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Acoustic Positioning Operator Station (APOS)

This document is the Operator manual for the Kongsberg Simrad Acoustic Positioning Operator Station (APOS) for use with the Kongsberg Simrad High Precision Acoustic Positioning (HiPAP) and Hydroacoustic Position Reference (HPR) 400 Series of systems.

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Rev. A First edition.

Rev. B Updated to implement minor corrections. Refer to EM 160841B.

Rev. C Updated to implement minor corrections in the text. Refer to EM 160841C.

Contents

1 INTRODUCTION

1.1 Manual content

This Operator manual provides a general introduction to the APOS, and how to get started. Operator maintenance and LBL and SSBL principles of operation are also included.

1.2 General description

The HiPAP and HPR 400 Series of systems are both controlled and operated by use of the APOS software. The APOS runs on the APC 10 as a stand alone system, or on the COS 100 unit in an integrated DP and HiPAP / HPR 400 system.

Examples of HiPAP / HPR configurations are shown in section 2, Product description.

The APOS software includes the following main functions:

- Integrates several HiPAP / HPR 400 transceivers
- Integrates DP and HiPAP / HPR 400 system
- User interface
- Interfacing HiPAP / HPR 400 transceivers
- Ray bending compensation
- Long Base Line calculations
- The SSBL calculations are done in the transceiver
- Interfaces DP and survey computer
- Online Help

The APOS software runs on a Windows NT platform. It uses standard Windows graphical user interface.

2 ABBREVIATIONS TERMS AND DEFINITIONS

2.1 Introduction

This chapter includes abbreviations used in this manual, general terms used within the APOS, and basic Windows terminology.

2.2 Abbreviations

APC	Acoustic Positioning Computer
APOS	Acoustic Positioning Operator Station
CCW	Counter- ClockWise
CG	Centre of Gravity
COS	Common operator Station
CW	ClockWise
DGPS	Differential GPS
DP	Dynamic Positioning
GPS	Geographical Positioning System
HiPAP	High Precision Acoustic Positioning
HPR	Hydroacoustic Position Reference
LBL	Long Base Line
OS	Operator Station
ROV	Remotely Operated Vehicle
SDP	Simrad Dynamic Positioning
SSBL	Super-Short Base Line
TD	TransDucer
TP	TransPonder
UPS	Un-interruptible Power Supply
UTM	Universal Transverse Mercator
VRS	Vertical Reference System

2.3 General terms

The general terms are described in alphabetically order.

Bearing

The horizontal direction of one terrestrial point from another, expressed as the angular distance from a reference direction, clockwise through 360°.

Cartesian coordinate system

A coordinate system (local system) where the axes are mutually-perpendicular straight lines.

Clump weight

An anchor line element connected at a fixed position on an anchor line, causing a concentrated vertical force downwards on the anchor line.

Course

The horizontal direction in which a vessel is steered or is intended to be steered, expressed as angular distance from north, usually from 000° at north, clockwise through 360°. Strictly, this term applies to direction through the water, not the direction intended to be made good over the ground. Differs from **heading**.

Datum

Mathematical description of the shape of the earth (represented by flattening and semi-major axis).

Geodetic coordinate system

A mathematical way of dealing with the shape, size and area of the earth or large portions of it. Normally UTM coordinates with reference to a datum.

Heading

The horizontal direction in which a vessel actually points or heads at any instant, expressed in angular units from a reference direction, usually from 000° at the reference direction clockwise through 360°. Differs from **course**.

2.4 Windows terminology

2.4.1 General

Windows are the basic objects of the Microsoft Windows operation system. They will always be displayed with the same layout and functionality, as long as the system programmer did not change the configuration.

Note ! *The APOS online help includes an illustration of a general window, and the including general properties.*

The following paragraphs present a short description of the most used general properties in alphabetical order.

Check box

A small square box 

that appears in a dialogue box and that can be turned on and off. A check box contains a tick mark when it is selected and is blank when it is not selected.

Choose

To perform an action that carries out a command in a menu or dialogue box. *See also* **Select**.

Command

A word or phrase, usually found in a menu, that you choose in order to carry out an action.

Command button

A rectangle with a label inside that describes an action, such as OK, Apply or Cancel. When chosen, the command button carries out the action.

Cursor

The pointer symbol that is displayed on the screen and that can be moved with the trackball.

Dialogue/Dialog box

A box that appears when the system needs additional information before it can carry out a command or action. *See also* **Check box**, **Command button**, **List box**, **Option button** and **Text box**.

Greyed

Describes a command or option that is listed in a menu or dialogue box but that cannot be chosen or selected. The command or option appears in grey type.

List box

A box within a dialogue box containing a list of items. If the list of available items is longer than the displayed list box, the list box will have a vertical scroll bar that lets you scroll through the list. A list box may be closed when you first see it. Selecting the down arrow next to the first item in the list will display the rest of the list.

Menu

A group listing of commands. Menu names appear in the menu bar beneath the caption bar. You use a command from a menu by selecting the menu and then choosing the command.

Option button group

A group of related options in a dialogue box. Only one button in a group can be selected at any one time.

Point

To move the cursor on the screen so that it points to the item you want to select or choose.

Radio button

A small round button appearing in a dialogue box 

(also known as a “Option” button). You select a radio button to set the option, but within a group of related radio buttons, you can only select one. An option button contains a black dot when it is selected and is blank when it is not selected.

Select

To point and click at the item that the next command you choose will affect. *See also* **Choose**.

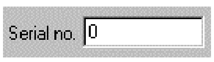
Slider

Used to setting parameter values between a minimum and a maximum value. Drag the slider in the required direction.

Status bar

Displays general useful information.

Text box

A box within a dialogue box 

in which you type information needed to carry out a command. The text box may be blank when the dialogue box appears, or it may contain text if there is a default option or if you have selected something applicable to that command. Some text boxes are attached to a list box, in which case you can either type in the information or select it from the list.

Title bar

Displays an application-defined line of text. The title bar also used to move / drag the window.

Toolbar

A collection of buttons to give a fast entry to the most used commands.

2.4.2 The screen

The screen presentations are described in detail in the APOS online help.

Menus

Main menus are items in the menu bar. They may contain:

Sub menus:	marked by ▶
Dialogue windows:	marked by **...**
Commands:	unmarked

2.4.3 The cursor operation

The trackball is used to positioning the cursor on the screen. The most common operations are:

Function	Definition	Common use
Click	To press and release a button, without moving the cursor. If no trackball button is specified, the left button is assumed.	Select the cursor insert point, activate an operation, activate / inactivate windows or controls.
Drag	To press and hold down a button while moving the trackball.	Move items. For example, you can move a dialogue box to another location on the screen by dragging its title bar. Press and hold the button down while moving the trackball.
Point	Move the cursor to the wanted screen location.	Prepare for selection / operation.

3 GETTING STARTED

3.1 General

This chapter describes the basic operation, how to switch the APOS on and off, and how to lower and raise the transducer(s).

The “getting started” description is based on an already installed APOS software.

Note ! *For more information refer to the APOS online help system.*

3.2 User levels

The APOS is – regarding functional possibilities and operation, configured in the following two user levels:

Operator: This level is used for the daily normal operation.

Service: This level requires password, and is for service personnel only.

3.3 Keyboards

Two types of keyboard may be used, depending on the system.

- The WinKeyboard is used with:
  - All types of operator stations

The WinKeyboard is described below.

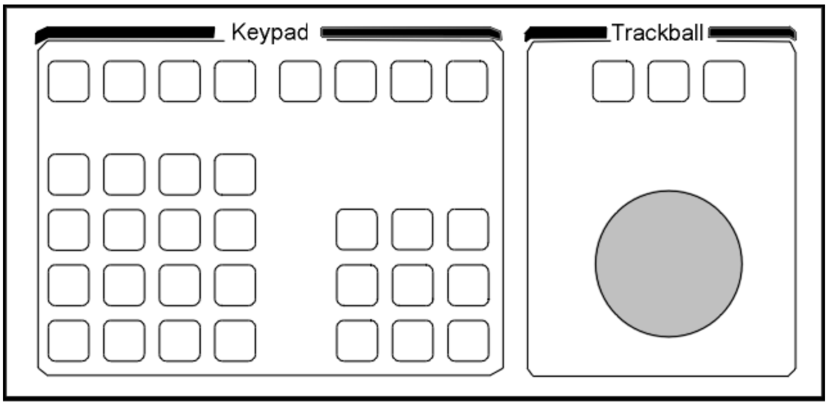
- A standard QWERTY keyboard is used with:
  - The portable system.

For description of the QWERTY keyboard, refer to separate manual, the *Compaq Reference Guide*.

3.3.1 WinKeyboard

The WinKeyboard is a special designed keyboard. Most system operations and menu functions can be operated from the keyboard. As illustrated in Figure 1, the WinKeyboard is divided into the following 2 sections:

- Keypad
- Trackball



(CD4258)

Figure 1 WinKeyboard layout

Use of trackball

The trackball is used to position the cursor on the screen. Each movement of the trackball moves the cursor. The trackball layout is shown in Figure 2.

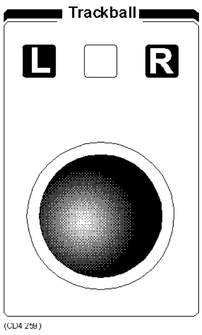


Figure 2 Trackball layout

L The left button is used to click on buttons, operate menus and select displayed symbols.

The middle button is not used.

R The right button is used to display menus and pop-up windows.

The most common trackball operations are; pointing, clicking and dragging. An overview of these basic operations is given in paragraph 2.4.3.

Use of keypad

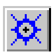
The Keypad provides function, numeric and cursor keys. The numeric keys are used to enter values into dialogue boxes, the function keys to select predefined view configurations, and the cursor keys to move the cursor. The following keys are available:

Keys	**Description**
Function	F1 is used for Help. F2 – F8 to be implemented later.
Numeric	Standard keyboard operation. It includes 16 buttons as follows: Numeric: 0-9, Escape (ESC), Backspace (BKSP), space (SPACE), hyphen (-), period (.) and Return (↵).
Cursor	The following arrows: UP / DOWN, and LEFT / RIGHT END: Go to end of line HOME: Go to start of line TAB: Tabulator PGUP / PGDWN: Go to start / end of page.

3.4 To start and stop

3.4.1 Start up procedure

The following procedure describes how to start the APOS from *Power Off* position. (Normally the system is kept on 24 hours a day.)

1. Switch on the power. (The power On / Off switch is normally located at the front of the cabinet.) The APOS is ready for use after approximately 1 minute.
2. Switch on the monitor. (The power On / Off switch is normally located at the lower front part of the monitor.)
   - First the desktop menu appears, and after some time the APOS main window appears.
3. If required, adjust contrast and brightness in order to obtain required display settings. (The buttons are located at the lower front part of the monitor.)
4. Ensure that you are in control of the system by pressing the  button. When in control, the button becomes disabled. (If the system is already in control, do not click the button).

Note ! *If there are more than one operator station in the system, the button will automatically become enabled again if another operator station takes control.*

Note ! *Ensure that the configuration of the transponders available in your system is performed. How to configure the transponders, see the APOS online help.*

Caution ! ***Remember to lower the transducer(s)! Refer to paragraph 3.5.***

You are now ready for operation!

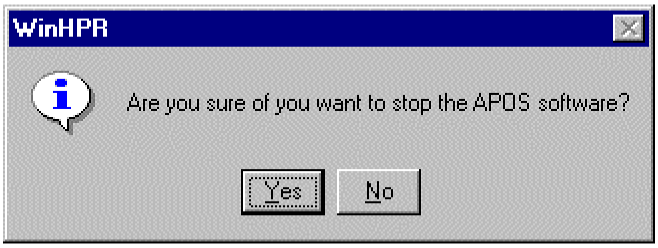
Note ! *How to operate the APOS, see paragraph 3.6 and the APOS online help system.*

3.4.2 Stop procedure

Normally the system is kept on 24 hours a day. If a controlled shutdown is required, it is important to proceed as follows:

- 1. Select **File -> Stop/Shutdown**

The following windows is displayed.



2. Select **Yes**.
3. The APOS software will shut down, and you will return to the desktop.

3.5 To lower and rise the transducer(s)

Note ! *The HiPAP/HPR may be a part of a larger system. Switching on the larger system will then normally power up the HPR system as well, and only lowering of the transducer will be required.*

3.5.1 Using the Remote Control

1. To lower the transducer, press the **DOWN** button on the Remote Control Unit. Observe that the **IN** and **STOP** lamps extinguish. When the transducer is fully lowered, the yellow **OUT** lamp will be lit.
2. To rise the transducer, press the **UP** button on the Remote Control Unit. Observe that the **IN** and **STOP** lamps extinguish. When the transducer is fully risen, the yellow **IN** lamp will be lit.

Note ! *The red STOP button on the Remote Control Unit may be used to stop the transducer hoisting and lowering operations at any position. When this button is pressed, the yellow STOP lamp will light. The hoisting or lowering operations are continued from the stop position by pressing the UP or DOWN buttons.*

3.5.2 Using the Hoist Control

1. To lower the transducer, open the Hoist Control Unit door and set rotary switch **S1** to **LOWER**. Once the Hull Unit has reached the required position, (will stop automatically) set the switch **S1** to **STOP**.
2. To rise the transducer, open the Hoist Control Unit door and set rotary switch **S1** to **HOIST**. Once the Hull Unit has reached the required position, (will stop automatically) set the switch **S1** to **STOP**.

Note ! *The red STOP button on the remote control unit may be used to stop the transducer hoisting and lowering operations at any position. When this button is pressed, the yellow STOP lamp will light. The hoisting or lowering operations are continued from the stop position by pressing the UP or DOWN buttons.*

3.6 The APOS Online help system

When operating the APOS, the Online help is available by activating the APOS Help menu button, or the F1 button on the WinKeyboard.

The online help may also be activated from a dialogue box, provided that the help button is available in that particular dialogue box.

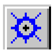
The online help menu includes the following selections:

- **Help:**
  General help – Command reference and operation.
- **About APOS:**
  Includes the APOS version.

3.6.1 Online help presentation

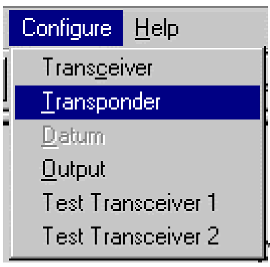
The following paragraph gives an example of the actual Online help. As you will see, the Online help is a combination of text and illustrations, which makes it easy to use and understand.

Getting started

We assume the installation of the system has been carried out and the system configuration with correct transceivers and transducers etc. is correct.
Prior to activating transponders, the system should be set up with the transponders available on the vessel. This will simplify the operation of the system. The transponder setup is normally a one time operation and needs only to be changed whenever new transponders become available. First make sure that you are in control of the system by pressing the  button. When in control, the button becomes disabled (greyish). (When in control, there is no need for taking control. If there are more than one operator station, the button will automatically become enabled again if another operator station takes control.)

Select transponders in the Configure menu or use Transponder toolbar button.

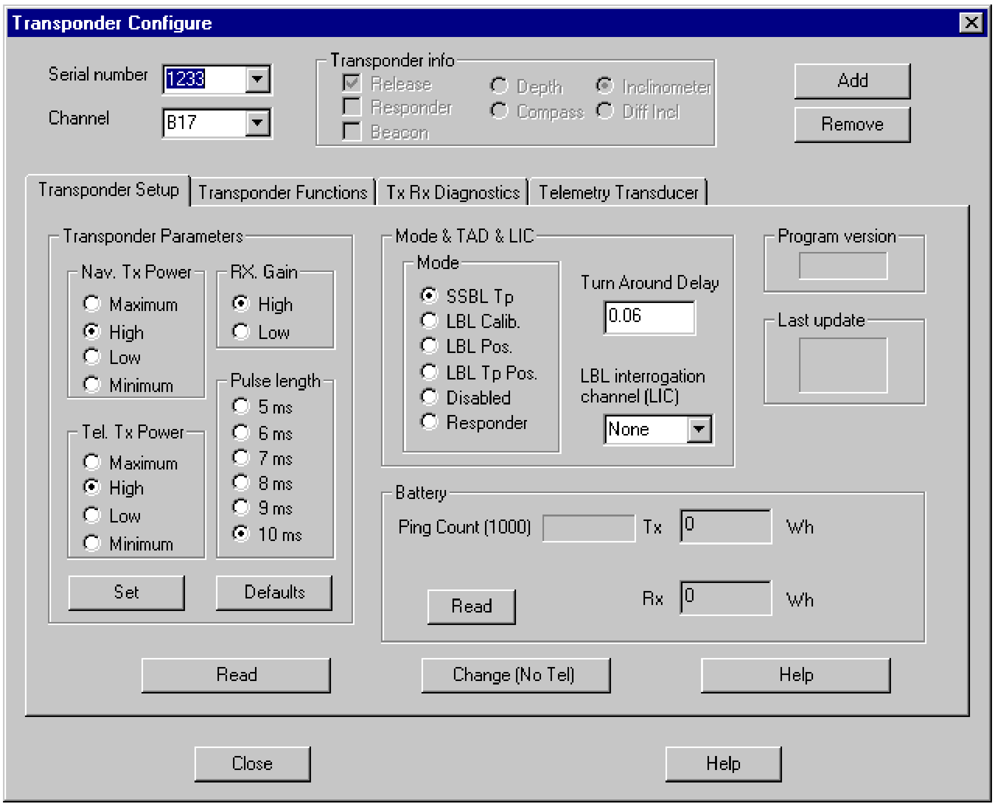
 The transponder toolbar button.



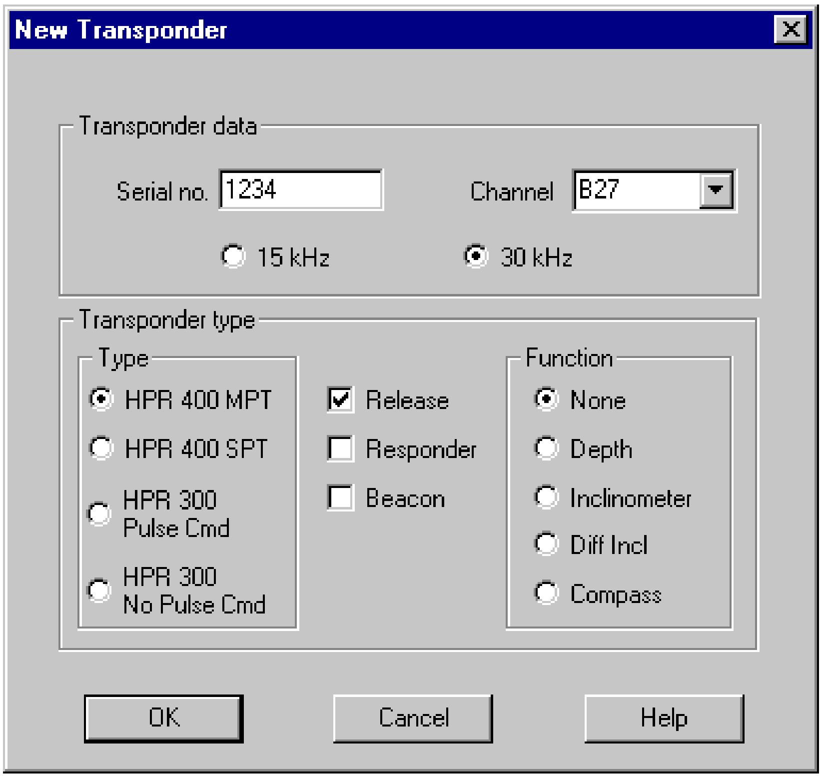
The Transponder menu.

Note! **menu** is an active link in the online help.

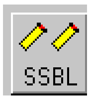
When either of these is selected, the following dialog will be displayed;



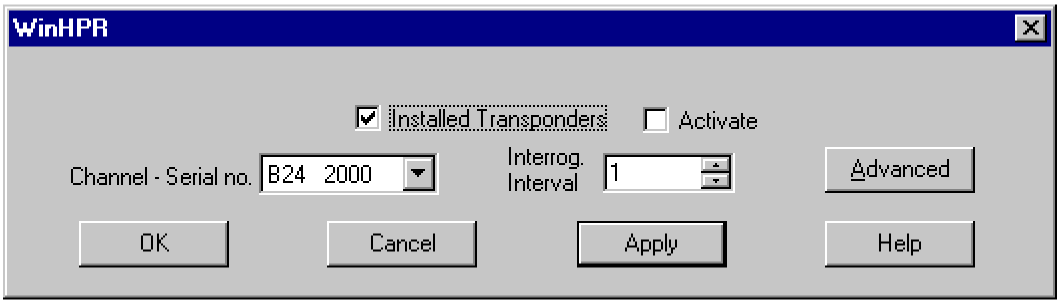
This dialog is used both for defining available transponders and to carry out telemetry to transponders. We will add transponders. Push the Add Button to define a new transponder. The following dialog is displayed.

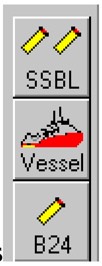


Now select the transponder type, function, serial no and channel. These settings should match the actual transponder. When filled in, press OK and you will return to the main transponder dialog above. Repeat the Add Transponder procedure for all available transponders. When complete, press close on the main transponder dialog.

Now we are ready for positioning. Press the 

button on the transponder toolbar. The following dialog should pop up;



Make sure the Installed Transponders check box is on. Select one of the Channel - Serial no combobox entries. Here you should have all transponders defined. Press OK. You should now have a button for this transponder on the positioning toolbar like this 

Press the button (B24) to start positioning. Press it again to stop positioning on this transponder. Press the SSBL button again and select a new Channel - Serial no if you want to activate more transponders. That is all. The display should now display transponder positions both numerically and graphically. Use the mouse or trackball and click with the right mouse button in any of the view sections to get the view presentations menu. Click on the vessel or transponder symbols with the right button to get menu's for these items.
See also sections **The Screen** and **Screen Views** for more information.

Note ! ***The Screen*** *and* ***Screen Views*** *are active links in the Online help.*

4 OPERATOR MAINTENANCE

4.1 Maintenance philosophy

For the APOS, corrective maintenance is normally performed by replacing modules and circuit boards. This type of maintenance must be carried out by a qualified maintenance engineer.

Further information about maintenance of the Kongsberg Simrad Acoustic Positioning systems are found in the following manuals:

- HiPAP Instruction manual
- HPR 400 Series Maintenance manual.

Preventive maintenance however, may be performed by the system operator.

4.2 Preventive maintenance

Caution ! ***Do not use strong liquid detergent when cleaning the units. This may be fatal to the surface.***

4.2.1 Cable terminals

All cables should be checked and tightened at least once every three months. This will prevent the screws from loosening resulting in poor contact for the cables.

4.2.2 The operator station

Clean the operator station and display exterior with a damp cloth to remove dirt, dust, grease etc.

The keyboard should be cleaned carefully with a damp cloth.

5 LBL PRINCIPLES OF OPERATION

5.1 Introduction

This chapter describes the theory of operation of the Long Base Line (LBL). The terms used in LBL positioning are defined, and the mathematical principles are described.

5.2 Definitions

5.2.1 Mathematical terms

Standard deviation tells how much a variable varies around its mean value. It is often written as σ. If the variable is normally distributed, 68% of its values are expected to be between (Mean_value - σ) and (mean_value + σ).

Variance is the square of the standard deviation, i.e. σ^2.

Root Mean Square (RMS) of a set of values is a mean of the values in which the greater values contribute more than the smaller values. It is often used instead of the mean value.

Iteration is a repetitive mathematical process. Some algorithms need starting values for some of the variables before they may be executed. The result of the calculation is a new set of values for those variables that are closer to the answer than the old ones. By repeating the algorithm starting at the new values, the result becomes more accurate each time. Each execution is called an iteration, and the algorithm is termed iterative.

Cartesian coordinates are measured in a coordinate system with three mutually perpendicular axes. In this text, the axes are named EAST, NORTH and DEPTH. NORTH is normally the geographical north direction, and EAST the geographical East direction. You are allowed to select other directions, but you must be consistent. The origin of the coordinate system has the coordinates (0,0,0).

Polar coordinates. The polar coordinates of a point are:

- Range The horizontal distance from the origin to the point.
- Bearing The horizontal direction from the origin to the point. 0 is the north direction. The bearing increases clockwise to 360º.
- Depth The vertical distance from the origin to the point.

5.3 LBL terms

TP Array. LBL positioning is based on range measurements to the transponders on the seabed. These transponders are called a “transponder array”.

Local calibration. The LBL positioning algorithms must know the coordinates of the transponders in the transponder array relative to a local origin. The process to decide these coordinates is called the local calibration of the transponder array. It is performed by first measuring the ranges between the transponders in the array and then calculating their coordinates based on the ranges.

Geographical calibration. Decides the location of the local origin in latitude and longitude, and the rotation of the local north axis relative to geographical north.

Range residual. HiPAP / HPR measures ranges to decide the position of a transponder or a transducer. Normally, more ranges than necessary are measured. Then the position is calculated based on a best fit of the measured ranges. The residual of a range is the measured range minus the range calculated by using Pythagoras' theorem on the calculated positions.

Local coordinates. The origin of the local coordinate system is in the area covered by the transponder array. The axes are called EAST, NORTH and DEPTH. The NORTH axis is not necessarily pointing in the geographical north direction. The names of the axes in the coordinate system are written in upper case letters (EAST, NORTH), and the geographical directions are written in lower case letters.

Geographical coordinates. When a geographical calibration is performed, positions may be presented in geographical coordinates; either in latitude and longitude or in UTM coordinates.

Initial positions. The positions of the transponders in the transponder array inserted before the local calibration is performed. The positions are given in local or geographical coordinates. The only requirement to the accuracy of these positions is that they roughly indicate the transponder positions relative to each other.

Calibrated positions. The positions of the transponders in the transponder array calculated in the local calibration. The positions are given in local coordinates.

Error ellipse. There is an uncertainty associated with all positions, both initial and calibrated. This uncertainty is expressed as a 1-sigma error ellipse both in the input to and the output from the HiPAP / HPR system. The error ellipse has a major and a minor semi-axis, and the direction of the major semi-axis relative to north is specified. Assuming that the uncertainty of the position is normally distributed, the probability that the position really is within the error ellipse is 0.67 x 0.67 = 45%.

5.4 HiPAP/HPR terms

The APOS is the HiPAP / HPR System Controller. It consists of a Pentium based PC. It can also contain a keyboard and circuit boards for serial lines, Ethernet etc. as options.

HPR 400 is a transceiver. It consists of single Europe circuit boards normally mounted in a 19" rack. The PCBs may be mounted in a cylinder for subsea use. The transceiver measures ranges and SSBL directions and handles telemetry.

HiPAP is a transceiver with one spherical transducer.

A Transducer consists of elements (vibrators) and some electronics. It converts the electrical transmission signals generated by the transceiver into hydroacoustic pulses. It also converts the hydroacoustic pulses received into electrical signals for the transceiver.

The transducer may be of the ordinary LBL type or of the SSBL type. Both are capable of measuring ranges. The SSBL transducer can also measure directions.

The HPR 4xx consists of an Operator unit, transceiver(s) and transducer(s). There may be up to four transceivers connected to the Operator Unit, and there may be two LBL transducers plus two SSBL or LBL transducers connected to each transceiver.
HPR 410 is an SSBL system, HPR 408 is an LBL system while HPR 418 is a combined LBL and SSBL system.

A Transponder consists of a LBL type transducer, electronics and batteries. It is placed on the seabed or on an ROV. The transponders may be commanded by telemetry to execute functions.

Most LBL transponders contain a pressure and a temperature sensor. These are used to decide the transponder depth.

When enabled for positioning, the transponder may be interrogated by two pulses on different frequencies and will then reply with a pulse on a third frequency. The HiPAP / HPR system may command it to switch frequencies.

Each transponder is uniquely identified by a serial number.

5.5 LBL Measurement principles

LBL positioning is based on range measurements, both for the calibration and for the positioning. The principle is basically the same for positioning and for calibration, but the explanation is split into separate paragraphs in this text.

5.5.1 Positioning

The HiPAP / HPR system measures ranges from a transducer to the transponders on the seabed. A common interrogation channel is used for all the transponders in the transponder array. The HiPAP / HPR system knows the transponder positions. Each range measurement indicates that the transducer is on a sphere with its centre at the transponder and with its radius equal to the range. If more than one range measurement is made, the transducer's position must be on the lines where the spheres intersect.

When the measurements are done on a SSBL type of transducer, the directions may be used together with the range in the calculations. In shallow water, and when an accurate HiPAP transducer is used, the measured directions contribute to a more accurate position.

The depth of the transducer is often known. In these cases, each range measurement indicates that the transducer is on the circle where the sphere around the transponder intersects with the horizontal plane at the transducer. This is illustrated in Figure 3. Here three circles are drawn where the transducer's depth plane crosses the three spheres.

Normally there will be noise on each measurement. That is illustrated on the figure by not letting the three circles intersect exactly in one point. There are three intersections close to each other, and the position can be assumed to be somewhere in the triangle formed by the intersections.

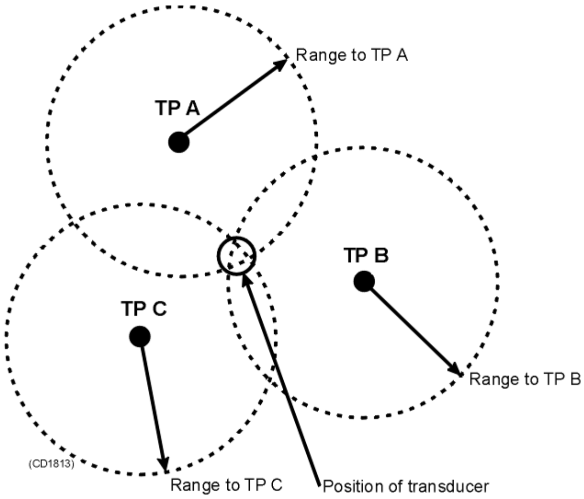


Figure 3 LBL positioning

Normally, more ranges than necessary are measured, and the number of intersections close to each other increases. Still the best guess of the position is somewhere in the space between these intersections. The program uses a weighted least square error algorithm to decide the position. The algorithm is iterative, and the errors are the differences between the measured ranges and the corresponding ranges calculated by using Pythagoras' theorem on the vessel position. These errors are called range residuals.

The iterations start at the vessel's previous known position, and continue until the increment from the previous iteration is less than a preset number of centimetres. The accuracy of the old position does not influence the accuracy of the new position.

Situations may arise when too few ranges are measured. Then there are two possible solutions for the new position. The programs will iterate towards the position closest to the old one.

In standard LBL, the replies from the transponders in the TP array are received on the same transducer as doing the interrogation of the array. In the APOS you can request the replies to be received on other transducers too. The extra measurements make the LBL system more accurate and robust.

5.5.2 Calibration

The "position" used during the calibration consists of the position of each array transponder. Consequently, it contains many coordinate values.

The programs must know something about the transponder positions before the calibration calculations can start. These positions are called “Initial positions”. That information must be inserted by you, or it may be read from an ASCII file. SSBL measurements may be used to identify the initial transponder positions.

You must inform the system of the accuracy of the initial positions. This is achieved by specifying a 1-sigma error ellipse for the horizontal position and a standard deviation for the depth. The transponders are often at approximately the same depth, and the range measurements then contain no information about their relative depths. In this case, the depth standard deviation should be set to 0.00 m for all the transponders.

The next step of the calibration is to measure the subsea ranges between the transponders. The range from one transponder to another is normally measured many times. The mean value and the standard deviation of these ranges are then calculated and used later in the calculations.

The programs use a weighted least square error algorithm to decide the positions of the transponders. The algorithm is iterative, starting at the initial positions of the transponders. There are two types of errors as seen from the algorithm.

The **range errors** are the differences between the measured ranges and the corresponding ranges calculated by using the Pythagoras formula on the transponder positions. These errors are called **range residuals**. In the algorithm the squares of the range residuals are weighted with the inverse of the variance calculated during the range measurements. In this way the ranges measured with a small standard deviation have a greater impact on the resulting transponder positions than the ranges measured with a large standard deviation.

The **position errors** are the differences between the calculated transponder positions and the starting values of those positions. In the algorithm, the squares of these errors are weighted with the inverse of the squares of their uncertainties. The uncertainty of a transponder position starts at the error ellipse for the initial position. The uncertainty reduces in size during the calculation, and the result is the uncertainty of the calibrated transponder position.

5.5.3 Combined use of LBL and SSBL

When a transponder array is active on an SSBL transducer, the HiPAP / HPR system may perform SSBL measurements when receiving the replies. The direction information is then used together with the range information to make the system more accurate and robust. The transponders in the transponder array are still classified as LBL transponders.

Transponders may be interrogated as SSBL transponders. They are interrogated using their individual frequencies, and the SSBL measurements are performed as on a pure SSBL system.

The same transponder may not be interrogated as an SSBL transponder and an LBL transponder simultaneously.

When both a transponder array and one or more SSBL transponders are active, the system will alternate between LBL interrogations and SSBL interrogations. The sequence is controlled by the interrogation rate parameters for the LBL and SSBL interrogations.

The transponders used as SSBL transponders are of the same physical type as the LBL transponders. They are, however, commanded to be interrogated on their individual channels and not on the LBL common interrogation channel.

5.5.4 Geographical calibration

Many LBL applications do not perform geographical calibrations. For those applications, you may ignore this chapter.

The relative positions of seabed transponders in TP arrays are calculated based on range measurements between the transponders. When finished, the transponder positions relative to an origin are calculated. This process is called the local calibration.

Normally the position of the origin, and the rotation of the local North axis relative to the geographical north axis, remain unknown after the local calibration. These unknowns are decided in the geographical calibration.

The APOS uses positions of the vessel, simultaneously received from a DGPS system and calculated by the LBL system, as basis for the geographical calibration. DGPS and LBL position pairs are logged at many positions in the area before the calculation is performed. The calculation decides the origin latitude and longitude, and the rotation of the local north axis relative to geographical north axis, using a least square error algorithm.

When the latitude, longitude and rotation of the local origin are calculated, the LBL positions logged are converted to geographical coordinates. There is normally a difference between the LBL geographical position and the DGPS position logged in the same place. This is called the distance residual of the position pair. The residual is the statistical sum of the DGPS error and the LBL error. When these systems work correctly, the sound velocity profile used is accurate, and the local calibration was performed accurately, these residuals are normally in the 1 m order of magnitude.

The most accurate results for the origin position calculations are given if the position pairs are logged evenly distributed around the area. If for example the sound velocity profile is inaccurate, the distance residuals of the position pairs logged in the outer parts of the array may be much larger than the error in the origin calculated. If, on the other hand, position pairs are logged in only one part of the array, the situation could be the opposite - with small residuals but an inaccurate calculation of the origin. It must always be remembered that the objective of the calibration is to establish accurate positions, not to obtain small residuals.

The three parameters calculated in the geographical calibration are the latitude, longitude and rotation. When performing LBL positioning in the area later, errors in latitude and longitude will always contribute to errors in the LBL geographical position. The error in the rotation contributes an error proportional to the distance from the centre of the area in which the position pairs were logged.

The origin calculated is valid for the locations in the transponder arrays used in the LBL positioning during the geographical calibration.

5.6 Super array and Tp array

A limit of eight transponders can be in use simultaneously when performing LBL positioning or range measurements for local calibration. The limit is due to the use of frequencies within the frequency band available. The transponders in use simultaneously are named a TP array. The APOS can handle many TP arrays, but only one can be active at any one time.

In many applications, as for example pipe laying and inspection, there is a need to use more than 8 transponders. The places on the seabed where the transponders are placed are called locations.

When all the locations are grouped together, the resulting array is often called the “superarray”.

Each location is a physical transponder. The same physical transponder may be used in more than one TP array, meaning that the TP arrays can overlap.

Example: Location 8 and 9 are used in both TP array 1 and TP array 2 because the arrays overlap, as shown in below.

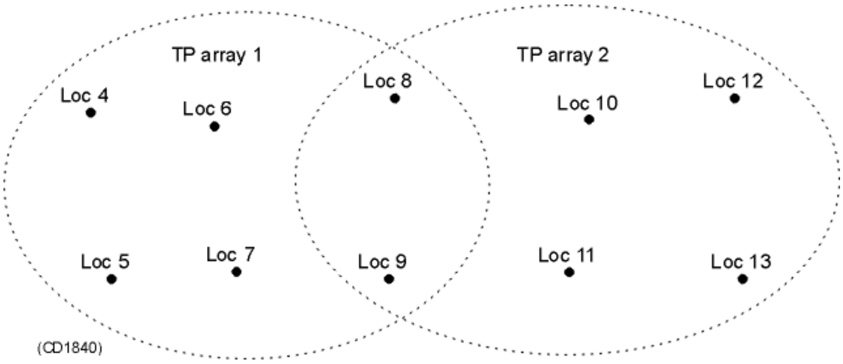


Figure 4 Two TP arrays with overlapping locations

All range measurements for the local calibration are performed within the TP arrays. When finished with the measurements in one TP array, a calculation using only those measurements should be performed to check the measurements. Then, only the locations specified as being part of the actual TP array receive new calibrated positions. The positions of the other locations will remain at their initial values. Normally, some of the locations receiving new calibrated positions will also be used in other TP arrays. The new positions will then also be valid for those arrays, i.e. one location has one and only one position, even when used in more than one TP array.

When the ranges are measured in all the TP arrays with overlapping locations, a local calibration calculation for the super array should be performed. The range measurements performed in all the TP arrays are then used, and all locations receive new calibrated positions.

5.7 Geographical coordinates

Many LBL applications do not use geographical coordinates. For those applications, you may ignore this chapter.

The APOS may receive geographical positions from a DGPS receiver, and it may present the calculated LBL positions in geographical coordinates.

Geographical coordinates are always referred to a datum defining the ellipsoid model of the earth. The APOS may work with three datum simultaneously. They are:

1. **A reference datum**. This datum is used by the HiPAP / HPR system in the internal calculations. It is by default WGS 84, and you should not change it.
2. **A GPS datum**. This datum is the one used by the DGPS receiver. After having received a geographical position from the DGPS receiver, the HiPAP / HPR system converts the position to the reference datum before starting any calculations. You may select the GPS datum from a list of datum in a menu.
3. **An APOS datum**. This datum is used by the HiPAP / HPR system when presenting LBL positions in geographical coordinates, both on the screen, in printouts and in binary telegrams. You may select the APOS datum from a list of datum in a menu.

The system always performs the LBL calculations in local coordinates. If the LBL positions are to be presented in geographical coordinates, the transformation from local to geographical is performed just before the presentation. The APOS must know the geographical coordinates of the local origin and the rotation of the local north axis to perform this conversion.

When the initial coordinates for the locations are entered in UTM coordinates, the APOS must convert the position to local coordinates before performing any calculations. To perform this conversion, it must know the geographical coordinates of the local origin to be used. That is inserted by you as a UTM centre. The rotation parameter of this origin is calculated automatically to the angle between the geographical north and the UTM north. You should not change the UTM centre when it is in use for the locations.

The use of the UTM centre as an origin is similar to the use of the origin calculated in a geographical calibration.

The UTM centre or the origin calculated in the geographical calibration may be transferred to the origin(s) of the TP array(s). When transferred to a TP array, the origin is used when:

- Positioning in the TP array. The LBL position calculated may be presented in UTM or in geographical coordinates.
- Printing the calibrated positions of the locations. The calibrated positions are always printed in local coordinates. Those locations used in a TP array with an origin are also printed in UTM coordinates.

5.8 Quality control of the data

The quality control of the data is performed on many levels. The HiPAP / HPR system measures more than is strictly necessary, and thereby gains the possibility to check the quality of the results.

5.8.1 Local calibration

The calibration is primarily based on range measurements between the transponders. Each range is measured many times, and the program calculates a standard deviation on each range. You may examine the measurements, and the ranges may be measured anew. You may exclude ranges from the calibration calculations if no acceptable standard deviation is obtained.

The inverse of the standard deviations are used by the algorithms as weights when calculating the optimum transponder array positions.

After having calculated optimum positions for the array transponders, the APOS checks how the measured ranges fit with the calculated positions. Ranges that do not fit well have large range residuals, and these ranges may be measured anew or excluded before the calibration calculations are performed again.

The APOS calculates the uncertainties of the calibrated positions, and presents them as error ellipses around the positions.

5.8.2 Geographical calibration

The APOS uses positions of the vessel, simultaneously received from a DGPS system and calculated by the LBL system, as the basis for the geographical calibration. Only two DGPS / LBL position pairs are necessary to calculate the origin latitude, longitude and rotation, but up to many hundreds position pairs may be logged and used in the weighted least square error calculation. The calculation is over determined, and distance residuals are calculated for each position pair. The RMS value of these residuals indicate how well the position pairs match.

Each position pair has associated statistical information indicating its uncertainty. This information is used in the calculations, and it contributes to the statistical data giving the uncertainty of the origin calculated.

5.8.3 Positioning

During positioning the HiPAP / HPR system normally measures more ranges and SSBL directions than is necessary. After having calculated the position, it checks how well the measured ranges and directions fit with the position. Measurements obviously wrong may be automatically excluded when the position is calculated again.

The APOS calculates residuals of all measurements, and the uncertainty of the LBL position

The uncertainty of the local LBL position calculated, depends on several factors:

- The number of ranges and SSBL angles measured, and the geometrical crossings of the vectors from the transponders to the transducer.
- The accuracy with which the ranges and the angles are measured.
- The uncertainty of the sound velocity profile used. You insert this uncertainty in a menu.
- The uncertainty of the calibrated positions of the transponders in the array.

The local LBL positions calculated may be presented in geographical coordinates. In that case, the uncertainty of the origin is statistically added to the uncertainty of the local position before being presented. (The graphical presentation on the screen is always in local coordinates. The printouts however may be in geographical coordinates.)

5.9 Transponder Modes

Each transponder may be in one of the following modes.

- *SSBL mode.* The transponder enters this mode after power on and after reset. It must be in this mode when being interrogated as an SSBL transponder.
- *LBL calibration mode.* The transponder must be in this mode when performing the subsea range measurements during the Local calibration.
- *LBL positioning mode.* The transponders must be in this mode when measuring ranges from a transducer to the transponders. In this mode, the transponder is interrogated on an LBL interrogation channel, which is usually different from the transponder s channel. The transponder s reply frequency is decided by its channel number. This mode enables all the transponders in an array to be interrogated on the same interrogation channel, while replying on their individual frequencies.

In the LBL positioning mode, the turnaround delay is set individually for each transponder. This possibility is used to prevent the transponder replies being received at the transducer simultaneously.

5.10 Operation

The following paragraphs give an overview of the operations without going into details. For detailed description of the operation, refer to the APOS online help system.

5.10.1 Measure ranges

The transponders in the transponder array must all be in the Calibration mode before the subsea ranges are measured.

The local calibration is primarily based on range measurements between the transponders. They send the results up to the HiPAP / HPR system by telemetry. You may choose to request one transponder at a time to measure the ranges to all the others, or you may request all the transponders, one at a time, to measure the ranges to all the others. This operation will last for some minutes, depending upon the ranges and the number of ranges to measure. The second option should only be selected when the vessel has good telemetry communication with all transponders from a single position. In both cases only one telemetry function is performed at any one time in the water.

5.10.2 Execute the local calibration

Once the subsea ranges have been measured, the positions of the transponders in the array can be calculated.

When the APOS has completed the calculations, it displays the maximum and the RMS values of the range residuals. These indicate how well the calibrated positions fit with the measured ranges. If you are not satisfied with the residuals, you should identify the ranges contributing the most to the RMS value of the residuals. Ranges with large residuals should be measured again and the calibration calculations repeated. This iteration may need to be performed many times before the resulting residuals are considered to be small enough.

The left part of the screen is normally used to present graphical information. In the LBL local calibration process, it is better to use it to display the ranges. Then the display gives an overview over the ranges, the standard deviations and the range residuals. The ranges and the standard deviations are updated after each range measurement. The range residuals are updated after each local calibration calculation.

5.10.3 Position a vessel or ROV

When satisfied with the result of the local calibration, you can start the positioning operation. First the turnaround delays of those transponders in the array must be decided, then the transponders must be commanded to the LBL positioning mode.

5.10.4 Position a transponder

The transponders are able to measure the ranges to other transponders, and send the result, on telemetry, to the HiPAP / HPR system. This capability is used in the LBL transponder positioning mode. The transponder to be positioned is called the master transponder, and it is not part of the TP array. The master transponder measures ranges to transponders in a TP array, these other transponders being called the slaves. Up to six slaves may be used simultaneously by one master. The transponders in the TP array must be in the calibration mode. The master is commanded to be in a special TP range positioning mode, in which it knows the channels of the slaves to which it is to measure the ranges. The positioning sequence is initiated by the HiPAP / HPR system transmitting a short message to the master on telemetry. The master measures the ranges to the slaves, just as in calibration mode. Only one range is measured towards each slave. When it has finished, the master transmits the ranges, on telemetry, up to the HiPAP / HPR system, then waits for the next request to measure ranges.

The LBL transponder positioning mode is a flexible and simple solution for many applications. The drawback is the speed. Both the ranges and the request to measure are sent on telemetry, and the master transponder measures only one range at a time. The time used for a sequence depends on the number of slave transponders used, and if there are timeouts on the replies from the slaves. The positions may be updated as fast as once every 12 seconds, though more time may well be required, resulting in a slower update rate.

5.10.5 Geographical calibration

The geographical calibration requires that you position the vessel in local LBL coordinates and that the APOS reads the vessel position from a DGPS receiver simultaneously. An LBL position and a DGPS position, logged simultaneously, are named a position pair.

When logging the position pair, the vessel should be drifting to avoid noise and air bubbles from the thrusters and propellers disturbing the LBL measurements. 8 to 10 position pairs should be logged while the vessel is drifting in one position, then the vessel should be moved to another position and a new 8 to 10 position pairs should be logged. This procedure should be repeated at many positions, evenly distributed, in the area covered by the transponder array. Do not log only while located in the centre of the area as that will give a high uncertainty for the rotation of the local north axis.

When logging position pairs, attention should be paid to the ranges measured and the range residuals calculated. The best results are achieved when the position pairs are logged when many ranges are measured correctly and their residuals are small.

When enough position pairs are logged, the geographical calibration calculation is performed. Some position pairs will often have larger distance residuals than the others. In that case, you may exclude some of the position pairs with the large distance residuals and repeat the calculation. When performing the exclusions, be aware that the position pairs used in the calculation should be evenly distributed in the area.

6 SSBL PRINCIPLES OF OPERATION

6.1 Introduction

For Super-Short BaseLine (SSBL) information please refer to the *HiPAP and HPR 400 Series systems, Product description* - section two in the APOS Instruction manual.

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