KONGSBERG

HiPAP

High Precision Acoustic Positioning

Product description

400578/F

400578/F

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About this document

Purpose

The purpose of this document is to describe the complete HiPAP Model 602/502/452/352/102 systems.

It provides a general description of the systems, each module and technical specifications. It also includes outline dimension drawings of the main units.

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References

For more information about the functions of the system, see *HiPAP and µPAP System function* (KM document number 433831).

System description

Kongsberg HiPAP system is designed for optimal positioning of subsea objects in both shallow and deep water.

HiPAP systems

The HiPAP systems are designed to provide accurate positions of subsea objects such as Remotely Operated Vehicles (ROVs), autonomous underwater vehicles (AUVs), towed bodies or fixed seabed transponders. To achieve the accuracy, the HiPAP system uses unique signal processing techniques. This technique enables narrow transmitter and receiver beams to be generated in all directions within the lower half of the transducer using electronic beam control.

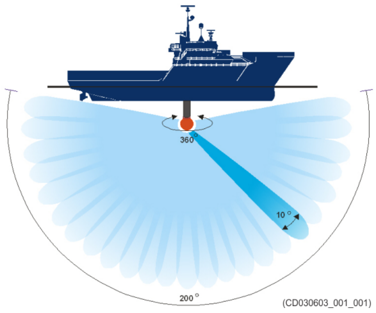
The HiPAP Model 602/502/452/352/102 systems are the third generation HiPAP systems. These models have a new transceiver unit and a new signal processing algorithms for Cymbal processing.

Cymbal is KM’s acoustic protocol for positioning and communication.

All HiPAP systems; HiPAP 602, HiPAP 502, HiPAP 452, HiPAP 352 and HiPAP 102 have common software and hardware platforms, and thereby offer the same kind of additional functionality and options.

- The HiPAP 602, HiPAP 502, HiPAP 452 and HiPAP 352 systems are medium frequency systems operating from 21 kHz to 31 kHz.
- The HiPAP 102 system is a low frequency system operating from 10 kHz to 15.5 kHz.

HiPAP 502 system



The HiPAP 500 transducer has a full spherical transducer body including 241 transducer elements. This model has close to full accuracy in the half sphere sector and is the preferred system where the best possible performance is required. The HiPAP 500 transducer can also track targets above the half sphere sector.

The use of *very narrow beams* provides:

- High accuracy
- Long range capabilities

- Good noise reduction capabilities
- Good multipath suppression

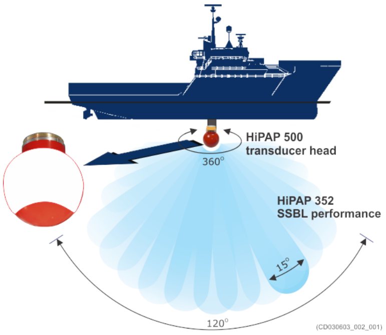
The HiPAP 500 transducer has a diameter of 392 mm and is installed with the 500 mm gate valve.

HiPAP 452 system

The HiPAP 450 transducer is the same unit as the HiPAP 500 transducer. The system has Transmitter/Receiver boards for only 46 elements, similar to the HiPAP 352 system.

The HiPAP 452 system has the same operational and technical performance as the HiPAP 352 system.

The HiPAP 452 uses the same hull units as the HiPAP 502.



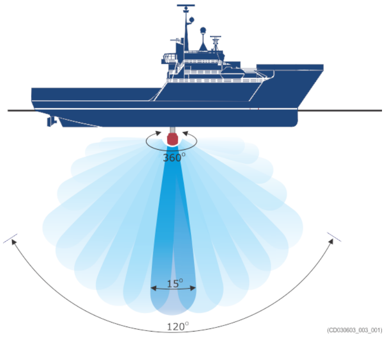
Upgrading from HiPAP 452 to HiPAP 502

The HiPAP 452 can be upgraded to full HiPAP 502 performance. This is done by:

- Inserting 6 additional Transmitter/Receiver Boards in the transceiver unit which is fully prepared for this.
- APOS software upgrade.

HiPAP 352 system

The HiPAP 350 transducer has a spherical transducer with a cylindrical body including 46 transducer elements. This model has good accuracy in the ± 60º sector and is suited for operations where the major positioning objects are within this sector. The total coverage is ± 80º.



The use of *narrow beams* provides:

- High accuracy
- Long range capabilities
- Good noise reduction capabilities
- Good multipath suppression

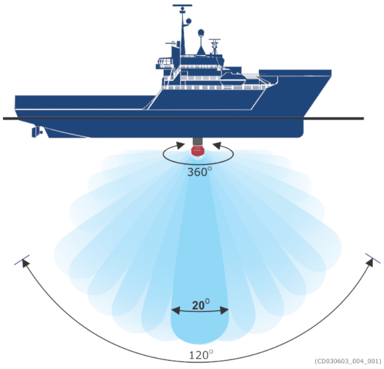
The HiPAP 350 transducer has a diameter of 320 mm and is installed with a 350 mm gate valve. Installing the system with a 500 mm gate valve will enable an easy upgrade to a HiPAP 502 system.

HiPAP 102

The HiPAP 100 transducer has a planar transducer array with a cylindrical body including 31 transducer elements. This model has good accuracy in the ± 60º coverage sector and is suited for operations where the major positioning targets are within this sector.

A tilt adapter is available for this transducer, making it able to pointing the covering sector towards for example towed bodies. The adapter tilts the transducer.

The HiPAP 100 transducer has a diameter of 452 mm and will be installed with the 500 mm gate valve.



Operating modes

- **SSBL** - Positions various targets by directional and range measurements, using a unique processing technique that provides very high accuracy.
- **LBL** - Positions the surface vessel by simultaneously use of combined directional and range measurements to transponders in an LBL array.
- **MULBL** - Positions the surface vessel in an MULBL transponder array.
- **Telemetry** – acoustic communication to:
  - transponders for LBL calibration, metrology
  - measurements and set-up.
  - instrument units and BOP systems.

APOS

APOS is a Windows based software used to operate the HiPAP system. The system can be operated from one single APOS station or from a wide number of APOS operator stations connected on a network.

Sensors

The HiPAP system has a wide range of interfaces to sensors from different manufacturers.

The HiPAP system needs high accuracy heading, roll and pitch sensors to be interfaced.

The accuracy of the sensors has direct impact on the position.

Examples of search sensors are Seapath and MRU.

System functions

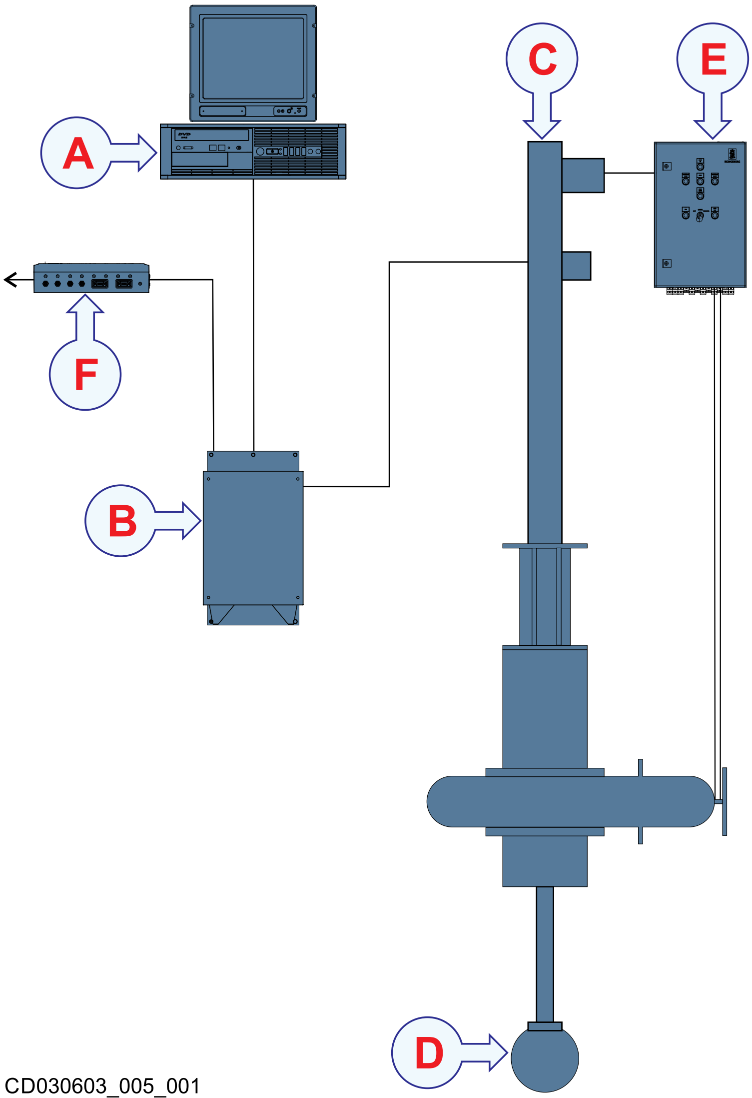
The system can be delivered with several software defined options. These options are described in a separate document number 433831 *HiPAP and µPAP System functions.*

System configuration

A HiPAP system may be configured in several different ways, from a single system to a redundant system with several operator stations. Some of the configurations are outlined here.

Single HiPAP system

The single HiPAP system has one transceiver and hull unit, but it may have one or more operator stations.



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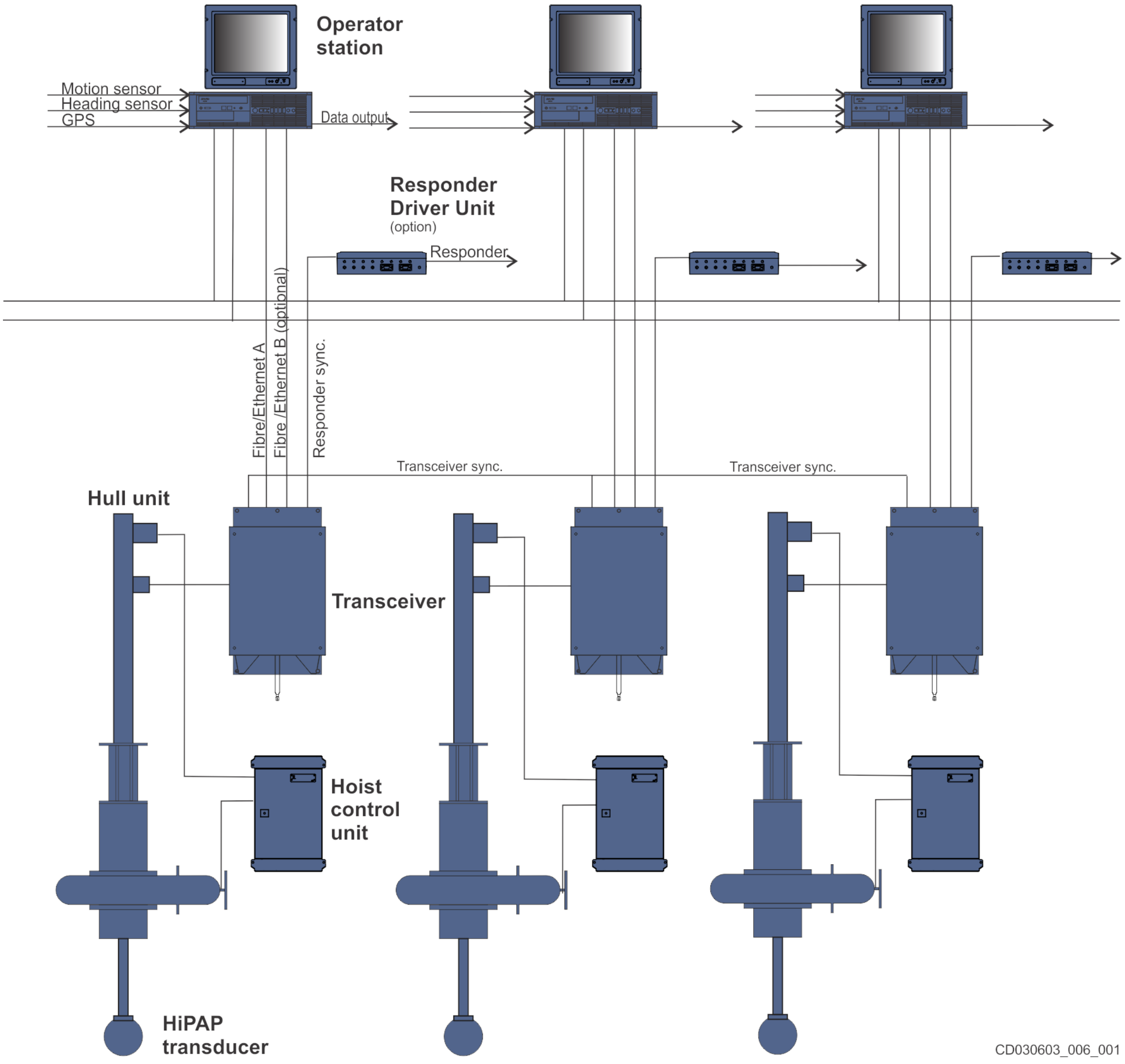
Redundant HiPAP system

The redundant HiPAP system has two or more operator stations and two or more transceivers and hull units. All transceivers are accessible from all operator stations. The redundant system will operate with two transponders, one on each transducer, or two LBL arrays. The redundant system is still operational after one single failure in the system.



Dual HiPAP system

A dual system applies for the HiPAP 502 only. HiPAP is designed to operate two sets of transceivers/transducers, both operated from the same operator station(s).

The dual system uses both transducers to measure the position of one single target (transponder/responder) by controlling beam forming and directional measurement separately for each system in parallel. This means that both systems will measure and calculate a position for the same reply pulse from the transponder.

If the signal is lost due to noise or air bubbles on one of the transducers, it may still be possible to receive it on the other one.

A position estimator will use the position information from both systems to estimate one optimal transponder position. Each system calculates a variance for its measurements, determined from the known system accuracy and the standard deviation of the measurements. The position estimator receives the position and the variance from the two systems, and calculates the weighted mean of the two positions. The variances are used as the weights.

The quality control function uses variance data, standard deviation and position difference to perform a quality control of the position. If the variance and the position difference are outside a pre-set limit, a warning will be displayed for the operator.

For the dual configuration, a synchronisation line between the transceivers is required.

Some of the benefits of a dual HiPAP system are:

- **Accuracy improvement**

  The improvement factor from 1 to 2 transducers is $\sqrt{2}$. This is based on the statistical improvements when using two independent systems.

- **Redundancy improvement**

  The two transducers will normally be installed at different locations onboard. One transducer may then have a better location with respect to noise environments and reflections than the other. The computed position will be a weighted mean of these two measurements, if one of the systems fails to receive a reply, the other system may still receive it and the position will still be computed.

System units

Transceiver

The transceiver is provided to transmit acoustic energy through water. This transmission and reception are commonly referred to as a *ping*. After each transmission, the transceiver receives the echoes from the targets in the water and/or the seabed. These echoes are filtered and amplified and then converted into digital format.

Three types of HiPAP transceiver units are available:

- HiPAP x82-M3 transceiver unit for HiPAP 602
- HiPAP x82-M8 transceiver unit, for HiPAP 502
- HiPAP x82-M2 transceiver unit, for HiPAP 352 or 452
- HiPAP x82-L1 transceiver unit, for HiPAP 102

The transceiver models have identical form and function, but is equipped with transmitter/receiver and filter board for the various transducers. The unit contains power supply, transmitter and receiver boards and interface to the optical fibre link.

The transceiver is designed to be installed on a suitable bulkhead and are fitted with vibration/shock absorbers to reduce the effects of vessel vibrations.

Responder Driver Unit (optional)

The Responder Driver Unit provides responder trigger signals to responders.

The Responder Driver Unit is a stand-alone unit. The Responder Driver Unit is connected to the interface unit and the switch. APOS controls which drive is being active while the sync/timing is received from the transceiver.

Transducers

HiPAP 600 transducer

The HiPAP 600 transducer has a planar transducer array with a cylindrical body including 85 transducer elements. The transducer is mounted on the hull unit.

HiPAP 500 transducer

The HiPAP 500 transducer has a full spherical transducer body including 241 transducer elements, the elements covers its entire surface area except for a small cone around the ”north-pole”. The large number of elements enables narrow receiver beams to be generated. The transducer is mounted on the hull unit.

HiPAP 450 transducer

The HiPAP 450 transducer is the same unit as the HiPAP 500 but only the 46 lower sector elements of the sphere are activated and in use. The transducer is mounted on the hull unit.

HiPAP 350 transducer

The HiPAP 350 transducer has a spherical transducer with a cylindrical body including 46 transducer elements, the elements covers its’ ± 60° cone pointing downwards. The large number of elements enables narrow receiver beams to be generated. The transducer is mounted on the hull unit.

HiPAP 100 transducer

The HiPAP 100 transducer has a planar transducer array with a cylindrical body including 31 transducer elements. This model has good accuracy in the ± 60º coverage sector and is suited for operations where the major positioning targets are within this sector. The transducer is mounted on the hull unit.

Hull unit description

The hull unit is a large mechanical construction designed to lower the transducer into the water when the HiPAP system shall be used. When the HiPAP system is turned off, the transducer is hoisted for protection.

The hull unit lets the transducer to be lowered through the vessel’s hull deep enough to minimise the effects of noise and air layers below the vessel. The hull unit is installed on top of a gate valve, which can be closed during maintenance and transport. The hull unit also holds the guide-rail arrangement for keeping the transducer exactly aligned with the vessels reference line.

External interfaces

The HiPAP system can be connected to many different external sensors and systems.

Position outputs

The HiPAP system can be interfaced to other computers allowing them to process the position data for various applications. The system is flexible in the way it interfaces other computes. Several binary and ASCII formats are available on serial line and Ethernet using UDP protocol.

A dual Ethernet is available for secure DP operations.

An accurate time-tagged position output is available if the system is interfaced to a GNSS and synchronised to 1PPS.

Surface navigation

The HiPAP system can be interfaced to a surface navigation system. As standard the system uses Global Navigation Satellite System (GNSS). When GNSS is interfaced, a number of features will become available; UTM grid on display, UTM position of transponders, transducer alignment and geographical calibration of LBL arrays.

Motion Sensor Unit

The motion sensor unit is interfaced to the transceiver unit. The system can thereby automatically compensate the transducer position for the vessel's roll and pitch movements. The HiPAP system can use the same sensor as the Dynamic Positioning (DP) system (if one is fitted).

Heading sensor

The heading sensor (gyro compass) provides the HiPAP system with the vessel's heading relative to north. The HiPAP system may then provide transponder coordinates relative to north. It is also used to update the position filter and tracking algorithms as the vessel changes heading.

Attitude sensors

These sensors integrate rate gyros, accelerometer and GPS to provide an accurate roll, pitch, heave and heading output. These sensors are superior to traditional gyros and motion sensors. The HiPAP system may be interfaced to such sensors.

Interface specification

The HiPAP system has several interface formats available. These are described in the **Attitude formats description** document in APOS online help.

Transponders

The position calculation is based on range and/or direction measurements from the onboard transducer to the subsea transponder(s). There is a wide range of transponders available for the HiPAP system. The various transponders models have different depth rating, source level, lifetime, beam pattern and function.

cNODE series

The cNODE series consist of these models:

- **Maxi transponder**

  A full size transponder with large battery capacity well suited for seabed deployment and long life operation.

- **Midi transponder**

  A short transponder with good battery capacity well suited for installation on structures etc.

- **Mini transponder**

  A small sized transponder suited for ROV mounting.

- **MiniS transponder**

  The smallest transponder suited for ROV mounting.

The cNODE transponders have a flexible design based on a standard housing which can have various transducers, release mechanism and sensor modules attached.

Positioning principles and processing

The HiPAP system uses two different principles for positioning; the SSBL and the LBL. These two principles have different properties that make the system flexible for different applications.

- The SSBL principle is based on a range and direction measurement to one transponder, while the LBL principle is based on range measurements to minimum three transponders on the seabed.
- The position accuracy in SSBL is proportional to the slant range to the transponder, while the LBL accuracy is determined by the geometry of the seabed transponders array and the vessel that is being positioned.
- The SSBL principle, due to its simple operation, is the obvious choice if the accuracy is good enough for the application performed. The LBL principle is the obvious choice if the SSBL accuracy is not good enough for the application performed, though it requires a more complex operation.
- Cymbal is a signal processing technique used for all positioning modes. Cymbal utilizes Direct Sequence Spread Spectrum (DSSS) signals for positioning and data communication. DSSS is a wide band signal. The Cymbal protocol provides new characteristics for both positioning and data communication.

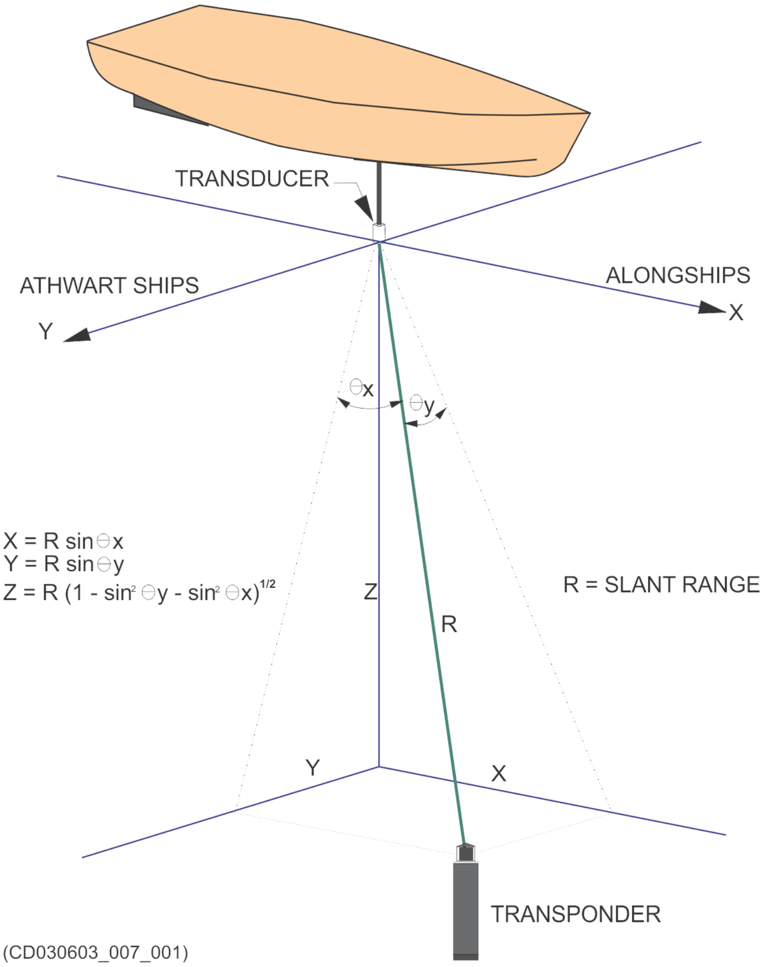
SSBL positioning

In SSBL, the system calculates a three-dimensional subsea position of a transponder relative to a vessel-mounted transducer. The position calculation is based on range and direction measurements to one transponder. The onboard transducer transmits an interrogation pulse to a subsea transponder, which then answers with a reply pulse. When using a responder the interrogation is replaced by a hard wire trigger connection.

- The onboard system will measure the time from the interrogation to the reply pulse is detected and use the sound velocity to compute the range.

- The transponder position is presented both numerical and graphically on the operator station. Only one onboard SSBL type transducer is necessary to establish this position.

Using a pressure sensor in the subsea transponder can increase position and depth accuracy. The pressure is measured and transmitted to the surface HiPAP system using acoustic telemetry. The depth is then used in the algorithms for establishing the 3D position. The system can also read the depth via a serial line input from a pressure sensor. Simultaneous use of many transponders is made possible by using individual interrogation and reply frequencies.



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LBL positioning

The LBL principle is based on one vessel-mounted transducer, and normally 4 - 6 transponders on the seabed.

Calibration

The LBL principle is based on one vessel-mounted transducer, and normally 4 - 6 transponders on the seabed. This seabed transponder array must be calibrated before LBL positioning operations can begin. The calibration determines the transponder's positions in a local geographical coordinate frame.

The HiPAP system supports two calibration techniques:

1. Baseline measurements

   This technique uses automatic calibration functions in the HiPAP system. This allows all the ranges to be measured and made available by acoustic telemetry communication between the transponders and the vessel's system. Based on the baseline measurements and initial positions of the transponders, the calibrated transponder positions are computed.

2. Runtime calibration

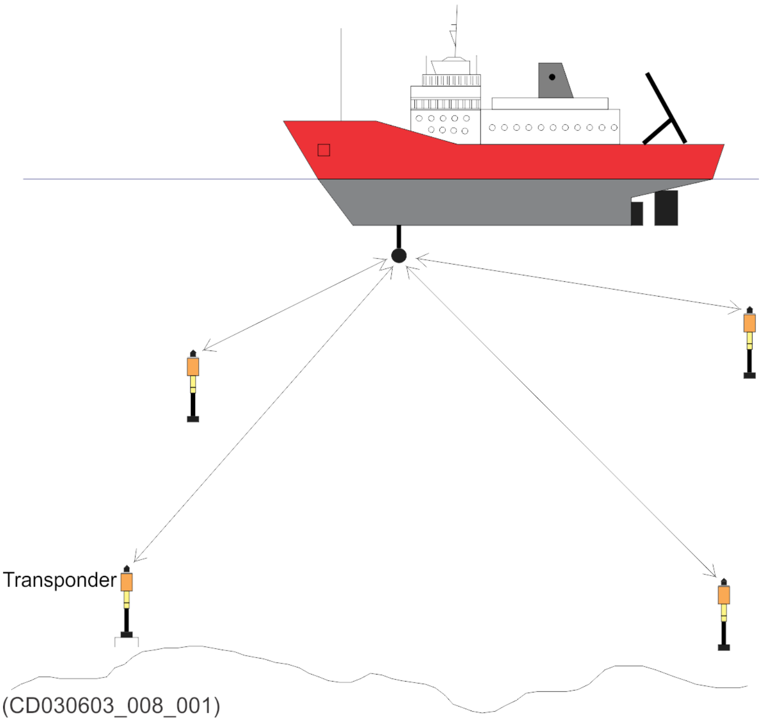
   To use this technique, the system is run in LBL positioning mode, using the SSBL positions of the seabed transponders for the vessel LBL position calculation. The runtime calibration function logs the measurements. Based on this, new optimised seabed transponder positions will be computed. This technique makes the baseline measurements redundant. If the baselines measurements are done, they are also used in the calculations.

The calibration is performed only once prior to positioning operation, since the transponders will remain in the same location during the operation.

Positioning

When the transponder positions are known, positioning of the surface vessel can begin. All the seabed transponders will be interrogated simultaneously, and each will respond with its specific reply signal. The LBL system will then calculate the ranges from the individual transponders. By using the calibration data together with the calculated ranges in software algorithms, the vessel or an ROV can be positioned. ROV positioning requires an cPAP 34 transceiver to be mounted on the ROV.

- The system can take the depth from an ROV-mounted pressure sensor via a serial line. By using this depth in the computation, it will increase the position accuracy of the ROV.
- The range capabilities of a medium frequency LBL system will be approximately the same as those of an SSBL system.
- LBL positioning will give better position accuracy at greater water depths, but is more complex to operate, and it needs more transponders than the SSBL.
- LBL TP positioning method uses one transponder to measure the ranges to the transponders in the array and telemetry the data to the surface vessel, which computes the position of the transponder.



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Multi-user LBL positioning

Several individual vessels and ROV units can now position themselves using the same seabed transponder array. The system and principle has the following main advantages:

- Provides high position accuracy (comparable to standard LBL).
- A small number of transponders serve all vessels and ROVs.
- Secures high position update rate (down to approximately 2 seconds), which is essential in DP operations.
- Avoids transponder frequency collisions when vessels are working in the same area (all vessels are “listening” only).

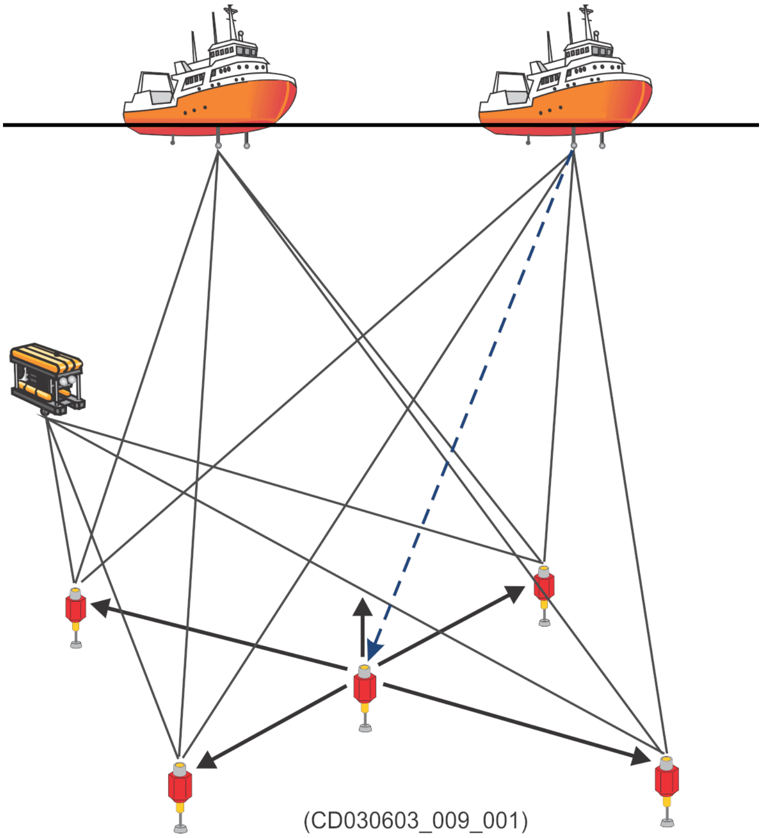
A transponder array is deployed and calibrated by use of subsea baseline measurements. One transponder is used as the Master in the positioning phase. The other transponders are Slaves.

The Master transponder acts as a beacon. It starts a positioning sequence by doing the steps described below. This is done regularly with an interval set by telemetry from one of the vessels.

- The Master interrogates the Slaves.
- The Master transmits its individual transponder channel to be received by the vessels/ROVs positioning in the array.
- Each Slave transponder receives the interrogation from the Master and transmits its individual reply channels after a turnaround delay.

A MULBL system positioning in the array listens for the individual channels transmitted by the master beacon, and by the Slave transponders. When they are received, the system uses its knowledge about their positions in the TP array to calculate the differences in range to the transponders in the TP array. The time difference between the Master interrogation and the start of the reception of the pulses at the system is unknown. It has to be calculated together with the position of the vessel or ROV.

All vessels who uses the MULBL array need the coordinates of the transponders and the channel numbers, which will be distributed with a file.



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Combined SSBL and LBL positioning

The combined SSBL/LBL system uses an onboard multi-element transducer. The system may operate as an SSBL system and as an LBL system simultaneously.

As an example, the vessel may be positioned relative to the seabed using LBL while an SSBL transponder/responder on an ROV is positioned relative to the vessel. The vessel is displayed relative to the array origin and the ROV relative to the vessel.

The combined system will also use the measured directions in 2D together with the measured ranges in the LBL positioning. The combined measurement gives a robust system with increased accuracy. An LBL solution is achievable when only two transponder replies are detected.

Multi-LBL positioning

The HiPAP Multi-LBL solution enables the HiPAP systems onboard one vessel to utilize one LBL transponder array to provide several separate independent position inputs to the DP system. The vessel may be equipped with two, three or four HiPAP systems. Each system provides position input to the DP based on independent measurements.

Principle of operation

One of the HiPAP systems onboard provide the acoustic interrogation of the LBL transponder array and output an electric trigger signal to the other HiPAP systems. All HiPAP systems receives the same signal from the transponder array and can thereby compute an independent position. The electrical trigger enables independent range measurements to the transponders.

In case the interrogating system fails, one of the other systems automatic takes over and interrogates the seabed LBL array and provides the electrical trigger signal. The seabed transponder array can consists of from 3 to 8 transponders. Typically 4 to 5 transponders will be used in one array providing good redundancy, three transponders are required to provide a full LBL solution. By this, redundancy is achieved both onboard the vessel and on the seabed array.

A hardware trigger line must be installed between the HiPAP transceivers, similar to installation of DUAL HiPAP for SSBL mode used on several survey vessels.

Common mode failure is handled onboard by automatic takeover if the interrogating system is failing or a failure on the trigger line occurs. On the LBL transponder array common mode failure is handled by use of redundant transponders in the array.

Features:

- No additional transponders
- No extra battery consumption
- No interference problem from several acoustic interrogations
- Reduced time on transponder deployment
- Reduced time on LBL calibration
- Less maintenance and battery replacement

HiPAP processing

HiPAP SSBL processing

- The HiPAP system determines the position of a subsea target (transponder or responder) by controlling a narrow reception beam towards its location. The system uses a digital beam-former, which takes its input from all the transducer elements.

- The system uses a number of wide fixed beams to generate an approximate position for the target. Once this is achieved, it uses data from all the elements on the hemisphere facing the target to compute the narrow reception beam and optimise the directional measurement.
- The range is measured by noting the time delay between interrogation and reception. The system will control the beam dynamically so it is always pointing towards the target. The target may be moving, and the vessel itself is affected by pitch, roll and yaw. Data from a roll/pitch sensor is used to stabilise the beam for roll and pitch, while directional data from a compass is input to the tracking algorithm to direct the beam in the correct horizontal direction.
- The HiPAP transceiver can operate with up to 560 transponders simultaneously. The data is sent to the computer.

HiPAP LBL processing

- This mode is similar to the HiPAP SSBL processing, but the transceiver positions up to 8 LBL transponders for each single LBL interrogation. Both ranges and directions to the transponders are measured.

HiPAP MULBL processing

- This mode is similar to the HiPAP LBL processing, but the transceiver does not interrogate the MULBL transponder array, it only listen for the replies from the array. The transceiver can listen for to 8 LBL transponders. The direction to the transponders and the time difference between the received replies is transmitted to the computer.

HiPAP MULTI-LBL processing

- This mode allows all HiPAP systems on the vessel to share one LBL array. One of the transceiver/transducers in the system interrogates the network and all transceiver/transducers receives the replies and compute a individual position. This reduces the need for two arrays at the seabed.

HiPAP telemetry processing

- The unit transmits acoustic telemetry messages, and receives and decodes the acoustic telemetry message from the transponder. The data is sent to the computer.

Cymbal acoustic protocol

Cymbal is the acoustic protocol used for both positioning of subsea transponder in SSBL/LBL mode and data communication to and from transponders.

Technology

Cymbal utilizes Direct Sequence Spread Spectrum (DSSS) signals for positioning and data communication. The data communication speed is variable and can be adapted to the acoustic communication conditions; noise and multi-path.

DSSS is a wide band signal.

The Cymbal protocol provides new characteristics for both positioning and data communication.

Range capability and reduced impact from noise

Cymbal protocol can transmit more energy in each positioning pulse. Compared to the current HiPAP 500 this extra energy will provide higher position accuracy at low signal to noise ratio. It will also provide longer range capabilities. This improvement in energy is 5dB.

Range accuracy

The Cymbal signal gives range accuracy in the order of 0.01 m. Error contribution from sound velocity and ray bending not included.

Directional measurements

In SSBL operation, the accuracy of directional measurement is the main contributor to the position accuracy. The HiPAP 502 has new and improved algorithms for directional computation when using Cymbal. At low signal to noise ratio the system will be more robust.

Number of channels

The Cymbal protocol has increased number of unique codes for transponder channels compared to the current system. At present there are 560 unique transponder channels.

Multi-path capability

The Cymbal protocol is designed to have good multi path properties. The processing technique allows signals to and from the transponder to overlap and still be able to have correct detection.

Power management - lifetime

The Cymbal protocol has a power management function that can command the transponder to adjust transmit power to save batteries. This is done automatically by the system.

Data Link with variable data rate - adaptable

The Cymbal protocol supports variable data rate and high reliability level. The obtainable data rate is defined by the signal to noise level and multi-path conditions. By default the system uses data rates that will secure long range and high reliable communication.

Integrated navigation and data link

Data that needs to be sent to and from a transponder will be interleaved between the positioning signals. The cNODE transponder can any time send status and data to the HiPAP and the other way around. If the cNODE transponder detects low battery level, this can be directly sent to HiPAP and displayed to the operator.

cNODE - modeless transponder

The Cymbal protocol is able to use transponders in SSBL and LBL mode without changing the mode of the transponder. A transponder in an LBL array can by the operator be deselected from the LBL positioning and directly be used in SSBL mode. No data telemetry is required.

The cNODE transponders will either listen for a Cymbal or a HPR 400 channel.

Measurement compensation

Roll - pitch - heading compensation

In order to compensate for the vessels roll/pitch/heading movements, vertical reference sensors and heading sensors are interfaced. Data from these sensors are used to compute position data that is relative to horizontal level and to north.

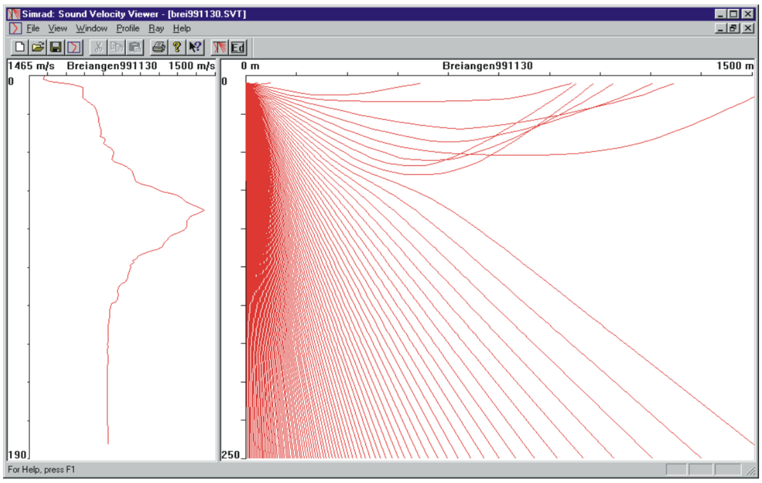
The absolute accuracy and the standard deviation of the position are very dependent of the roll/pitch/heading sensors performance. Especially when working at great water depths the roll/pitch/heading error contribution is significant and when working at long horizontal range the heading error contribution is significant. This compensation is used in all positioning modes.

The accuracy of the attitude data is of crucial significance for the total accuracy of the HiPAP system, and the error from the attitude sensor will add to the error of the HiPAP system.

> *Example*
>
> A roll or pith error of 0.25 degrees will give an error of 4.4 m at 1000 m depth, and an error of 13 m at 3000 m depth - while a roll or pitch error of 0.05 degree will give respectively 0.9 m and 2.6 m.

Ray bending compensation

Positions calculated from the raw measurements are influenced by variable sound velocity through the water column. The variable sound velocity causes an error in both range measurements and the angular measurements. By use of a sound profile, the system can correct these errors.



The sound velocity values may be measured by a probe and transferred to the system. If the depth of the target (transponder) is known either by depth sensor in the transponder or by an ROV depth sensor, these data can be transferred to the system and they will be used in the compensation.

The range calculation is compensated for the error caused by different sound velocities in the water column, and for the extra propagation path caused by the ray bending. The angular measurements are compensated for the ray bending.

The compensation is used in all positioning modes.

Transducer alignment

After a HiPAP installation, it is necessary to determine a number of offsets between various sensor reference points and axes. These are:

- **Vertical angular**

  The offset between transducer axis and roll / pitch sensor axis.

- **Horizontal angular**

  The offset between roll / pitch sensor and heading reference.

- **Horizontal distance**

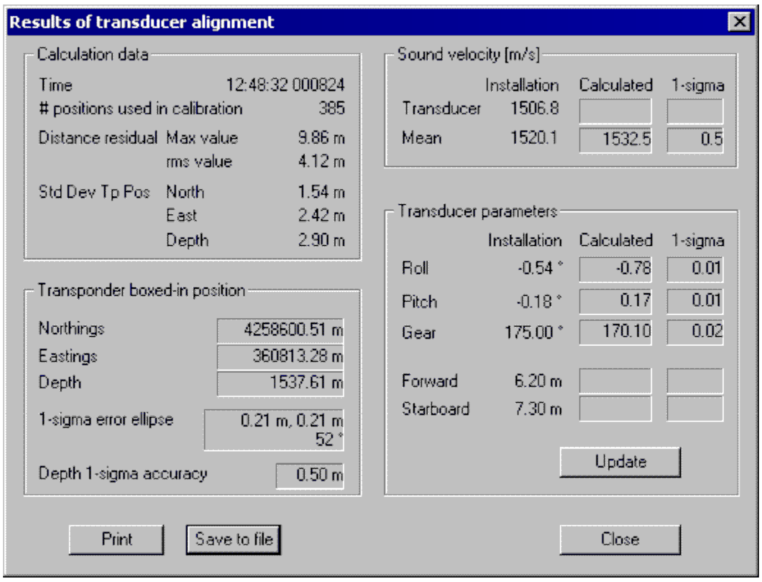
  The offset between transducer location and reference point.

The principles for these alignment adjustments are based on the position of a fixed seabed transponder relative to the vessel and the geographical position of the vessel.

In order to simplify and improve the quality of the alignment scenario, the alignment function in APOS is used. By logging the vessel position from GNSS along with the measured HiPAP position of a seabed transponder, the program computes the alignment parameters. The normal procedure is to locate the vessel at four cardinal points and on top of the transponder with four headings.

Immediately the alignment parameters can be computed and automatically be transferred to the APOS alignment parameters. No manual transfer is needed. The results from the alignment are shown both numerical and graphically in APOS.

An example is shown in the two following figures.



Results of transducer alignment

Calculation data

Time		12:48:32 000824
# positions used in calibration		385
Distance residual	Max value	9.86 m
	rms value	4.12 m
Std Dev Tp Pos	North	1.54 m
	East	2.42 m
	Depth	2.90 m

Transponder boxed-in position

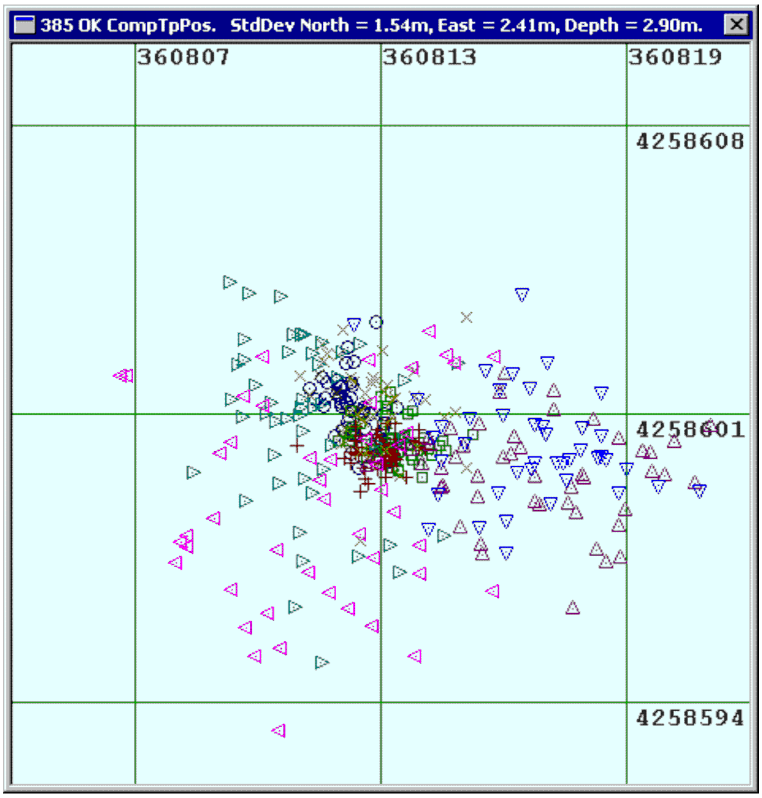
Northings	4258600.51 m
Eastings	360813.28 m
Depth	1537.61 m
1-sigma error ellipse	0.21 m, 0.21 m 52 °
Depth 1-sigma accuracy	0.50 m

Sound velocity [m/s]

	Installation	Calculated	1-sigma
Transducer	1506.8		
Mean	1520.1	1532.5	0.5

Transducer parameters

	Installation	Calculated	1-sigma
Roll	-0.54 °	-0.78	0.01
Pitch	-0.18 °	0.17	0.01
Gear	175.00 °	170.10	0.02
Forward	6.20 m		
Starboard	7.30 m		



The figure shows the positions at the seabed transponder in UTM coordinates after the compensation values are determined and applied. The various symbols are used so readings from different locations easy can be separated from each other.

Applications

Dynamic Positioning (DP) reference

The position data can be used by a DP system as the reference signals for keeping the vessel in the desired position. High position accuracy and reliability ensure a secure and stable reference input to the DP systems. SSBL and LBL systems may be used.

Subsea survey and inspection

Positioning of ROVs carrying instruments for survey and inspection is another important application for the HiPAP system. The ROV position relative to the vessel is integrated with the position from surface navigation to provide a geographical position of the ROV. In this application, a responder is suitable.

Tracking towed bodies for similar applications may also be done. In survey applications, a best possible geographic position is wanted. To obtain this, sound velocity and depth (pressure) sensor input to the HiPAP system may be used.

Rig and Riser monitoring

The HiPAP system can be used to monitor the drill rig position relative to the well/Blow Out Preventer (BOP). It can also be used with inclinometer transponders to monitor the BOP and riser inclination. Used with the Acoustic Control Subsea (ACS500) it can be used for BOP.

Acoustic Blow Out Preventer (BOP) control

The HiPAP system is also used for transmitting and receiving acoustic telemetry command with high security. This is used for acoustic BOP control, which includes BOP valve operation and monitoring critical functions by reading subsea status information and sending this information to the operator onboard the vessel.

A separate unit, the ACS500, is required on the BOP stack. The ACS500 contains electronics and batteries for interfacing the BOP.

A portable control unit, the Acoustic Command Unit (ACU30), is also available. The ACU30 contains electronics and batteries for operating the BOP functions.

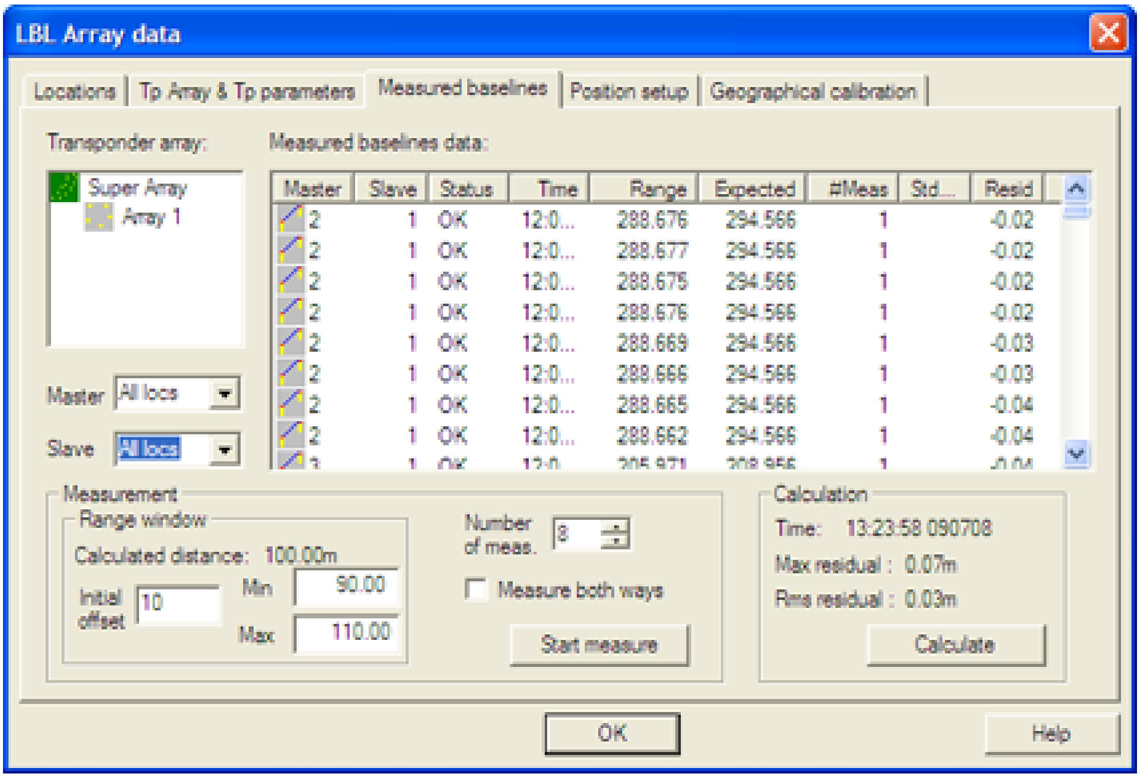
Construction work and metrology

The HiPAP system forms a powerful platform for performing several tasks for positioning and acoustic data communication for construction and metrology work:

- LBL array calibration
- Box-in of locations
- Telemetry of sensor data
- Highly accurate baseline measurements

The cNODE transponder has high performance range measurement and data communication capabilities. A variety of sensors are available for cNODE and the sensor data is available to the operator from the HiPAP system.

The accuracy of baseline measurements obtained by use of cNODE transponders can be in the order of 0.01 m. However, to obtain this kind of accuracy it is essential that the operator has full control of the sound velocity. The figure below shows an APOS screen dump showing the statistics from a LBL calibration. The RMS residuals are calculated to be 0.03 m. There were 7 transponders in the array.



Master	Slave	Status	Time	Range	Expected	#Meas	Std...	Resid
2	1	OK	12:0...	288.676	294.566	1		-0.02
2	1	OK	12:0...	288.677	294.566	1		-0.02
2	1	OK	12:0...	288.675	294.566	1		-0.02
2	1	OK	12:0...	288.676	294.566	1		-0.02
2	1	OK	12:0...	288.669	294.566	1		-0.03
2	1	OK	12:0...	288.666	294.566	1		-0.03
2	1	OK	12:0...	288.665	294.566	1		-0.04
2	1	OK	12:0...	288.662	294.566	1		-0.04
3	1	OK	[illegible]	[illegible]	[illegible]	1		[illegible]

Master: All locs
Slave: All locs

Calculated distance: 100.00m
Initial offset: 10
Min: 90.00
Max: 110.00
Number of meas.: 8
☐ Measure both ways

Calculation
Time: 13:23:58 090708
Max residual : 0.07m
Rms residual : 0.03m

Technical specifications

Performance specifications

These performance specifications summarize the main functional and operational characteristics of the HiPAP.

SSBL accuracy

The given values for accuracy are 1σ figures.

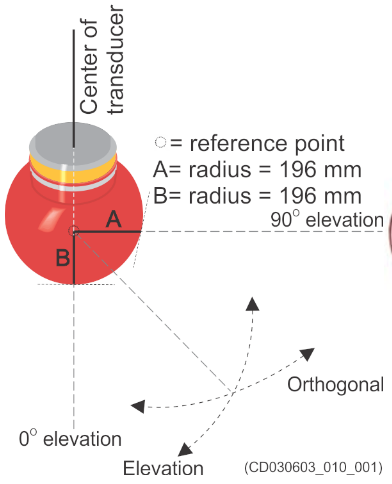
The specification is based on:

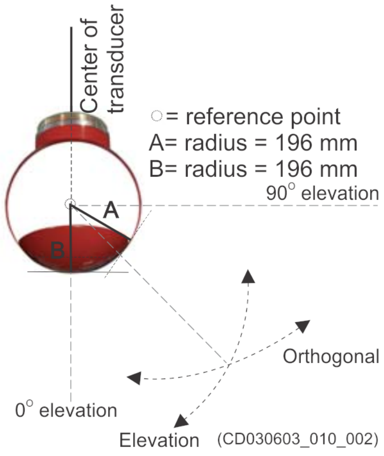
- Free line of sight from transducer to transponder.
- No influence from ray-bending.
- Signal to Noise ratio in water in the 250 Hz receiver band.
- No error from heading and roll/pitch sensors.

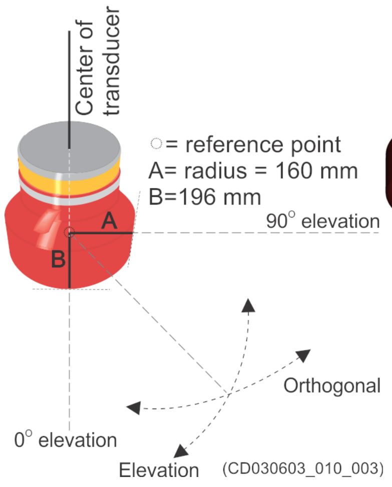
Transducer reference point

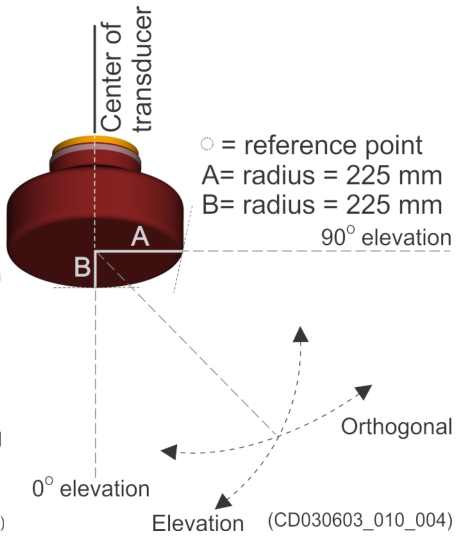
The reference points shown below are the origin for the position measurements.

The elevation and orthogonal angles are used in the accuracy curves.









HiPAP 502

	HiPAP 502 Single system	HiPAP 502 Dual system
S/N [dB rel. 1µPa]	20	20
Angular accuracy (X & Y direction) [°]	0.06	0.042
Cymbal range accuracy [m]	0.02	0.02
Angular repeatability up to [°] S/N 30 dB rel. 1µPa	0.01	0.01
Receiver beam [°]	10	10
Operational coverage [°]	±110	±110
Main coverage [°]	±100	±100

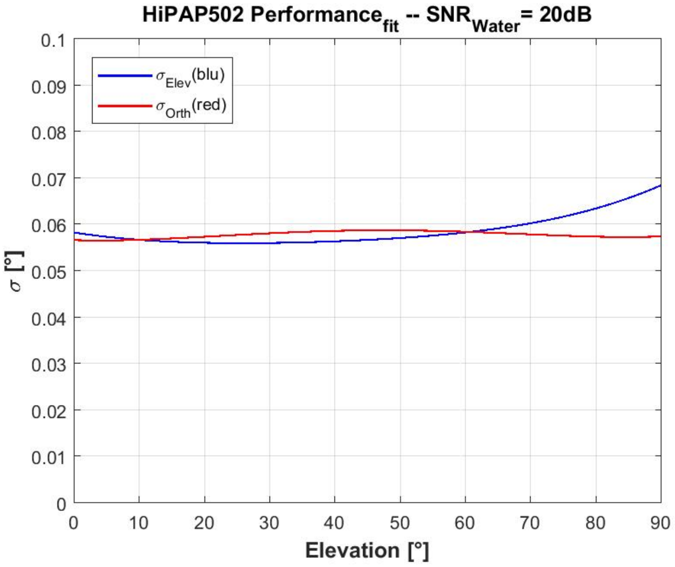
Angular accuracy (X & Y direction) [°] is the accuracy in each of the x and y axis.

Operational coverage defines the sector where acoustic positioning and communications are operational.

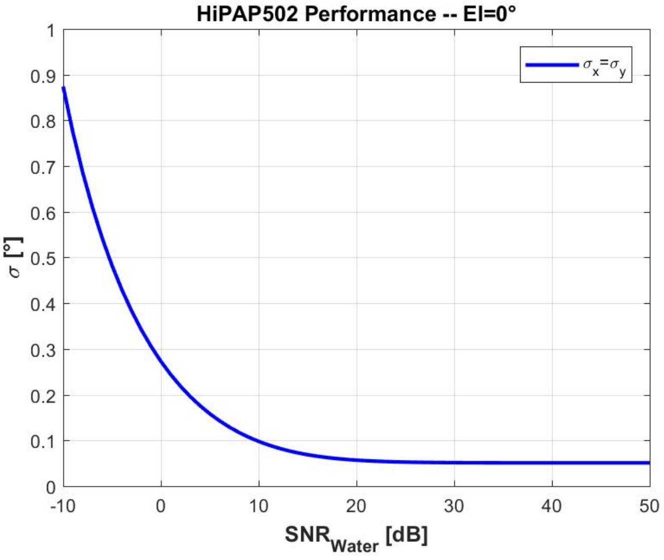
Main coverage is the sector where maximum range and angular accuracy can be achieved.

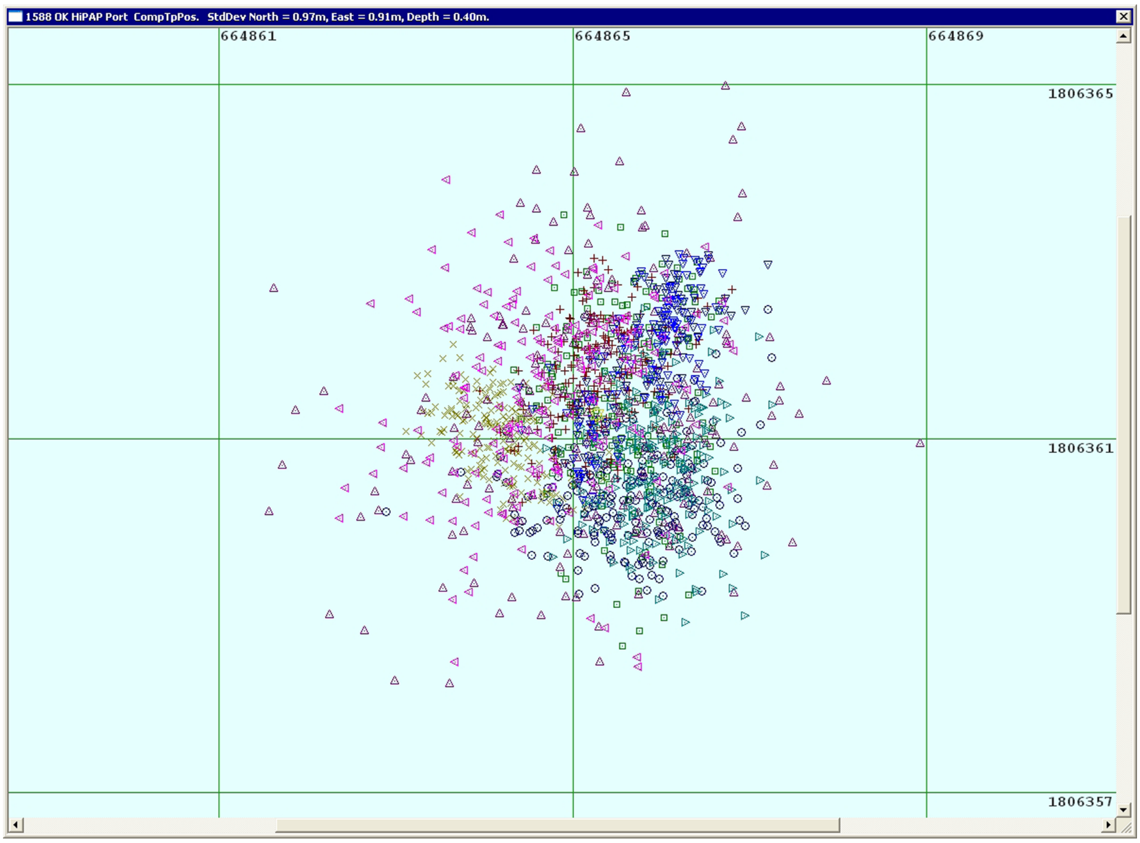
Outside the main coverage range and elevation angular accuracy are reduced, therefore a depth input for aiding is recommended.

The following figure shows the accuracy as a function of elevation angle. The signal to noise ratio of 20 dB is within the signal bandwidth.



The following figure shows the accuracy as a function of signal to noise ratio. The elevation angle is 0° (at vertical).





1588 OK HiPAP Port CompTpPos. StdDev North = 0.97m, East = 0.91m, Depth = 0.40m.

During transducer alignment at 1200 meter water depth with data logged with 4 different heading on top of transponder and 4 cardinal points a total accuracy of the seabed position is estimated to a standard deviation is N0.97 m and E0.91 m

This equals to 0.08% of water depth or 0.046º accuracy. A cNODE Maxi 34-30V was used.

HiPAP 602

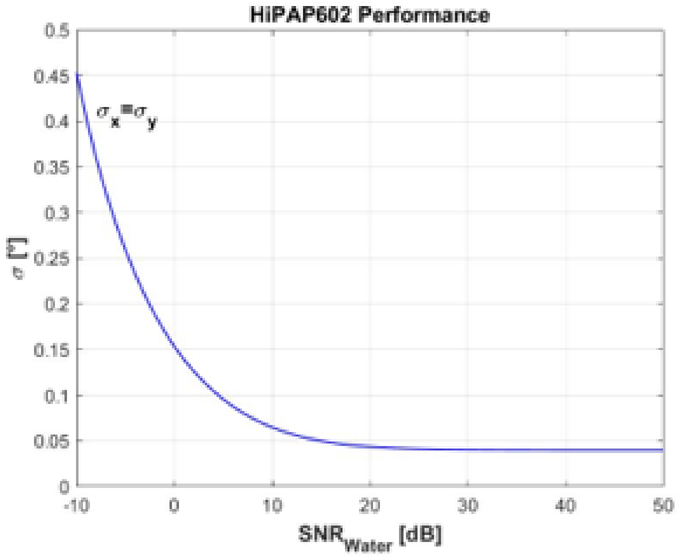
	HiPAP 602 Single system
S/N [dB rel. 1µPa]	TBD
Accuracy, direction	0.04° within ±30° sector 0.06° from ±30° to ±60° sector
Repeatability, direction	0.01°, within ±30° sector
Range accuracy, Cymbal [m]	0.02
Angular repeatability up to [°] S/N 30 dB rel. 1µPa	0.018
Receiver beam [°]	8
Operational coverage [°]	±90
Main coverage [°]	±60

Accuracy is in X and Y direction. @SNR 20dB rel.1µPa, 1sigma/RMS. Free line of sight, no raybending.

Operational coverage defines the sector where acoustic positioning and communications are operational.

Main Coverage is the sector where maximum range and angular accuracy can be achieved.

Outside the main coverage range and elevation angular accuracy are reduced, therefore a depth input for aiding is recommended. Whilst within the main coverage, range is up to 5000 m, operational tests show ranges out to 1000 m at 80 degrees or near the horizontal.



HiPAP 452

	HiPAP 452 Single system
S/N [dB rel. 1µPa]	20
Angular accuracy (X & Y direction) [°]	0.1
Range accuracy, Cymbal [m]	0.02
Angular repeatability up to [°] S/N 30 dB rel. 1µPa	0.018
Receiver beam [°]	15
Operational coverage [°]	±90
Main coverage [°]	±80

Angular accuracy (X & Y direction) [°] is the accuracy in each of the x and y axis.

Operational coverage defines the sector where acoustic positioning and communications are operational.

Main Coverage is the sector where maximum range and angular accuracy can be achieved.

Outside the main coverage range and elevation angular accuracy are reduced, therefore a depth input for aiding is recommended. Whilst within the main coverage, range is up to 5000 m, operational tests show ranges out to 1000 m at 80 degrees or near the horizontal.

HiPAP 352

Model	HiPAP 352P	HiPAP 352P-5	HiPAP 352P-MGC
Motion sensor [°]	0.05 Range ±180°	0.02 Range ±180°	0.01 Range ±180°
HiPAP only [°] S/N [dB rel. 1µPa]	0.1	0.1	0.1
Total [°], [1 σ]	0.11	0.1	0.1
% of slant range [1 σ]	0.19	0.17	0.17
Range accuracy [m]	0.1	0.15	0.2
Range accuracy, Cymbal [m]	0.02	0.02	0.02
Receiver beam [°]	15		
Operational coverage [°]	±90		
Main coverage [°]	±80		

Angular accuracy (X & Y direction) [°] is the accuracy in each of the x and y axis.

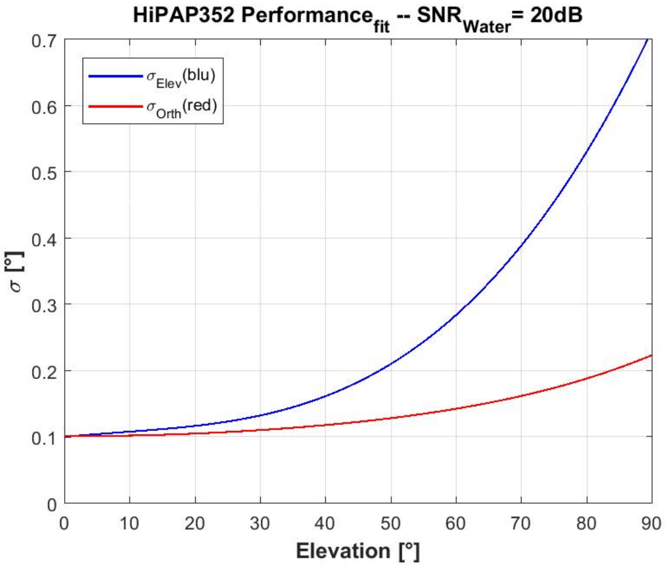
Operational coverage defines the sector where acoustic positioning and communications are operational.

Main Coverage is the sector where maximum range and angular accuracy can be achieved.

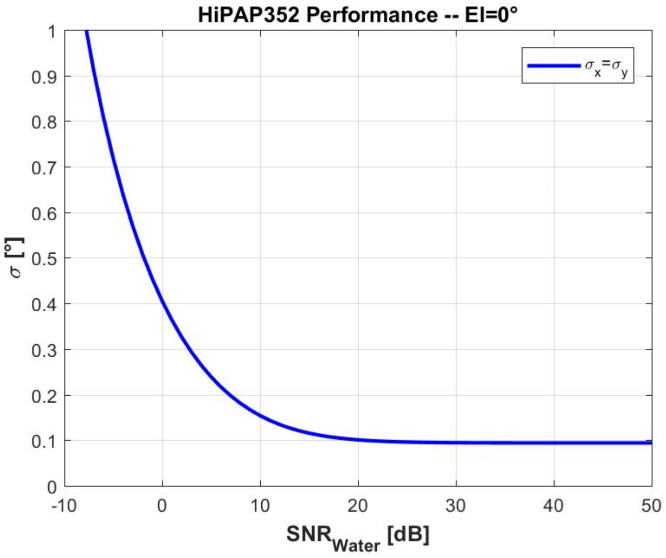
Outside the main coverage range and elevation angular accuracy are reduced, therefore a depth input for aiding is recommended. Whilst within the main coverage, range is up to 5000 m, operational tests show ranges out to 1000 m at 80 degrees or near the horizontal.

The elevation and orthogonal angles are used in the accuracy curves.

The following figure shows the accuracy as a function of elevation angle. The signal to noise ratio 20 dB is within the signal bandwidth.



The following figure shows the accuracy as a function of signal to noise ratio. The elevation angle is 0° (at vertical).



HiPAP 102

	HiPAP 102 system
S/N [dB rel. 1μPa]	20
Angular accuracy, (X and Y direction) [°] (At 0° elevation)	0.1
Angular repeatability up to [°] S/N 30 dB rel. 1μPa	0.025
Cymbal, range accuracy, 1σ [m]	0.02
Receiver beam [°]	15
Operational coverage[°]	±90
Main coverage [°]	±60

Angular accuracy (X & Y direction) [°] is the accuracy in each of the x and y axis.

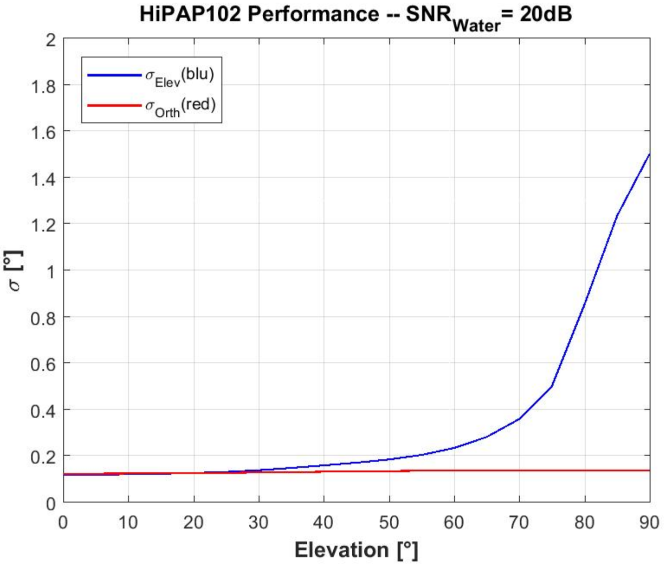
Operational coverage defines the sector where acoustic positioning and communications are operational.

Main Coverage is the sector where maximum range and angular accuracy can be achieved.

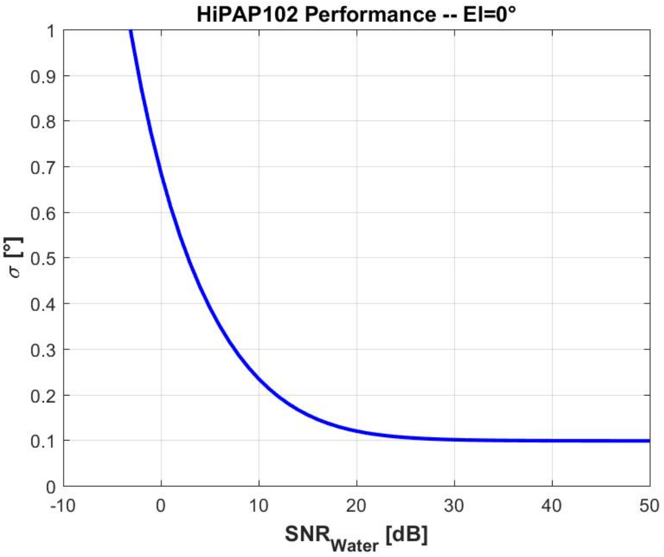
Outside the main coverage range and elevation angular accuracy are reduced, therefore a depth input for aiding is recommended. Whilst within the main coverage, range is up to 13000 m, operational tests show ranges out to 3500 m at 86 degrees or near the horizontal.

The elevation and orthogonal angles are used in the accuracy curves.

The following figure shows the accuracy as a function of elevation angle. The signal to noise ratio 20 dB is within the signal bandwidth.



The following figure shows the accuracy as a function of signal to noise ratio. The elevation angle is 0° (at vertical).



LBL accuracy

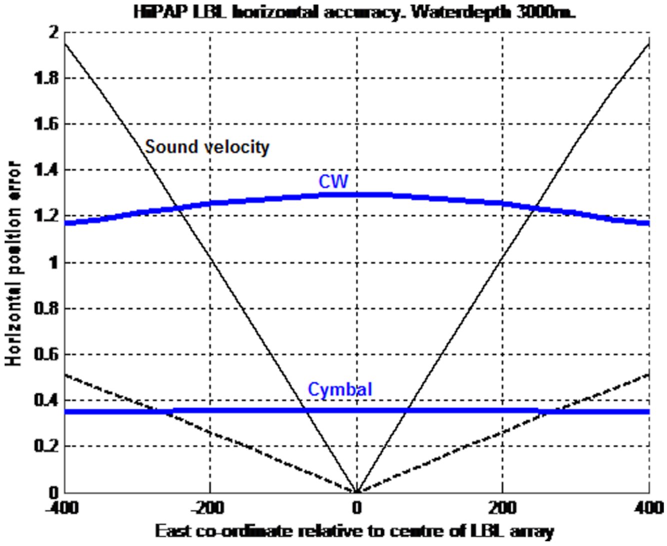
LBL accuracy

The position accuracy for LBL operation depends on the transponder array geometry, sound velocity errors and signal to noise ratio. Range accuracy’s down to a few centimetres can be obtained, while ROV and vessel positions can be calculated to within a few decimetres.

The following table and figure show acoustic parameters and position accuracies, achieved in deep waters when using an array with four transponders at 3000 metre water depth.

Source of random error	1σ CW	1σ Cymbal
Range reception with 20 dB S/N	0.15 m	0.02 m
Range reception in the transponder	0.15 m	0.02 m
Range error due to transponder movements	0.01 m	
Range error due to rig movements	0.05 m	
HiPAP angle accuracy	0.15 °	

The following figure is LBL position error in the horizontal plane as a function of the East coordinate. The North coordinate is zero. The blue lines show random error due to acoustics. The black line is systematic error due to 1 m/s wrong sound velocity settings.



The blue lines show the random error in the horizontal position when the rig moves within a transponder array with 4 transponders placed on a circle with 500 m radius at water depth 3000 m. The lower line shows the expected error when the Cymbal acoustics is used and the upper line when the CW acoustics is used.

The black line shows the systematic error when the sound velocity is set 1 m/s wrongly in APOS. This error is zero in the centre of the array due to the symmetry. The LBL run time calibration should be done when the rig is in the centre of the array. Then the effect of a wrong sound velocity setting in APOS is strongly reduced, as shown with the dotted black line.

Range capabilities

Range capabilities

The range capabilities of an acoustic system are dependent of the vessels noise level and attenuation of the transponder signal level due to ray bending. The transponder source level and the signal to noise ratio are crucial factors for calculating maximum range capability. The following figures are recommended guideline for maximum operating range.

Please also be aware of:

- Figures for cNODE are when used in Cymbal mode (Wideband)
- The HiPAP system will in many cases have longer range capabilities that specified below due to its narrow receiving beam.
- The figures are approximate values for guidance.
- Ray bending can limit the maximum range
- Ray bending is normally not a problem for vertical positioning operations

System/transponder	**Transponder source level (dB rel.1µPa ref. 1 m)**	**Max Range (Typical, m)**
HiPAP 502/352/452/ cNODE 180º transducer	190	2000
HiPAP 502/352/452/ cNODE 40º transducer	203	4000
HiPAP 502/352/452/ cNODE 30º transducer	206	5000
HiPAP 602/ cNODE 30º transducer	206	7000
HiPAP 102/ cNODE 50º transducer	203	13000

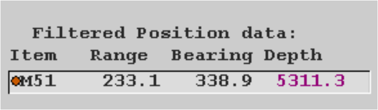
The specification is based on:

- Free line of sight from transducer to transponder
- No influence from ray bending
- Signal to Noise ratio ≥ 12 dB. rel. 1µPa

The HiPAP 502/452/352/ systems operates with 56 channels in 10 different frequency bands enabling a total number of 560 unique transponder channels to be utilized.

Proven range capabilities

HiPAP 502:

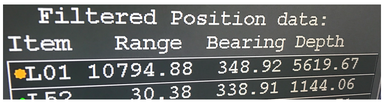


```
  Filtered Position data:
Item    Range   Bearing Depth
●M51     233.1    338.9  5311.3
```

The above results show a slant range of 5321 meters from HiPAP to the cNODE transponder.

The application is for AUV tracking.

HiPAP 102:



```
  Filtered Position data:
Item     Range   Bearing Depth
L01  10794.88   348.92 5619.67
          30.38   338.91 1144.06
```

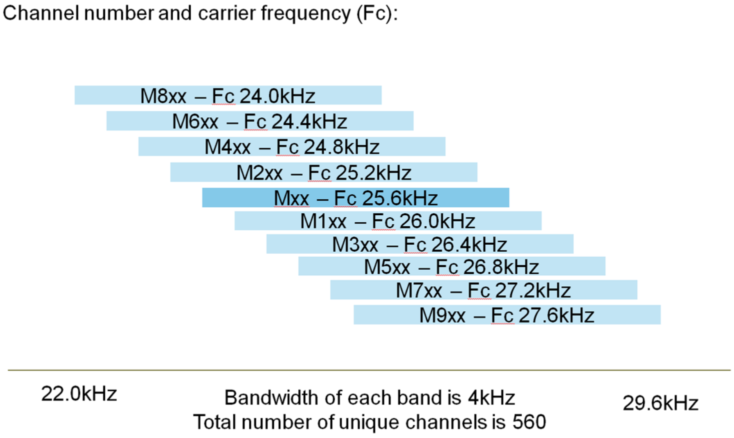
The above results show a slant range from HiPAP to the cNODE transponder of 12169 meters.

The application is for AUV tracking.

Multi-Band

Multi-Band

The Cymbal acoustic protocol includes operation in several frequency bands. Telemetry executes in the same band as the selected transponder interrogation and reply occurs. Each band consist of 56 positioning channels and 6 LBL interrogation channels. A total of 560 unique channels for positioning along with 60 unique LBL interrogation channels are available.



Channel number and carrier frequency (Fc):

Bandwidth of each band is 4kHz
Total number of unique channels is 560

Weights and outline dimensions

These weights and outline dimension characteristics summarize the physical properties of the HiPAP system.

Operator station

	Weight	Height	Width	Depth
Computer:	Approx. 7 kg	379 mm	338 mm	100 mm
Display:		444 mm	483 mm	82 mm
Keyboard:	0.5 kg		298 mm	142 mm

Transceiver unit

- **Width**: 525 mm
- **Height**: 909 mm
- **Depth**: 548 mm
- **Weight**: 72 kg

Hoist control unit

- **Width**: 300 mm
- **Depth**: 250 mm
- **Height**: 400 mm
- **Weight**: 12 kg

Responder driver unit

Weight	Height	Width	Depth
2.8 kg	73 mm	280 mm	200 mm

Power specifications

These power characteristics summarize the supply power requirements for the HiPAP system.

Operator station

	Value
Voltage:	110/220 VAC, 50/60 Hz autosensing, 240 W 85+ autosensing power
Maximum voltage deviation:	15%
Maximum current draw:	5 A

	Value
Normal current draw:	0.5 A
Nominal power:	150 W

Transceiver unit

- **Voltage requirement**: 115/230 VAC — 50/60 Hz
- **Maximum voltage deviation**: Min. 85 VAC / Max. 264 VAC — 47-63 Hz
- **Immunity**: Fast transient burst EN61000-4-4 (4 kV)
- **Maximum voltage deviation**: 15%
- **Maximum current draw**: 40 A
- **Normal current draw**: 0.8 A

Hull unit

- **Voltage**: 230/440 VAC 3-phase
- **Frequency**: 50 to 60 Hz
- **Maximum consumption**: 750 W

Hoist control unit

- **Voltage**: 230/440 VAC 3-phase
- **Frequency**: 50–60 Hz
- **Power consumption**: 750 to 1100 W, depending on application

Raise and lower motor

- **Voltage**: 230/440 VAC 3-phase
- **Frequency**: 50–60 Hz
- **Power consumption**: 750 W
- **Speed**: 1500 RPM
- **Timken OK Load, ASTM D2509**: Lb 40

Responder driver unit

	Value
Power:	85 to 264 VAC
Frequency:	40 to 440 Hz
Maximum inrush:	5 A AC
Maximum current drawn:	0.4 A
Normal current drawn:	0.06 A
Nominal power consumption:	15 W

Environmental specifications

The environmental specifications summarize the temperature and humidity requirements for the HiPAP system.

Operator station

	Value
Operational temperature:	0 to 55°C
Storage temperature:	-20 to 70°C
Humidity:	5 to 95% (non-condensing)

Transceiver unit

- **Protection**: IP 44
- **Vibration range**: 5 to 100 Hz
- **Excitation level**: 5-13.2 Hz ± 1.5 mm, 13.2-100 Hz 1 g
- **Operating temperature**: 0 to 55 °C
- **Storage temperature**: -20 to 65 °C
- **Humidity**: 15% to 95% (non condensing)

Hoist control unit

- **Protection**: IP 54
- **Operational temperature**: 0 °C to 55 °C
- **Storage temperature**: -20 °C to 60 °C
- **Operational humidity**: 80% relative
- **Storage humidity**: 90% relative

Responder driver unit

	Value
Protection:	IP44
Operation temperature:	0 to 55°C
Storage temperature:	-40 to 75°C
Humidity:	15% to 95% (non condensing)
Vibration range:	5 to 100 Hz
Vibration excitation level:	5 to 13.2 Hz ±1.5 mm, 13.2 to 100 Hz 1 g

Input formats

Transceiver unit

The HiPAP transceiver accepts the following input formats:

Gyro

- NMEA $**HDT
- NMEA $**VHW
- Yokogawa $**HRC
- SKR
- STL

VRU/Attitude

- EM 3000
- $SPSXN,10
- $SPSXN,23
- IxSea Octans TAH ($PHOCT) R-P-H (UTC)
- IxSea Octans $PHTRO (roll and pitch)
- Ixsea Octans $PHLIN (Heave only)

For attitude data, the data rate should be at least 25 Hz, 100 Hz is recommended.

Data input can be either serial line RS-232 / RS-422 or Ethernet UDP.

Serial line speeds can be from 1200 baud up to 115200 baud, 1 or 2 stop bits, 7/8 bit data and parity none, even or odd.

Drawing file

Topics

Computer outline dimensions, page 47

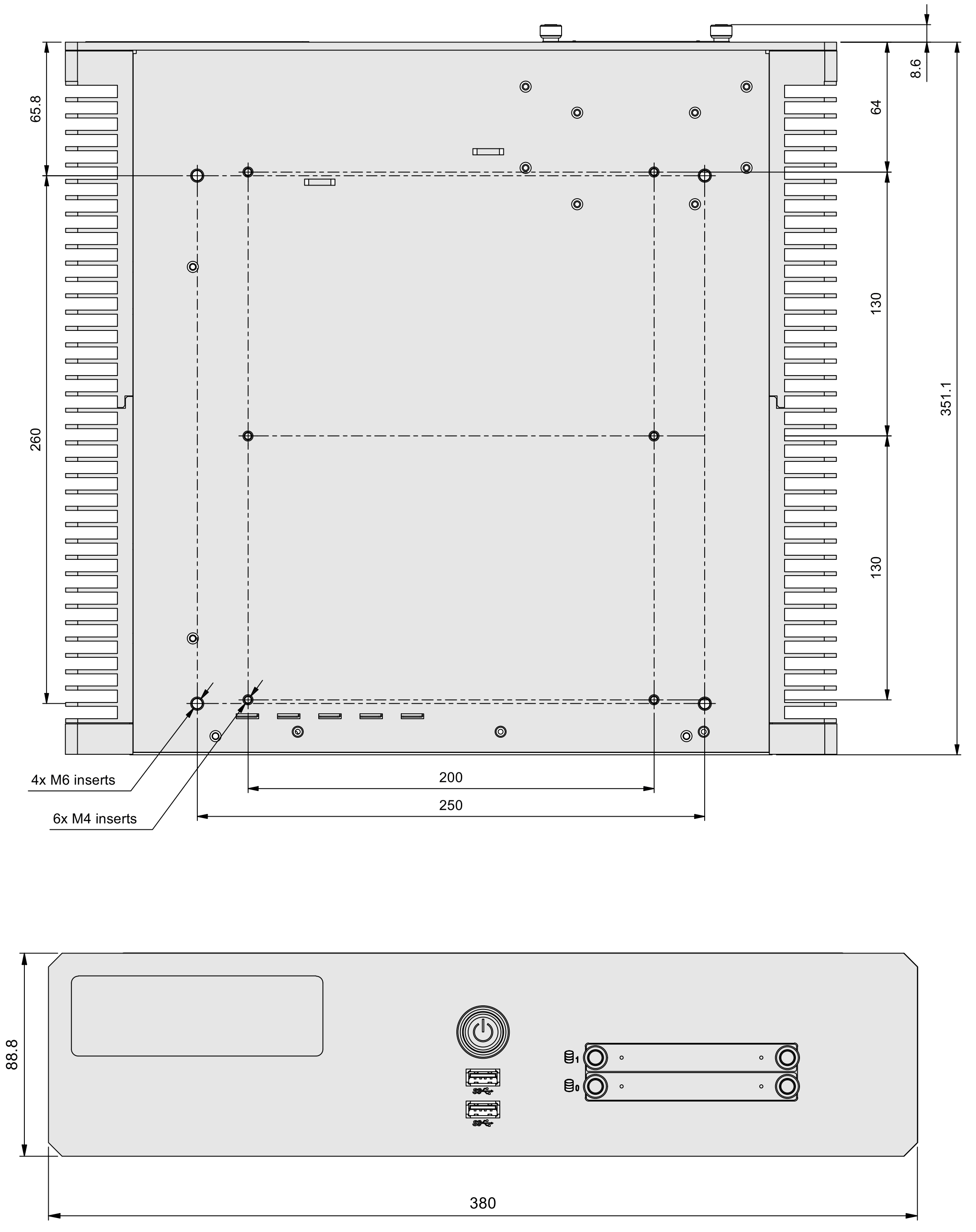
JH19T14 Display dimensions, page 48

Responder Driver Unit outline dimensions, page 49

Transceiver Unit dimensions, page 50

Hull unit controller outline dimensions, page 51

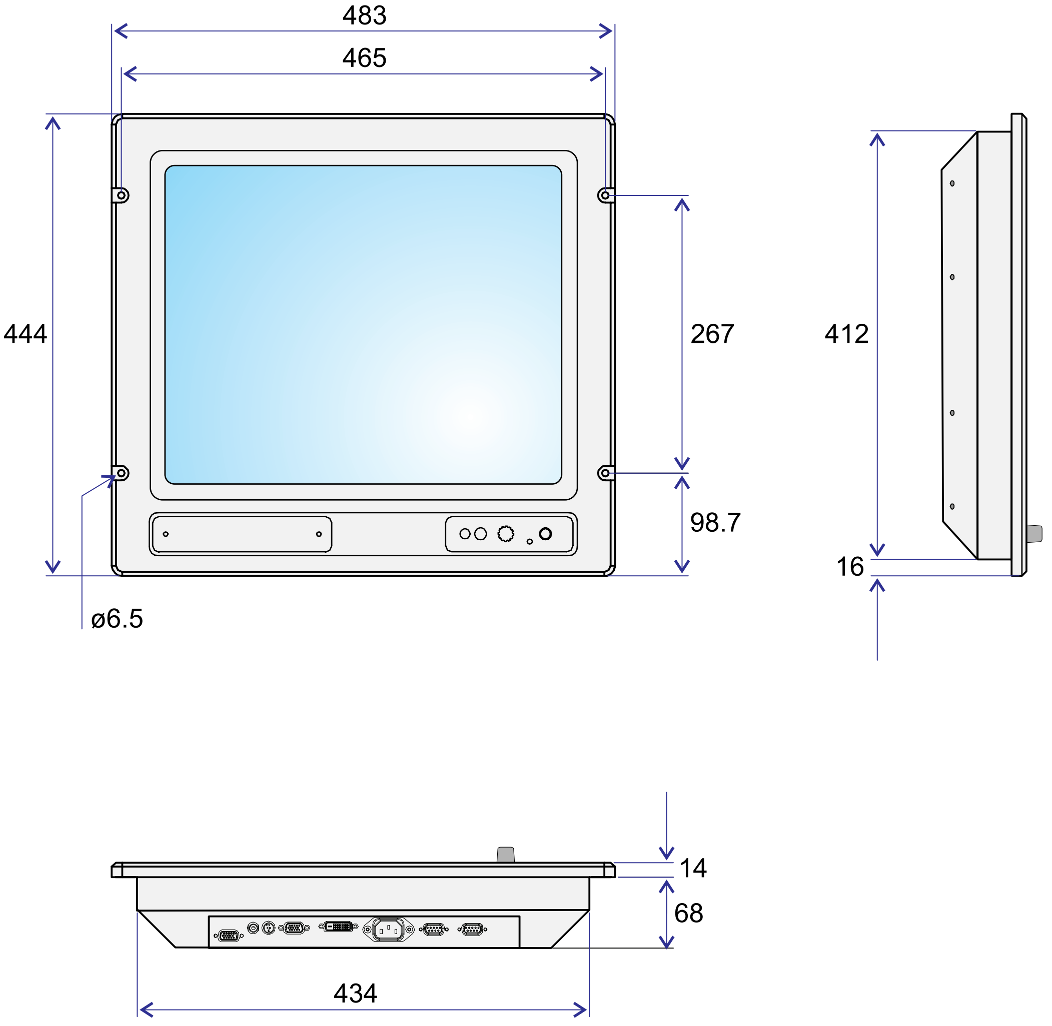
Computer outline dimensions



All measurements in mm.
The drawing is not to scale.
Information may be omitted. Observe the source drawing for additional details.

[472992] Rev.A
AI_12_472992_001_001

JH19T14 Display dimensions

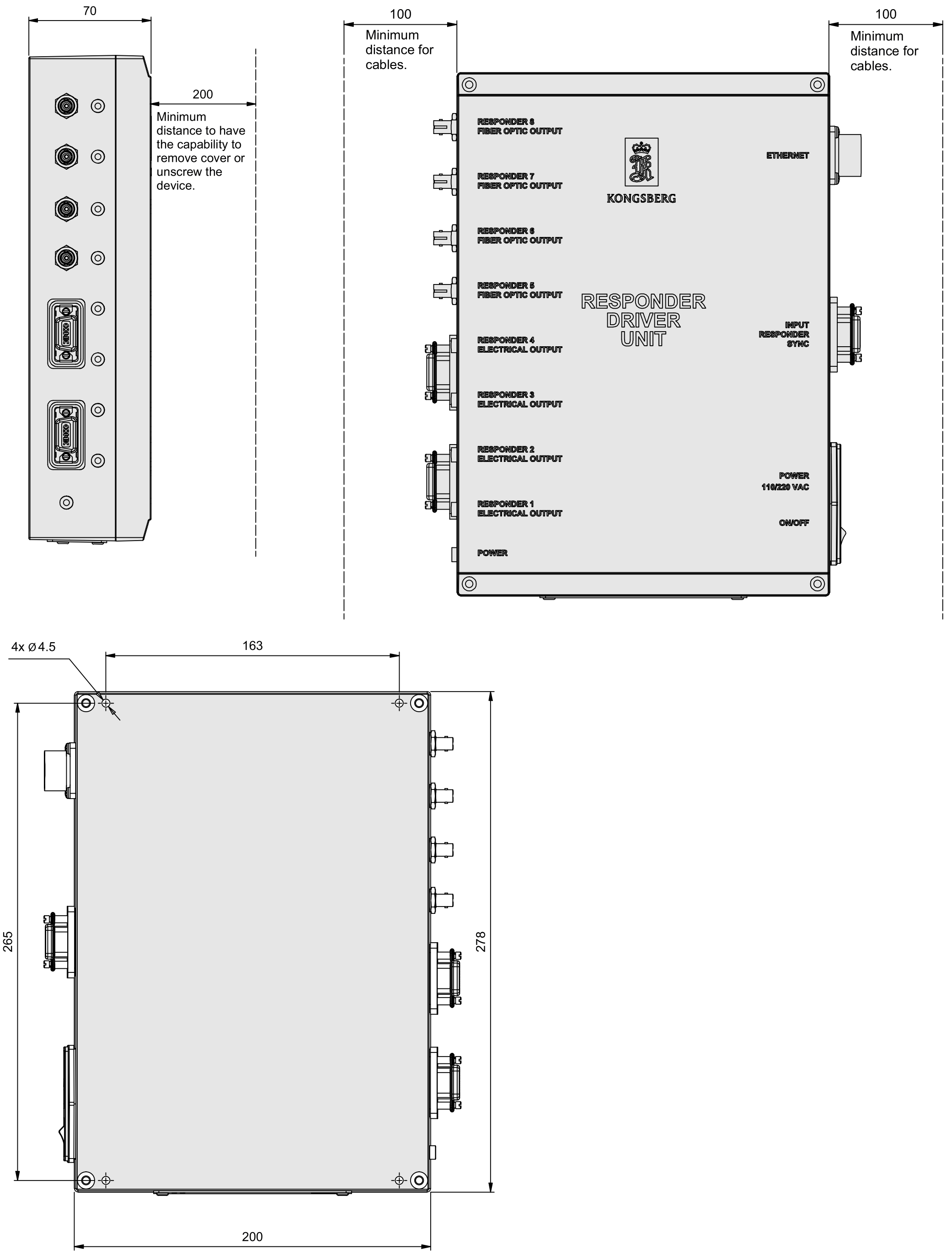


NOTE:
This is a copy of the original drawing made by the manufacturer. We are not responsible for errors. Changes made by the manufacturer may not be reflected in this copy.
For the original drawing, see
http://www.hatteland-display.com

All measurements in mm.
The drawing is not in scale.

[Hatteland Displays]
CD12_000101_001_001

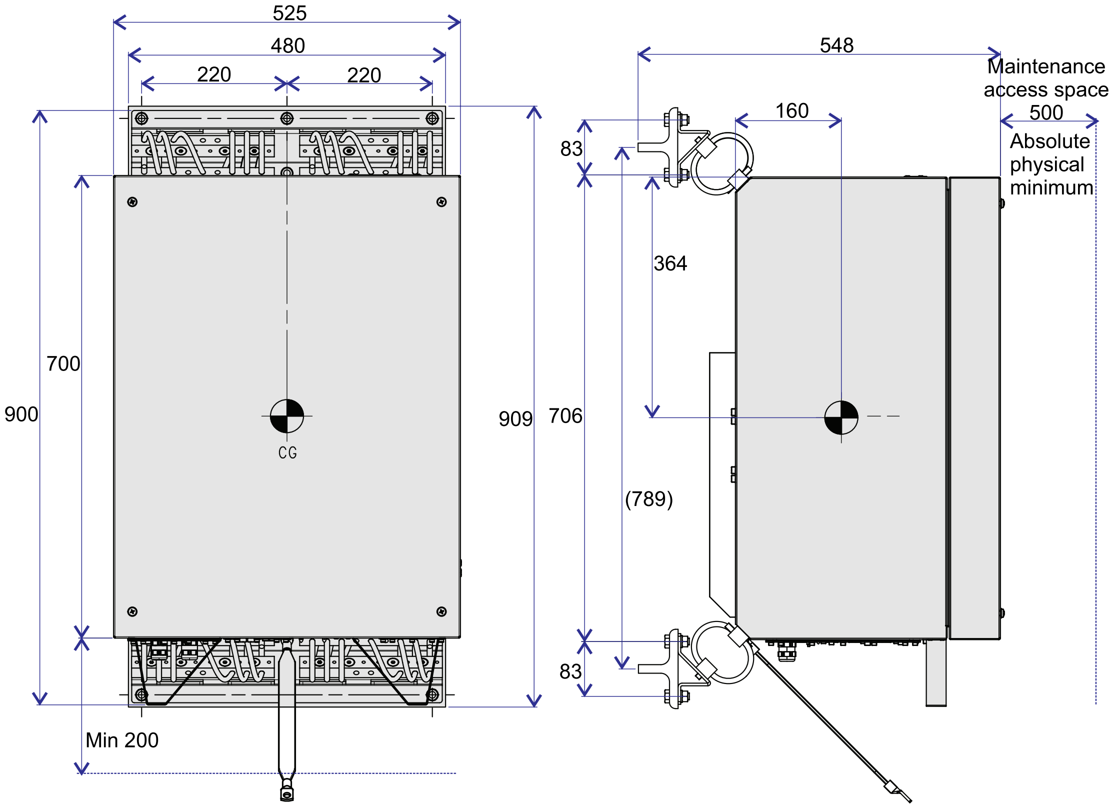
Responder Driver Unit outline dimensions

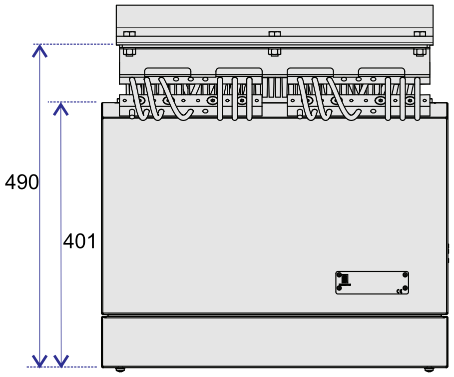


All measurements in mm.
The drawing is not to scale.
Information may be omitted. Observe the source drawing for additional details.

[316067] Rev.D
AI12_316067_001_001

Transceiver Unit dimensions





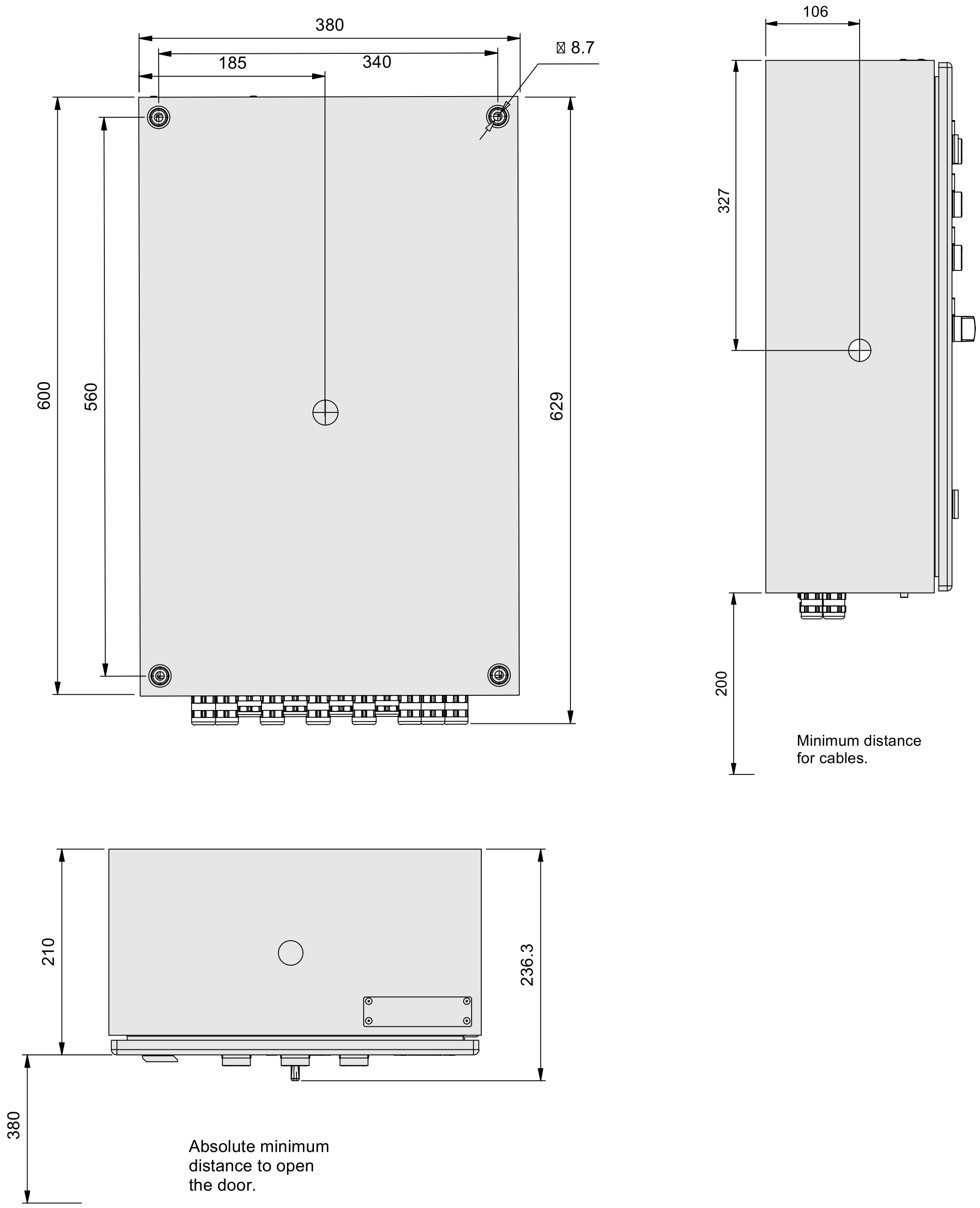
Weight 72 kg

Note:
The centre of gravity may vary slightly according to different configurations within the cabinet.

All measurements in mm.
The drawing is not in scale.

[400538] Rev.A
CD12_400538_001_001

Hull unit controller outline dimensions



All measurements in mm.
The drawing is not to scale.
Information may be omitted. Observe the source drawing for additional details.

[462456] Rev.B
AI12_462456_001_001

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