SOP-009 LBL PROCEDURE

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## REVISION HISTORY

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Section</th>
<th>Revision Description</th>
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<tbody>
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<td>20 May 11</td>
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</tbody>
</table>
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 INTRODUCTION</td>
<td>5</td>
</tr>
<tr>
<td>1.1 Purpose</td>
<td>5</td>
</tr>
<tr>
<td>1.2 Scope</td>
<td>5</td>
</tr>
<tr>
<td>1.3 Definitions and Abbreviations</td>
<td>5</td>
</tr>
<tr>
<td>2 RESPONSIBILITIES</td>
<td>6</td>
</tr>
<tr>
<td>2.1 Survey Manager/ Chief Surveyor</td>
<td>6</td>
</tr>
<tr>
<td>2.2 QHSE Manager</td>
<td>6</td>
</tr>
<tr>
<td>2.3 Project Manager</td>
<td>6</td>
</tr>
<tr>
<td>2.4 Party Chief or UTEC Senior Site Representative</td>
<td>6</td>
</tr>
<tr>
<td>2.5 Acoustic Engineer</td>
<td>7</td>
</tr>
<tr>
<td>2.6 Survey Team</td>
<td>7</td>
</tr>
<tr>
<td>3 HEALTH AND SAFETY</td>
<td>8</td>
</tr>
<tr>
<td>4 OVERVIEW OF LBL SYSTEMS</td>
<td>9</td>
</tr>
<tr>
<td>4.1 Definition of LBL Positioning</td>
<td>9</td>
</tr>
<tr>
<td>4.2 LBL Accuracy</td>
<td>10</td>
</tr>
<tr>
<td>4.3 LBL Equipment</td>
<td>10</td>
</tr>
<tr>
<td>4.4 Auxiliary equipment</td>
<td>11</td>
</tr>
<tr>
<td>4.5 LBL Navigation Methods</td>
<td>11</td>
</tr>
<tr>
<td>5 CALIBRATION, DEPLOYMENT AND RECOVERY OF LBL SYSTEMS</td>
<td>13</td>
</tr>
<tr>
<td>5.1 General Principles</td>
<td>13</td>
</tr>
<tr>
<td>5.2 Array Planning</td>
<td>13</td>
</tr>
<tr>
<td>5.3 Deployment of the Array</td>
<td>14</td>
</tr>
<tr>
<td>5.4 Baseline Measurement – Relative Calibration Method</td>
<td>17</td>
</tr>
<tr>
<td>5.5 Single BOX-IN – Absolute Calibration Method</td>
<td>17</td>
</tr>
<tr>
<td>5.6 Multiple BOX-IN – Absolute Calibration Method</td>
<td>19</td>
</tr>
<tr>
<td>5.7 Cloverleaf and Other Patterns – Absolute Calibration Method</td>
<td>19</td>
</tr>
<tr>
<td>5.8 Adjustment of the Array</td>
<td>21</td>
</tr>
<tr>
<td>5.9 Recovery of the Array</td>
<td>22</td>
</tr>
<tr>
<td>6 LBL OPERATIONS</td>
<td>23</td>
</tr>
<tr>
<td>6.1 Surface Vessel Tracking</td>
<td>23</td>
</tr>
<tr>
<td>6.2 ROV Tracking</td>
<td>23</td>
</tr>
</tbody>
</table>
6.3 Multiple Vehicle Tracking 23
6.4 Structure Installation 24
6.5 Metrology 24
6.6 Pipelay Operations 25
6.7 Marker Buoy Installation 25
6.8 Drilling Operation 25

7 REFERENCES 27
7.1 UTEC References 27
7.2 External References 27

8 APPENDICES 28
1 INTRODUCTION

1.1 Purpose

The purpose of this procedure is to detail the requirements and responsibilities for the calibration, installation, and operation of LBL equipment so that accurate acoustic survey operations are carried out. It is intended to ensure UTEC employ industry best practice and meet customer expectations.

1.2 Scope

The procedure is to be followed by all UTEC personnel. It details the processes and responsibilities for the installation, calibration and operation of equipment used in LBL operations so as to ensure effective and accurate use. The procedure details the accuracy of instrumentation used, installation and tooling, calibration requirements, operation methods and reporting requirements.

1.3 Definitions and Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-O</td>
<td>Calculated minus Observed</td>
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<tr>
<td>CTD</td>
<td>Conductivity, Temperature and Depth</td>
</tr>
<tr>
<td>LBL</td>
<td>Long Baseline</td>
</tr>
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<td>LOP</td>
<td>Lines of Position</td>
</tr>
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<td>QC</td>
<td>Quality Control</td>
</tr>
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<td>RMS</td>
<td>Root Mean Square</td>
</tr>
<tr>
<td>ROV</td>
<td>Remotely Operated Vehicle</td>
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<td>SV</td>
<td>Sound Velocity</td>
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<td>SVS</td>
<td>Sound Velocity Sensor</td>
</tr>
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<td>TAT</td>
<td>Turn Around Time</td>
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<tr>
<td>USBL</td>
<td>Ultra Short Baseline</td>
</tr>
</tbody>
</table>
2 RESPONSIBILITIES

2.1 Survey Manager/ Chief Surveyor

The Survey Manager is responsible for:

- Ensuring the LBL Procedure is based on industry best practice and that the content of the procedure is regularly reviewed and revised where necessary, when improvements in technology or practice are identified; and,
- Ensuring that the Survey Team includes personnel competent to carry out the tasks involved in carrying out LBL operations.

2.2 QHSE Manager

The QHSE Manager is responsible for:

- Ensuring that the LBL Procedure is adequately controlled with regards to review, revision and approval, and that the relevant version is available at the point of use.

2.3 Project Manager

The Project Manager is responsible for:

- Ensuring that all project personnel are aware of their responsibilities with regards to the LBL Procedure;
- Ensuring that adequately certified equipment is supplied to the project to meet customer specification; and,
- Ensuring that any hazards associated with the tasks involved are adequately risk assessed and that project personnel are made aware of these hazards.

2.4 Party Chief or UTEC Senior Site Representative

The Party Chief or UTEC Senior Site Representative is responsible for:

- Ensuring that the Survey Team follow the requirements of the LBL Procedure during operations;
- Ensuring that the QHSE including risk assessment, toolbox talks and SIPs (Safety in Progress) must be carried out aboard;
- Advising the Project Manager when any deviations from the procedure is felt necessary due to changes in operational method, procedural inadequacy or change in project specific requirements; and,
- Review, verification and approval of the LBL Results.
2.5 **Acoustic Engineer**

The Acoustic Engineer is responsible for:

- Ensuring that equipment is installed, tested and maintained in accordance with this procedure;
- Deployment and recovery of LBL equipment;
- Acquisition and processing of data to produce the LBL results; and,
- Recording deployment, recovery and results from in operations in the appropriate logs.

2.6 **Survey Team**

All members of the Survey Team are responsible for:

- Ensuring that they follow the requirements of the LBL Procedure during operations; and,
- Ensuring that they comply with all controls in place to protect the health and safety of themselves and others.
3 HEALTH AND SAFETY

Installation, testing, maintenance and deployment of LBL equipment are potentially hazardous activities. Most, but not all, of these hazards occur during mobilisation of the equipment and are dealt with in SOP-001 Mobilisation Procedure. Prior to commencement of any activities related to this procedure a risk assessment shall have taken place to ensure that all hazards have been identified, the associated risk assessed and that all personnel are aware of the necessary control measures. Particular attention should be taken to ensure that adequate controls are in place in relation to deployment of transponders.
4 OVERVIEW OF LBL SYSTEMS

4.1 Definition of LBL Positioning

LBL (Long Baseline) is the method used to position objects on the seabed or in the water column using the observation of ranges from a mobile transceiver or transponder to an array of transponders whose absolute or relative positions are known. This produces a precise positioning system whose relative accuracy is independent of water depth.

An LBL system is comprised of two primary components – fixed transponders on the seabed in a calibrated array and a mobile transducer or transponder which takes ranges to the fixed transponders in order to determine the position of the transducer or transponder.

LBL positioning can be used in the following sample applications:

- Surface Vessel Tracking;
- ROV Tracking;
- Multiple Vehicle tracking;
- Structure and Jacket Installation;
- Metrology;
- Pipe-lay Operations;
- Marker Buoy Installation; and,
- Drilling Operations.

An LBL system may be configured to perform tasks such as positioning subsea structures using input from gyros, digiquartz depth sensors and inclinometers to refine the positioning and determine structure or vehicle attitude.

For further reference to LBL Positioning theory refer to the Sonardyne document, *Sonardyne LBL Long Baseline Positioning Theory TD_07_02LBL_IssA_Rev0*.

LBL positioning is a four stage process:

1. Planning – preparation onshore to determine the best geometric layout for the subsea array with regard to the structures, seabed topography, deployment methods of the equipment and the required accuracy.

2. Array deployment.

3. Array Calibration – process to determine the best estimates of the transponder positions in the array.

4. Tracking – actual application of the transponder array to derive positions for the structure or vehicle to be tracked or positioned.
4.2 LBL Accuracy

Sonardyne, who are the market leaders in LBL Positioning Systems have stated that their Wideband Compatt 5 can achieve range accuracies of better than 0.03m independent of water depth. Validation tests have also been carried out which confirm range accuracies of +/- 0.03m.

Kongsberg also have a Multi User LBL (MULBL) system however it is more normal to be used for dynamic positioning purposes rather than surveying purposes.

The method used in the positioning solution for LBL is “trilateration” employing the geometry of triangles similar to triangulation; however, instead of using measurement of angles and one known distance, trilateration uses known locations of two or more references and the measured distances from these references to the item to be positioned. This means the system requires three or more measured distances from references to calculate the solution. However, this is the minimum number in order to compute an unambiguous position. In order to provide redundancy and QC parameters, at least 4, but preferably 5 to 6 ranges are required. While positioning within an LBL array the depths of the array transponders require regular updating to account for tidal changes, which would otherwise cause a mismatch between the array and the measured depth of the object being positioned.

As trilateration is a range only solution, geometry has a significant effect on the quality of a position fix. The optimal angle subtended by the intersection of lines of position (LOP) formed by circles of constant range from any two reference points is 90°. The uncertainty (error) associated with each LOP means that the possible position of the “fix” lies within an error ellipse the dimensions of which will increase as the angle of cut becomes more acute. For this reason, the angle of cut between LOPs should be limited to between 45° and 135°. The estimated size of the error is reported as the RMS.

When tracking a vehicle most LBL navigation software uses Least Squares Position estimation or a kalman filter. Once the best estimate for a position is derived, it can be used as a reference for expressing variation in the measured values. The differences between this best estimate and the measured values are known as the residuals. The residuals and RMS provide the QC factors for the system.

4.3 LBL Equipment

Although actual project requirements will differ, typically the equipment for an LBL project will be as follows:

• Vessel Surface Positioning System (DGPS);
• USBL System (Kongsberg HiPAP or Sonardyne Ranger System);
• Vessel mounted survey class gyro;
• Vessel mounted Pitch and Roll Attitude Sensor;
• ROV mounted Pitch and Roll Attitude Sensor;
• ROV mounted survey class gyro;
• ROV mounted Bathymetric Sensor and Altimeter or Paroscientific Depth Sensor;
• ROV mounted CTD or SVS Probe;
• Sonardyne Fusion LBL System comprising:
  o Sonardyne Compatt 5(Wideband) – The number of transponders required will depend on the operation required, however the following need to be taken into account when planning:
    • Geometry
    • Redundancy
    • Line of sight;
  o RovNav 5 Transceiver with MF remote transducer;
  o Navigation Computer with Fusion LBL Software; and,
  o Navigation Controller Unit (NCU).

All equipment will be installed and calibrated as per UTEC standard procedures and the manufacturer’s manuals.

4.4 Auxiliary equipment

For projects where high accuracy is required to install subsea structures using the LBL system specialist Compatts may be required; these may be fitted with digiquartz depth sensors, inclinometers or sound velocity sensors.

The use of stabs and receptacles provide the highest accuracy and repeatability of measurements. These have the advantage of allowing instrumentation to be changed subsea without the need to recover the structure and reduce the number of spares required. Details of these are available in SOP-014 Metrology Procedure.

4.5 LBL Navigation Methods

As they are rarely used, cyclic and sequential methods of navigation are not covered in this procedure. If required the manufacturers documentation should be consulted.

For all navigation methods the turnaround time (TAT) for the transponders should be set to avoid replies arriving at the transducer at the same time (pulse overlap). Care should be taken as increasing the turnaround time to avoid pulse overlap may cause the update rate to increase significantly. In this case it is better to have redundant transponders within the array which can be turned on and off as required.

For all Navigation methods the depth of the array and appropriate sound velocity must be updated at regular intervals.
4.5.1 Standard LBL Positioning

Standard LBL positioning involves interrogations of an array by a transducer/transceiver which is connected to the surface unit. This may be pole mounted on a vessel or a RovNav transducer on an ROV. In order to achieve the maximum update rate the maximum range should be set to be appropriate for the array.

The depth of the transducer is required in order to accurately calculate the position. In the case of pole mounted systems this will be fixed, however this is not the case for ROV mounted systems. The RovNav bottle includes a depth sensor, which may be used, however the accuracy of this depth sensor must be appropriate e.g. a digiquartz sensor must be interfaced to the fusion system for high accuracy operations.

4.5.2 Simultaneous LBL Positioning

Simultaneous LBL positioning involves interrogations of an array by a transponder which then sends the range data back to a transducer or transceiver which may be either vessel or ROV mounted. The data is sent back by way of telemetry. In addition to the ranges the transponders depth is also transmitted.

If using tone signals and a normal baud rate the time to transmit two ranges is approximately one second. Therefore there is a trade off between having additional transponders for redundancy and the update rate of the fix. This is improved with wideband signals, however the principal remains.

4.5.3 Fast Simultaneous LBL Positioning

Fast simultaneous LBL positioning is the same in principle to Simultaneous LBL positioning. The difference is that the transponder being positioned must be in Fast Simultaneous mode. In this mode the receipt of a single signal on the interrogation frequency of the transponder will trigger an interrogation of the array. This can lead to problems if there is an unplanned source of the interrogation frequency e.g. another transponder within the array or a USBL beacon which uses the same frequency. These problems are not as acute with wideband signals as a USBL interrogation is less likely to trigger an interrogation, however care should still be taken.

If it is suspected that an unplanned fast simultaneous interrogation is occurring, the Fast Simultaneous transponder must be disabled – this may take several attempts. Once the transponder is disabled the source of the trigger should be identified. Firstly, by checking that none of the array transponders are working on the same frequency, and, then by looking at external sources.

Note: Sonardyne Compatts with firmware V10.07s can have problems when using Wideband Fast Simultaneous. The solution to this is to increase the TAT of the mobile transponder to 250ms. See Sonardyne Technical Bulletin 07-009.
5 CALIBRATION, DEPLOYMENT AND RECOVERY OF LBL SYSTEMS

5.1 General Principles

The objectives of an array calibration are to define the co-ordinates for the seabed transponders, relative to each other and as a whole to the geodetic datum being used.

Sonardyne refer to the process of obtaining the coordinates of the transponders relative to each other as a “Relative Calibration” and the process of tying the array to the geodetic datum as an “Absolute Calibration”. For ease of understanding these terms are used in this procedure.

5.2 Array Planning

Array planning needs to take account of the following:

- Enough transponders to provide sufficient redundant ranges at all ‘target’ locations within the array;
- Minimize the number of transponders to keep costs down;
- Line of sight to the ‘target’ locations;
- Line of site between adjacent transponders for calibration;
- Good geometry for calibration and use. Each transponder should have acoustic line of sight to a minimum of three and preferably four other array transponders such that the angle of cut formed by adjacent LOPs is greater than 45° and less than 135°;
- Use of directional transponders for deep water calibration – note the distance between transponders for baseline measurement will need to be decreased;
- Frequency Management – In order to prevent interference within the LBL system being used or from external sources e.g. HPR on another vessel, the frequency of the transponders needs to be selected carefully. Prior to operations commencing, the frequency of any other acoustic systems in use in the field should be obtained. The channels chosen for operations should then be set to avoid clashes. Refer to the manufactures documentation for the latest frequency charts. Sonardyne arrays should be set to distinct families. The client should be informed of planned frequencies;
- Accuracy – When considering accuracy requirements the following should be considered:
  - What is the required positional accuracy at the 95% confidence level?
  - Where is positioning required both in terms of plan position and elevation above the seabed?
  - What deployment methods are available? Use of frames will provide a more accurate solution than weights and strops;
  - Is relative or absolute accuracy of importance?
  - Frequency of array depth measurements to adjust for tide
- Frequency and accuracy of Sound Velocity measurements; and,
- Length of baselines – Sound Velocity errors will be magnified over longer baselines

- Coverage – if positioning is only required in a localised area, for metrology for example, the array can be small. In general positioning should always be conducted within the bounds of the array. Due consideration must also be given to the masking effects of seabed topography and existing or proposed seabed structures. The array beacons must be located such that a minimum of three and preferably four LOPs are visible at the required depths in the expected target area(s);

- Calibration requirements – if the array is required to derive positions in a global reference frame it will be necessary to complete an “absolute calibration” to fix the orientation of the array with respect to true North. It is common practice to achieve this by “box-in” of the two transponders that form the longest baseline in the array. The accuracy with which the array can be orientated will depend upon the “box-in” accuracy and the baseline length. For this reason baselines of a few tens of metres may be acceptable in an array that will be used to record positions on a local grid, as in the example of spool metrology, but would not be appropriate for a project that required the installation of a seabed structure at a designated heading with respect to true North using LBL; and

- Ray Tracing – Using existing sound velocity data for the region and ray tracing software, areas of shadow due to refraction and maximum baseline lengths can be identified and the array modified if necessary.

In order to design the optimum array for the job the following information should be requested from the client:

- Water Depth;
- Tidal Variation;
- Sound Speed Profiles;
- Seabed Topography; and,
- Through-column and seabed currents.

### 5.3 Deployment of the Array

Once the array has been planned the user will have a set number of transponders to deploy. Prior to deploying transponders a JSA should be carried out. The appropriate safety equipment in terms of life jackets and safety lines should be used. If deployment involves any part of the body over the side of the vessel then a permit to work must be obtained.

Prior to deployment the transponder must be deck tested and as a minimum the following parameters recorded: Serial Number, Address, USBL code and depth reading on the surface. The conditions of any anodes and protection should be checked and replaced if necessary. Refer to the manufacturer’s documentation for the full list of checks for the instrument.
When a transponder is placed on the seabed, the approximate drop position of the transponder must be recorded in the log. The positioning method must be appropriate for the method of deployment and availability of positioning systems. At a minimum the vessel position must be logged.

5.3.1 Clump Weights and Floatation Collars

Standard transponders are fitted with a release mechanism. A D-shackle connected to a strop and clump weight is fitted to the release hook – Refer the manufacturer’s documentation for details on how to activate and prime the release mechanism. When ordering the shackles, check that they are the right size for the release mechanism.

A purpose made floatation collar is attached to the transponder. The floatation collars should be rated to the correct depth for operations.

For Sonardyne beacons the combined lift of the floatation and compatt in water is 35kg, therefore a weight 60 kg is appropriate. If sandbags are being used as weights then they should be double bagged to prevent loss of sand and the transponder floating away.

Strop length should be of a suitable length. Issues to consider are potential damage to the release mechanism during deployment, the amount of movement a longer strop will allow due to current, the topography and the accuracy required. A strop length of 2 metres is usual, this will allow approximately 0.25m of movement due to a current of 1 knot. Longer strop lengths may be required in areas of rough topography or steep slopes. These may significantly degrade the quality of the array. Proper planning using ray tracing software and a DTM of the seabed are preferable methods of overcoming difficult terrain.

If it is planned to release the transponders and recover after allowing the instrument to float to the surface, a recovery strop should be fitted to the top of the transponder. It is good practice to fit a recovery strop for all scenarios.

Deployment may be either by releasing from the surface and allowing the transponder c/w weights etc to free fall to the seabed or by ROV.

Two methods of release from the surface are suggested. If a crane is available the transponder and weight system is lifted over the side. Either a sacrificial strop or quick release mechanism is then used to free the transponder once the vessel is in the correct location for deployment. Alternatively if the stern of the vessel is open then the transponder may be streamed over the stern with the weight kept on board. When the vessel goes over the target location, the weight is pushed over the side. Personnel must be aware of any bite in the strop and the vessel must maintain forward motion to prevent entanglement.

Deployment by ROV may involve either the ROV taking the transponders down with them when they launch (in either the manipulator or hanging from the TMS/garage) or deployed either singly by crane or in multiples by basket. USBL is then used to guide the ROV to the drop location.
5.3.2 Fast Markers and Floatation Collars

Fast Markers are a specialised weight which consists of a weighted base with a vertical hook and a pad eye on the top. The transponder is prepared in the normal manner with floatation and recovery strop. The shackle is fitted to the release mechanism connected to a 5m strop. Approximately 1m below the transponder, a 150mm diameter ring is attached to the strop. The end of the strop is attached to the pad eye. A radar reflector near the top of the hook provides a strong reflective target for the ROV scanning sonar when replacing transponders or recovering the fast marker.

This method requires a crane for deployment. The transponder and fast marker system is lifted over the side. Either a sacrificial strop or quick release mechanism is then used to free the transponder once the vessel is in the correct location for deployment. Once on the bottom the ROV is then deployed to lower the transponder by hooking the ring onto the hook of the fast marker. It is usually more time efficient to deploy all the fast markers and then have the ROV lower the transponders in a single dive.

The advantages of the fast marker are that the strop is shorter and therefore the transponder will have less movement in any current. More importantly transponders may be changed out without the need to recalibrate, although check ranges to adjacent transponders is advisable.

To change out a transponder, the original transponder is released and recovered either by floating to the surface (refer Section 5.9) or by ROV. The ROV should ensure that it has a good grasp of the recovery strop prior to releasing the transponder. The replacement transponder may either be deployed from the vessel or taken down by the ROV. It is then carried to the fast marker and the ring on the new transponder strop is slipped onto the hook.

5.3.3 Seabed Frames

Seabed frames provide the most stable and accurate method of deployment. The design of the frame depends on the type of material on the seabed, line of sight requirements and methods of handling the frames. Typically the frame consists of a bucket with a funnel supported by a tripod arrangement. The funnel should be made from round bar to prevent multipath. The legs of the tripod should be on feet, usually flat plate with a spike below to prevent slippage. A flat plate should protrude from the bucket to provide a platform for Digiquartz measurements. ROV handles, anodes and padeyes should be placed appropriately.

The diameter of the bucket should be sufficient to allow the insert of a transponder with a spacer collar attached. Refer to the manufacturers’ specifications for the diameter of the transponder in use.

The base of the bucket should be rubber lined to prevent contact with metallic parts of the transponder. This is particularly important if the transponders are expected to be down for any length of time.
Spacer collars are not required if the transponder is unlikely to be changed, e.g. for metrology – once installed the transponder need only be stable for the baseline measurements.

Seabed frames are traditionally deployed by vessel crane or by ROV if it is safe to do so. Once on the bottom, the frames are placed in the correct position by ROV.

5.4 Baseline Measurement – Relative Calibration Method

The basic method for carrying out a baseline calibration is as follows:

A sound velocity profile must be produced prior to carrying out the baseline measurements. As a rule, a sound velocity profile should be obtained before and after baselines have been measured to ensure there are no changes in sound velocity.

Tides should be taken into consideration if the measurements are to be taken over a period of time. This can be either by correcting depth measurements for tide from tidal corrections or deriving local tidal corrections by designating one transponder as the reference and adjusting measured depths accordingly.

Once deployed in the correct formation, taking into consideration the geometry of the layout and the line of sight to and from each transponder, baseline measurements can be made between each transponder. This will be done using the appropriate system for the job specifications, nominally using Sonardyne's Fusion LBL system. If a vessel mounted system is not available, the ROV will be deployed with the RovNav 5 attached as the main transducer for measuring the baselines.

Depending on client specifications, 10 baselines will be measured to each transponder in both directions. It is a required practice to observe baseline distances in both directions to assist in the detection of bias due to multipath, sound speed variation or turn-around time discrepancies.

Where an absolute position is not required the data may then be processed and adjusted as described in Section 5.8. If an absolute position is required then data to relate the array to the geodetic datum should be acquired by one of the methods described in the sections which follow.

5.5 Single BOX-IN – Absolute Calibration Method

The single “box-in” is a method to determine an absolute position for a transponder on the seabed in order to relate the position of the array to the geodetic datum. At least two transponders need to be boxed-in, in order to carry out an absolute calibration, however the most accurate results are obtained by boxing in at least three transponders in order to best fit the array to the surface navigation system and provide adequate checks and redundancy.

In order to carry out a “box-in”, the vessel measures ranges from a surface mounted transducer – either a RovNav transducer mounted to a vessel pole or a USBL transceiver mounted on the vessel - to the transponders on the seabed. If
the vessel does not have a pole mounted RovNav for purposes of collecting data then the USBL system can be used. If the USBL system on board is Sonardyne then the box-in can be performed using Fusion. However if the USBL system on board is the Kongsberg HiPAP System then the data must either be collected separately and imported into Fusion using a spreadsheet with a specified format or calculated using third party software. In the latter case the position is entered into Fusion as an observation with the appropriate error. Fusion can then process this data and apply it to the calibration. File formats can be found in the Fusion Program Files directory of the installed Fusion Navigation Computer. Refer to the Fusion LBL User Manual for further guidance.

Sound velocity profiles should be measured prior to the box-in along with the depth of the transponder, to correct for any tidal variation between box-ins and applied to the Fusion LBL software and in the USBL system.

Noting that the objective is to produce a coordinate for a transponder on the Seabed, acceptable patterns are:

- Four headings at four cardinal points – provides the most accurate solution;
- Reciprocal headings at four cardinal points;
- Single heading at four cardinal points;
- Triangle on same heading – preferably run in both clockwise and anti-clockwise directions; and,
- Circle on varying heading – preferably run in both clockwise and anti-clockwise directions.

![Potential wind and sea direction](image)

*Figure 1 Example of Box-in on Reciprocal Headings at Cardinal Points*
Each set of data should consist of at least 50 fixes. Some software packages may have limits on the number of total fixes in which case this needs to be adjusted accordingly. The client may request more fixes at each location e.g. 100; however there is little gain by gathering further data and this will lengthen the time taken to carry out the calibration.

Experience has shown that a distance equal to water depth is sufficient in shallow water. When a directional beacon is being used or in deeper water, the distance may be limited to 50% of water depth. If the depth of water is such that a distance equal to the water depth causes loss of signal then the distance should be shortened until reliable ranges are obtained. The reliability of ranges should be tested through the noisiest sector – normally through the vessel thrusters wash.

5.6 Multiple BOX-IN – Absolute Calibration Method

If in deeper water and a Sonardyne pole is being used, it is valid to perform a box-in of multiple transponders simultaneously using one of the patterns described in Section 4.5 over the array. This will minimise errors introduced by tidal variations and substantially shorten the time taken to carry out the operation.

Sound velocity profiles should be measured prior to the box-in along with the depth of the transponders, and applied to the LBL software and in the USBL system.

The box-in should be centred over the geometric centre of the array. If the array is too large to provide reasonable coverage by this method, then either the “Clover Leaf” or “Reverse” box patterns shown in Section 5.7 should be used.

5.7 Cloverleaf and Other Patterns – Absolute Calibration Method

If a Sonardyne system is being used for the absolute calibration then the calibration data may be collected from all the transponders in the array simultaneously by the following methods. These methods have the advantage of providing the maximum data for a best fit of the array to the surface positioning whilst taking the same time as a single box-in.

- **Cloverleaf** – gathering simultaneous LBL ranges and surface positions whilst the vessel performs a cloverleaf manoeuvre over the entire array. Refer Figure 2 for details of the pattern for a clover leaf manoeuvre. To plan a Clover Leaf Manoeuvre always turn in the same direction e.g. to starboard.
• **Reverse Box** – gathering simultaneous LBL ranges and surface positions whilst the vessel steams in a box pattern in both directions. The reverse box should be at the centre of the array but need not encompass the whole array. This substantially decreases the steaming time and the data will not significantly degrade with the box sides being 50% of the distance across the array. Refer Figure 3 for details of the pattern for a reverse box manoeuvre.
Sound velocity profiles should be measured prior to the calibration along with the depth of the transponders, and applied to the LBL software and in the USBL system.

5.8 Adjustment of the Array

Adjustment of the array is carried out within the LBL software. Within Sonardyne’s Fusion software datasets form different stages of the adjustment, including “box-in” or other absolute calibration, may be combined to form a single data set which may be adjusted together.

Prior to adjustment, the dataset should be processed to remove any spurious data. This is particularly important for baseline data where the relatively small number of readings may have a high weighting due to the accuracy of the baseline measurements and outliers will have a disproportionate effect on the results. It may be necessary to re-measure some baselines. For this reason, the array should always be adjusted prior to recovery of any equipment.

When editing baselines one should look for early and late detections, noting that late detections are more likely than early detections. The spread and standard deviation of the dataset should be within acceptable limits for the purpose of the array. Prior to adjustment, the C-O for the baselines will be calculated from the initial coordinates. If the C-O is much larger than the accuracy of the initial coordinates, then an error should be suspected and investigated.
If the array is to be tied to external coordinates then these should be entered as observations with an appropriate associated error. External coordinates may be derived from “box-ins” or supplied from other sources e.g. client field data. The error associated with the coordinates should reflect the source and method of obtaining the coordinate. Holding coordinates completely fixed is likely to create distortions within the array and should be avoided.

Wideband measurements provide baselines of sufficient accuracy to allow 3d calculation. However, care should be taken as the vertical geometry is poor, although using the 3d calculation is a useful tool for identifying erroneous depth measurements. This is especially true if depths have not been reduced to a benchmark or correctly adjusted for tide.

When reviewing the QC statistics for the adjustment if any are seen to be larger than expected then the cause should be investigated.

The Calibration report should be exported and included in any reporting for the project.

5.9 Recovery of the Array

Prior to recovering an array a JSA should be carried out and appropriate safety equipment such as life jackets and safety lines used. If recovery involves any part of the body over the side of the vessel then a permit to work must be obtained.

The method of recovery will depend on the availability of a fast rescue craft, vessel and environmental restrictions, the availability of cranage and an ROV; where feasible, full recovery by ROV and crane/basket is preferred.

If the transponders have been deployed with floatation and weights, array recovery may be by either releasing the transponders and recovering them on the surface by the fast rescue craft or manoeuvring the vessel alongside the transponder and recovering directly to the vessel. In either case the potential for damage to the transducer and weight of the transponder and floatation should be highlighted to those carrying out the recovery.

Seabed frames require recovery by ROV or crane. The security of the equipment should be checked prior to recovering to the surface.

Once onboard any equipment should be washed down, checked for any damage and prepared for redeployment or demob.
6 LBL OPERATIONS

6.1 Surface Vessel Tracking

In addition to using LBL ranging from a surface vessel during calibrations it can also be used for surface vessel tracking when it is important to tie the surface positioning to subsea positioning during operations. Examples of this are:

- Mining where the position of the mining tool is dependent on the surface vessel position;
- Structure installation where the surface position is critical to operations and to provide redundancy for the surface navigation; and,
- Where the surface positioning is inadequate for the task. For example when the LBL positioning of the vessel within the array is more accurate relatively than the surface positioning or where the array has been installed by another vessel with more accurate surface positioning.

During these operations it is important to update the sound velocity through the full water column. Care should be taken to ensure that the depth of water is not too great and causing a weak geometrical solution.

Care should be taken to design the array taking into the account of the needs of surface positioning.

When using LBL for surface tracking the transducer must be mounted on a rigid pole.

6.2 ROV Tracking

LBL positioning can be used for tracking an ROV where the accuracy of the position of the ROV is important for operations either from a safety and general navigation point of view or where the sensors on the ROV need to be referenced to accurate positions for example during a pipeline survey.

Ideally, the ROV should be fitted with a real time Sound Velocity probe to provide continuous sound velocity information. This is important from an accuracy point of view and has the additional benefit of doing away with the need to stop operations in order to gather sound velocity information.

The transducer on the ROV should be mounted such that it has 360° line of sight around the vehicle. Where this is not possible due to potential damage to the transducer from the tether or during docking, it is recommended that the transducer be put on a small hydraulic RAM. This will allow it to be raised sufficiently to prevent acoustic shielding from the vehicle floatation.

6.3 Multiple Vehicle Tracking

Multiple vehicle positioning using LBL is available by sequentially interrogating the array from each vehicle or tracking each vehicle within two independent arrays by frequency management (different families) with wideband systems.
Multi vehicle tracking will not only allow multiple vehicles to be tracked but also allow the measurement of other sensors acoustically, e.g. the inclination or depth of the transponder, whilst tracking operations are ongoing.

6.4 **Structure Installation**

Structure Installation by LBL positioning involves installing transponders in known positions on the structure. The transponders then interrogate the array by simultaneous or fast simultaneous positioning methods and transmit the resulting ranges and transponder depth to the surface via acoustic telemetry.

Care should be taken to ensure that there are sufficient array transponders to provide redundancy during crucial stages of the operation.

Transponders on the structure should be placed a sufficient distance from the structure to avoid multipath effects. With tone systems this distance would be a function of the detection and validation times and which in turn are dependent on frequency. For a Medium frequency system a transponder should be placed >0.6m from a structure to avoid detection errors and >2.4m to avoid validation errors. As validation errors are easier to detect than detection errors and are unlikely to occur on successive interrogations they are easier to filter out within software. A realistic distance for MF would be 2m and 0.75m for EHF. Although Wideband systems are supposed to be less susceptible to multipath this has not proved to be conclusively the case. Therefore, it is recommended that the 2m distance be maintained for MF wideband systems wherever possible.

A typical set-up would be two transponders with inclinometer and Digiquartz end caps, a battery powered gyro which can be read through the transponder. Note: The use of gyros mounted on stabs allow easy replacement without recalibration in case of battery or system failure.

The heading of the structure should be checked by both gyro and calculated heading between the two transponder positions.

Refer [SOP-019 Structure Installation Procedure](#) for full details of Structure Installation Procedures.

6.5 **Metrology**

LBL acoustic metrology uses two LBL transponders to determine the distance between two points. In order to provide redundancy and QC checks a further two transponders are placed on the seabed, using tripods or frames, to form a well-conditioned braced quadrilateral. Measuring the baselines between all four transponders allows relative coordinates to be calculated. In addition to any QC function, this also allows the coordinates to be reduced to a particular reference point by offset and attitude calculations. To provide orientation for the array within the same reference as the flange headings, it is sometimes necessary to place a further transponder along the pipeline or deploy a survey class, north seeking gyro in a frame.
In addition to the baselines it is necessary to measure the relative depths of the transponders and the inclination and heading of the flange.

Orientation of the array may be determined from as built co-ordinates of the hubs or by use of a subsea survey quality gyro.

Refer SOP-014 Metrology Procedure for full details of metrology procedures.

### 6.6 Pipelay Operations

LBL positioning may also be used in pipelay operations. Examples include:

- Touchdown monitoring where the lay corridor is narrow;
- Installation of aids to lay;
- Cut to length calculations; and,
- Ensuring that Start up and Lay down positions are within tolerance.

Refer SOP-015 Pipeline and Umbilical Survey Procedure for full details of Pipelay Operation Procedures.

### 6.7 Marker Buoy Installation

LBL positioning can be used for marker buoy placement during well “spudding”, pipelay and structure installation on the seabed.

For marker buoy placement the ROV should be fitted with a ‘V’ bracket, ideally with the apex of the V under the RovNav transducer to minimise offset errors. If there is an offset then these should be corrected using a survey quality gyro on the ROV.

Note: During marker buoy placement it is recommended that the ROV make lateral and fore/aft movements to get on target. Rotating the vehicle will cause loss of position and make accurate positioning more difficult, thus delaying the operation.

### 6.8 Drilling Operation

The primary method for determining the final well position will be by positioning the two Compatts attached to the drill string within a LBL array. A secondary, contingency method, of well positioning will be to butt the ROV up against the conductor at four quadrants and use the results to determine the mean position of the conductor centre.

#### 6.8.1 Primary Method

The two Compatts attached to the drill string support bracket will be positioned in Simultaneous mode within the array. The bracket will be defined as a ‘structure’ type vehicle in Fusion LBL that is instrumented with the two Compatt transducers, a Digiquartz depth sensor and Sound Speed sensor. The dimensions of the bracket will be used to define the offset between each transducer and the common reference point (centre of the drill string).
The derived position of the drill string will be published to the navigation software for display on the navigation screen. The target position of the well will also be entered into the Fusion LBL software and the range and bearing from the derived drill string position to the proposed well location also displayed in this system.

6.8.2 Secondary method

As an alternative to the primary method of well positioning the ROV will be used to determine the centre of the conductor by fixing the position of the vehicle reference point whilst it is butted up against the conductor at four reciprocal headings (0, 90, 180 & 270 degrees). The centre of the conductor will be derived from the mean of these four sets of positions.

The position of the ROV will be derived from the LBL system by positioning the RovNav transducer within the array. Depth information from the Digiquartz sensor on the ROV will be interfaced to the Fusion LBL software which will be configured to apply the external depth value as a depth observation in the position computation.
7 REFERENCES

7.1 UTEC References

<table>
<thead>
<tr>
<th>Document Title</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobilisation Procedure</td>
<td>SOP-001</td>
</tr>
<tr>
<td>Metrology Procedure</td>
<td>SOP-014</td>
</tr>
<tr>
<td>Pipeline and Umbilical Survey Procedure</td>
<td>SOP-015</td>
</tr>
<tr>
<td>Structure Installation Procedure</td>
<td>SOP-019</td>
</tr>
</tbody>
</table>

7.2 External References

1. Sonardyne LBL Long Baseline Positioning Theory: TD_07_02LBL_IssA_Rev0

2. Sonardyne LBL General Acoustic Theory: TD_07_01LBL_IssA_Rev0 General Acoustic Theory

8 APPENDICES

None