say MF, but the baselines were measured with the other frequency of the COMPATTS, in this case EHF. Because the PAN in this example is MF it will remove the MF detection time so the baselines need to be corrected by the difference between the EHF and MF detection times. Choose whether to add or subtract the correction from the group box **PAN frequency** below. Since the correction is applied to the raw data, all the computations listed (e.g. sound velocity, TAT, etc.) need to be performed. In this selection only baselines are recomputed.

The third choice 'c' will reprocess all observations and will apply the detection time correction mentioned above to the baselines.

Records to Correct

The Records to Correct group allows you to select specific records to process or all of them. The reference to 'those applicable' means that if option b above is selected only baselines will be recomputed.

If the re-calculation of the scaled LBL LOP is **successful**, you will see an information message box stating:

Re-calculation of Scaled LBL LOPs successfully completed

If the re-calculation was **unsuccessful**, a warning message box appears and provides information concerning the problem encountered. The warning messages are listed below:

General

- No Working Xponder File, unable to re-process LOPs
- No Working Velocity File, unable to re-process LOPs
- Continued un-reported errors...

The message 'Continued un-reported errors' only appears if the number of warnings results in a message that exceeds the allowed length.

Baselines

- Record 278, Transponder T106 to T110 (BL 4) depth(s) outside Velocity File extents.
- Record 281, Transponder Address 106 baseline to Tx code 13 , To Transponder not in Xponder File.
- Record 276, Transponder Address 113 not in Xponder File.

Ranges

- Record 23, Transponder T106 depth outside Velocity File extents.
- Record 56, Transponder Address 107, Tx Code7, not in Xponder File.

Depths

- Record 23, Station T106, Transponder Address not in Xponder File.

Note: the appearance of any warning at all indicates the need to review the associated files to ensure the processing is being correctly applied.

Summary of the LBL Calibration Process

1 Evaluate the requirements and design the network array to provide the required coverage and geometry. Prepare the route that the vessel will follow to perform the data collection.

2 Deploy the array ensuring that reasonable estimates of the transponder positions are logged.

3 Review the directory on the WinFrog computer, to ensure that there is an appropriate directory in which to store the calibration file(s). Prepare the naming procedure for the calibration files. It is recommended that the name reflect the transponder array, calibration number, and the date.

4 Ensure that the correct **Velocity** file is opened and set to be the **Working Velocity** file (first toggle any existing **Working Velocity** files to **not working**). Configure the **Vehicle Text** window to display the **Working Velocity** file name.

5 Create a new Xponder file, open it, and set it to be the **Working Transponder** file. Add the relevant stations and transponder information with the correct parameters, including the best estimates for the positions. Address any double occupancy issues. The **Vehicle Text** window should be configured to display the **Working Xponder** file name.

6 Determine the depths of the deployed transponders as accurately as possible and enter these depths for the respective stations in the Xponder file.

7 Review the devices (as added to WinFrog) and the data items (as attached to the calibration vehicle).

- Ensure that all devices are valid. Remove any from the vehicle that are not currently operational.
- Check the configurations for the data items. Pay specific attention to the offsets and accuracy settings.

8 Finalize the data collection procedure and collect the data. Monitor the process to ensure any problems are detected quickly and addressed immediately. Save the data regularly to disk.

9 Upon completion of the data collection process, make sure the data are saved to disk. Using Windows Explorer™ or a similar application, copy the file to an archive directory, and set it to **read only**. This will secure the data prior to proceeding with the calibration processing.

10 Review the data, editing out (de-weighting) the obvious outliers. Use the graphical editor, to view the LOPs, not the residuals.

11 Setup the calibration and solve. If the solution does not converge, review this manual for potential reasons and address them. If the solution does converge, review the data using both the LOP and residual graphical editors. Refine the editing by removing any questionable data.

12 Repeat Step 11 until the calibration solution is optimized, indicated by the transponder coordinates remaining unchanged between iterations, the correction values remaining unchanged between iterations, residuals for the used LOPs consistent with the expected accuracy of the systems used, an acceptable a posteriori variance, and passing of the c^2 test.

13 Save the calibration data to a final calibration file and print a report. Remove any unwanted, intermediate calibration files from the directory.