



Product Description

ATLAS HYDROSWEEP DS-2

Hydrographic Deep Sea Multibeam Echosounder

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CHANGE LOG

Version	CHANGES	Author(s)	Date
1.0	- Initial version (based upon an existing product description from Holger Klindt)	Ch. Zwanzig	25.04.2002
1.1	- Change of ATLAS Hydrographic Logo	S. Birnstiel	01.03.2003
1.2	- Revision and completion of technical data	Ul. Lütticke	23.05.2003
1.2.1 final	- minor changes	S. Könnecke	07.10.2003

1 Introduction

The worldwide constitution of National Exclusive Economic Zones (EEZ) focuses the nations attention on the enormous resource potential of oceanic regimes. The utilisation of vast areas, extending from inshore to the high seas, offers a broad spectrum of technological challenges. The future management of these marine resources highly depends on the availability of appropriate technologies for surveying, monitoring and exploitation. The ATLAS HYDROSWEEP DS-2 has been developed as a unique surveying tool for continuous and gap-less acquisition of highly demanded seafloor data. International Marine Research Institutions, National Hydrographic Services, Offshore Surveyors and Engineers as well as Environmental Agencies utilise the instrument's outstanding accuracy, resolution and the wide swath width in a demanding environment.

The ATLAS HYDROSWEEP DS-2 multibeam echosounder utilises an enhanced preformed beam detection technology in order to overcome classical array aperture limitations. A dual-principle beamforming device combines traditional, stabilised time-delay beamforming with ATLAS Hydrographics' advanced high-resolution bearing discriminator, a technology originally introduced with ATLAS Hydrographics' shallow water multibeam echosounder system ATLAS FANSWEEP 20. Swath angles of up to 120 degrees can be achieved and resolved into up to 240 independent depth information channels.

ATLAS HYDROSWEEP DS-2 has been designed to meet the following performance characteristics:

- *The range*, to include all world oceans independent of their specific boundary conditions, i.e. depths from shallow shelf regions all the way down into the abyssal plains and deep oceanic trenches.
- *The coverage*, to provide utmost operational efficiency. With its horizontal "T-type" transducer array, the ATLAS HYDROSWEEP DS-2 provides coverage of up to 120 degrees.
- *The accuracy*, to comply with Hydrographic standards as specified by the International Hydrographic Organisation, Special Publication No. 44 (see reference /5/). The ATLAS HYDROSWEEP DS-2 achieves full SP44-compliant data accuracy within swath widths of typically 2 to 3 times the water depth.
- *The angular resolution*, to provide a maximum of operational and scientific value for a wide variety of applications from object search and detection to route surveys. The ATLAS HYDROSWEEP DS-2 achieves up to 240 depth data per swath. Acoustic footprints can be arranged in either an "equal-footprint" or an "equal-angle" pattern in order to adapt to specific survey conditions.
- *The efficiency*, to support the operator from the initial investment phase through to the full instruments life cycle with innovative solutions to minimise its procurement and installation costs while simultaneously offering superior operational capabilities in a highly demanding commercial and technical environment.

With its symmetrical mills-cross transducer configuration, the ATLAS HYDROSWEEP DS-2 allows to acquire simultaneous and independent data sets for:

- Precise bottom bathymetry with a maximum of 240 depth channels
- High-resolution 2-D seafloor imaging

- Full 3-D sonar imaging of the ensonified water column
- Acoustic measurement of sound velocity distribution for real-time ray correction
- Calibrated bottom backscatter analysis, providing seafloor sediment classification
- Look-ahead acoustic navigation for scientific station planning

With the actual topographic bottom profile available in each sounding, all additional data sets can be viewed online in their correct geographical context. This enables the operator to correlate on-the-fly all of the above information for an efficient real-time interpretation of the acquired marine environment.

2 Description of the ATLAS HYDROSWEEP DS-2

2.1 General

The revolutionary new hydro-acoustic transducer configuration, the so-called symmetrical T-shaped transmitter-receiver array has been developed with special emphasis given to flexible, high-resolution ocean volume and seafloor topography detection. Precisely synchronised amplitude and phase sampling followed by advanced real-time signal plausibility filters provide the basis to reach the projected performance and quality requirements and increase the ability of unambiguous bottom target detection.

This unique, patented technique enables the system to train the normal multibeam fan around its vertical axis from the normal across track orientation into the for-aft plane. This realignment offers a three-fold advantage over conventional multibeam echosounders:

- Mean-sound velocity calibration for real-time ray bending corrections.
- Angular bottom backscatter calibration for reliable bottom type classification.
- Forward-looking acoustic navigation for scientific station planning.

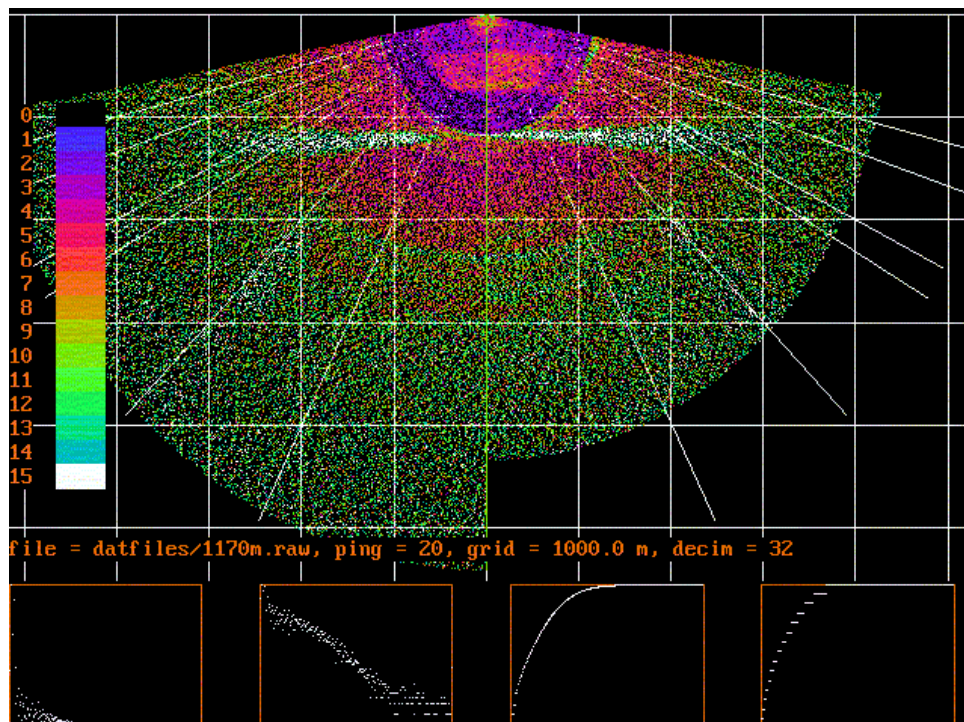


Figure 2-1: Sonar diagram of an ATLAS HYDROSWEEP DS-2

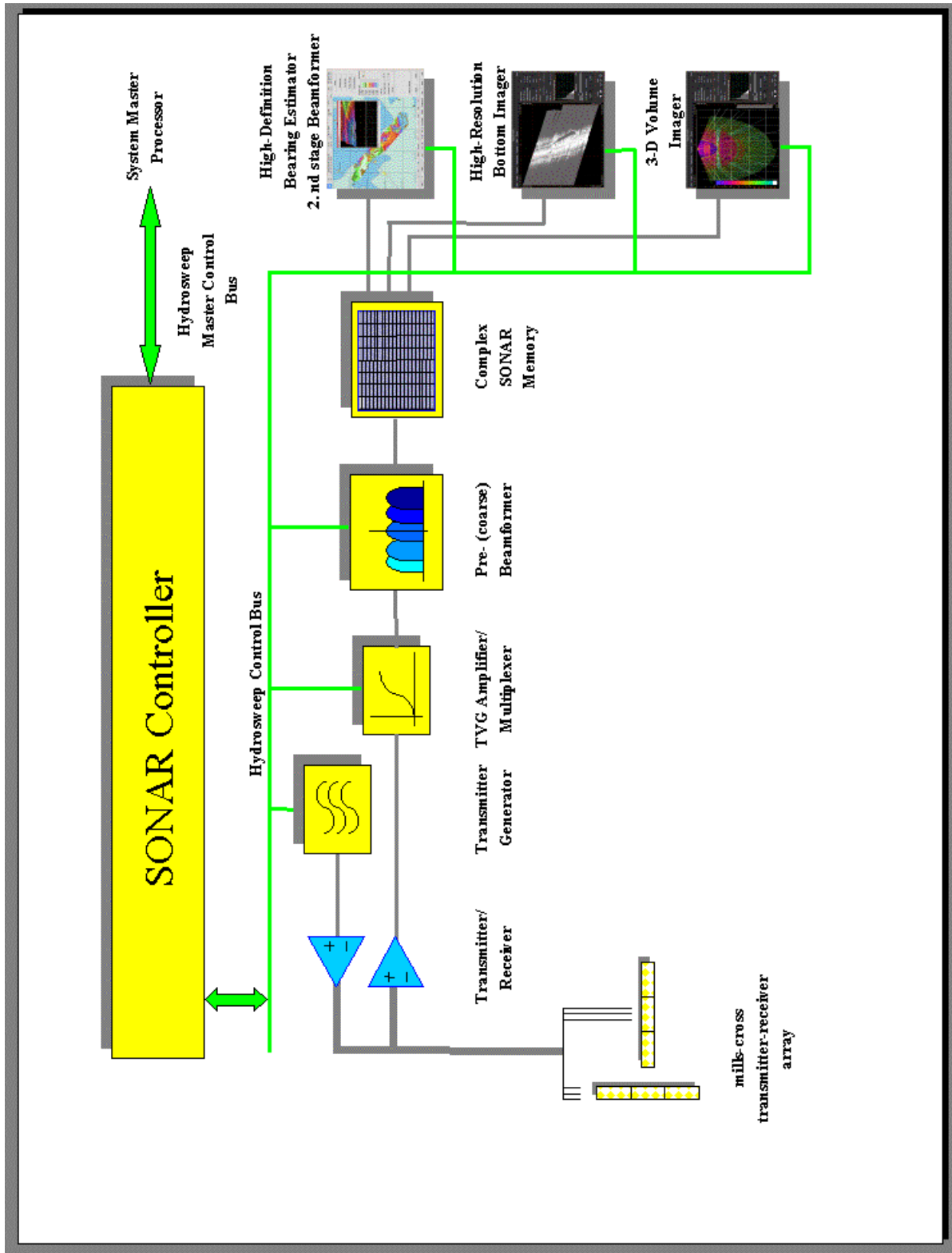


Figure 2-2: Functional block diagram of the ATLAS HYDROSWEEP DS-2

The ATLAS HYDROSWEEP DS-2 ensonifies the seafloor within a sector of 120 degrees. Each of the "illuminated" bottom elements contributes to the total echo trace with a specific signal containing information about position and characteristic features of that particular bottom location.

Upon return of the full bottom echo, the backscattered sound signal is received by an array of hydrophone elements. The output signals are corrected for differences in the individual receiving characteristics and amplified to a standard calibrated level by means of individually adjusted preamplifiers. These circuits are closely mounted to the hydrophones. Thus a high signal-to-noise ratio is maintained throughout the complete electronic system. Digitally controlled Time Variable Gain (TVG) amplifiers subsequently correct for acoustic transmission losses. The properly adjusted analogue signals are sampled and then digitised by analogue-to-digital flash converters.

A preformed beam analysis combined with the new ATLAS high-resolution bearing discriminator (High Definition Bearing Estimation – HDBE) allows sorting the information into up to 240 small, pencil-like acoustic detection elements. The corresponding amplitude and phase data from each of these channels are subsequently converted into:

- Precise bottom bathymetry with a maximum of 240 depth channels.
- High-resolution 2-D seafloor imaging with up to 6 kByte samples per sounding cycle.
- Full 3-D sonar imaging of the ensonified water column.
- Acoustic measurement of sound velocity distribution for real-time ray correction.
- Calibrated bottom backscatter analysis providing seafloor sediment classification.
- Look-ahead acoustic navigation for scientific station planning.

2.2 Backscatter Data for Seabed Classification

For each of the acoustic beams, the ATLAS HYDROSWEEP DS-2 acquires both the acoustic echo travel times as well as the corresponding signal amplitudes. These raw amplitudes, however, are the result of a complex convolution of the following characteristics and transfer functions:

- Transmit signal time series
- Acoustic and electric transducer transfer functions
- Sea water propagation transfer function
- Seafloor scatter function
- Receiver transfer function

In order to provide all necessary data for conversion of the measured relative amplitudes into absolute acoustic signal levels (which is necessary for backscatter calculations), the ATLAS HYDROSWEEP DS-2 measures all electric and acoustic system parameters as e.g.:

- Transmit frequency
- Acoustic source level
- Transmit pulse length
- Acoustic transmitter beam pattern
- Acoustic receiver beam pattern
- Receiving voltage response
- Constant and time variable gain settings

Up to this point, any normal multibeam echosounder would be capable of providing similar information. It must, however, be considered that each of the individual beams because of their different alignment angles can only measure one sample of the full angular backscatter distribution of separate bottom locations. It is therefore important to note that in this classical configuration the angular ambiguity cannot be resolved and hence an unbiased classification result of the full ensonified swath width cannot be calculated.

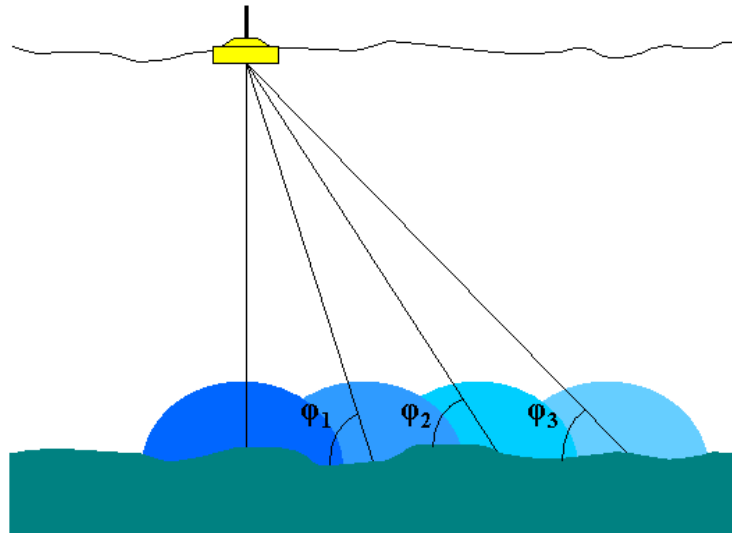


Figure 2-3: Backscatter ambiguity in multibeam data acquisition

The ATLAS HYDRSWEEP DS-2 mills-cross arrangement of transmitter and receiver transducer, however, allows training the normal across-track orientated fan into the fore-aft plane. While steaming along the pre-planned track line and the fan trained into the fore-aft orientation at regular user-selectable intervals, individual backscatter samples of the depth profile underneath the track line are simultaneously taken by all depth channels eventually revealing the full angular backscatter distribution of individual bottom locations. These along-track scatter curves can be applied as normalisation functions to calibrate the individual across-track backscatter samples to one common reference.

2.3 Optimally Chosen Operating Frequency

Previous deep-sea echosounders had generally been designed for 12 kHz operations. Today, modern transducer ceramics offer significantly increased receiving sensitivities. The capability to reach the full ocean depth of 10,000 metres or more can therefore now be achieved with the higher 15.5 kHz frequency of the ATLAS HYDROSWEEP DS-2. Amongst the advantages, narrower focussing beam patterns, lower ambient noise levels and a smaller transducer design are of prime importance:

- With 15.5 kHz, a shorter “near field condition” is generated; hence shorter pulses and more accurate signal threshold discrimination are provided.
- Typical open-ocean ambient noise levels drop at a rate of -5 to -6 dB per octave, offering a higher detection probability.

- Maintaining the geometrical acoustic beam structure and alignment, a 15.5 kHz transducer can be shortened by approx. 20%.
- The seafloor backscatter coefficients are typically higher at 15.5 kHz, providing better results at larger grazing angles.
- A 12 kHz signal penetrates more easily into the bottom surface layers. The quality of the return signal is compromised by this effect, resulting in a reduced accuracy of the travel time and backscatter measurements.

The ATLAS HYDROSWEEP DS-2 has been optimised for the full application range from water depths as shallow as 10 metres down to more than 10,000 metres. A successful customer record gives impressive evidence for the correctly chosen system parameters (see chapter 6).

2.4 “Open” Front-end Technology

The ATLAS HYDROSWEEP DS-2 has been designed with a very flexible transmitter and receiver front-end in order to support a number of standard system functions and to be open for additional user applications, now or in the future. The major differences to other multibeam systems are four-fold:

1. Transmitting and receiving transducers are of identical construction.
2. The connection between the transducers and the transmitting/receiving amplifiers is performed via processor-controlled switches. These two features are primarily required for the patented “Cross Fan Calibration Method”, but they are also providing a unique computer control capability of the direction of sound emission and reception, either along or across the vessel’s axis.
3. The transmitter is capable to energise the transducers either in the ODT or in the RDT mode with roll and pitch stabilised directivity.
4. The receiver is (with the exception of the pre-amplifiers and TVG amplifiers) built-up completely in digital technology. The digital controlled Time Variable Gain (TVG) can be overridden via the system operator station (workstation or PC).

The latter two features are primarily designed for optimising the hydro-acoustic functions, to cope with the conditions differing between shallow and deep water and smooth or rough bottom and the like, but they also provide a unique flexibility for future application variations, e.g. backscattering analysis, where the changes of operation parameters could then be performed by external commands which would override the standard parameters, e.g. TVG start depth, TVG gain factor or longitudinal fan transmission (calibration mode).

2.5 Modular Receiver Concept

The ATLAS HYDROSWEEP DS-2 transducer array includes separate transmitter and receiver arrays, each one consisting of 3 modules of 8*12 individual acoustic elements.

The original ATLAS HYDROSWEEP DS Beamformer had been designed as a straight-forward time-delay Beamformer with orthogonal 90° envelope sampling and an effective 62 kHz sampling rate per beam.

A bottom-tracking controlled echo processor was fed by the digitised envelope data. An iterative weighting estimator calculated the echo's centre-of-energy straight from the online raw data and converted these into the acoustic travel times for each individual acoustic beam. Due to limited capabilities of real-time data acquisition systems in 1985, except for the travel times no acoustic envelope data were kept. The resulting beam pattern parameters were:

Transmitter: 90° • 2,3°

Receiver: 2,3° • 20°

Today, modern inexpensive data acquisition systems do provide the necessary means to keep and handle the full envelope signal for all acoustic beams (see example below, taken by an ATLAS HYDROSWEEP DS-2).

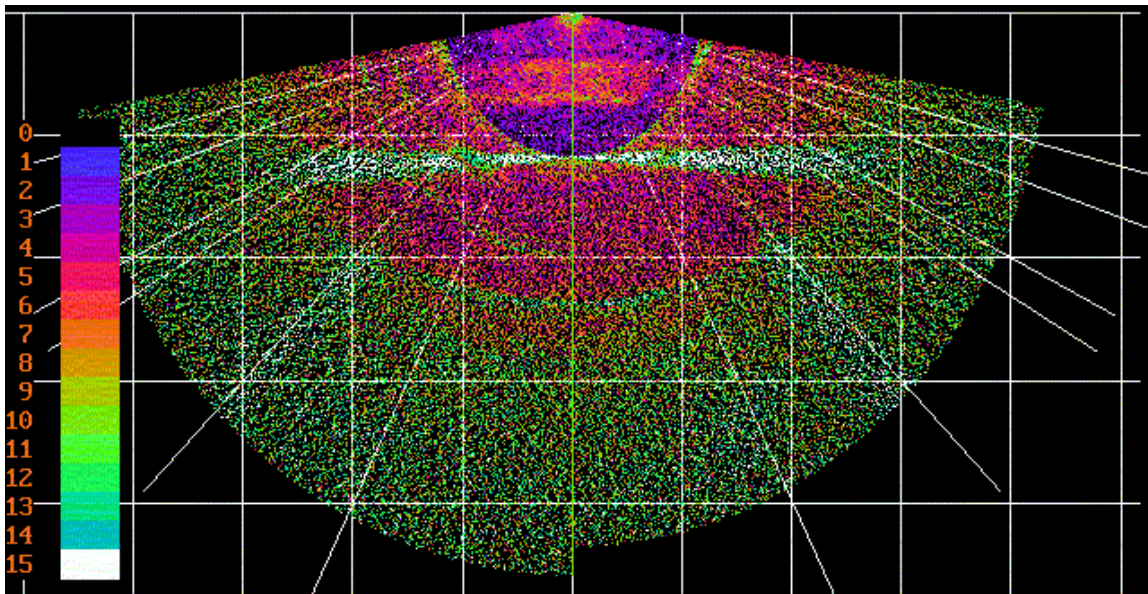


Figure 2-4: Full coverage memory image of sonar buffer of ATLAS HYDROSWEEP DS-2

The ATLAS HYDROSWEEP DS-2 provides advanced signal processing techniques, offering superior system performance: The algorithms implemented in the ATLAS HYDROSWEEP DS-2 include a combination of a classical time-delay Beamformer technique and a so-called "High Definition Bearing Estimation (HDBE)" in order to achieve very high depth resolution in the across-ship direction.

The acoustic raw signals are picked up by the pre-amplifier signal conditioner and fed into a coarse time-delay Beamformer. This, however, only serves as an initial preformed beam conditioner. The raw beam time series comprises unbiased, unmasked full-length envelope data, each one representing the beam-oriented signal trace for the full sounding cycle.

HDBE is based on the information provided by the classical time-delay Beamformer, i.e. the amplitude time-series from each beam. The per beam amplitude information is analysed to arrive at an angular information of the incoming sound wave that is of a much higher resolution than the angular information derived from the beam pattern alone. Using a priori knowledge of the beam directivity pattern, the amplitude ratio between adjacent beams is computed and an across fan arrival angle of the incoming wave is deduced.

The ATLAS HYDROSWEEP DS-2 uses the knowledge of the beam pattern together with the per beam amplitude information to generate an amplitude-angle trajectory in travel time

space. This trajectory is used to generate a number of so called soft-beams that are used in conjunction with the hard-beams to arrive at an improved angular resolution of the bottom. The following processing steps are carried out (see also figure 2-5):

- The per stave data from the transducer is processed in a classical time-delay Beamformer.
- The per beam amplitude information is smoothed and noise is reduced with a noise reduction algorithm.
- A number of arithmetic support beams are generated.
- From the amplitude information of the soft-beams the angle and amplitude function is computed.
- The individual amplitude-angle information is associated with the corresponding soft-beams.
- The per beam information of the soft-beams is used to detect the bottom using a weighted soft-beam approach.
- Where no information on the bottom could be gained through HDBE, the depth is detected using the hard-beam patterns.

Considering the required accuracy and the actual signal-to-noise ratio, between 120 and 240 beams can be handled by HDBE. For broadband applications, the current configuration is preset to 140 nominal beams.

Experience with this innovative beam forming concept have been gained with a variety of different ATLAS HYDROSWEEP MD-2 and ATLAS HYDROSWEEP DS-2 system installations (see, for example, the list of delivered ATLAS deep sea systems in chapter 6).

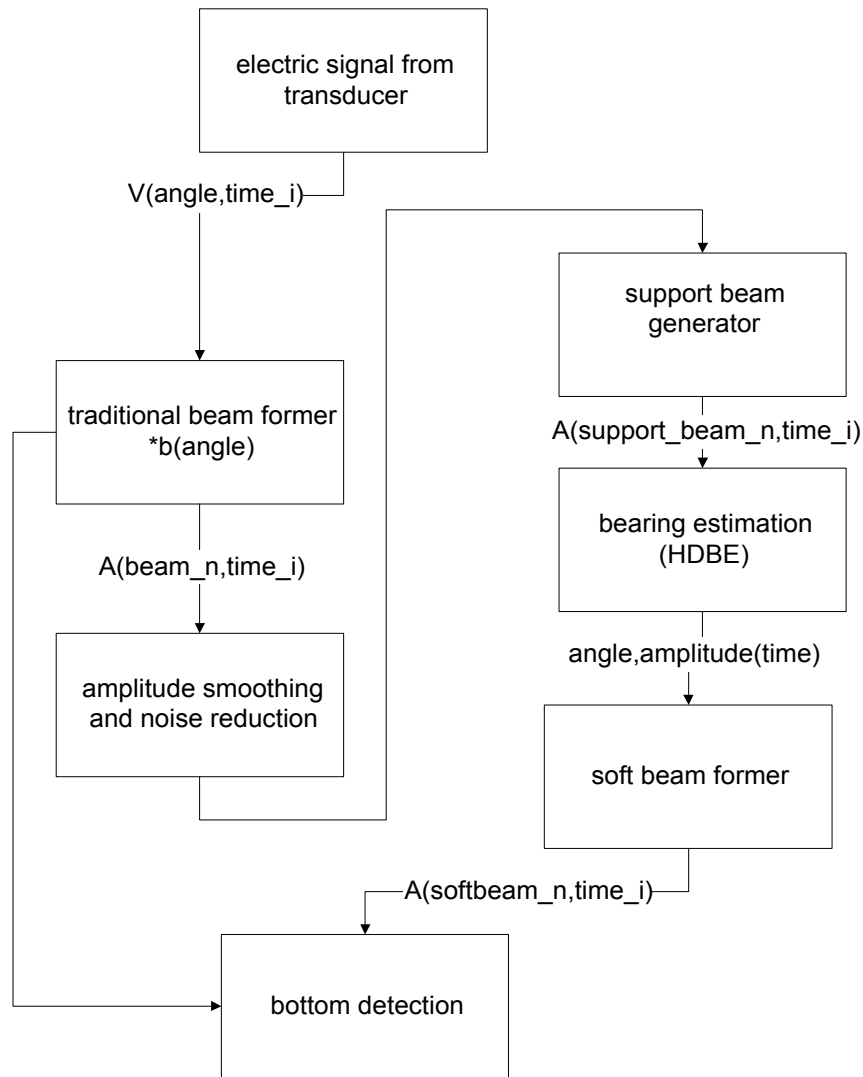


Figure 2-5: ATLAS HYDROSWEEP DS-2 Beamformer block diagram

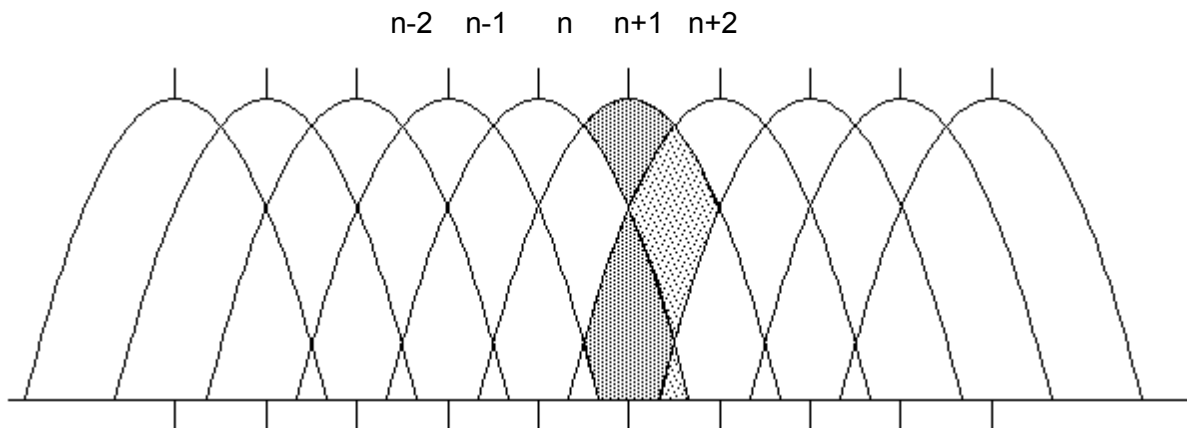


Figure 2-6: Support beam generation within HDBE

2.6 Sound Velocity and Ray Bending

The acoustic sound propagation in seawater depends on the physical parameters of the seawater, i.e. temperature, salinity and ambient pressure. Both, signal amplitudes and directional spreading are affected. As under normal environmental conditions oceans are stratified media. Both speed and directional variations of sound propagating through such an environment under oblique angles can be observed. The directional changes are commonly referred to as ray bending effects.

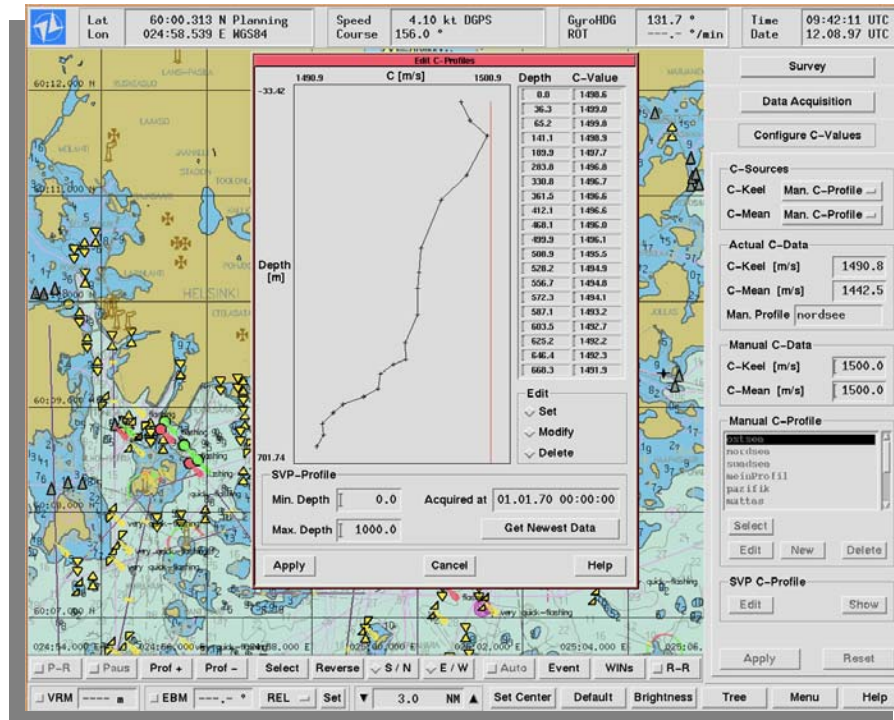


Figure 2-7: Typical sound velocity profile as observed during an ATLAS HYDROSWEEP DS-2 survey

The ATLAS HYDROSWEEP DS-2 offers four different approaches to compensate for this propagation effect, which, depending on the survey conditions, always provide the user with optimally compensated bathymetric data sets. All of these methods can be utilised in real-time. However, if during the later offline processing procedure better and more accurate oceanographic information becomes available, data re-alignment procedures including sound velocity corrections are provided in state-of-the-art post-processing software module.

1. As a first and basic approach, the ATLAS HYDROSWEEP DS-2 provides access to a manual adjustment of sound velocity correction factors. These factors can be derived from a variety of different sources as e.g. external, separate sound velocity sensors (see below) or prediction models. Quality and accuracy of such corrections are strictly within the responsibility of the operator.
2. If an external sound velocity profiler is available, the ATLAS HYDROSWEEP DS-3 allows interfacing such a device through interface types like e.g. RS 232/422. This enables the user to efficiently transfer measured profile data in near real-time straight into the multibeam processor. Commonly used sound velocity profilers are CTD's (conductivity, temperature, depth probes), XBTs (expandable bathy thermographic probes), XSVs (expandable sound velocity probes) and USVs (continuous, undulating sound velocity

probes). These oceanographic probes have to be lowered into and through the water column. The user can choose between memory-logging and cable-connected configurations.

CTD's require the ship to stop while conducting the vertical sound velocity profile acquisition. At typical winch speeds of 1 metre per second, a Mid-Atlantic station at 5,000 metres would take 10,000 seconds or 2 hours 47 minutes plus handling off the valuable ship's and survey time.

Both XBTs and XSVs can be dropped while sailing at normal survey speed without any risk of interference with the acoustic survey activities. However, both probe types are designed as a one-time, non-recoverable item, which after full wire length has been paid out, snap off the connection and drop to the seafloor. Thus additional operating costs of, depending on the chosen model, 60 US \$ to 120 US \$ per profile must be added to the overall survey costs – an additional financial burden which under certain oceanographic conditions, like e.g. in coastal and/or shelf areas might become a quite significant subject.

USVs are tow fish based continuous profilers undulating between preset minimum and maximum depth values. Technically, these systems offer perfect control over the acoustic propagation conditions; however, their high procurement costs as well as their limiting effects on ship's manoeuvrability must be considered upfront.

3. Both, in many shelf areas as well as in the abyssal planes, the variations in bottom topography can be described by means of a simple stationary stochastic process. The ATLAS HYDROSWEEP DS-2 utilises this fact to calculate the mean sound velocity in the water column by means of a statistical analysis of a subset of subsequent cross profiles.
4. The Cross Fan Calibration Method is based upon the "ATLAS Ziese¹ Principle" – a unique and patented acoustic method for a near real-time sound velocity assessment. This method is based on the symmetrical transmit and receive beam pattern of the ATLAS HYDROSWEEP DS-3. With the multibeam fan trained into the fore-and-aft plane, an in-situ acoustic assessment of the ray-bending effect under the given oceanographic conditions can be carried out. This method as compared to normal oceanographic profile measurements becomes a highly efficient survey tool especially under deep-sea conditions with no separate ship's time required. This unique, patented method can save between 3 and 6 hours of ship's time every day.

While steaming along the pre-planned track line and the fan trained into the fore-aft orientation at regular, user-selectable intervals, all depth channels simultaneously take individual samples of the depth profile underneath the track line. Comparing all of these measurements of the same bottom profile, however taken under different beam angles, in a robust, least-square estimator does provide a best-fit mean sound velocity correction factor.

At the negligible small costs of some extra soundings this method provides a stable and reliable ray bending correction for most survey conditions without the necessity to stop the vessel for any kind of time-consuming profile acquisition.

2.7 Motion Compensation

Wide swath sonar systems with slant beam geometry are subject to significant propagation effects in the water column. Thus for any high-precision bathymetric multibeam echosounder

¹ Mr. Ziese was a former senior development manager of ATLAS Hydrographic.

systems, an active real time beam stabilisation is an absolute prerequisite for any accurate depth measurement. A full 3-axis rotational plus an additional single axis translation correction including roll, pitch, yaw and heave is required.

ATLAS Hydrographic recommends utilising either a high-precision motion sensor, as e.g. the ATLAS DYNABASE 2-05, combined with an accurate gyro or, alternatively a combined instrument as the TSS POS/MV for active beam-steering of multibeam echosounder systems. The motion sensor may simultaneously be used for real-time heave correction of optionally connected single-beam survey echosounders as e.g. the ATLAS DESO 17, the ATLAS DESO 25 or the ATLAS DESO 30.

3 System Operation and Echosounder Control

Under most survey conditions, the ATLAS HYDROSWEEP DS-2 provides fully automatic bottom tracking without any operator intervention being necessary. It automatically adjusts the operating mode (deep or shallow water), the gain, the transmission voltage and the range-dependent parameters, as required.

The results of the echo evaluation are transferred into a second independent dual-CPU-processor, controlling all internal operations and being responsible for the complete timing. External sensors and data sources, as there are the ship's navigation system and the roll, pitch and heave sensor platform, are connected. The measured depth profiles are assembled together with the corresponding external information into a common data record. Upon completion of each data acquisition and evaluation cycle, this record is transferred to the operator station via a local area network (LAN) connection.

The ATLAS HYDROSWEEP DS-2 multibeam echosounder can be operated with different types of software packages for measurement data acquisition, data storage and data processing. The possible solutions are described below.

3.1 Operation with the ATLAS HYDROMAP ONLINE

On one hand, it is possible to operate the ATLAS HYDROSWEEP DS-2 via the well-proven ATLAS HYDROMAP ONLINE software package, providing *an entire functional spectrum* for full echosounder control, data acquisition and data storage, data processing, data visualisation, data export, data printout and data replay. This software package cannot only be used for the ATLAS HYDROSWEEP DS-2, but also for all other ATLAS multibeam echosounders like the ATLAS HYDROSWEEP MD-2, the ATLAS FANSWEEP 20 and the ATLAS FANSWEEP 15. It includes also functions for the acquisition of data from single beam echosounders.

The graphical user interface of the ATLAS HYDROMAP ONLINE provides easy and self-explanatory access to all system functions including survey planning, data acquisition, quality control, system calibration and maintenance. It provides application-oriented and user-friendly menu operation and guarantees widely uniform and self-explanatory operation of all modules. The user interface is based on the international software standards X-Windows and OSF/Motif (OSF = Open Software Foundation) and includes extensive online help facilities. As hardware platforms for the ATLAS HYDROMAP ONLINE, standard PCs with Linux 7.3 (or higher) or standard Unix workstations (e.g. from Hewlett Packard or Sun Microsystems) are used.

The ATLAS HYDROMAP ONLINE includes the modules ATLAS HYDROMAP/ACQUIRE for data acquisition, ATLAS HYDROMAP/NAVIGATE for navigation planning and control and the ATLAS HYDROMAP/ECDIS for electronic chart display (ECDIS = Electronic Chart Display and Information System). Detailed information concerning the ATLAS HYDROMAP ONLINE can be found in reference /2/.

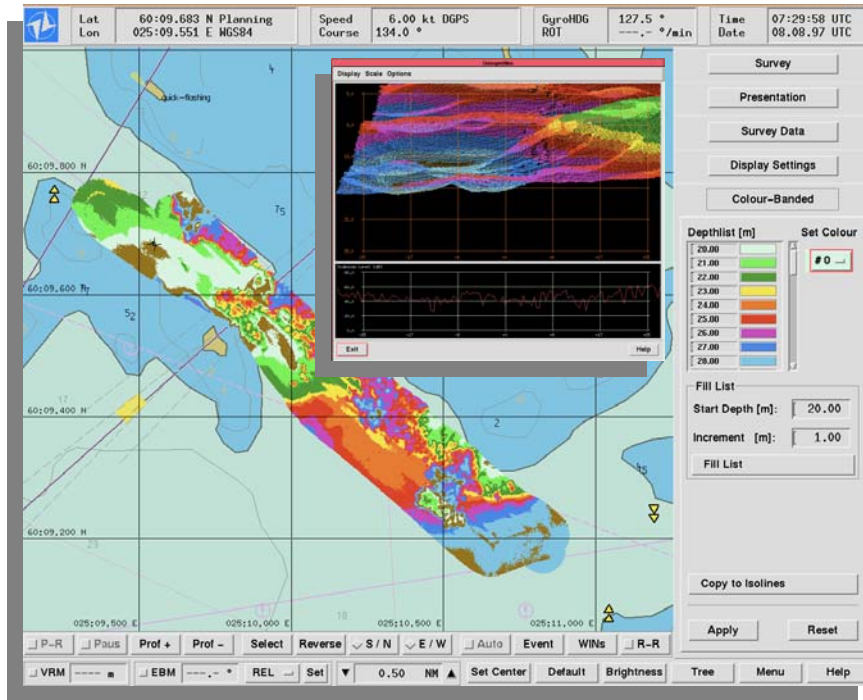


Figure 3-1: Visualisation within the ATLAS HYDROMAP/ACQUIRE software module

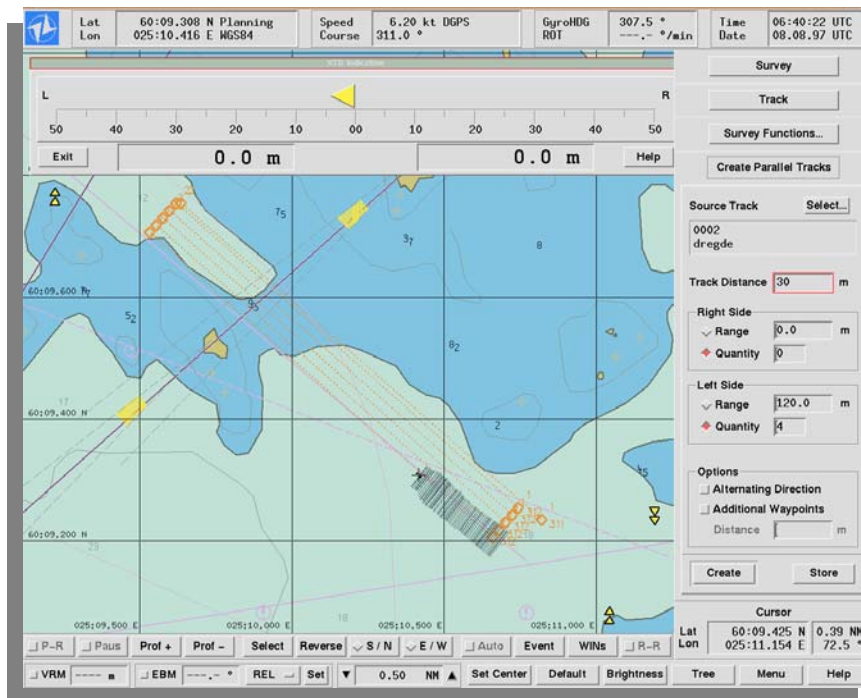


Figure 3-2: Visualisation within the ATLAS HYDROMAP/NAVIGATE software module

3.2 Operation via ATLAS HYDROMAP CONTROL

On the other hand, it is possible to use non-ATLAS software products for measurement data acquisition, data storage and data processing. In this case, the ATLAS HYDROSWEEP DS-2 is controlled by a software application called ATLAS HYDROMAP CONTROL (see reference /1/).

ATLAS HYDROMAP CONTROL is a state-of-the-art software product for the operational control of all ATLAS echosounders, running on PC platforms with Windows NT/2000 (or higher) or Linux 7.3 (or higher). ATLAS HYDROMAP CONTROL does not include measurement data acquisition. Therefore, ATLAS HYDROMAP CONTROL is usually installed together with "external" software packages for data acquisition and data processing (e.g. ATLAS HYDROMAP NT). However, it is of course possible to install ATLAS HYDROMAP CONTROL alone on a PC platform. This is useful when special PC platforms shall be dedicated only for echosounder control, but not for measurement data acquisition.

Besides all functions specific for the control of an ATLAS echosounder, ATLAS HYDROMAP CONTROL provides the following functionality:

- Graphical presentations
- Total quality control
- Logging of all user transactions and system messages
- Storage, import and export of different types of parameter sets
- TPE calculations (TPE = Total Propagated Error)
- Alarm generation
- User administration.

ATLAS HYDROMAP CONTROL includes an internal object-relational SQL database, in which the following information is stored:

- Predefined sensor definition parameter sets for most of the commercially available sensors belonging to an echosounder system
- Predefined sensor control parameter sets for different surveying situations
- Predefined quality control parameter sets, e.g. concerning the different orders of the IHO Standards for Hydrographic Surveys (SP44) or the different classes of the USACE Accuracy Performance Standards for Corps of Engineers Hydrographic Surveys
- User-defined parameter sets
- The system log
- User administration information (user names, permissions and passwords).

At time of delivery, the ATLAS HYDROMAP CONTROL database includes already predefined sensor definition parameter sets and sensor control parameter sets, which have been created and approved by ATLAS Hydrographic. At time of delivery, the database also includes predefined quality control parameter sets referring to quality standards like the IHO Standards for Hydrographic Surveys according to which surveying may be carried out.

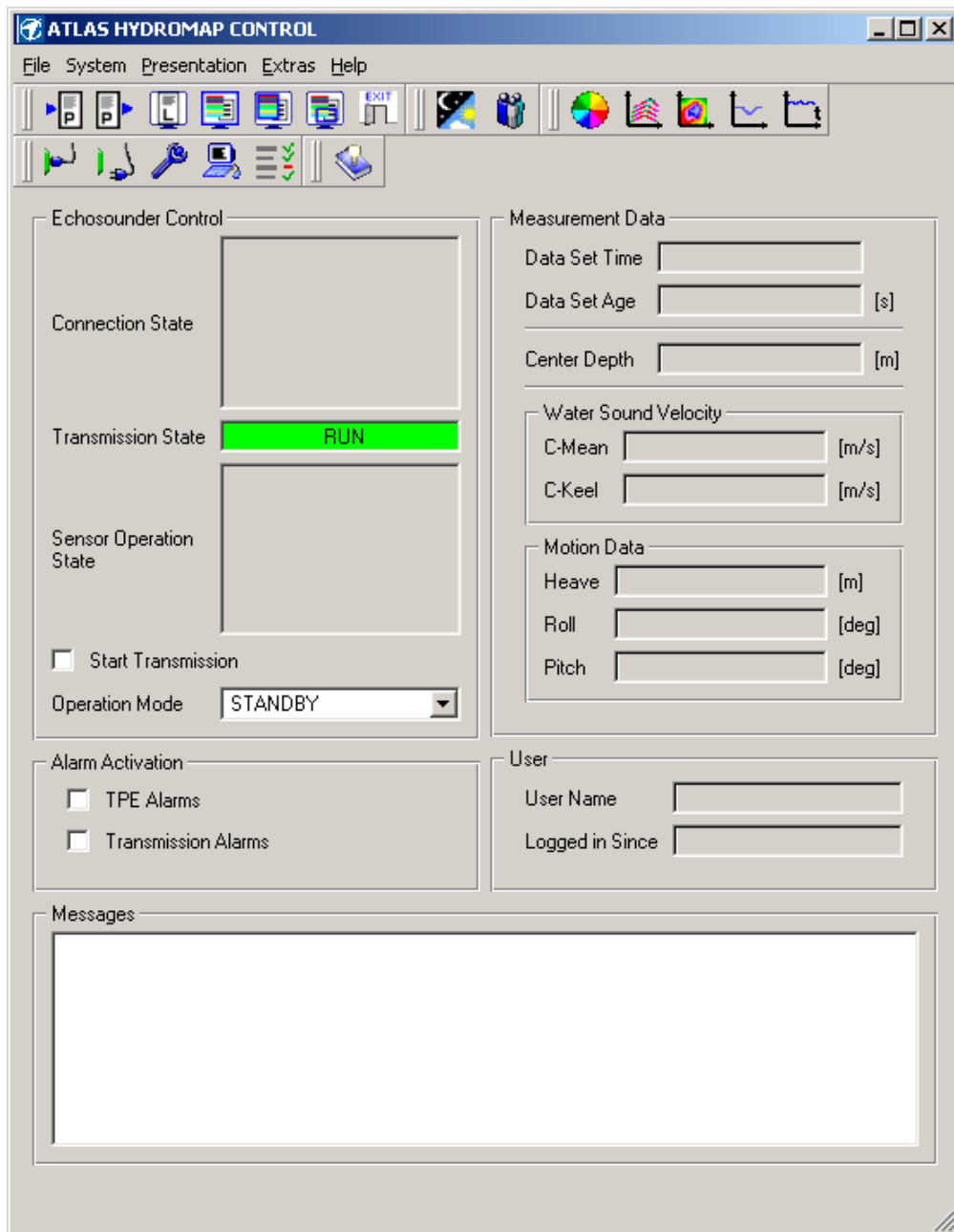


Figure 3-3: Main Window of ATLAS HYDROMAP CONTROL

ATLAS HYDROMAP CONTROL is based upon a client/server architecture including a CORBA link (CORBA = Common Object Request Broker Architecture) for the communication between the ATLAS HYDROMAP CONTROL clients and the ATLAS HYDROMAP CONTROL server. The server includes the object-relational database. Because of the client/server architecture, it is possible to run several instances of ATLAS HYDROMAP CONTROL on separate PCs with respect to the same echosounder to be controlled. This feature is helpful for echosounder remote control or when it shall be possible to control an echosounder from different places on a ship.

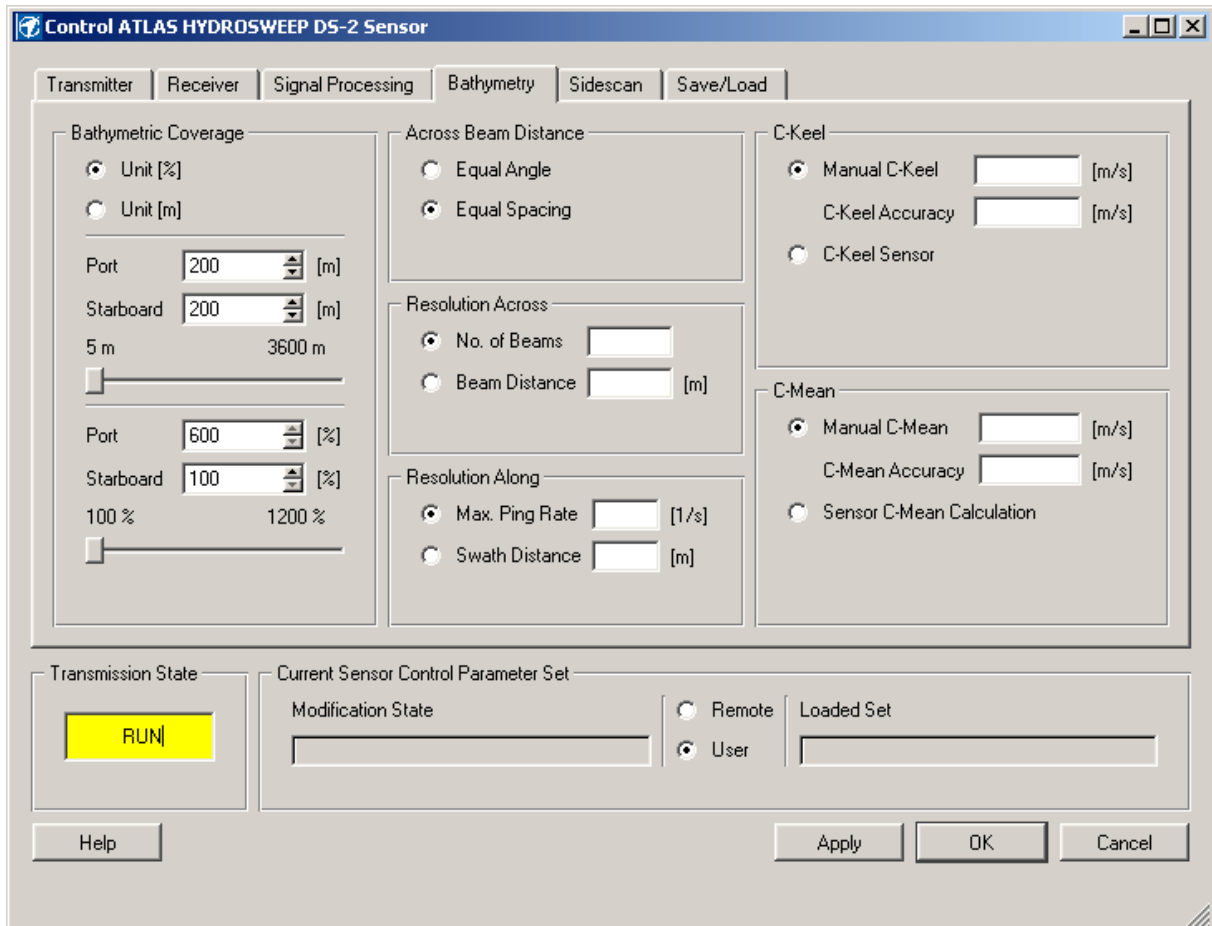


Figure 3-4: Tab "Bathymetry" of the "Control ATLAS HYDROSWEEP DS-2 Sensor" window

When different instances of ATLAS HYDROMAP CONTROL have been installed on different PC platforms, the ATLAS HYDROMAP CONTROL server including the internal database is installed only on one PC platform in order to avoid redundancies in data storage.

As a measure for total quality control of an entire surveying system, ATLAS HYDROMAP CONTROL logs all relevant system events with an exact time stamp in the internal database. These events include all user operations, which influence the measurement data quality. In this context, every change in the echosounder parameters is stored including the time of change, the values of the changed parameters and the user who performed the change. Also all system messages (alarms, error messages and warnings) which are internally generated by the system in reaction of alarms or peripheral malfunctions are stored in the system log.

For an inspection of the system log, ATLAS HYDROMAP CONTROL provides a special "View Log" window. Within this window, it is possible to specify filter parameters including a time range, the echosounder type and the message types (e.g. alarms, error messages or warnings) in order to search for specific log entries. Additionally, it is possible to search for special keywords. If desired, the displayed log entry results can be printed out. For a very detailed analysis, the system log can also be inspected by the aid of common database administration tools. The system log stores the system events over a time interval (history) that can be defined by the user.

ATLAS HYDROMAP CONTROL provides the possibility to calculate the total propagated error (TPE) of an echosounder system. The TPE calculations are based upon the stored accuracy values of the different sensors being part of the echosounder system. The

calculated TPE values are compared to allowed threshold values defined by the current quality standard according to which surveying has to be carried out. The quality standard selected for TPE threshold values can be, for example, the Special Order of IHO SP44, the Class 1 of the USACE Accuracy Performance Standards for Hydrographic Surveys or a user-defined quality standard.

It is possible to configure ATLAS HYDROMAP CONTROL in such a manner that alarms are automatically generated when

- the calculated TPE values are beyond the threshold values defined by the applied quality standard or
- when the transmission of the echosounder is disturbed.

For both types of alarms, it can be individually configured how the alarms shall be presented. Possible options are acoustic alarms, entries in the message list within the Main Window of ATLAS HYDROMAP CONTROL and/or alarm message boxes popping up on the screen.

ATLAS HYDROMAP CONTROL provides the possibility to handle the following different types of parameter sets:

- *Sensor control parameter sets:*

A sensor control parameter set includes all parameter values, which are necessary for the operation of a specific echosounder. Sensor control parameters are for example the sensor operation mode, the frequency of the transmitted acoustical pulses, the bathymetric coverage, the side scan coverage, the TVG start gain and the TVG stop gain. Sensor control parameter sets are with respect to the parameter structure and the parameter values specific for an echosounder type like the ATLAS HYDROSWEEP DS-2.

- *Visualisation parameter sets:*

Visualisation parameter sets refer to graphical presentations within ATLAS HYDROMAP CONTROL and include different kinds of colour tables.

- *Quality control parameter sets:*

A quality parameter set includes accuracy values for horizontal positions, depth accuracy values and minimum sizes for feature detection, which are required by a user-defined or common quality control standard (e.g. IHO SP 44, Special Order) according to which surveying has to be carried out. A quality control parameter set includes also settings with respect to the TPE calculation, alarm generation and alarm presentation.

- *Sensor definition parameter sets:*

The definition parameters of a sensor include its product-related parameters like the sensor type (e.g. multibeam echosounder, motion sensor, c-keel sensor or heading sensor), the manufacturer of the sensor, the sensor name (e.g. ATLAS HYDROSWEEP DS-2 or ATLAS DYNABASE), the sensor accuracy and the required calibration intervals.

- *Sensor installation parameter sets:*

An installation parameter set includes all installation-related parameters of the sensors being part of a surveying system. In this context, every sensor within a surveying system is given a logical name by which for example different sensors of the same type and name (e.g. two GPS sensors) can be distinguished. The installation-related parameters of a sensor include – among others – the serial number of the sensor, its installation position within the ship and the last time of calibration.

- *Ship's parameter sets:*

A ship's parameter set includes ship-related parameters like the ship's name, the coordinates of the ship's reference point and the ship's draught.

Within ATLAS HYDROMAP CONTROL, the different types of parameter sets can be saved for later usage. In order to apply a saved parameter set, it has to be loaded into the user interface. Additionally, it is possible to export individual parameter sets of different types from the internal database into files and to import individual parameter sets from files into the database. This feature is relevant for exchange of parameter sets between different instances of ATLAS HYDROMAP CONTROL and also for backup and restores purposes.

Within ATLAS HYDROMAP CONTROL, different users with different permissions can be administrated. All users with administration permission are able to create new user accounts, to delete existing user accounts and to modify the permission rights of existing accounts. Within ATLAS HYDROMAP CONTROL, access rights for administration, installation, survey control and monitoring can be assigned to each user account independently and individually.

3.3 Data Post-Processing

The high quality data collected by the ATLAS HYDROSWEEP DS-2 are the basis for a complete description of the seabed. This is, for example, possible in the form of charts, 3-D displays, combined bathymetry and acoustic imagery or backscatter analyses (seabed classification).

ATLAS Hydrographic is able to deliver a complete set of products for the post-processing not only of ATLAS HYDROSWEEP DS-2 data but also for all data collected with other sensors of the ATLAS Hydrographic multibeam and single beam echosounder family. One possible product for the post-processing of data from the ATLAS HYDROSWEEP DS-2 multibeam echosounder is the ATLAS HYDROMAP OFFLINE (see reference /3/).

The ATLAS HYDROMAP OFFLINE consists of the modules MANAGE, EDIT and CARIS and covers an extensive functional spectrum, including – among others – functions for data editing and data cleaning, data conversion, DTM calculations, 2-D and 3-D visualisations, side scan viewing, backscatter calculations and the generation of final chart products.

4 Technical Data of the ATLAS HYDROSWEEP DS-2

In the following, basic technical data of the ATLAS HYDROSWEEP DS-2 are provided. ATLAS Hydrographic reserves the right to alter the technical data of the ATLAS HYDROSWEEP DS-2 to similar or better standards without further notice.

4.1 General

Feature	Specification
Transmission principle	Stabilised, directional full swath transmission fan
Reception principle	Stabilised directional preformed beam reception with high-resolution bearing discriminator (HDBE)
Scanning angle	120°, corresponding to a coverage (swath width) of 3.5 times the vertical water depth; the achievable coverage depends on the acoustic conditions; please find more details enclosed.
Beam spacing (across)	“Equal-footprint” or “equal-angle”
Beam spacing (longitudinal)	2.3°
Operating frequency	15.5 kHz
Minimum depth	10.0 m below the transducers
Maximum vertical depth	> 11,000 m The maximum detectable depth depends on the acoustic conditions; please find more details enclosed.
Swath width	<ul style="list-style-type: none"> - 120° (~ 3.7 x water depth): 10 to 4,700m - 90° (~ 2.0 x water depth): 10 to 8,000 m - 60° (~ 1.5 x water depth): 10 to 11,000m <p>The actual achievable swath width depends on the acoustic backscatter properties of the seafloor and the water sound velocity profile, on the roll conditions (survey mode) and the pitch conditions (calibration mode) of the vessel. For details see the following figures.</p>

Table 4-1: General technical data of the ATLAS HYDROSWEEP DS-2

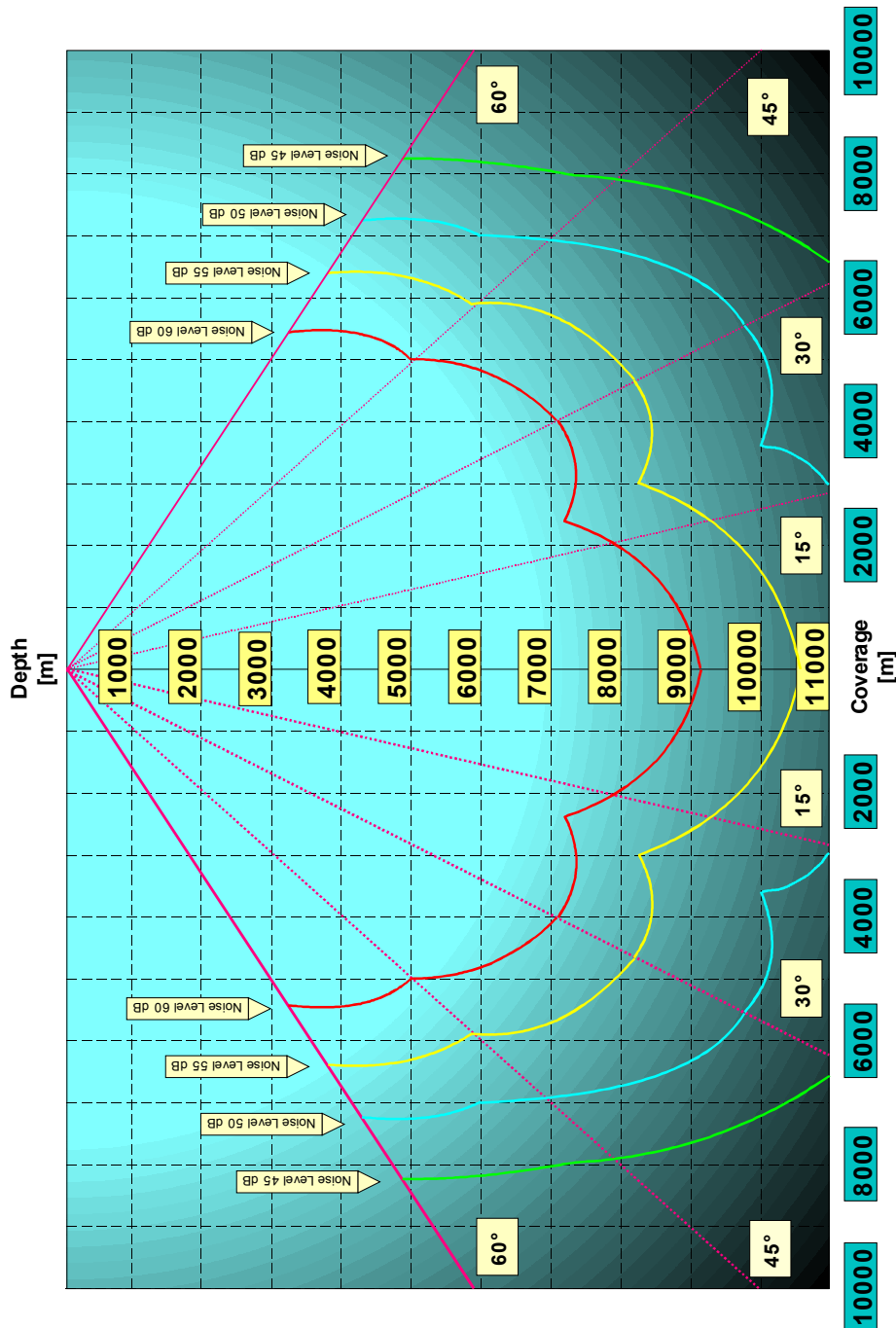


Figure 4-1: Range performance of the ATLAS HYDROSWEEP DS-2 for typical silt sediments:

- Backscatter coefficients ranging from -12 dB (near nadir) to -25 dB (at 30 degrees grazing angle)
- Assumed isotropic noise levels ranging from 45 dB [rel.1 μPa , $\text{Hz}^{-1/2}$] to 60 dB [rel.1 μPa , $\text{Hz}^{-1/2}$]
- Pulse length 12/20 ms

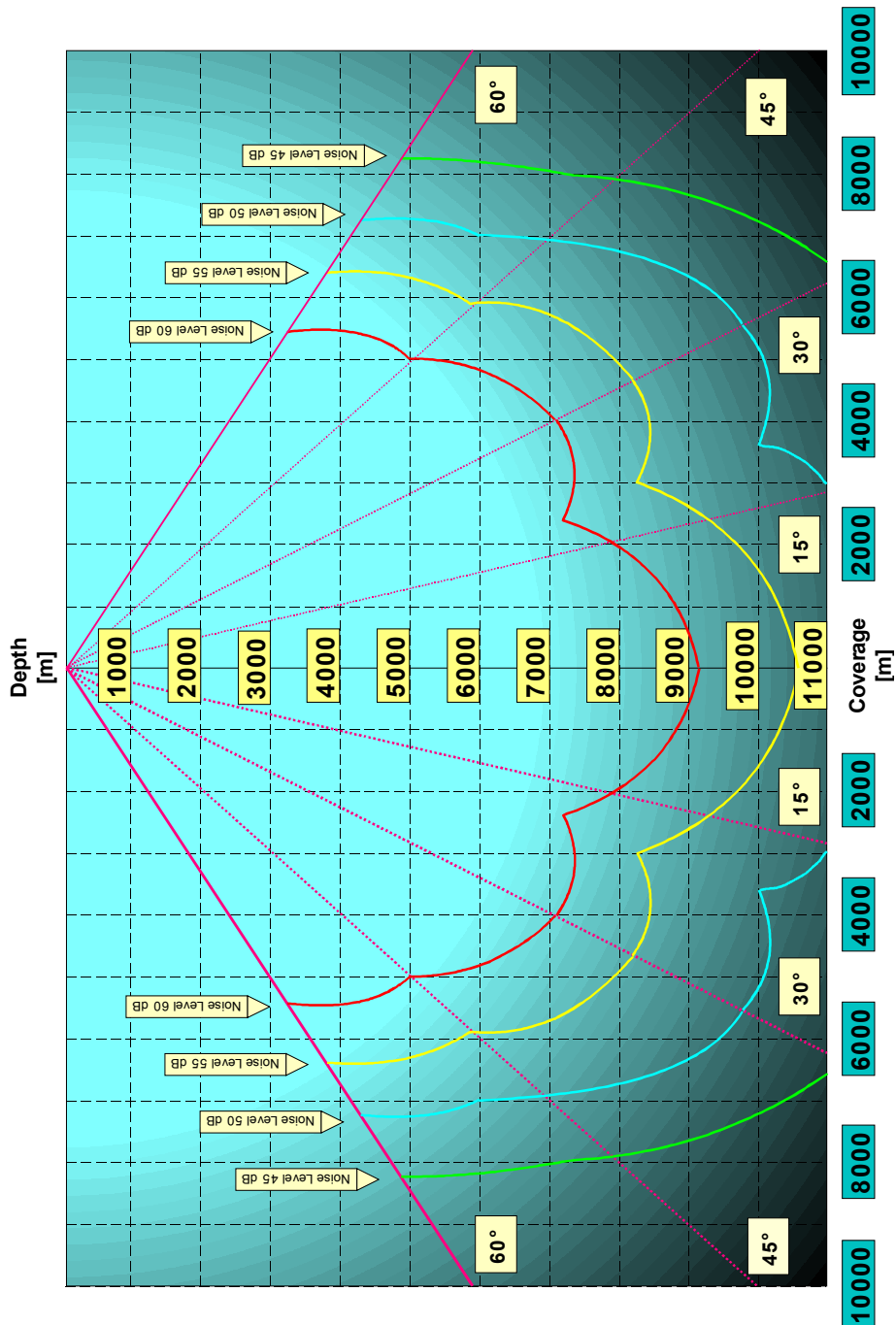


Figure 4-2: *Range performance of the ATLAS HYDROSWEEP DS-2 for typical clay sediments:*

- *Backscatter coefficients ranging from -25 dB (near nadir) to -33 dB (at 30 degrees grazing angle).*
- *Assumed isotropic noise levels ranging from 45 dB [rel.1 μPa , $\text{Hz}^{-1/2}$] to 60 dB [rel.1 μPa , $\text{Hz}^{-1/2}$].*
- *Pulse length 12/20 ms*

4.2 Transmitter

In order to reach the desired system capabilities and specifically the continuous operation from 10 metres to 10,000 metres, the ATLAS HYDROSWEEP DS-2, depending on the actual working depth, utilises nine different transmit modes. The system software, depending on the water depth and the coverage selected by the operator, automatically selects these.

In the RDT modes, all transmit pulses are sent out with minimum time spacing relative to each other, so that the overall sounding rate is kept at the optimum. Common to all RDT modes is the roll- and pitch stabilisation. This ensures a maximum transmit energy under all conditions and consequently projects stable footprints at the seafloor – the prerequisite for high signal-to-noise ratios and corresponding superior data quality.

At reception time, because of the chosen wide receiving beam width in the fore-aft direction (approx. 20°), a pitch stabilisation is not required.

The following tables summarise the available operation and transmission modes for Survey and Calibration soundings.

Operation Mode	Transmission Mode	No. of Beams	Coverage
Shallow Water Search	ODT	1	36° at -3 dB
Deep Sea Search	ODT	1	36° at -3 dB
Shallow Water	ODT ¹	1	120° at -5 dB
Medium Depth	RDT	3	90° at -3 dB
Medium Depth	RDT ²	5	120° at -5 dB
Deep Sea I	RDT	5	120° at -5 dB
Deep Sea II	RDT	3	90° at -3 dB

Table 4-2: Operation modes of the ATLAS HYDROSWEEP DS-2 (overview)

¹ ODT – Omni-Directional Transmission

² RDT – Rotational Directional Transmission

Operation Mode	Transmission Mode	Pulse Length	Range ³	Directions (approx.) ⁴
Shallow Water	ODT 1 Beam	1 ms	10 – 100 m	90° x 4.6° (0°)
Medium Depth I	RDT 3 Beams	4 ms 2 ms 4 ms	100 – 1,000 m	90° x 2.3° (-27°; 0°; +27°)
Deep Sea I	RDT 3 Beams	12 ms 6 ms 12 ms	800 – 3,700 m	90° x 2.3° (-30°; 0°; +30°)
Deep Sea II	RDT 3 Beams	24 ms 12 ms 21 ms	3,300 – 11,000 m	90° x 2.3° (-30°; 0°; +30°)
Shallow Water Search	RDT 1 Beam	1 ms	10 – 400 m	36° x 4.6° (0°)
Deep Sea Search	RDT 1 Beam	10 ms	100 – 12,000 m	36° x 2.3° (0°)

Table 4-3: *Transmission modes of the ATLAS HYDROSWEEP DS-2 for 90° swath width*

³ Ranges are “nominal”; the actual switching is automatically controlled by various parameters.

⁴ Nominal values

Operation Mode	Transmission Mode	Pulse Length	Range ³	Directions (approx.) ⁴
Shallow Water	ODT 1 Beam	1 ms	10 – 100 m	120° x 4.6° (0°)
Medium Depth II	RDT 5 Beams	4 ms 3 ms 2 ms 3 ms 4 ms	100 – 450 m	120° x 2.3° (-54°; -27°; 0°; +27°; +54°)
Medium Depth III	RDT 5 Beams	6 ms 4 ms 3 ms 4 ms 6 ms	400 – 1,000 m	120° x 2.3° (-54°; -27°; 0°; +27°; +54°)
Deep Sea III	RDT 5 Beams	12 ms 8 ms 4 ms 8 ms 12 ms	800 – 3,700 m	120° x 2.3° (-54°; -30°; 0°; +30°; +54°)
Deep Sea IV	RDT 5 Beams	16 ms 10 ms 8 ms 10 ms 16 ms	3,300 – 5,000 m	120° x 2.3° (-54°; -30°; 0°; +30°; +54°)
Shallow Water Search	RDT 1 Beam	1 ms	10 – 400 m	36° x 4.6° (0°)
Deep Sea Search	RDT 1 Beam	10 ms	100 – 12,000 m	36° x 2.3° (0°)

Table 4-4: Transmission modes of the ATLAS HYDROSWEEP DS-2 for 120° swath width

The following table describes technical data of the ATLAS HYDROSWEEP DS-2 transmitter.

Feature	Specification
Transmission source level	- > 237 dB [rel.1 μ Pa] 1 m (in RDT operation mode) - > 220 dB [rel.1 μ Pa] 1 m (in ODT operation mode)
Beam width (longitudinal)	- 2.3° in medium and deep-sea mode - 4.6° in shallow water mode
Pulse length	- 1 – 60 ms (depending on transmission mode)
Dynamic compensation	- Pitch and roll (in RDT) - Pre-trigger for heave compensation

Table 4-5: Technical data of the ATLAS HYDROSWEEP DS-2 transmitter

4.3 Receiver

Feature	Specification
Beam width (longitudinal)	Approx. 20° (at - 3dB)
Beam width (across)	- 0.5 to 2.3° in medium and deep-sea mode - 1.0 to 4.6° in shallow-water mode
Input Sensitivity	- 45 [rel.1 μ Pa] for shallow water - 50 [rel.1 μ Pa] for deep water
Reception directivity	- 23 dB for shallow water - 27 dB for deep water
Bandwidth	100 Hz to 1 kHz (Automatically determined by the water depth range)
Dynamic compensation	- Roll - Heave compensation by geometrical correction of depth output

Table 4-6: Technical data of the ATLAS HYDROSWEEP DS-2 receiver

4.4 Beamformer and Bottom Detection Algorithm

Feature	Specification
Beam forming principle	2-stage Beamformer structure with: <ul style="list-style-type: none"> - <i>Primary</i>_(coarse) stabilised time-delay Beamformer - <i>Secondary</i> (fine) high-resolution bearing discriminator (HDBE)
Primary acoustic channels	59 coarse channels
Depth channels	Up to 240
Bottom detection	The HYDROSWEEP DS-2 evaluates individual acoustic travel times by means of synchronised amplitude and phase detection with interlaced centre-of-energy and high-resolution bearing discrimination computation with automatic adaptive gate control. A subsequent series of advanced plausibility filters increases the ability of unambiguous bottom target detection.

Table 4-7: Technical data of the ATLAS HYDROSWEEP DS-2 Beamformer and bottom detection algorithm

4.5 Parameter Ranges for Motion Compensation

Parameter	Range
Roll angle	± 10° for 120° swath width ± 14° for 90° swath width
Pitch angle	± 10 °
Heave	± 5 m

Table 4-8: Parameter ranges for the ATLAS HYDROSWEEP DS-2 motion compensation

Input Scaling: roll 0.4444 V/°
 pitch 0.4444 V/°
 heave 2.0 V/m

Max: input voltage: ± 10V

4.6 Resolution and Accuracy

The resolution and accuracy characteristics of the ATLAS HYDROSWEEP DS-2 sensor, operated in the survey mode, are listed in the table below.

It has to be mentioned that the accuracy of an entire surveying system including an ATLAS HYDROSWEEP DS-2 is not identical to the accuracy of the ATLAS HYDROSWEEP DS-2 sensor, because it includes additional error sources coming from the motion sensor, the applied sound velocity probe and other sensors.

Parameter	Value
Depth resolution	- 0.1 m for 10 – 999 m water depths - 1 m for water depths > 999 m
Side scan resolution	- Up to 6 kB samples per sounding cycle
Typical standard deviation of depth	- < 0.5 % for 120° swath width - < 0.3 % for 90° swath width (for the depth range from 100 m to the maximum water depth)
Standard deviation of the mean sound velocity, calculated from cross-fan calibration	0.5 % (for the depth range from 100 m to the maximum water depth)

Table 4-9: Resolution and standard deviation of an ATLAS HYDROSWEEP DS-2

Remark: The values stated are expected values in normal survey situations and in the absence of adverse bottom or environmental conditions. Due to the “longitudinal” swath calibration method, the overall accuracy includes systematic and stochastic errors of the sensor. A possible bias due to any unknown sound velocity profile is compensated.

4.7 Calibration Mode

The technical data as specified above are applicable in the survey mode. In the calibration mode, above specification is applicable within the following constraints:

- The roll compensation is limited to $\pm 10^\circ$.
- The pitch compensation is limited to $\pm 5^\circ$.
- Accuracy values are not specified for the calibration mode.
- The estimated standard deviation for 90° swath width is < 1 %.

- The calibration mode is not executed at yaw angles > 5°.

Switching to calibration mode can be accomplished in:

- Automatic mode (depth / travelled distance)
- Manual mode (ratio between longitudinal and transversal soundings)

4.8 Operational Conditions

The depth ranges, accuracies and related technical data as specified above are valid under the following operational conditions:

- Isotropic noise level in deep water: < 45 dB [rel.1 µPa, Hz^{-1/2}]
- Isotropic noise level in shallow water: < 60 dB [rel.1 µPa, Hz^{-1/2}]
- Roll angle: Less than ±10 degrees
- Pitch angle: Less than ±5 degrees
- Continuously uninterrupted ray path
- Undisturbed acoustic contact between the water and the radiating transducer surface (no air bubbles beneath the transducers).

4.9 Environmental Conditions

Parameter	Range
Temperature of underwater parts (incl. cables)	- + 35° C maximum - - 4° C minimum
Temperature of electronic units	- + 40° C maximum average - + 50° C peak - 0° C minimum
Humidity	- Max. 95%, no condensation
Vibrations	- 0.35 g maximum (at 0 ... 100 Hz)

Table 4-10: Environmental conditions for the ATLAS HYDROSWEEP DS-2

COTS components such as PCs, workstations, printers, plotters, magnetic storage devices and storage media shall expose to environmental conditions according to manufacturer's specifications. It is recommended to provide an "office type environment" for the computer hardware and associated peripherals.

4.10 Equipment Dimensions and Weights

Equipment	Height	Width	Front-to-back	Weight
Transmitter cabinet 1 Type SH 6020 A 001	2180 mm	750 mm	420 mm	212 kg
Transmitter cabinet 2 Type SH 6020 A003	2180 mm	750 mm	420 mm	212 kg
Signal processing cabinet Type GE 6012 A 007	1950 mm	600 mm	600 mm	142 kg
Interface Processor cabinet Type GE 6028 O 300	500 mm	670 mm	500 mm	50 kg
Transducer array incl. cable (longitudinal)	350 mm	2839 mm	300 mm	393 kg
Transducer array incl. cable (transversal)	350 mm	2839 mm	300 mm	393 kg
Operator station and peripheral devices	Depending on the individual system configuration			

Table 4-11: Equipment dimensions and weights (nominal values) of the ATLAS HYDROSWEEP DS-2

4.11 Power Supply

Parameter	Range
Operating voltage	- 230 V \pm 10%, single phase - or 115 V \pm 10%, single phase
Frequency	47 – 63 Hz
Total power consumption	5 kVA – 7 kVA, depending on configuration
Type of fuse in main switchboard	16 A slow blow (230 V)
No. of separate fuses	6 (min.)

Table 4-12: Power supply requirements for the ATLAS HYDROSWEEP DS-2

5 Abbreviations

ATLAS	ATLAS Hydrographic
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off The Shelf
CTD	Conductivity Temperature and Depth Probe
DESO	Depth Sounder
DS	Deep Sea
DTM	Digital Terrain Model
ECDIS	Electronic Chart Display and Information System
EEZ	Exclusive Economic Zone
GPS	Global Positioning System
HDBE	High Definition Bearing Estimation
IHO	International Hydrographic Organisation
kB	Kilobyte
kHz	Kilohertz
LAN	Local Area Network
MB	Megabyte
MD	Medium Depth
NMEA	National Marine Electronics Association
ODT	Omni-Directional Transmission
OSF	Open Software Foundation
PC	Personal Computer
RDT	Rotational Directional Transmission
SP	Special Publication
SQL	Structured Query Language
TPE	Total Propagated Error
TVG	Time Variable Gain
USACE	U. S. Army Corps of Engineers
USV	Continuous Undulating Sound Velocity Probe
XBT	Expandable Bathy Thermographic Probe
XDR	External Data Representation
XSV	Expandable Sound Velocity Probe

6 Delivered ATLAS Deep Sea Systems

Vessel	Customer	Country	Delivery Date(s)	System Type
RV METEOR	Bundesministerium für Forschung und Technologie	Germany	1986, 1995	DS-2
RV POLARSTERN	Alfred Wegener Institut (AWI), Bremerhaven	Germany	1989, 1997	DS-2 120°
ORV SAGAR KANYA	National Institute of Oceanography, Goa	India	1989	DS
RV MAURICE EWING	Lamont Doherty Earth Observatory, Palisades	USA	1989, 2001	DS-2 120° HDBE
RV THOMAS THOMPSON	US Navy University of Washington, Seattle	USA	1990	DS
RV HAKUREI MARU II	Metal Mining Agency, Tokyo	Japan	1991, 2000	DS-2
RV SONNE	Reedereigemeinschaft Forschungsschiffahrt, Bremen	Germany	1991	DS
RV L'ESPOIR	Svitzer Ltd. / Britsurvey, Great Yarmouth	United Kingdom	1994, 1998, 2002	DS-2 120° HDBE
WFS PLANET	TNSW Emden	Germany	2003	DS-2 120° HDBE
AKADEMIK BORIS PETROV	Russian Academy of Sciences RAS, Moscow	Russia	2003	DS-2 120° HDBE

Table 6-1: Delivered ATLAS HYDROSWEEP DS and DS-2 deep-sea systems

7 References

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