Simrad EM 12
Product description

This document presents a general description of the Simrad EM 12 hydrographic multibeam echo sounder. It contains a general system overview, a technical description and the system's performance.

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1 INTRODUCTION

1.1 General

As the "Full ocean depth" member of Simrad's family of multibeam echo sounder systems, the EM 12 Multibeam Echo sounder harnesses technology from the latest developments in underwater acoustics and signal processing. The EM 12 design evolved from the well proven and highly productive EM 100 multibeam echo sounder. The success of the EM 100 can be attributed to its accuracy, high rate of data acquisition, reliability, and ease of operation. Survey teams operating the EM 12 will benefit from all of these advantages, achieving data quality and productivity levels to meet the most rigorous project demands.

The EM 12 operates at a frequency of 13 kHz, and provides precision swath mapping capability to full ocean depths (11,000 meters). The EM 12 is a complementary system to the shallow water EM 1000 and EM 950 multibeam echo sounders.

EM 12 users will complete survey tasks much faster than is possible with conventional single beam echo sounders and with as good or even improved accuracy. By applying advanced signal processing techniques, typical accuracies of 0.25% of water depth or 60 cm (whichever is greater) are achieved across the entire swath.

The introduction of the EM 12 marks a major leap into the future for digital hydrography, utilizing data acquisition of digital bathymetry integrated with position data and computerized map processing techniques. The sheer volume and consistency of the data made available by Simrad's high resolution swath covering systems provide a far better basis for construction of the desired digital terrain model than any earlier generation of equipment.

From such terrain models, seabed contour maps of any scale, size and shape may be drawn. Profiles may be calculated and plotted and any combination of data may be extracted, computed and presented for planning purposes (volumetric calculations, 3-dimensional views, etc.). The resulting maps offer quality and accuracy far beyond any map produced by conventional methods - and at a significantly lower cost.

The Simrad NEPTUNE post processing system is especially suitable for use with the EM 12 data, but other systems may also be used.

In addition to the bathymetric maps, the EM 12 measures the strength of the backscattered signal from the seabed inside the swath, with very high resolution. Seabed images equivalent to those produced by shallow towed sidescan sonars can be produced in real time, but with correct geometric registration. The digital sonar image data can be made available for postprocessing.

The EM 12 system has, at the time of writing (May 1993), been installed on 5 vessels and tested with excellent results, with the next system to be installed in August.

1.2 Highlights

Some of the major benefits of the EM 12 are:

- Excellent accuracy across the entire swath due to bottom detection by phase measurement (interferometric principle) with very good tolerance to bottom slope.
- Full ocean depth capability to 11000 m from 50 m (10 m optional).
- A large number of beams, with the detection point in the beam centers, and equidistant beam spacing horizontally.
- Increased range due to narrow transmitter beam angle, fast RDT mode without ping rate degradation, and bottom detection by phase measurement.
- Full and automatic compensation for ray bending caused by varying sound velocity profile in the water column.

- Fully automatic operation without operator intervention under almost any conditions.
- Installation of transducers can be tailored to the ship. Different solutions are available for new vessels, retrofitted vessels, and also for icebreakers and ships with ice classification.

- Simrad's multibeam technology has been proven through EM 100 field operation since 1986.

- High reliability using quality Simrad hardware.

2 SYSTEM OVERVIEW

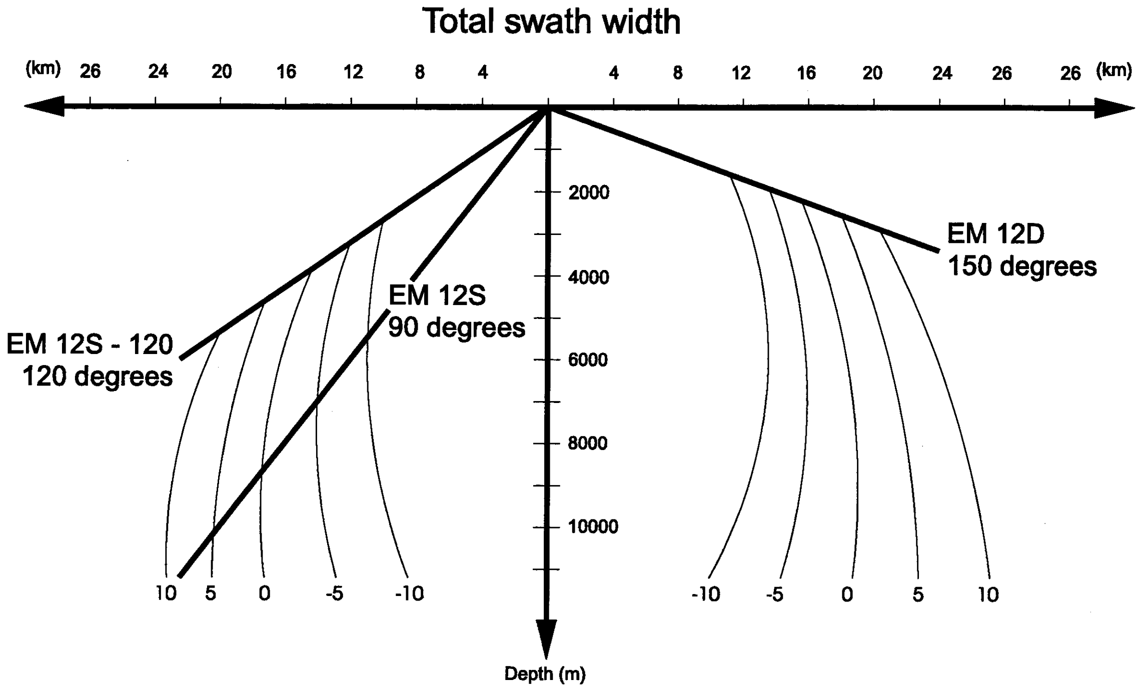
2.1 Introduction

The Simrad EM 12 is a low frequency (13 kHz) multibeam echo sounder with full ocean depth capability. The system is modular in its structure, so that it can be tailored to different user requirements. The basic model is the *EM 12S* which has an angular coverage sector of 90° with 81 beams spaced every 1.125°. The swath width is 2 times the depth and actual use has shown that this swath width performance is possible to full ocean depth.

The *EM 12S-120* is a version of the EM 12S with a software option which extends the angular coverage of the EM 12S to 120° with a swath width of 3.5 times depth. The gain in swath width is 4-5 km in the most common depth range of the oceans, 3000 to 6000 m. The beam spacing is either 1.5° in angle or equidistant horizontally.

In the *EM 12D Dual version*, an extra set of transducers, Preamplifier Unit, Transceiver Unit, and Bottom Detector Unit is added. This increases the coverage sector to 150° with 162 beams, covering a swath width of 7.4 times the water depth. This version has a typical acrosstrack coverage of 20 km from about 2500 m water depth to full ocean depth. Compared to the EM 12S, this gives an increase in swath width of approximately 10 km in the 3000 m to 6000 m depth range. The beam spacing is either 1° in angle or equidistant horizontally.

The calculated swath width verses depth, as a function of noise level and bottom backscattering strength, is shown in . Note that the typical backscattering strength is in the order of -30 to -40 dB, and that typical ship noise levels are in the order of 40 to 50 dB. The background noise level for sea state 4 is approximately 45 dB and for calm seas less than 40 dB.



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NL \ BS	- 40	- 35	- 30
50	- 10	- 5	0
45	- 5	0	5
40	0	5	10

The parameter is a function of the Noise Level (NL)
and the bottom Backscattering Strength (BS).

Figure 1 Calculated coverage performance

2.2 Operational modes

2.2.1 Shallow mode

This mode is intended for efficient surveying in shallow waters, typically between 50 and 1500 meters for the EM 12S, 50-1200 m for the EM 12S-120, and 50-700 m for the EM 12D. The transmission sector is tailored to the angular coverage sector, and is stabilized both for roll (±15°) and pitch (±10°). Transmitter pulse length is 2 ms. The receiver beams are roll stabilized and the sampling interval in each beam is 60 cm in range. The transmitter beamwidth is 1.8° and the receiver beamwidth is 3.5°.

2.2.2 Deep mode

This mode is intended for surveys in deep waters to full ocean depth. The transmission sector is tailored to the angular coverage sector, and is stabilized both for roll (±15°) and pitch (±10°). The transmitter pulse length is 10 ms, and to increase the source level the full transmission sector is covered by several beams within each ping. The reception beams are roll stabilized and the sampling interval in each beam is 240 cm in range. The transmission beamwidth is 1.8° and the reception beamwidth is 3.5°.

2.2.3 Very shallow mode

This optional mode may be used for surveying very shallow waters, between 10 and 200 meters. The transmission sector is tailored to the angular coverage sector, and is stabilized both for roll (±15°) and pitch (±10°). The transmitter pulse length is 1 ms. The reception beams (81 or 162) are roll stabilized, and the sampling interval in each beam is 30 cm in range. For depths less than 50 m, the number of beams is halved. The transmission and reception beamwidths are both 3.5°. Note that the performance of the EM 12 with this mode will not give the accuracy usually required for this depth range. It is therefore recommended for users who work extensively in this range to supplement the EM 12 with a high frequency multibeam echo sounder such as the EM 950 or EM 1000, instead of acquiring this mode with their EM 12.

2.2.4 Equidistant horizontal beam spacing

With the wide coverage sectors of the EM 12S-120 and the EM 12D, the sounding spacing will increase rapidly with acrosstrack distance from the center with equiangle beam spacing. This is not desirable as one would prefer a regular sampling of the seabed, but more seriously, it has been found that postprocessing systems have difficulty in handling the resulting wide spacing of the outer beams properly. Therefore the beam spacing of the EM 12S-120 and the EM 12D can now also be set to being equidistant horizontally. As angular coverage decreases with depth thus causing loss of beams, additional sectors are implemented for use in deeper waters, thus retaining the total number of beams. The EM 12 will automatically choose the coverage sector according to depth, bottom conditions, and number of beams with valid detections, unless the operator chooses otherwise.

The EM 12S-120 has three sectors with equidistant beam spacing, 120°, 105°, and 90°, all with 81 beams. The horizontal beam spacing and depth capability of these sectors are shown in the table below. Note that the coverage and depth capability of the 120° sector may be reduced if the vessel's roll is excessive, and the depth capability may vary according to the bottom conditions.

Angular sector	**Maximum coverage**	**Depth range**	**Horizontal spacing**
120°	3.5 x Depth	50-5500 m	0.043 x Depth
105°	2.6 x Depth	5000-8000 m	0.033 x Depth
90°	2 x Depth	7500-11000 m	0.025 x Depth

EM 12S-120 equidistant beam spacing

The EM 12D has five different sectors with equidistant beam spacing, 150 , 140 , 128 , 114 and 98 , all with 162 beams. The horizontal beam spacing and depth capability of these sectors are shown in the table below. Note that the coverage will not be roll dependent as for the EM 12S-120, but depth capability may vary with different bottom conditions.

Angular sector	**Maximum coverage**	**Depth range**	**Horizontal spacing**
150°	7.4 x Depth	50-3000 m	0.047 x Depth
140°	5.5 x Depth	2500-4200 m	0.035 x Depth
128°	4.1 x Depth	3500-6000 m	0.026 x Depth
114°	2.9 x Depth	5000-8000 m	0.019 x Depth
98°	2.3 x Depth	7000-11000 m	0.015 x Depth

EM 12D equidistant beam spacing

2.3 Main system units

2.3.1 General

The main system units of the EM 12 are as follows, refer to :

- Transducer arrays (separate for reception and transmission)
- Sea surface sound velocity sensor
- Preamplifier Unit
- Transceiver Unit
- Bottom Detector Unit
- Operator Unit

Several options may be delivered with the system:

- Acoustic windows (up to ice breaker strength)
- Transducer cable extensions with junction boxes
- Vertical reference unit (required, optionally delivered by Simrad)
- Sound velocity profile sensor (required, optionally delivered by Simrad)
- Track plotter
- Echogram beam presentation recorder
- Optical disk (ruggedized WORM) for data storage
- Quality Assurance Unit
- Sonar Imaging Unit
- MERMAID data logging system
- NEPTUNE postprocessing system
- VIDOSC real time contouring system

2.3.2 Transducer arrays

The transducer arrays are mounted in a cross-shaped configuration with one array for transmission and one array for reception. Both arrays are assembled from individual transducer modules. The transmission transducer has 24 modules and is 4.8 m long. The reception transducer has 14 modules and is 2.4 m long. Both transducers are 555 mm wide and 262 mm deep. In the EM 12D, two sets of transducer arrays are used, tilted 40° to each side from the horizontal.

A streamlined blister arrangement which is designed to move aerated water to the sides and is deep enough to protrude through the boundary layer, is often recommended for the EM 12S. The blister is shaped to avoid direct line of sight between the propeller(s) and the transducers, and is a good solution on many hulls. Alternatively, the transducers may be integrated on or into the hull with specifically designed streamlined appendages to reduce flow resistance and noise.

To achieve the best coverage performance it is recommended that the transducers are fitted without acoustic windows. The transducer faces will then be exposed to the open sea, and should therefore be protected from marine growth with anti-fouling paint. If mechanical protection is required, acoustic windows made of titanium may be installed. These windows may be up to 10 mm thick which will allow EM 12 operation on ice breaking vessels.

2.3.3 Sea surface sound velocity sensor

In order to keep accurate control of the direction of each beam, a sound velocity sensor is included with the EM 12. The sensor, an ME Meerestechnik-Elektronik model OTS, is preferably mounted in an isolated tank within the ship with sea water drawn in with a pump. This installation allows easy cleaning of the sensor.

2.3.4 Preamplifier unit

Each module in the receiver array is connected to the Preamplifier Unit. The standard cable length allows at least 11 meters separation between the transducer and the Preamplifier Unit, but extension cables may be fitted. The Preamplifier Unit should be mounted close to the Transceiver Unit.

2.3.5 Transceiver unit

The Transceiver Unit contains power amplifiers, data acquisition boards, interfaces, and digital signal processors for beamforming, filtering and system control. Each module in the transmitter array is connected to the Transceiver Unit. The standard cable length allows at least 10 meters separation between the transducer and the Transceiver Unit, but extension cables may be fitted.

The Transceiver Unit has built in interfaces for gyrocompass and heave/roll/pitch sensor (Vertical Reference Unit).

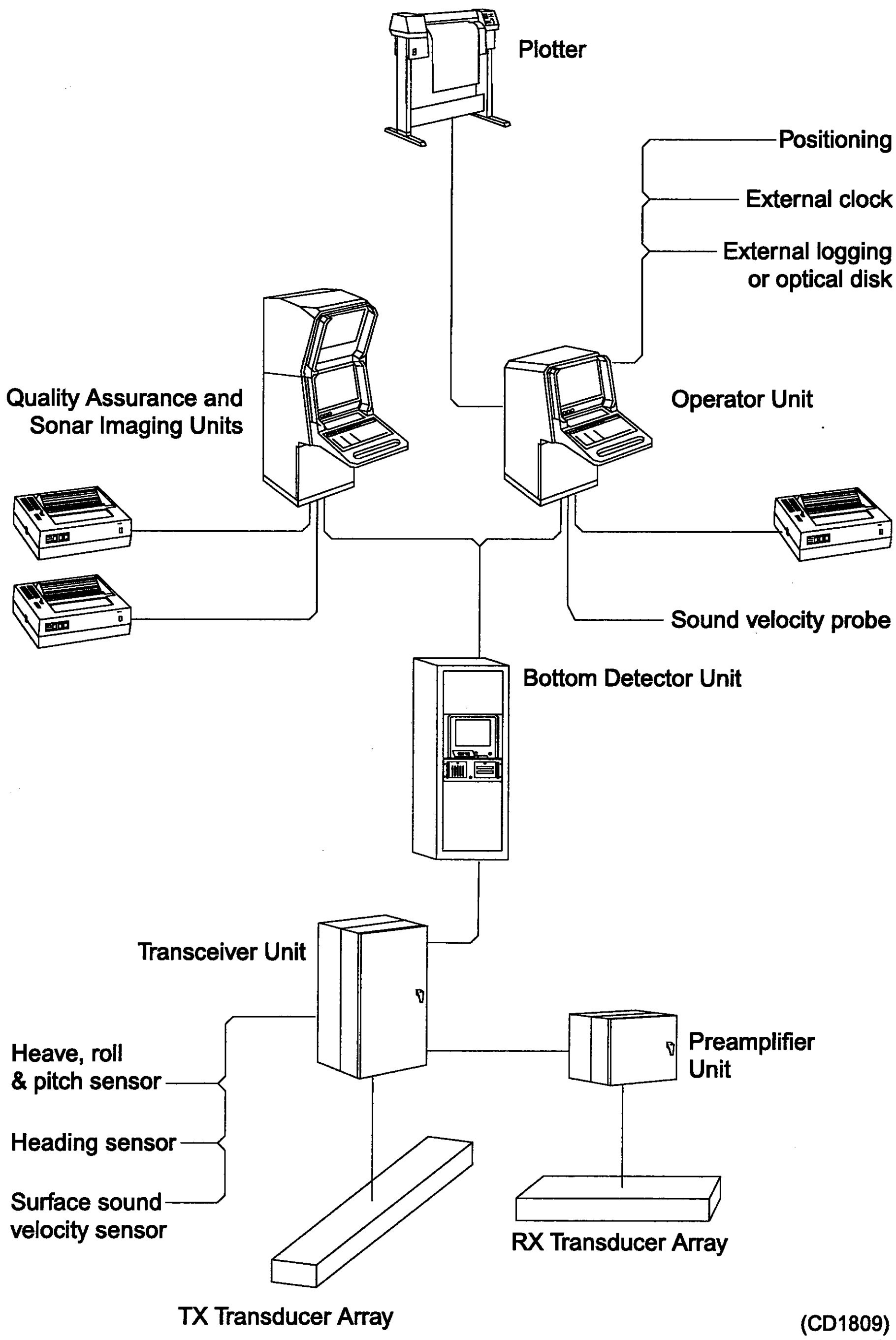

Figure 2 The Simrad EM 12 main units; a typical configuration

2.3.6 Bottom Detector Unit

The Bottom Detector Unit controls the EM 12 Transceiver Unit and, in automatic mode, sets all parameters such as operation mode, coverage sector, depth range, etc. It includes a colour monitor with display of raw receiver amplitude and beam amplitude and phase data, plus various detection parameters. A joystick on the display unit is used to access the menu. Data to and from the Transceiver Unit is passed through two coaxial cables (Ethernet), and it communicates with the Operator Unit, Quality Assurance Unit, and Sonar Imaging Unit on the EM 12 internal Ethernet. The Bottom Detector Unit is usually mounted in a standard 19" instrument rack.

2.3.7 Operator Unit

The Operator Unit is mounted in a single-height display console. The unit runs the operator interface via its colour graphic monitor and connects the EM 12 to all external units.

The EM 12 presents the sounding data on the Operator Unit display, and will usually output the bathymetric data ping by ping to an Ethernet port using a UDP protocol (a subset of the TCP/IP protocol family). It may receive position data and external clock synchronization on separate serial lines. A ruggedized optical disk (WORM) may be mounted in the console to log the data.

The optional track plotter is controlled by the Operator Unit and plots the area covered by the EM 12 for each ping. The Operator Unit may be interfaced to an HP PaintJet colour graphics printer for echogram presentation of any selected beam.

The standard sound velocity profile sensor may be read directly by the Operator Unit on a dedicated serial line. Alternatively, a sound velocity profile may be prepared on an external computer and transferred to the Operator Unit on Ethernet or serial line.

2.3.8 Quality Assurance Unit

The optional Quality Assurance Unit is usually mounted with the Sonar Imaging Unit in a dual-height display console. If the latter is not included, the console may be single-height. The console is usually installed next to the operator console, but this is not a necessity.

Depth and position data can be displayed in different modes on the Quality Assurance Unit's graphic monitor and printer:

- Contour map presentations
- Soundings colour coded in depth in a map format (coordinate fixed display)
- 3-D presentations (waterfall)
- Depths in every beam (colour coded depth)

In addition to these real time displays the Quality Assurance Unit contains the necessary functions to allow easy calibration of any offset errors in pitch and roll of the vertical reference unit, heading of the gyrocompass and time delay in the positioning system.

An HP PaintJet colour graphics printer is included with the Quality Assurance Unit, and may be used both for producing hard copies and for continuous recording.

2.3.9 Sonar Imaging Unit

The optional Sonar Imaging Unit is integrated with the Quality Assurance Unit which contains its operator interface. The Sonar Imaging Unit displays an acoustic backscatter image of the sea bed based on beam amplitude samples derived by the Bottom Detection Unit. The image is similar to that obtained by a shallow towed sidescan sonar, but is both geometrically and acoustically correct which is not the case with sidescan. The image may be coded in colour or grey-scale, and can be both displayed on screen and recorded on paper. The recorder may either be an HP PaintJet colour or a high resolution Dowty 85 or 195 grey-scale graphics printer. Data logging of bottom reflectivity may be accomplished via the Operator Unit.

2.3.10 External systems

The MERMAID data logging system, the NEPTUNE postprocessing system, and the VIDOSC real time contouring system are all workstation based software systems which receive their data from the Operator Unit on an Ethernet line. The workstation is typically a SUN Sparcstation running the UNIX operating system.

3 DETAILED TECHNICAL DESCRIPTION

3.1 Transducers and beamforming

3.1.1 General

Beamforming of the transmission pulse is applied to ensure that energy is transmitted only over the sector to be used for reception. Receiver beams are formed in real time during the reception period, according to the sector width selected. A steered linear array will have a conical beam diagram, thus the footprints of both receiver and transmitter will be curved on the bottom. This phenomenon is fully taken into account in the EM 12, both in the optimization of the transmission direction according to roll and pitch, and in the precise determination of the detection point in all beams, giving both across and alongtrack positions with depth.

The transmitter array consists of 384 elements which are all individually driven from separate power amplifiers mounted in the Transceiver Unit. Each element's drive can thus be individually controlled in both amplitude and phase, allowing compensation for roll and pitch and sidelobe shading in both directions. The alongtrack beamwidth is 1.8°. In the deep mode, the angular sector is covered by several beams to achieve the largest coverage possible. These beams are transmitted sequentially within a ping with no delay between the beams (Fast RDT). To avoid interference, the beams are transmitted using different frequencies, and digital filtering is used to separate them during reception.

The receiver array has 210 elements which in the preamplifier unit are connected via transformers into 42 staves, each with separate preamplifiers. The resulting alongtrack beamwidth is 18°, while the beamwidth acrosstrack is 3.5° (normal to the receiver array). The received beams are all stabilized for roll, but no pitch stabilization is required.

The sea surface sound velocity directly affects the beam pointing angles. At the maximum steering angle (60°) the sound velocity must be known to within 1.5 m/s to keep the beam pointing angle error to less than 0.1°. Thus a sensor which continuously measures the sound velocity at the transducers is an integral part of the EM 12.

As with the EM 100, a split aperture principle is used so that measurement within each beam of the instantaneous direction to the point of backscatter is possible. This interferometric technique is used in order to obtain the best accuracy of the soundings for all beams that hit the sea floor at an oblique angle. Depths are thus measured in the centerline of the footprint of each beam, implying that the accuracy of the measurements is much better than the 3.5° receiver beamwidth of the EM 12 would suggest based on an amplitude only type of detection.

3.1.2 Transducer installation

To achieve the best possible performance from the system it is critical that the transducers are installed properly. A good solution is usually derived by carefully considering the hull shape when deciding where and how to mount the transducers. The main causes of problems, which may be detrimental to system performance, are acoustic noise and aerated water flowing over the transducer face.

The most prevalent noise sources in addition to the sea background noise are normally the ship's propeller(s), and the engines. A good practice therefore is to mount the transducers as far as possible from the propeller(s). Noise transmitted from or through the hull is reduced by the acoustic insulation material within the transducer.

Air bubbles in the water are a very efficient means of inhibiting propagation. Aerated water in the sound path must be avoided if the system is to function properly. Each ship's hull is different, but there are some general guidelines:

- Surface water will be mixed with air at the ship's bow and some of this water will normally be forced downwards.

- Bulbous bows will often act as a pump moving aerated surface water down and under the hull.

- Tunnel thrusters may have a similar effect when the ship is passing through waves.

- A turbulent boundary layer with more or less air will be found along the hull. The thickness of this layer will increase with the distance from the bow.

A streamlined blister design, intended to move aerated water to the sides and deep enough to protrude through the boundary layer, is available. The blister is shaped to avoid line of sight between the propeller(s) and the transducers, and is a good solution for mounting the EM 12S and EM 12S-120 on many hulls, especially if other transducers are also to be included with the system. The speed reduction due to drag on the blister is typically 0.5 knots or less and the problems of docking are manageable.

If the transducer is to be mounted flush or nearly flush, very careful consideration of the problems with aerated water, as mentioned above, are required. A general recommendation is to mount the transducer near the ship's bow.

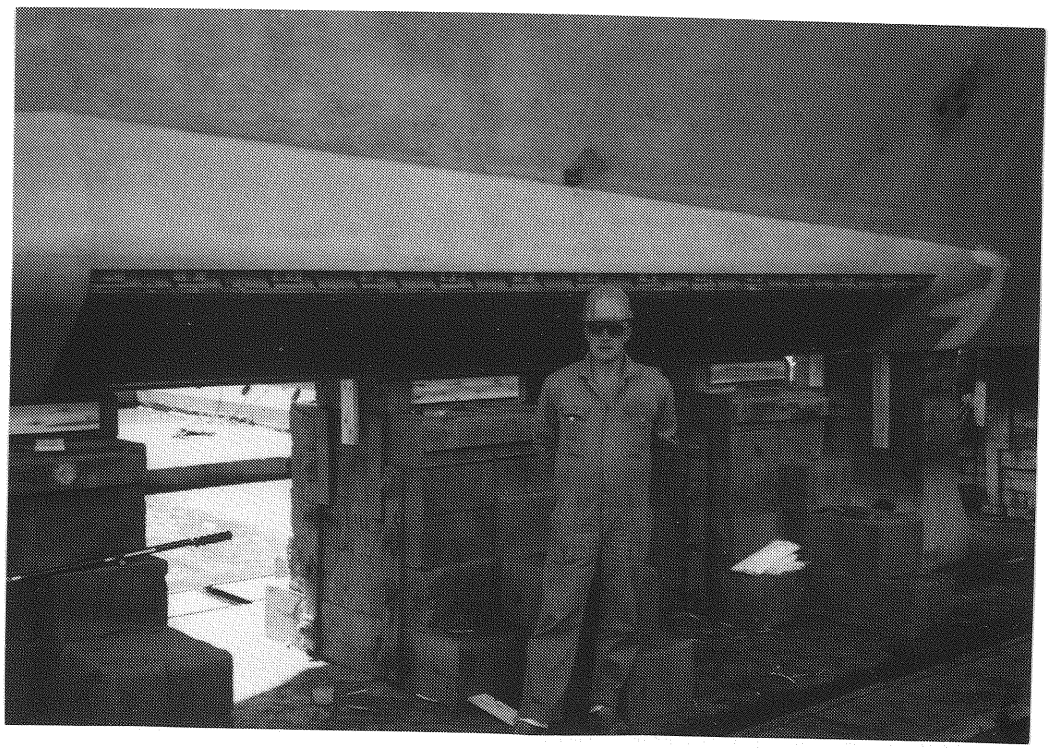

Figure 3 The transducer installation (transmitter array)

3.2 Preamplifier Unit

The Preamplifier Unit contains all low-level analog parts of the EM 12 receiver. All time varying gain (gain depends on depth) is run in the Preamplifier Unit.

3.3 Transceiver Unit

The Transceiver Unit includes transmitters, data acquisition boards, interfaces, memory and digital signal processors for beamforming, filtering and system control. The signal processors are used for:

- Beamforming
- Frequency filtering
- Roll compensation
- Determination of amplitude and phase in each beam
- Transmission of data to the Bottom Detector Unit

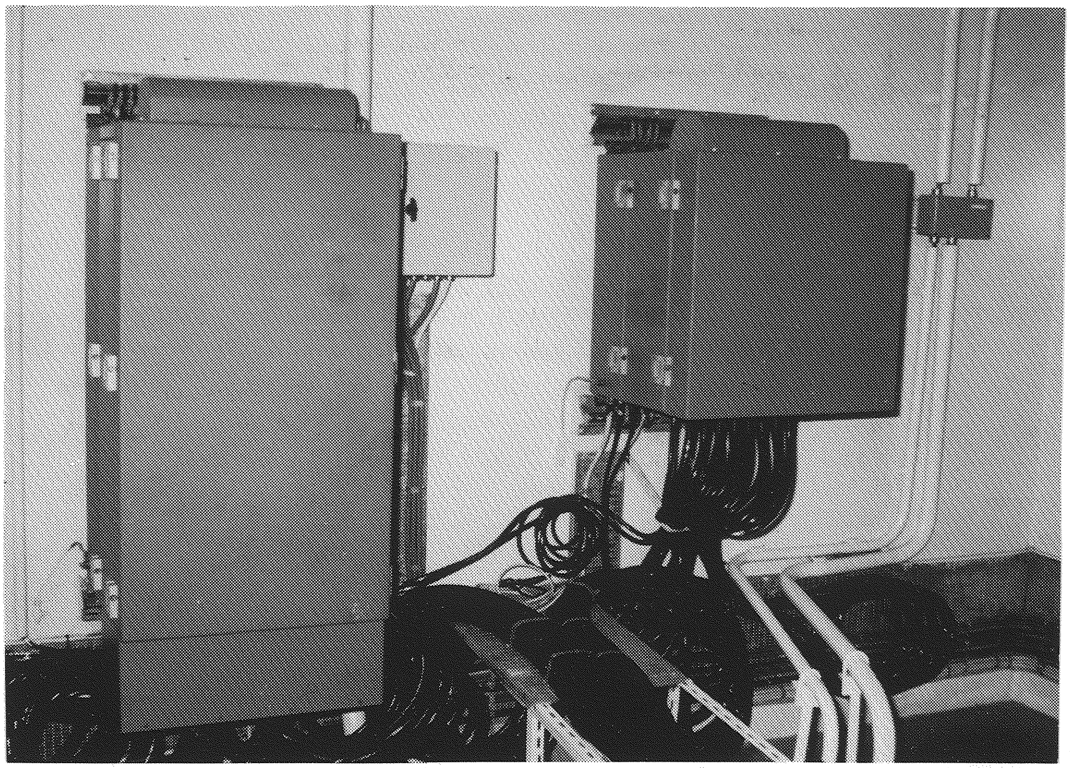

Figure 4 The Transceiver and Preamplifier Units

A control processor reads heave, roll and pitch data from the vertical reference unit, heading data from the gyrocompass, and the sound velocity from the sea surface probe.

3.4 Bottom Detector Unit

The Bottom Detector Unit receives data concerning each beam as a function of time from the Transceiver Unit. It will, for each beam, make a calculation of the travel time of the transmission pulse, from the moment of transmission until the signal backscattered from the geometric center point of the beam is received by the reception array. This calculation is based on interferometric signal processing, except for beams which have specular or near specular reflection from the sea floor, for which a centre of gravity algorithm is used. The travelling times and some additional information are transferred to the Operator Unit via an internal Ethernet line.

The Bottom Detector Unit is usually mounted in its own 19" rack which should be placed near the Operator Unit. Alternatively, the Bottom Detector Unit and Operator Unit may be integrated in a dual-height display console if floor or rack space is at a premium. The Bottom Detector Unit is used for local control of the multibeam echo sounder and for running most internal tests.

The Bottom Detector Unit display is useful for continuous supervision of weather performance and external sources of interference. The receiver amplitudes versus time are displayed before beamforming, giving an excellent view of any aeration blocking of the transducers or noise disturbance. The beam signal display allows pin-pointing of sources of external noise.

3.5 Operator Unit

3.5.1 General

The Operator Unit is mounted in a single-height display console, and from its keyboard and display the operator controls all the normal operation of the echo sounder. Final corrections for ray bending and the determination of depth and sounding position for all beams are performed in the unit.

The data is presented on the colour display, which is divided into two main sections, one for graphics and one for alphanumerics. The primary role of the graphic section is the presentation of depth data, while the alphanumeric section displays easily understood menu lists for system control via the keyboard (mainly by cursor operation), and also displays the system status.

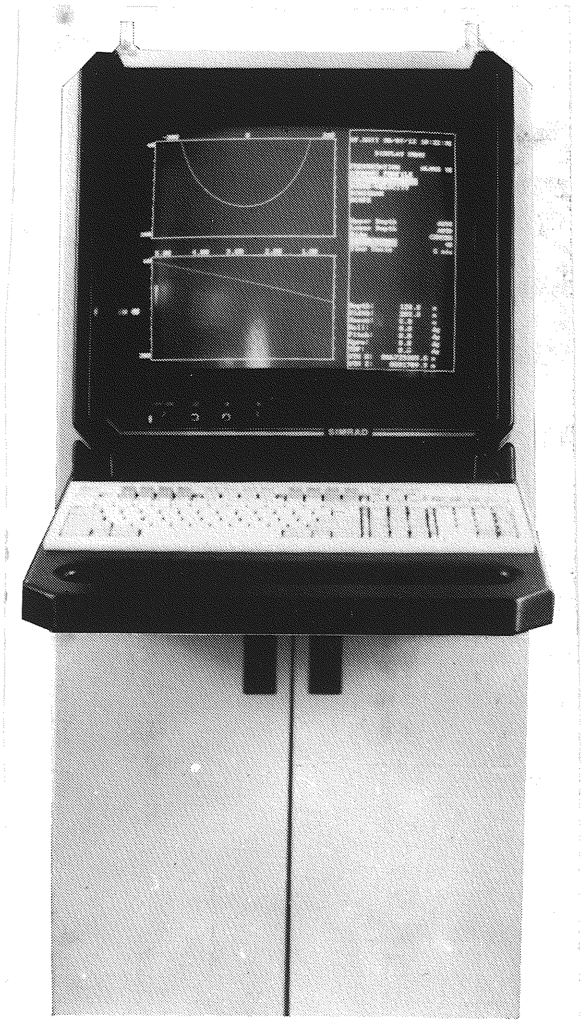

Figure 5 The Operator Unit console

3.5.2 Graphic section

While viewing depth data the operator may see the depth of each beam in real time. This information includes the transverse profile for the entire swath, and also the alongtrack profile for any one of the beams for the previous pings. Other functions such as the sound velocity profile or beam-specific data etc. may also be selected on the graphic part of the display.

3.5.3 Text section

The text section displays the operator control functions and system parameters. The control functions are organized in a main menu with corresponding sub-menus.

3.5.4 Error and status reporting

The operator unit has a built-in system for error and status reporting during operation. Commands are available for fault-finding, permitting the operator to locate errors as rapidly as possible. If an error occurs, an alert message is highlighted at the bottom of the text section.

3.5.5 Interfaces

The Operator Unit has the following built-in interfaces:

- Position data input (RS-232)
- External clock input (RS-232)
- Sound velocity profile input (RS-232 or Ethernet)
- Bathymetric data output (Ethernet)
- Sonar imaging data output (Ethernet)
- Position data output (Ethernet)
- Sound velocity profile output (Ethernet)
- Coverage track plotter (RS-232)
- Optical disk (SCSI)
- Echogram beam recording (Centronics)

3.6 Data storage

Simrad has developed a data logging software package called mermaid, which is recommended for storing the em 12 data. MERMAID is a workstation based software system which can log data to disk files. Optical disks may be used, or the data may be transferred to a magnetic tape for permanent storage. The hardware required to run the package is:

- SUN Sparcstation with hard disk
- Streamer tape for backup (or optical disk)
- Ethernet connection to the Operator Unit

It is also possible to connect a Mountain Optech 5¼" optical disk drive, Model SEL-2 to the Operator Unit. The SEL-2 features 200 megabytes of non-erasable (WORM) storage on each side of the disk, and is rugged enough to permit operation regardless of ocean conditions. Note that this solution is no longer recommended, due mainly to drive reliability problems and limited workstation support. It could however be considered as a secondary storage unit for extra security and permanent data archiving.

The data stored in digital form by mermaid (or on the disk) comprises:

Depth datagrams

Time, depths and relative positions of depths with respect to the ship's position reference center and heading at ping time, beam echo amplitudes, plus heading, heave, roll, pitch, and sea surface sound velocity data.

Position datagrams

Time, UTM or longitude and latitude position of the ship.

Miscellaneous datagrams

- Time, echosounder parameters, and annotation input.
- Sound velocity profile used by the system.
- Bottom backscattering strength (sonar imaging data).

This information, stored as separate records, is recorded continuously. Each survey line is recorded as a separate file on the optical disk. The name of the file identifies the date and time of recording. On MERMAID the data is stored in a similar fashion, but may also be split in different files according to datagram type.

3.7 External sensors

The EM 12 system is not completely autonomous. To make the system function correctly, the following external sensors have to be connected:

Heave / roll / pitch measurement (Vertical Reference Unit)

The standard sensor is the Hippy 120B/C which is interfaced to the Transceiver Unit's analog inputs. Other sensors may be used, either with analog or synchro outputs. A fixed delay of up to 100 ms in the sensor data can be compensated for in the EM 12.

Ship's course gyro

Any high precision gyrocompass which supports synchro output (1:1, 400 Hz) or RS-232 serial line can be used.

Navigation computer system

Position datagrams should be transferred regularly to the Operator Unit to allow the Quality Assurance Unit and the Sonar Imaging Unit to function properly, or for simultaneous logging of position and bathymetry. Position accuracy should be compatible with the intended map scale.

Sound velocity profiling instrument

The standard probe is the Applied Microsystems Ltd. SVP-16 (the old Navitronic SVP-1 will still be supported). The probe transmits the sound velocity profile to the Operator Unit after the measurement is finished. Alternatively a sound velocity profile may be put together on an external computer, for example using data from expendable probes, and loaded into the operator unit via Ethernet or serial line.

The standard probe is usually delivered with a 2000 m depth capability. For deeper waters the variation in sound velocity with position and time of year is very small, and the use of standard tables such as the NOAA database "Climatological Atlas of the World Ocean" is recommended. Alternatively the standard probe can be delivered with a 6000 m capability.

3.8 System options

3.8.1 General

To the basic system described above, it is possible to add system options of hardware, firmware, software or a combination. The available system options at the present time are:

- Protection of the transducers.
- Track plotter.
- Echogram presentation on recorder.
- Real time Quality Assurance Unit.
- Real time Sonar Imaging Unit.
- Output of sonar image data on Ethernet
- Data recording on separate workstation (MERMAID).
- Postprocessing on separate workstation (NEPTUNE)
- Real time contouring on separate workstation (VIDOSC).

3.8.2 Protection of transducers

The basic system includes painting of the transducer faces with a thin layer of antifouling paint. This gives the maximum range capability of the system. For mechanical protection against floating objects and ice, an acoustic window made of titanium may be installed. For vessels with ice capability, a 6 mm thick window with 2 dB insertion loss is recommended, while for ice breaking vessels a 10 mm thick window with 5 dB insertion loss is required. Note that the insertion loss will give reduced range capability.

3.8.3 Echogram presentation on recorder

This option will provide printing of the echogram of any selected beam in colour on a graphic recorder using 8" paper. The recorder is connected to the Operator Unit.

3.8.4 Track plotter

The track plotter is a pen plotter with the special task of displaying the area covered with the multibeam echo sounder and of the plotting of the ship's track on a geographic grid. This enables the surveyor, in real time, to produce documentation of the area which has been surveyed.

3.8.5 Real time Quality Assurance Unit

The real time Quality Assurance Unit is usually mounted side by side with the Operator Unit. Data processed in real time is displayed on the high resolution colour graphic monitor, and printed on an HP PaintJet printer for hard copy documentation.

The Quality Assurance Unit displays the information collected by the multibeam echo sounder in an organized and comprehensive manner, allowing a continuous and easy monitoring of the quality of the data to be used for final contouring and map production.

There are five modes of presentation:

Contour map This is a map with constant depth contour lines. The contour lines are colour coded according to depth to make the map easier to interpret. The map is centered on the ship's track, and position data are printed regularly, together with the time. The depths from the beam pointing vertical and a beam on each side are plotted as continuous curves on the right hand side of the map allowing easy interpretation of the depth contours.

Coordinate fixed map display This display is very useful for special applications where a limited area is to be surveyed and a hardcopy end product is needed immediately. The survey area is defined by its corner coordinates. As the vessel sails its survey lines within the area, the position of each individual sounding is calculated and the depth values are marked as colour coded dots. The result is a colour coded presentation of the depths as they are surveyed, geographically well-defined. As soon as the survey is finished, the display may be copied onto the graphic printer with full resolution. The shallowest depth is indicated to ease the investigation of shoals, etc.

Waterfall plot This is a rolling 3-D presentation of the seabed generated by accumulating transverse profiles in sequence.

Colour Coded Depth plot This is a colour coded depth plot with depths for each beam presented as a raw data profile in grid form. This plot provides excellent information for real time evaluation of the bottom tracking performance of each individual beam.

Calibration A special mode is included to enable the operator to verify the consistency of depth data from overlapping swaths. In this mode it is possible to calculate the fore-and-aft and athwartship calibration errors (pitch, roll and heading offsets, and position time delay), and to determine correction values which can be entered into the Operator Unit.

Figure 6 The dual height dispolay console for the Sonar Imaging and Quality Assurance Units

3.8.6 Real time sonar imaging unit

This optional subsystem will, on the basis of data collected in each beam as it moves across the sea floor, generate a composite backscattering strength image of the sea floor ping by ping. The geometry of the sonar is given by the composite beam pattern of the multibeam echo sounder. The intersection with the bottom is narrow alongtrack (1.8°), and extends to the full swath acrosstrack. The resolution in range corresponds to the beam range sampling rate. The position of each backscatter sample is precisely calculated relative to the ship or geographic position by using the bathymetric measurements for the same ping. This makes it possible to produce sonar overlays on bathymetric maps without systematic errors. The position calculation includes correction for ray bending. The sonar image is presented on a colour monitor. It can also be printed on a colour recorder. Interface to a high resolution grey-scale recorder is included.

3.8.7 Output of sonar image data to the ethernet

This software option is for the ping by ping output of sonar image data to the ship's Ethernet, for external logging and/or processing.

3.8.8 Real time contouring

The Quality Assurance Unit's contour plot is a strip chart alongtrack and has limited quality. In geographical coordinates the Quality Assurance Unit does not draw contours, but only soundings colour coded in depth. The track plotter shows only coverage, without any depth information. A combination of these functions is now available in the VIDOSC system, which generates real time contours in a geographical coordinate system on both screen and plotter. It has been developed by IFREMER and used extensively with the EM 12D, the EM 12S and also the EM 1000.

The standard hardware is a SUN Sparcstation. Minimum hardware requirements are:

- 32 Mbyte of RAM
- 1 Gbyte of disc storage
- HPGL Plotter

Note that the VIDOSC software may run on the same workstation as the MERMAID data logging software.

4 SYSTEM PERFORMANCE

The performance of a multibeam echo sounder may be judged by two main factors, accuracy of the soundings, and the achievable swath width. In addition, factors such as ease of installation and operation, weather performance, reliability, and support are important in determining a total system quality. In all these respects, the performance of the EM 12 is excellent.

A very extensive accuracy test of the EM 12D was conducted by IFREMER during sea acceptance trials in December 1990. The test was run in two parts, one on a low reflectivity, flat abyssal plain South of Madeira with a water depth of 4500 m, the other on an area with steep slopes East of Madeira with a mean water depth of 2900 m. In both areas a large number of closely spaced parallel survey lines were run, and a digital terrain model constructed from a small sample of the collected data. The error as a function of beam pointing angle was then determined as the deviation of the measurements from this terrain model. For the flat, deep area the standard deviation of the measurements was found to be approximately 0.1% of the depth, while the result for the area with steep slopes was 0.25% (refer to).

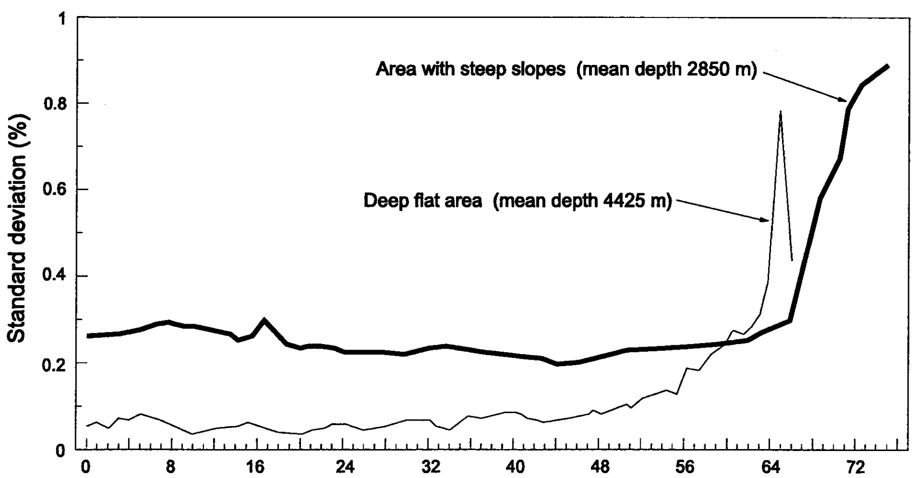

Figure 7 Accuracy of the EM 12D as measured by Ifremeer

A flat area test is mainly a test of the multibeam echo sounder, the sound velocity sensors and their use, and, provided that the sea is rough, the vertical reference unit. In an area with steep slopes, the results of the test will also depend on the quality of the positioning and the gyrocompass. The IFREMER test thus gives a good indication of both the performance of the EM 12 itself and what can be expected with all sensors connected. The conclusion drawn was that the accuracy in the determination of the angle to the center of each beam is in the order of 0.05°. The main limitations to the total system accuracy were errors in the sound velocity profile, (this was based on the NOAA database and XBT measurements in the upper parts of the water column), while the positional accuracy was very good, based on GPS with S/A not applied.

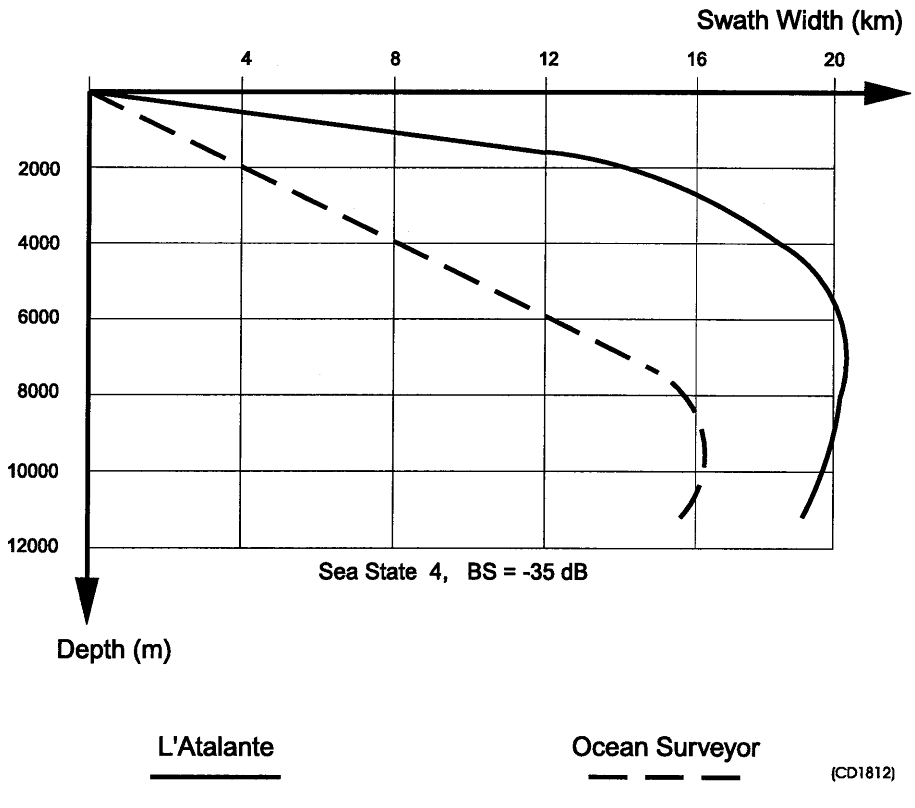

Figure 8 EM 12S and EM 12D coverage as observed by L'Atalante and Ocean Surveyor

Based on the results from the IFREMER tests, the accuracy of the EM 12 can typically be expected to be in the order of 0.25% of water depth, but not better than the range sampling distance (0.6 m in shallow mode and 2.4 m in deep mode). This accuracy will be almost independent of the beam pointing angle (assuming a sufficient signal to noise ratio of 10 dB or more), provided that the sound velocity profile has been correctly determined and that the vertical reference sensor has been properly calibrated. This specification will hold for typical bottom conditions, with even better results in flat areas.

The other important performance measure for a multibeam echo sounder is the swath width capability versus depth. The measured coverage performances of the EM 12S and EM 12D are shown in . This diagram is based upon what has typically been seen on the two first installations (the "Ocean Surveyor" and the "l'Atalante") for depths to 6000 and 8000 m respectively. This performance compares closely with the calculated coverage shown in .

Note that in May 1992, the EM 12S on the "Jean Charcot" achieved a swath width of 20 km at a maximum depth of 10800 m. This confirms the calculations as the sea was calm and the vessel has a low noise level.

5 POSTPROCESSING AND MAP PRODUCTION

The NEPTUNE postprocessing system is designed to process recorded multibeam data to contour maps, 3-dimensional plots, profiles, and volume calculations. It will take optical discs as input, but may also be adapted to other storage media. Parts of the software has been used for processing EM 100 data for several years, and is now also processing EM 12 and EM 1000 data. It produces contour maps with very high quality, offering full control of each processing step.

The postprocessing system is made for off-line operation. It can be set up on a ship, or it can operate on shore in an office environment. The same postprocessing system can be used for all Simrad's multibeam systems, and it may also be adapted to process single-beam sounder data.

The postprocessing software consists of four main components:

- Raw data interface software to read recorded data, adjust for tides and perform quality control, and then to calculate three numbers for each single sounding, giving the geographical position (in longitude/latitude or UTM), x and y, and the depth z. It is also possible to edit on raw data (depth and position).

- Binning and statistics module for data cleaning and analysis.

- Terrain model software to input (x,y,z) data, interpolate these to calculate a grid representation, and from this representation produce the final map products. There are also facilities for eliminating noise in the raw data by a statistical method, and data reduction facilities.

- Relational database to keep track of the equipment and the processing.

The standard hardware is a SUN Sparcstation. Minimum hardware requirements are:

- 32 Mbytes of RAM
- 1 Gbytes of disk storage
- Exabyte tape (or optical disk)
- HPGL A0 plotter

6 SERVICES OFFERED

6.1 Pre contract phase

As part of the discussions between the client and Simrad we will, free of charge and without any obligation, give advice regarding the suitability of a certain ship for mounting a multibeam system. We will also suggest practical solutions as to how and where on the ship the transducers and other equipment can be mounted. If necessary, we can assist on a contract basis to measure the ship's noise level, and calculate the predicted range performance of the echo sounder. We will also upon request, prepare proposals for the supply of complete instrument packages and/or systems.

6.2 Project management

As soon as a contract has been signed, and in some cases at an even earlier stage, we will appoint a manager for the project. The project manager will act as the point of coordination for the equipment production, documentation and testing at the factory. He will also coordinate the planning of the installation onboard the ship and the training to be supplied. The project manager will resolve all technical and commercial problems that arise during the project, until the system has been accepted by the client. Before the equipment is shipped from the factory, it is tested as a complete system (Factory Acceptance Test, FAT). The client is invited to be represented during these tests. The costs of the project management and level of responsibility are to be decided upon for each case.

6.3 Installation and commissioning

The normal procedure is that the installation of the equipment is performed by a shipyard, according to Simrad's documentation, and under the supervision of a field engineer. The equipment is then checked by Simrad field engineers. The shipyard normally works on a contract with the client, though it is possible to discuss alternative arrangements whereby Simrad undertakes more responsibility.

It is important to measure and document accurately the locations and mounting angles of the multibeam echo sounder transducers before the ship is put into the water. Simrad will provide procedures for these measurements, and will have these measurements conducted when required by the client.

The final testing consist of a Harbour Acceptance Test (HAT), which is performed with the ship along the berth, and a Sea Acceptance Test (SAT). The SAT procedure will be tailored to fit the actual delivery. If a complete mapping system is delivered, the SAT will comprise system calibration and a test mapping.

6.4 Training

Simrad will conduct the training of operators and maintenance personnel to the extent which has been agreed upon in the contract. The training can be arranged on shore, at the factory locations in Norway or at some other agreed site, and/or onboard the ship. For the data processing, it is our experience that the training should be split into 2 sessions. After the first session, the user should practice on the system for some time, with his own data or with test data supplied by us. The final training session will then be useful for brushing up on details and for resolving problems that have been experienced.

6.5 After sales support

6.5.1 Service department

After the SAT has been performed and the training finalized, the project manager will hand over the responsibility for the continued support to our service department. This department has a 24 hour duty arrangement, so it can be contacted by telephone at any time. The service department will assist in solving all problems that may be encountered during the operation of the system, whether the problem is caused by finger trouble, insufficient documentation, software bugs or equipment breakdown.

6.5.2 Maintenance contract

The guarantee conditions will be stated in the contract. As a supplement to the guarantee, we can offer system maintenance agreements tailored to fit the needs of the client. This agreement can be defined so that it covers repair work only, or complete support for preventive maintenance, repair work, and system upgrading of both hardware and software as the system design is improved by Simrad. Such upgrading would also cover upgrading of spare parts, documentation, and repeated/additional training courses. The maintenance contracts also contain a life time guarantee for the transducers, so that new transducer(s) are supplied free of charge if the transducer ceases to function or is degraded to the extent that the performance of the system is significantly reduced.

6.5.3 User forum

We have defined a forum for users of Simrad Multibeam echo sounder systems (FEMME), with the aim of improving communication both between the users and us, and between the system users. We will arrange FEMME meetings at approximately 18 months interval. So far (May 1992), 3 meetings have been arranged. The first was in Bergen, the second in Southampton in December 1990, and the most recent meeting took place in Horten in April 1992. The next meeting is planned for Paris in September 1993. Close to 100% user participation has been experienced at these meetings.

6.5.4 Information bulletin

We are now planning an information bulletin, to be edited by us and distributed to existing and potential users. The bulletin will contain information on new systems and functions, tips and tricks on the use of the systems, ongoing projects, and we will also be open for including material supplied by users of our systems. The present aim is to issue this bulletin on a 6 monthly basis.