

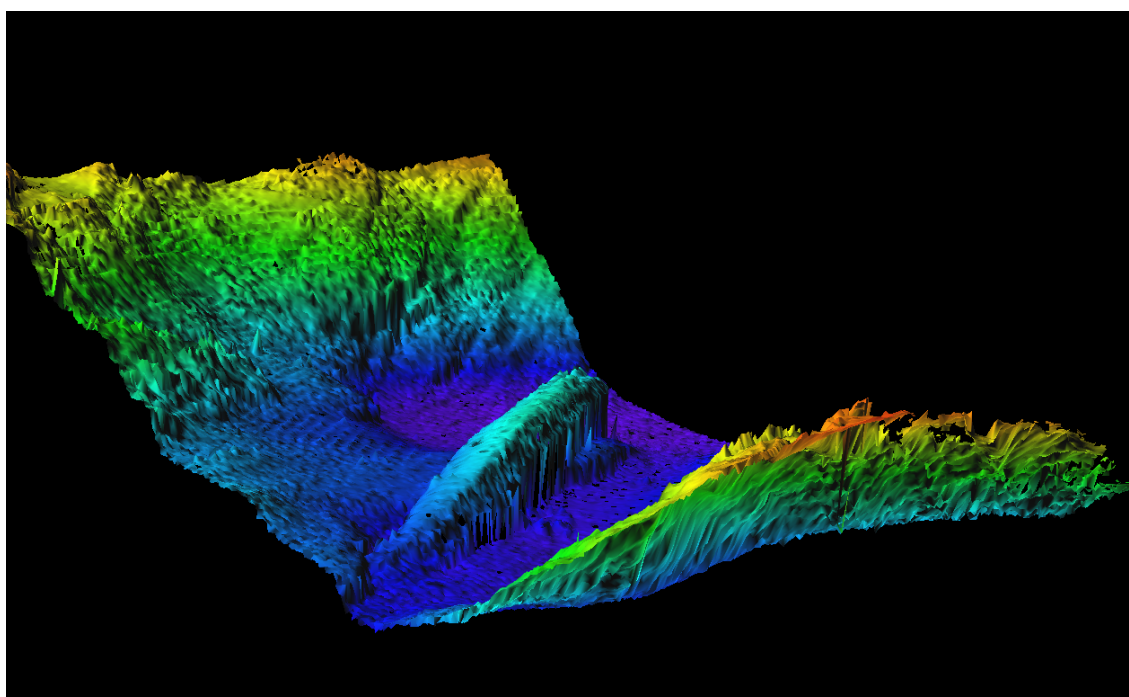


KONGSBERG

Product Description

EM 710

Multibeam echo sounder



EM 710 Multibeam echo sounder

Product description

This document presents a brief technical description of the EM 710 multibeam echo sounder.

About this document

Rev	Date	Written by	Checked by	Approved by
A	18.03.05	EB/EHa	KEN	FP
	Original issue.			
B	13.06.05	EB	KEN	FP
	Minor corrections.			
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	LCD monitor changed from 17" to 19". New data: Depth accuracy, horisontal resolution, crosstrack resolution and object detection capability.			

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SYSTEM OVERVIEW

Key facts

The EM 710 multibeam echo sounder is a high to very high resolution seabed mapping system capable of meeting all relevant survey standards. The system configuration can be tailored to the user requirements, allowing for choice of beamwidths as well as transmission modes. The minimum acquisition depth is from less than 3 m below its transducers, and the maximum acquisition depth is up to 2000 m.

Acrosstrack coverage (swath width) is up to 5.5 times water depth to a maximum of more than 2000 m. The sounding density is very high, allowing even the very demanding LINZ special order survey specification for object detection to be met in full.

There are three basic versions of the EM 710:

- **EM 710** - Full performance version.
- **EM 710S** - Continuous wave (CW) pulse forms only.
- **EM 710RD** - Short CW pulse only.

The reduced performance versions EM 710S (shallow) and EM 710RD (reduced depth) are upgradable to full performance.

Innovative acoustic principles

The EM 710 operates at sonar frequencies in the 70 to 100 kHz range. The transmit fan is divided into three sectors to maximize range capability but also to suppress interference from multiples of strong bottom echos. The sectors are transmitted sequentially within each ping, and uses distinct frequencies or waveforms.

Both CW pulses of different lengths and even longer, compressible waveforms (chirps) are utilized. The alongtrack beamwidth depends upon the chosen transducer configuration with 0.5, 1 and 2 degrees available as standard. Focusing is applied individually to each transmit sector to retain the angular resolution inside the near field. A ping rate of more than 25 per second is possible. The transmit fan is electronically stabilized for roll, pitch and yaw. The yaw stabilisation is accomplished by applying individual tilt control.

The EM 710 has a receive beamwidth of either 1 or 2 degrees, according to the size of the chosen receiver transducer. The number of beams are 256 or 128 respectively, with dynamic focusing employed in the near field. The distribution pattern may be set to be either equiangular or equidistant. All receive beams are electronically roll stabilized.

The swath coverage may be limited by the operator either in angle or in swath width without reducing the number of beams. A combination of phase and amplitude bottom detection algorithm is used, in order to provide soundings with the best possible accuracy.

High density beam processing mode provides up to 400 or 200 soundings per swath by using a limited range window for the detections, which in practice is equivalent to synthetically sharpening the beamwidth. In the high density mode more than one sounding may be created for each beam. In this mode, the size of each acoustic footprint is reduced to fit the higher sounding density. At the swath edges, the effective accuracy footprint is equivalent to a 0.2 degree beam.

With a 1 degree receive transducer the system is able to generate two separate alongtrack swaths per ping, thus doubling the alongtrack sounding density. The system produces up to 800 soundings per ping in this mode.

The coverage may be limited by the operator either in angle or in swath width without reducing the number of beams. This can be used to increase the sounding density if a particularly high resolution survey is to be done.

A combination of phase and amplitude bottom detection algorithm is used, in order to provide soundings with the best possible accuracy.

Acoustical seabed imaging

Integrated seabed acoustical imaging capability is included as standard. Software to use this data for automatic seabed classification is available.

Water column backscatter

A real time display window for water column backscatter is available. Logging of water column data and of raw stage data (before beamforming) is a system option.

Choice of operator softwares

The EM 710 is delivered as a complete stand-alone seabed mapping system. The Operator Station, a high-performance PC workstation, includes the necessary operator controls for setting up and running the system, data logging and system testing. The **Seafloor Information System (SIS)** by Kongsberg Maritime also includes an extensive set of graphical displays for data quality control, as well as system calibration and other tools which are required. SIS supports on-line real-time data cleaning to improve the overall survey efficiency.

Post-processing software for the EM 710 is available from both Kongsberg Maritime and third-party suppliers.

System drawing

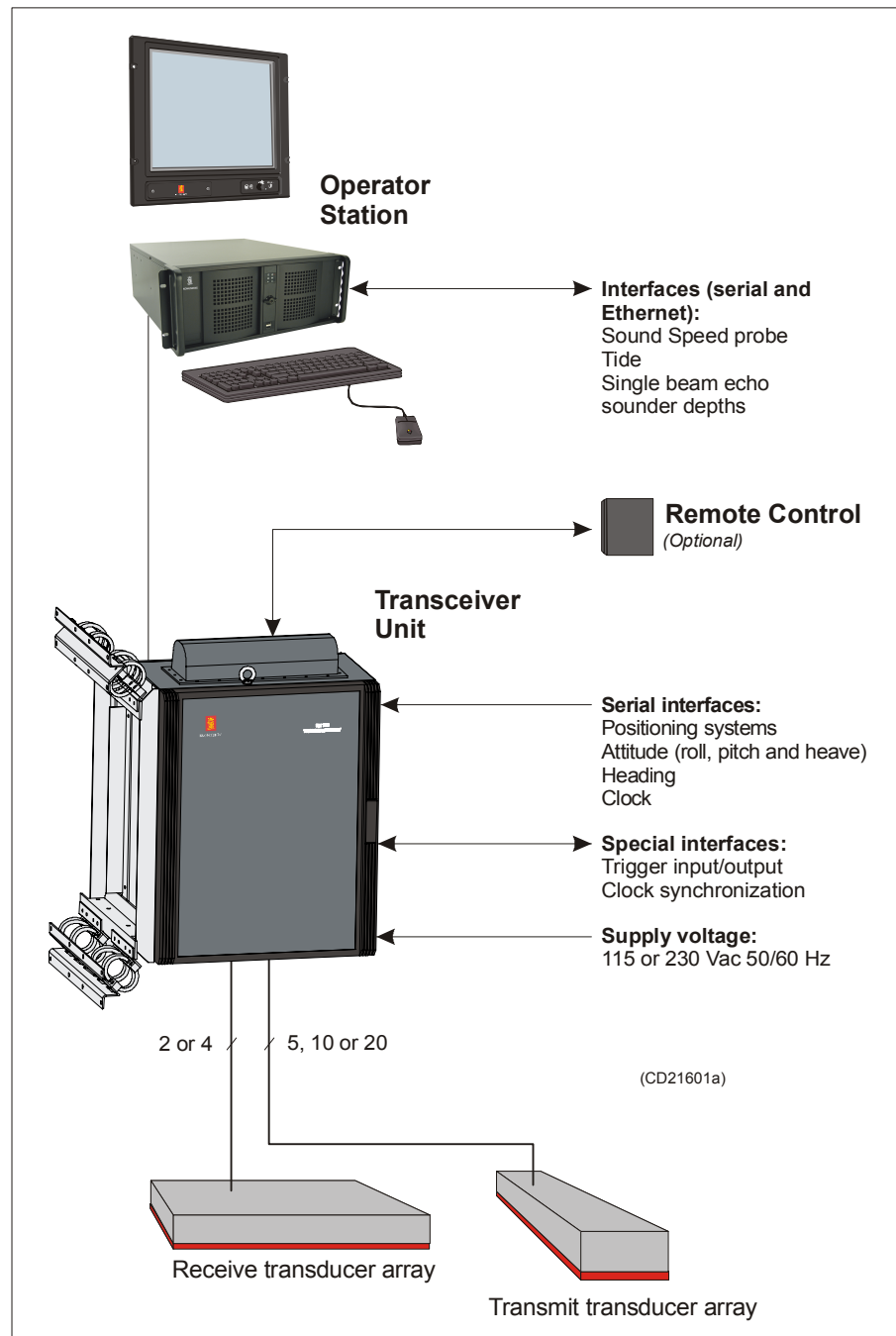


Figure 1 EM 710 system units and interfaces

System characteristics

Main units

The basic EM 710 multibeam echo sounder consists four units:

- Transmit Transducer
- Receive Transducer
- Transceiver Unit
- Operator Station

A complete mapping system will in addition include a vessel motion sensor, heading sensor, sound velocity sensor(s) and a positioning system.

Transducers

The EM 710 transducers are fully water tight units intended for many years of trouble-free operation in rough seas. The transmit and receive transducers both have a width of 224 mm and a height of 118 mm. Their length depends upon the chosen beamwidth, either 970 mm for a 1 degree unit or 490 mm for a 2 degrees unit. The weights are respectively 35 and 18 kg (excluding cables). The transducers have a maximum depth rating of 250 m.

A transmit beamwidth of 0.5 degree is achieved by mounting two 970 mm transmit transducers together alongship. Such a beamwidth reduction is not possible with the receive transducer.

The transducers are supplied as standard with 15 m long underwater cables terminated with a surface connector directly pluggable into the Transceiver Unit. On special order underwater connectors or longer cables may be supplied. Five or ten cables are used on the transmit transducer, two or four on the receive transducer, in accordance with the transducer length.

Transceiver Unit

The EM 710 Transceiver Unit contains all transmit and receive electronics, and the Processing Unit which performs the beamforming, bottom detection, and motion and sound speed corrections. It contains all interfaces for time-critical external sensors such as vessel attitude (roll, pitch, heading and heave), vessel position and external clock. More than one sensor of each type may be connected simultaneously, with one in use but all logged.

The Transceiver Unit comprises two 19" sub-racks contained in a cabinet designed for bulkhead or deck mounting. The number of circuit boards will depend upon the chosen transducer configuration. Twisted pair Ethernet is used for data communication with the Operator Station.

Operator Station

The Operator Station of the EM 710 is the Hydrographic Work Station (HWS) high performance dual-processor PC workstation. The operator software is the Seafloor Information System (SIS). The HWS is dual bootable to either Linux® or Windows XP®.

SIS, as a minimum, allows setting the EM 710 installation and runtime parameters, data logging and running self-test on the system without restrictions.

The SIS software also includes functionality for survey planning, 2D and 3D geographical display of the survey results, seabed image and water column displays, plus real-time data cleaning algorithms.

Alternatively, third-party software solutions can be used for the operator interface and real-time processing.

The HWS is normally supplied with a 19" industrialized LCD monitor with a resolution of 1280x1024 pixels. Support for a second monitor is included. A spill-proof US keyboard and a standard optical mouse is normally supplied, but optionally a small IP 65 rated keyboard with integrated track stick can be delivered.

PERFORMANCE

Introduction

The operating frequencies of the EM 710 multibeam echo sounder are in the 70 to 100 kHz range. The lower frequencies are used to maximize range capability for deeper waters and at maximum beam pointing angles, while the higher frequencies provide maximum resolution for the near vertical beams. The frequency range has been chosen carefully to achieve an optimum balance between small dimensions, narrow beams, and range and depth capability. It also provides backward comparison compatibility with the widely used 95 kHz EM 100/950/1000/1002 multibeam echo sounder family.

Echo sounder models

The EM 710 is a flexible system with different beamwidths being available, 0.5 by 1°, 1 by 1°, 1 by 2° and 2 by 2° (along by across respectively), to allow a trade-off between performance, transducer size and cost. A beamwidth of 1° at the EM 710 sonar frequency corresponds to a transducer length of about 1 m. A long transmit array is beneficial for higher resolution alongtrack and better range and depth capability. A long receive array gives better accuracy, improved acrosstrack resolution, and to a lesser extent better range capability.

Overview of the different EM 710 models			
<i>Model</i>	<i>Transmit beamwidth</i>	<i>Receive beamwidth</i>	<i>Transmit waveforms</i>
EM 710 0.5 x 1	0.5 degree	1 degree	CW + chirp
EM 710S 0.5 x 1	0.5 degree	1 degree	CW
EM 710 1 x 1	1 degree	1 degree	CW + chirp
EM 710S 1 x 1	1 degree	1 degree	CW
EM 710 1 x 2	1 degree	2 degrees	CW + chirp
EM 710S 1 x 2	1 degree	2 degrees	CW
EM 710RD 1 x 2	1 degree	2 degrees	CW short
EM 710 2 x 2	2 degrees	2 degrees	CW + chirp
EM 710S 2 x 2	2 degrees	2 degrees	CW
EM 710RD 2 x 2	2 degrees	2 degrees	CW short

The higher resolution models will have somewhat better sounding accuracy than the models with wider beams, especially in rugged terrain, and will have a better capability for object detection.

The depth capability of the EM 710 extends to about 2000 m with the 0.5 by 1° model. The transmit signal is then a pulse compressible signal (chirp) with a duration of up to 200 ms and a bandwidth of 500 Hz. With a 2 ms long CW pulse the depth capability will be in the order of 1000 m. With the highest resolution, which is achieved with a pulse length of 0.15 ms, 140° coverage is achievable to more than 100 m (depending on the model). These figures assume fairly standard ocean conditions with respect to bottom reflectivity, noise level, absorption coefficient and sound speed variations. Extreme conditions may lessen the achievable coverage, as may excessive ship noise levels and severe roll.

Swath width calculations

The calculation results, shown on the following pages, assume constant sound velocity throughout the water column, as well as combined observed ship and sea noise level of less than 40 dB (sea state 5 or lower limited by the system's internal noise).

The coverage curves have been calculated for three bottom types, characterized by backscatter strengths of -20, -30, and -40 dB at 30 degrees incidence angle. This corresponds to bottom surfaces composed theoretically of gravel, sand and mud respectively. Experience shows that most real-life bottoms will fall between the -30 dB curve and the -40 dB curve (the two lower ones).

Figure 2
EM 710
FM sweep

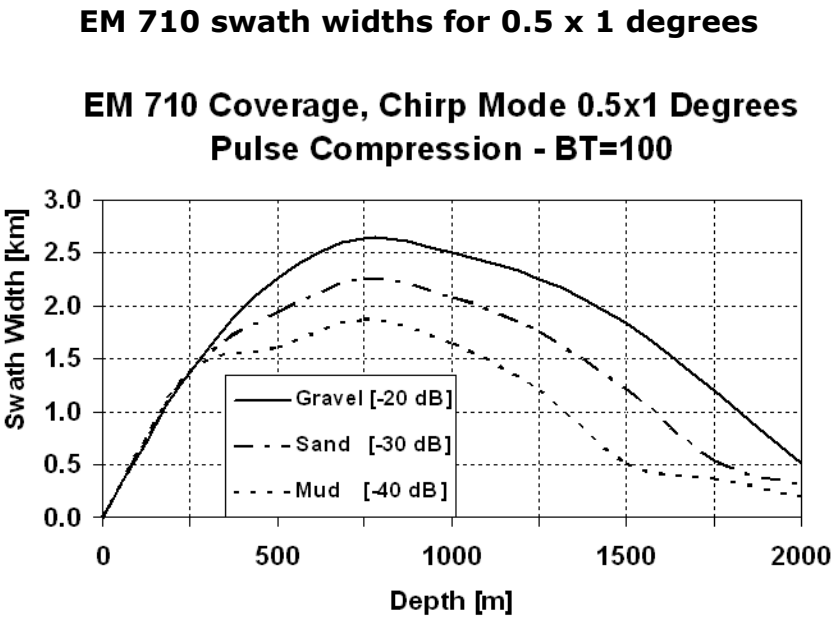
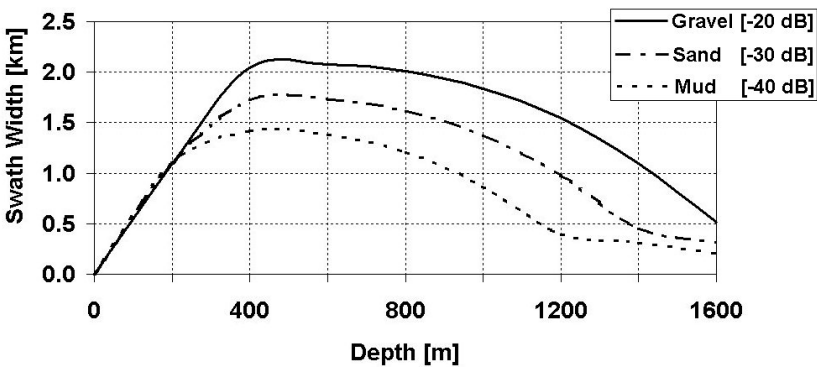


Figure 3
EM 710S
CW long pulse



EM 710 swath widths for 1 x 1 degrees

Figure 4
EM 710
FM sweep

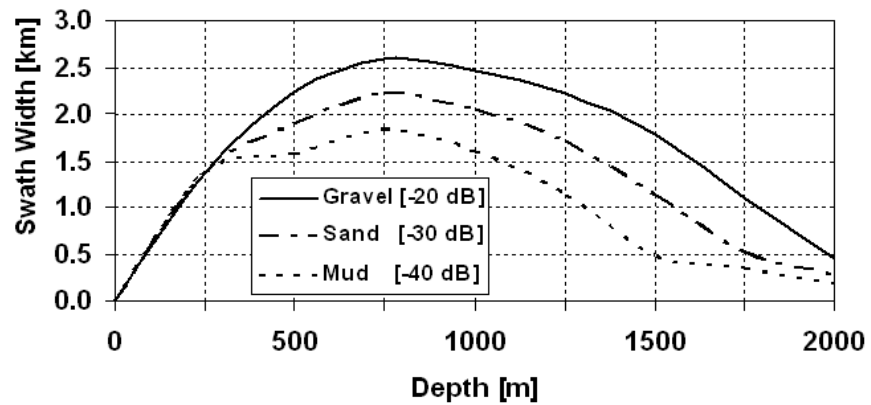
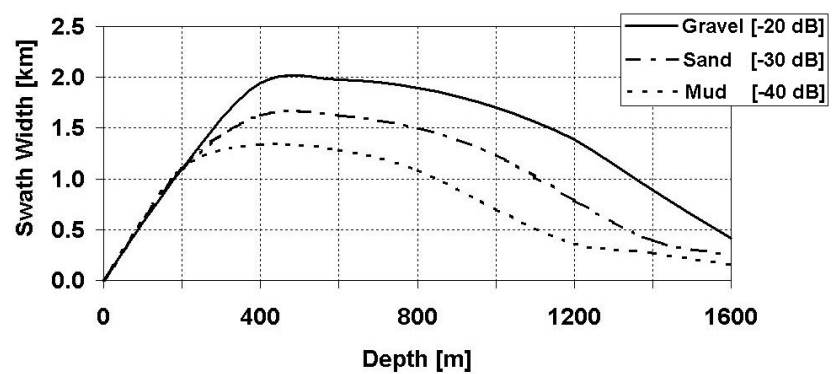
**EM 710 Coverage, Chirp Mode 1x1 Degrees
Pulse Compression - BT=100**

Figure 5
EM 710S
CW long pulse



EM 710 swath widths for 1 x 2 degrees

Figure 6
EM 710
FM sweep

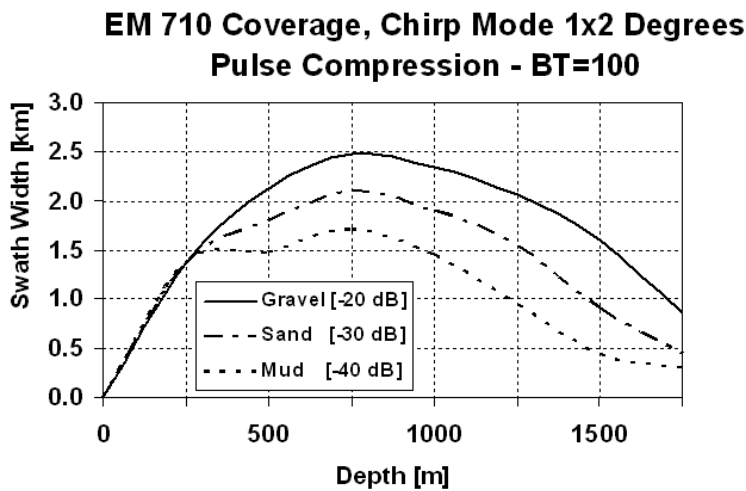


Figure 7
EM 710S
CW long pulse

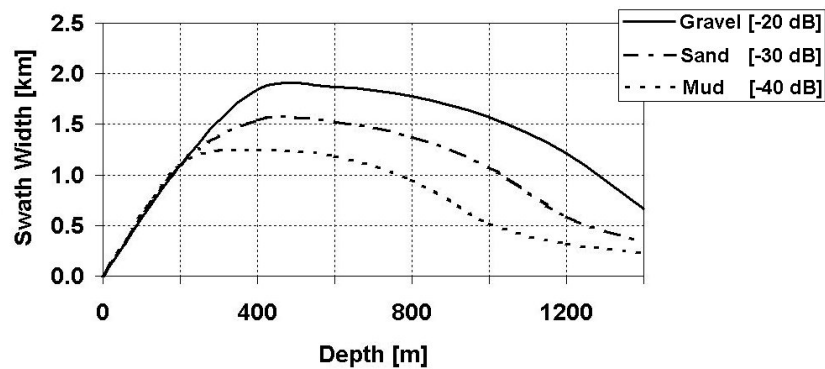
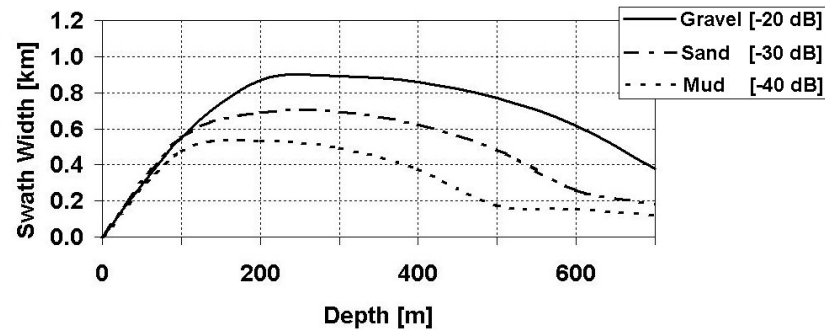


Figure 8
EM 710RD
CW short pulse



EM 710 swath widths for 2 x 2 degrees

Figure 9
EM 710
FM sweep

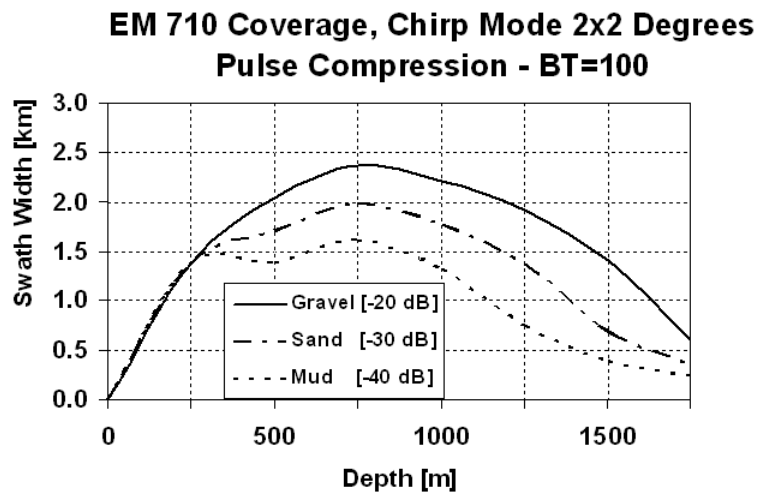


Figure 10
EM 710S
CW long pulse

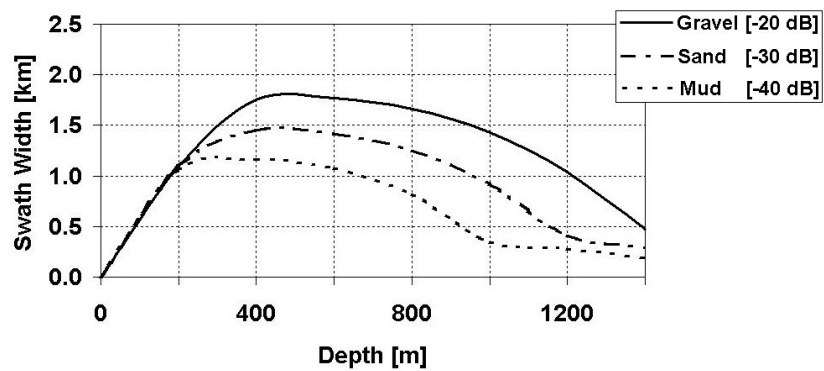
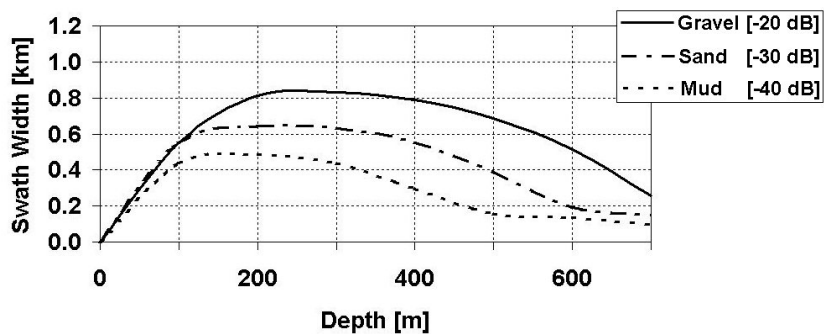


Figure 11
EM 710RD
CW short pulse



Depth accuracy

The depth sounding accuracy of EM 710 is very good thanks to precise digital beamforming, beam focussing and high sampling rate. But most important is the advanced bottom detection methods proven through many years of experience with the Kongsberg range of multibeam echo sounders.

Near normal incidence at center of gravity amplitude detection is used, but for the majority of the beams the system uses interferometric phase detection.

For every range sample an interferometric measurement of the angle of arrival of the returned signal is done, and from all bottom returns, inside a processing window inside a beam, the exact range and angle to the bottom in the centre of the processing window is derived.

The total system error will also depend upon the quality of the positioning, vessel motion and sound speed sensors.

The expected total system RMS accuracy, assuming good quality external sensors, is then the largest number of 5 cm and:

- 0.2% of the depth (from vertical up to 45 degrees)
- 0.3% of the depth (up to 60 degrees)
- 0.5% of the depth (up to 70 degrees)

These numbers are valid for signal to noise ratio better than 10 dB.

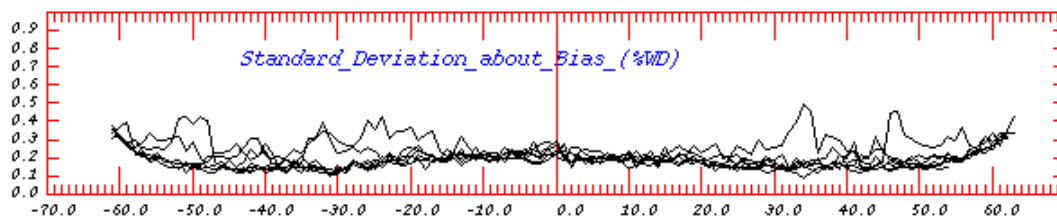


Figure 12 Example of total system accuracy for EM 710 2x2. Courtesy of the University of New Brunswick.

Horizontal resolution

The horizontal resolution of EM 710 is much improved in relation to previous models, due to the introduction of focussed beams (for both transmission and reception) and the new high density signal processing.

Alongtrack resolution

The size of the alongtrack acoustical footprint of the EM 710 transmit beam:

Alongtrack footprint for EM 710 [m]						
Water depth [m]	<i>0.5 degree TX</i>		<i>1 degree TX</i>		<i>2 degree TX</i>	
	Vertical	Outer edge	Vertical	Outer edge	Vertical	Outer edge
5	0.1	0.3	0.2	0.5	0.3	0.5
50	0.5	1.3	0.9	2.6	1.8	5.2
100	0.9	2.6	1.8	5.2	3.5	10.4
200	1.8	5.2	3.5	10.4	7.0	20.9
400	3.5	10.4	7.0	20.9	14.0	41.8
800	7.0	20.9	14.0	41.8	28.1	83.5
1600	14.0	26.3	28.1	52.6	56.1	105.3

Table 1 Alongtrack resolution for the transmit beam.

The alongtrack sounding density, or distance between two consecutive sounding profiles, is a function of the water depth, the swath width, and the vessel speed.

For the high end models with a 1 degree receiver, two profiles are obtained per acoustic ping, so the sounding density is doubled. A narrower swath gives a higher ping rate and thus improved sounding density. In practice, it is useful to apply alongship sampling of 2-3 times per acoustic footprint.

Alongtrack distance between profiles [m]					
<i>120 deg swath, one profile per ping</i>					
Water depth [m]	Swath width [m]	Ping rate	4 knots	8 knots	12 knots
5	18	22.0	0.1	0.2	0.3
50	180	4.9	0.4	0.8	1.2
100	360	2.7	0.8	1.5	2.3
200	720	1.4	1.4	2.9	4.3
400	1440	0.7	2.8	5.7	8.5
800	1500	0.5	3.8	7.5	11.3
1600	1500	0.3	6.0	12.0	18.1

Table 2 Alongtrack for a 2x2 degree system, 120 degree swath width.

Alongtrack distance between profiles [m]					
<i>140 deg swath, one profile per ping</i>					
Water depth [m]	Swath width [m]	Ping rate	4 knots	8 knots	12 knots
5	28	17.8	0.1	0.2	0.3
50	275	3.6	0.6	1.1	1.7
100	550	1.9	1.1	2.1	3.2
200	1100	1.0	2.0	4.1	6.1
400	1500	0.7	2.9	5.9	8.8
800	1500	0.5	3.8	7.5	11.3
1600	1500	0.3	6.0	12.0	18.3

Table 3 Alongtrack for a 2x2 degree system, 140 degree swath width.

Alongtrack distance between profiles [m]							
<i>120 deg swath, two profiles per ping</i>							
Water depth [m]	Swath width [m]	Ping rate	4 kn	8 kn	12 kn	16 kn	20 kn
5	18	33.6	0.05	0.1	0.1	0.1	0.1
50	180	5.8	0.2	0.3	0.5	0.7	0.9
100	360	3.0	0.3	0.7	1.0	1.3	1.6
200	720	1.5	0.6	1.3	1.9	2.6	3.2
400	1440	0.8	1.3	2.6	3.8	5.1	6.4
800	2300	0.5	2.2	4.3	6.5	8.6	10.8
1600	2300	0.3	3.0	6.1	9.1	12.1	15.2

Table 4 Alongtrack for a 1x1 degree system, 120 degree swath width.

Alongtrack distance between profiles [m]							
<i>140 deg swath, two profiles per ping</i>							
Water depth [m]	Swath width [m]	Ping rate	4 kn	8 kn	12 kn	16 kn	20 kn
5	28	27.4	0.05	0.1	0.1	0.1	0.2
50	275	4.2	0.2	0.5	0.7	1.0	1.2
100	550	2.2	0.5	0.9	1.4	1.9	2.3
200	1100	1.1	0.9	1.8	2.7	3.6	4.6
400	2200	0.6	1.8	3.6	5.4	7.2	9.0
800	2300	0.5	2.2	4.3	6.5	8.6	10.8
1600	2300	0.3	3.0	6.1	9.1	12.1	15.2

Table 5 Alongtrack for a 1x1 degree system, 140 degree swath width.

Crosstrack resolution

The crosstrack resolution is determined by the sounding density and the effective acoustic footprint which is applied to each sounding.

By the high density signal processing, the effective acoustic footprint is controllable for all soundings derived from phase detections. In practice this means all soundings except for some few at the vertical or specular incidence angle.

This is a great achievement, and gives a nearly constant crosstrack physical size of sounding spots over the whole swath.

The normal setting is a crosstrack acoustic footprint size of 200% of the crosstrack sounding interval.

The 1 degree receiver array versions have 400 soundings per profile, while the 2 degree receivers have 200 soundings per profile. Since the swath width is operator controllable, the sounding density can be completely controlled by the operator. Our calculations are made for a 140 degree swath width.

Size of acoustic footprint - crosstrack								
Water depth [m]	1 deg RX				2 deg RX			
	Oblique soundings, swath width				Oblique soundings, swath width			
	Center	90 deg	120 deg	140 deg	Center	90 deg	120 deg	140 deg
5	0.09	0.05	0.09	0.14	0.18	0.10	0.18	0.28
50	0.88	0.50	0.88	1.38	1.75	1.00	1.75	2.75
100	1.75	1.00	1.75	2.75	3.51	2.00	3.50	5.50
200	3.50	2.00	3.50	5.50	7.00	4.00	7.00	11.00
400	7.00	4.00	7.00	11.00	14.00	8.00	14.00	22.00
800	14.00	8.00	14.00	-	28.10	16.00	28.00	-
1600	28.10	16.00	-	-	56.1	32.00	-	-

Table 6 Size of acoustic footprint in crosstrack direction, high density mode.

Spacing - neighbour soundings crosstrack						
Water depth [m]	<i>One deg RX swath width</i>			<i>Two deg RX swath width</i>		
	90 deg	120 deg	140 deg	90 deg	120 deg	140 deg
5	0.03	0.04	0.07	0.05	0.09	0.14
50	0.25	0.44	0.69	0.50	0.88	1.38
100	0.50	0.88	1.38	1.00	1.75	2.75
200	1.00	1.75	2.75	2.00	3.50	5.50
400	2.00	3.50	5.50	4.00	7.00	11.00
800	4.00	-	11.00	8.00	14.00	-
1600	-	-	22.00	16.00	-	-

Table 7 Spacing between neighbour soundings, crosstrack direction, high density mode

EM 710 object detection capability

There is increased interest for surveys performed according to IHO-S44 order 1 or special order. EM 710 is well suited for such surveys. Depending upon which version of EM 710 is selected, different capabilities for object detection are obtained.

IHO special order requires that objects of a 1m size and larger shall be detected, while IHO order 1 requires that objects of a 2 m size and larger shall be detected to about 40 m depth.

LINZ raises an additional condition or clarification; that the object should have at least 9 hits, 3 along and 3 across. The idea behind this is that automatic algorithms for cleaning of bathymetric data will remove isolated soundings but accept a cluster of soundings. By experience we know that the acoustic footprint on the object cannot be more than 150% of the object size for reliable detection.

It is easy to see that equidistant pattern of soundings is ideal for object detection, as well as the controlled and small acoustic footprint which is obtained with the high density signal processing.

A necessary feature for reliable object detection in waves, is active stabilisation of the beams for ships pitching. At least for depths of more than 20 m in croppy seas and with a small boat, this is an important requirement.

The figure is calculated for a modest ± 3 degree of pitch and the wave period is sinusoidal with a 3 second period.

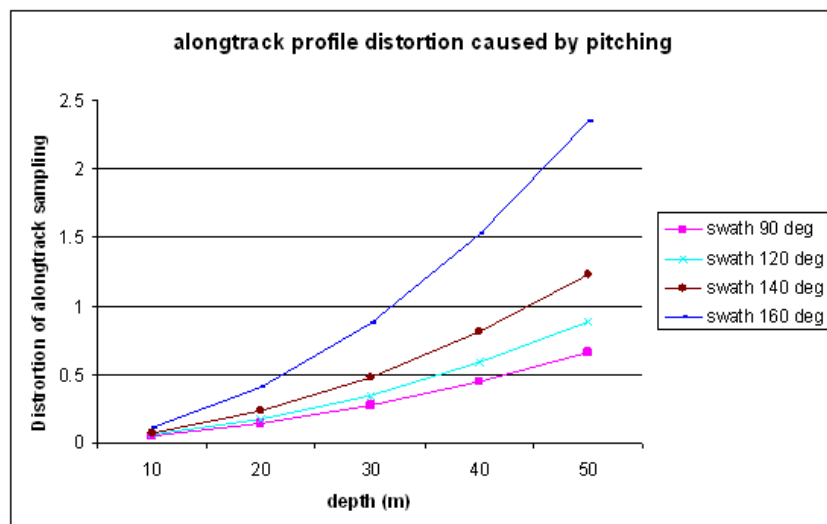


Figure 13 Non stabilized transmit beam. Alongtrack position shift between soundings caused by waves.

Since EM710 applies active pitch (and roll) stabilisation, vessel motions will not be a problem for the system.

The diagrams below indicate what level of object detection capability will be obtained by the different versions of EM 710, for different vessel speeds and swath widths. Green means it will comply and red not comply.

EM 710 - 2 x 2

<i>Special order 20 m</i>				
Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90	Green	Green	Green	Red
120	Green	Green	Red	Red
140	Red	Red	Red	Red

<i>Special order 40 m</i>				
Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90	Red	Red	Red	Red
120	Red	Red	Red	Red
140	Red	Red	Red	Red

<i>Order 1 - 20 m</i>				
Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90	Green	Green	Green	Green
120	Green	Green	Green	Green
140	Green	Green	Red	Red

<i>Order 1 - 40 m</i>				
Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90	Green	Green	Green	Green
120	Green	Green	Green	Red
140	Red	Red	Red	Red

EM 710 - 1 x 2

Special order 20 m

Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90				
120				
140				

Special order 40 m

Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90				
120				
140				

Order 1 - 20 m

Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90				
120				
140				

Order 1 - 40 m

Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90				
120				
140				

EM 710 - 0.5 x 1*Special order 20 m*

Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90				
120				
140				

Special order 40 m

Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90				
120				
140				

Order 1 - 20 m

Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90				
120				
140				

Order 1 - 40 m

Swath width [deg]	4 knots	8 knots	12 knots	16 knots
90				
120				
140				

The 1x1 degree version of EM 710 with 2 profiles per ping will have the same capability for object detection as the 0.5 x 1 version.



Figure 14 1 m cubic object used for verification of object detection performance.

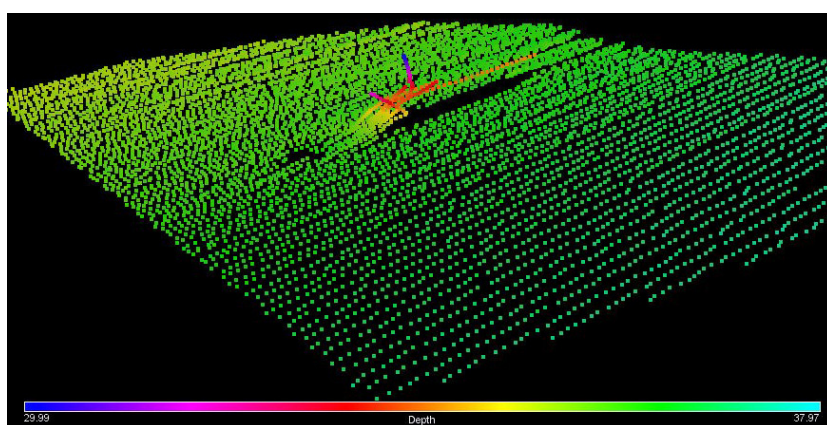


Figure 15 Raw soundings on the 1 m cube, depth 32 m, crosstrack distance 57 m.

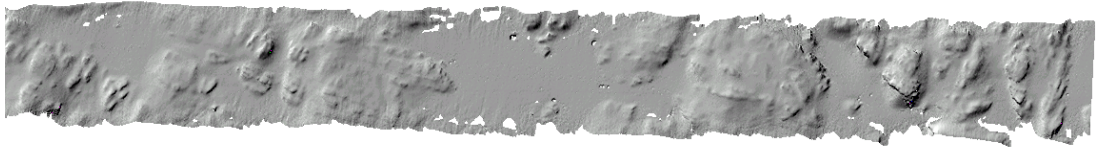


Figure 16 Sun illuminated terrain model, 1 EM 710 2x2 survey line. Courtesy of University of New Brunswick.

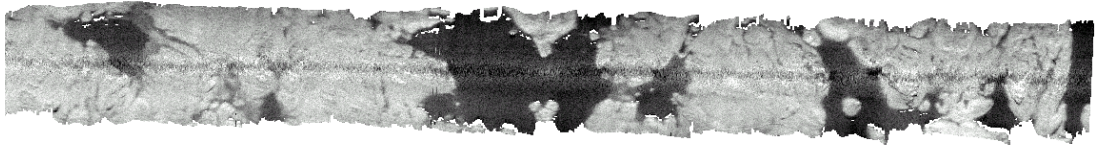


Figure 17 Co-registered seabed imagery of the same survey line.

INSTALLATION

Introduction

The compactness of the EM 710 multibeam echo sounder is a guarantee for a fast and easy installation.

Permanent hull mounting

Operator Station

The Operator Station is a ruggedized PC workstation, prepared for mounting in a standard 19" rack (requires 4 rack height units). It is supplied with a rackable 19" industrial LCD monitor, a keyboard and an optical mouse. A bracket for the monitor is included for table top, bulkhead and roof mounting.

Transceiver Unit

The Transceiver Unit is to be mounted on a bulkhead in a room close to the transducers to reduce the amount of cabling. A deck mountable version will also be available.

Where space is restricted, it is possible to install the two 7U (U = 44.45 mm) high sub-racks without using the supplied cabinet. However, it is then the responsibility of the customer to ensure adequate environmental protection (heat, humidity, vibration, EMC etc.) of the sub-racks, and to provide adequate fastening of all cables.

Transducer arrays

The transducers should be mounted in the forward part of the vessel, taking into account hull shape, potential aeration problems and ease of cable installation.

The transducers may be fixed to the hull with bolts from the front, either directly on or recessed into the hull, or within sea chests. A mounting frame is normally required for the 0.5° transmit transducer as it consists of two separate modules. This should not be necessary for the other transducer models. These are self-contained units and due to their internal (very strong) carbon-fibre structures, they may be bolted directly to a flat mounting plate (for example).

A fairing will usually be added around the transducers to ensure laminar water flow without any aeration problems. A blister or gondola installation may help in avoiding air bubble blockage of the sound path under the transducers by aerated water. Blisters and gondolas may also contain additional transducers for other systems.

The cables connecting the transducers to the Transceiver Unit have a standard length of 15 m, and are terminated with connectors which plug directly into the cabinet. Normally, in a permanent installation, the cables enter the hull through tubes which are fitted with standard ship type cable glands (Roxtec or equivalent) to provide water tightness. The cable glands should be of the type having a pressure rating of 4 bars or more. The glands should be installed above the vessel water-line if diver replacement of transducer is envisioned. If the tubes end below the water-line, classification requirements may require a double set of glands.

After installation it is necessary to measure the location of the transducers and their angular orientation in the vessel coordinate system accurately. There are no stringent requirements with regard to physical alignment, neither with respect to the vessel nor between transmit and receive transducers. However, the transmit and receive transducers should not have a large separation.

Portable mounting

For a portable 2 by 2° EM 710 model, Kongsberg Maritime will offer a standard mounting arrangement. This will have the transducers mounted, including a surrounding fairing, ready to be fitted to a mounting tube either going over the bow or over the side. To lessen the effort with respect to surveying of the transducers' location and orientation and to improve the system accuracy, it may be best to fit the motion sensor to the mounting arrangement close to the transducer. This will however still require a survey of the mounting frame location and orientation with respect to vessel heading and location of the positioning system (i.e. GPS antenna). To avoid such a survey completely, the mounting arrangement must include a sufficiently accurate heading sensor and the positioning system must give the position of the multibeam, i.e. the GPS antenna should also be fixed to the mounting arrangement, for example at the top of the pole holding it.



Figure 18 Installation of the 2x2 degrees transducer array on “HMS Endurance”



*Figure 19 Installation of the Transceiver Unit
on “HMS Endurance”*

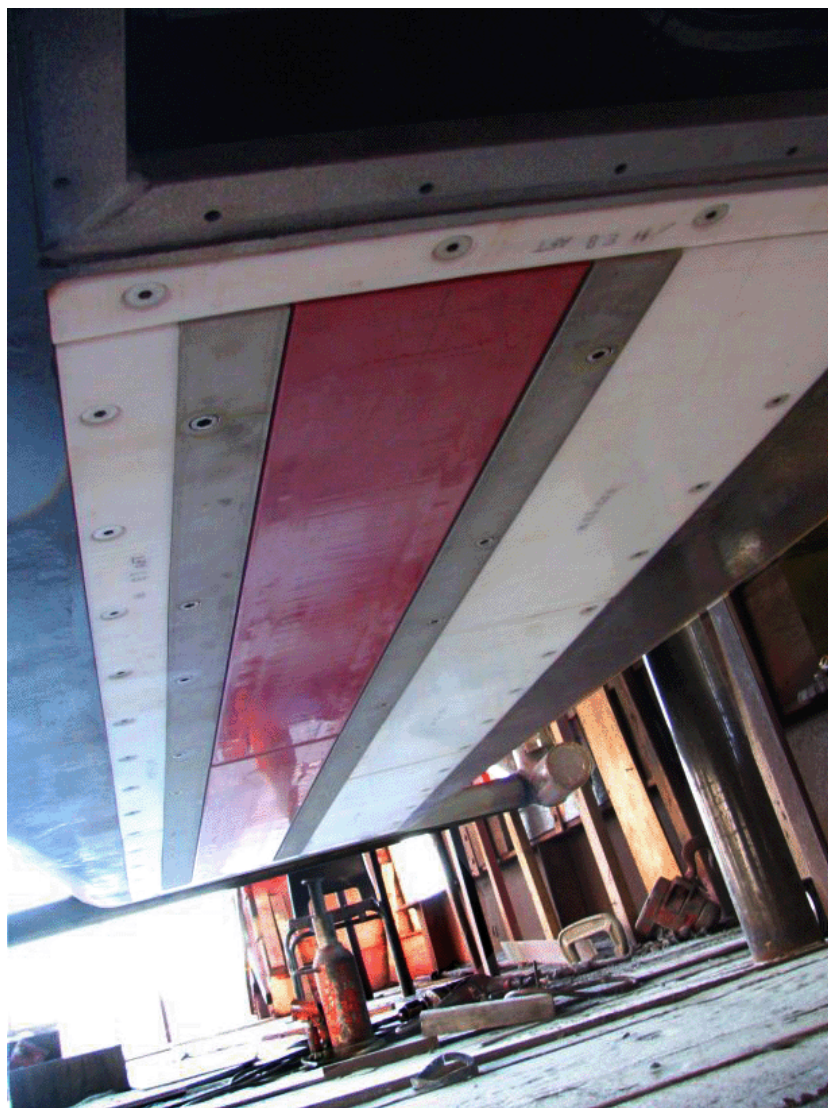


Figure 20 0.5 degree EM 710 TX transmit array.



Figure 21 1 degree RX receive array.



Figure 22 Transportable EM 710 1 x 2 degree array

OPERATION

System features

The EM 710 multibeam echo sounder is controlled from the HWS Operator Station using a standard click and point graphical user interface. The software, Seafloor Information System (SIS), may either be run under the Microsoft Windows XP or Linux operating systems which can both be installed on the HWS. As standard, the system software includes the necessary features for system installation, testing and running the multibeam, ping related displays (including water column display) and the capability of logging the acquired bathymetry data.

The EM 710 system does not require operator intervention during normal operation, but tracks the bottom automatically while adjusting mode, gain and range dependent parameters as required. Before operation is started, the necessary external sensors, such as positioning and vessel motion sensors, are connected and calibration procedures followed in order to define the system and sensor installation parameters.

Parameters critical to data quality are password protected, and most of the parameters can be recalled from a disk file.

Seabed imagery data is available from the system as standard. The imagery data, representing the acoustic backscatter strength of the bottom in 0.1 dB resolution, is available in two forms, one with range resolution nominally corrected for the effect of incidence angle, the other given per beam as an absolute measure. The imagery data may be useful for object detection, but the most important application is probably geophysical for seabed characterization.

Quality control

Quality control of the acquired data is done through graphical displays. In addition a message window and alphanumeric displays are included to allow a quick overview of the system status, indicating any interface or hardware related problems. SIS provides the graphical displays required for real-time checking of the EM 710. These include:

- Cross-track depth profiles
- Beam intensities and quality measures
- Time series display of beam samples and sensor values

- 3D waterfall display
- Sound speed profile display and editor
- Water column display

Graphical user interface

Using the SIS software, the operator will normally be viewing gridded data in a geographically oriented 2D or 3D display as his primary means of quality control of the survey. The grid has six levels of detail, allowing rapid zoom in and out. Previous survey results can be imported to allow visualisation of any differences between the current and old surveys in overlapping areas.

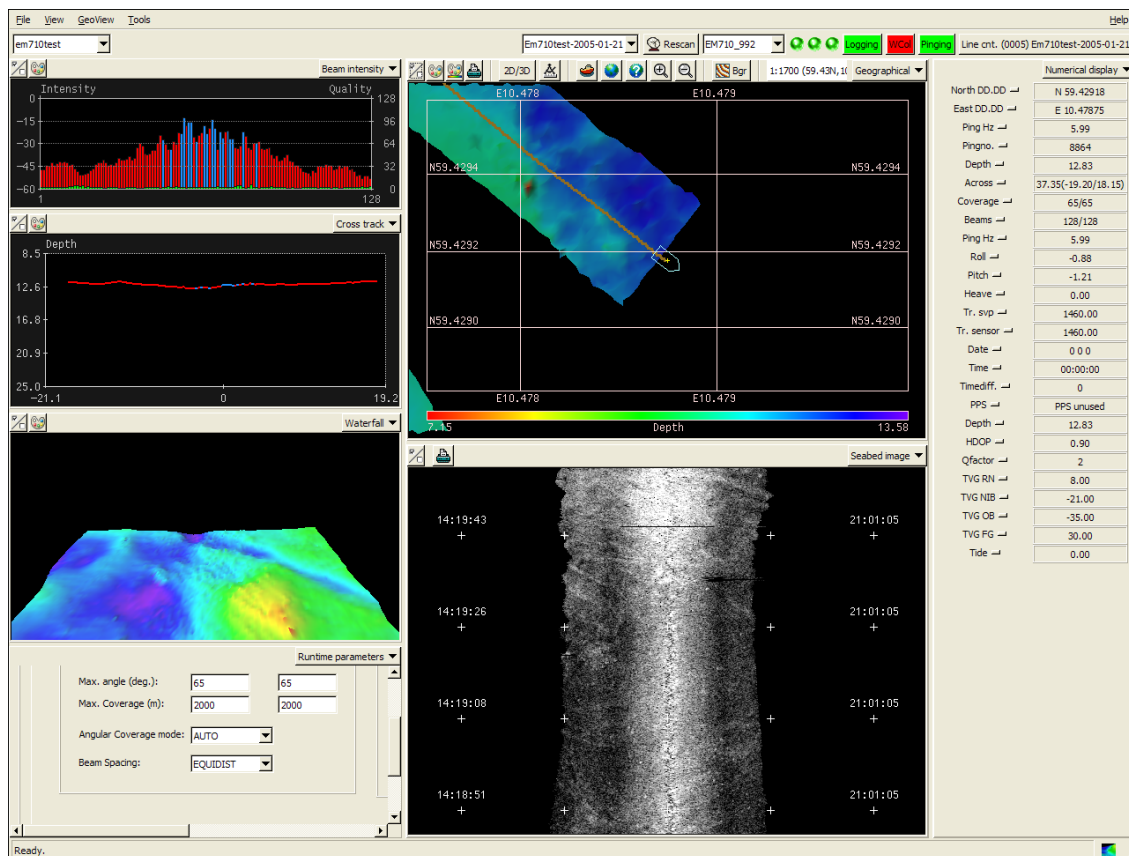


Figure 23 Example of SIS graphical user interface

The grid may also be utilized for real-time data cleaning. Based upon a set of user defined rules, outliers in a grid cell, whether from old or new survey lines, are flagged. The flags may be retained or updated through the processing. Optionally the CUBE data-cleaning package from the Center for Coastal and Ocean Mapping Center at the University of New Hampshire is also available in SIS.

Among other features included are:

- System (sensor) calibration
- Planning of surveys
- Real time cleaning of data, for separate survey lines or for the complete survey area
- Helmsman Display
- Full use of the chosen operating system for data export, plotting and printing

Electronic chart data can be displayed as a background in the geographical displays.

Logging of beamformed water column data and raw hydrophone stave data is an option.

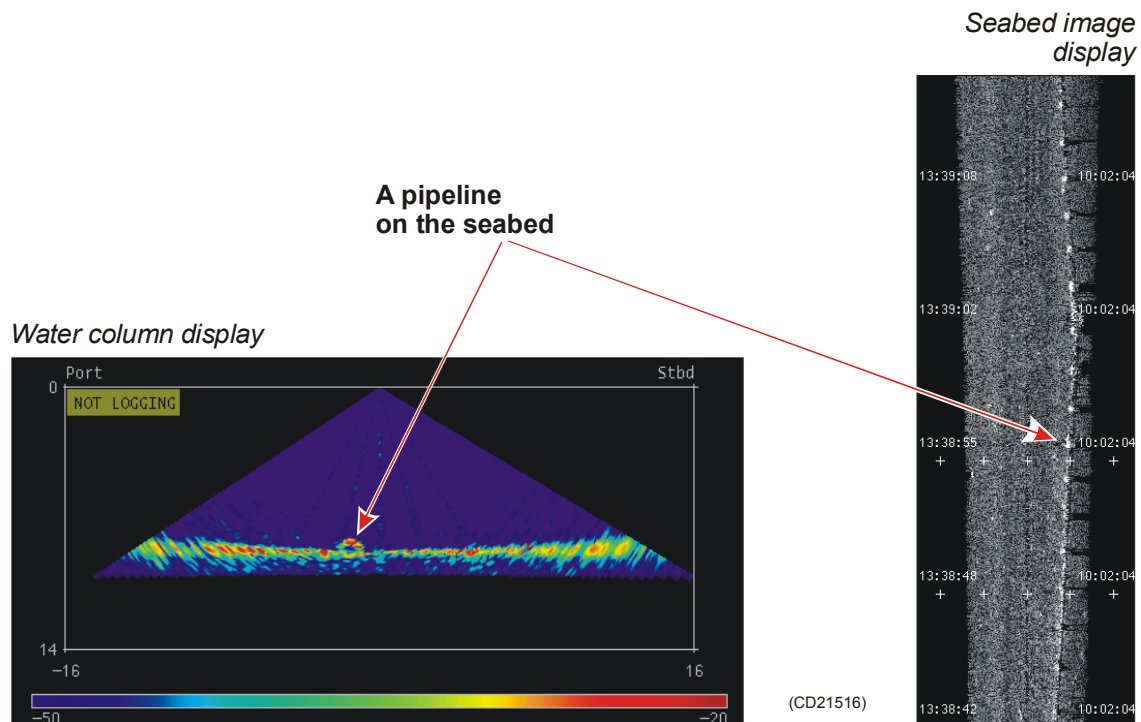


Figure 24 Example of water column and seabed image displays

While SIS is the standard solution for operator software, the system is prepared for support of third party software solutions. Such software, for example QINSY or Hypack, may be used as a complement to SIS or as a replacement for SIS.

Data logging

It is of the utmost importance to ensure that all survey related data is logged in a safe way. The data is always stored on disk and the geographical displays take data only from disk. In this way, what the operator sees is what is safeguarded and already stored. As standard the HWS runs two high performance SerialATA disks connected in a RAID1 array, i.e. one disk may fail without loss of data. The disks are optionally mounted in mobile storage bays, thus they may be removed for security reasons or for transporting the acquired data. The stored data may be written to DVD at any time. The Firewire, SATA and USB interfaces may be used for transfer of data to external storage devices, such as disk or tape, according to user preferences. All data are also available on an external Ethernet.

The logged data sets include:

- Raw sensor data
- Beam ranges and beam pointing angles
- Depth datagrams
 - In each depth datagram range/angle data from one ping have been merged with motion sensor data and the current sound velocity profile to derive a rigorous solution for vessel motion and raybending, calculating sounding depth and position as Cartesian coordinates. The depth datagrams are suited for immediate presentation in the geographical display.
- Seabed image data
- System parameter settings

The gridded data (terrain model) is also available for logging. The data formats are public and published on the Kongsberg Maritime web site, ensuring that EM 710 is a truly open solution, allowing third party or own software to be developed for data processing.

POST-PROCESSING

Post-processing options

The high quality data produced by the EM 710 multibeam echo sounder is an excellent basis for producing a complete description of the seabed in the form of charts, 3D displays, combined bathymetry and acoustic imagery, seabed classification, etc. Kongsberg Maritime can deliver a complete set of products for post-processing EM 710 bathymetric data. Interfaces to other post-processing software is also available.

Neptune Post Processing Suite

The **Neptune** post-processing system, which is compatible with the real time SIS software, comprises 3 main modules + data export to further 3. party processing software.

The **Neptune B** is used for post-processing of bathymetric data. Such post-processing involves cleaning and filtering of position data, analysis and corrections for depth data, tidal height adjustment, automated data cleaning based upon statistical rules, manual editing, controlled data thinning, and export of the final sounding data to further processing.

The results of real time data cleaning which may be done by SIS, are imported into Neptune B and can be used as the basis for further cleaning of noisy bathymetric data.

The **Neptune S** is used for post-processing of seabed image data into seabed image mosaic map overlay. This involves merging of data from overlapping survey lines, applying systematic corrections which are required, filtering and interpolation.

The **Neptune C** is used for seabed sediment classification. This process extracts signal features from the seabed image data, and applies this data to a statistical classification procedure in order to obtain the best estimate for seabed sediment type as a function of position in the form of a map overlay. The classifier can be trained and adapted to local conditions by use of a training module to correlate acoustical signature to ground truth information.

Software to be used for digital terrain modelling and plot generation can be delivered integrated with Neptune to derive a digital terrain model from an interpolation of the cleaned sounding data. From the terrain model contour maps, 3D plots, depth profiles along specified routes, fairsheets, volume calculations, etc, are easily produced. This additional third-party software is usually the **Cfloor** system or a Caris solution.

Caris HIPS/SIPS post processing

Caris is a well known suite of programs for processing of hydrographic data, developed and maintained by the Canadian company Caris. The modules which resemble Neptune B and S, are HIPS and SIPS. Caris can offer a complete processing environment, taking care of all steps until the final mapping products - both on paper and electronic form (S-57). Caris HIPS can import data from SIS as well as from Neptune B, and is integrated with CUBE (Combined Uncertainty and Bathymetry Estimator, by University of New Hampshire).

Fledermaus interactive 3D visualization

Fledermaus is a high capacity, interactive software for visualizing large geographical data sets, developed and maintained by the US based company IVS (Interactive Visualisation Systems). It also has interactive 3D functionality for editing soundings, and is integrated with CUBE. It is an efficient tool for inspecting survey results, and can import and export data to/from both Neptune B and HIPS, including data cleaning "flags". It can also create fly-through videos.

CUSTOMER SUPPORT

Introduction

As a major supplier of multibeam echo sounders with many years of experience, Kongsberg Maritime has developed a marketing and service organization tuned to customer needs.

Installation

As part of the discussions with the client Kongsberg Maritime will - free of charge and without any obligations - give advice regarding the practical installation of the EM 710 system. We will also - upon request - prepare proposals for the supply of complete instrument packages and/or systems. A project manager will usually be appointed to supervise the delivery, installation and testing of larger instrumentation systems.

The installation and final testing of an EM 710 system should be done according to Kongsberg Maritime's documentation. If required, Kongsberg Maritime field engineers can be made available to:

- Supervise the installation.
- Perform the measurement of final location and attitude of the transducers and/or sensors.
- Perform system check-out and final testing.

Documentation and training

The EM 710 is delivered with complete documentation for installation, operation and maintenance. If required, the manuals may optionally be modified to reflect the actual system on the client's vessel.

Kongsberg Maritime can conduct the training of operators and maintenance personnel to the extent required by the client. Such training courses can take place on the vessel, on any of Kongsberg Maritime's facilities, or any other location decided by the client.

Service

The Kongsberg Maritime service department has a 24 hour duty arrangement, and can thus 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.

FEMME

A forum for users of Kongsberg Maritime's multibeam echo sounder systems (FEMME), with the aim of improving communication both between the users and Kongsberg Maritime, but also between the system users, is arranged at approximately 18 months intervals. Close to 100% user participation has been experienced at these meetings.

Warranty and maintenance contract

The normal warranty period of the EM 710 is 24 months after delivery.

A system maintenance contract tailored to fit the needs of the client is available. This contract 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 Kongsberg Maritime.

SCOPE OF SUPPLY AND OPTIONS

Standard system

A basic EM 710 multibeam echo sounder delivery includes:

- 1 Operator Station HWS with 19" LCD monitor
- 2 Transceiver Unit configured according to chosen model
- 3 Transducers in accordance to chosen model
 - Transmit transducer (includes mounting frame for 0.5 degree version)
 - Receive transducer
 - Necessary transducer cables (15 m length)
- 4 Signal and control cables
 - Ethernet cable between Transceiver Unit and Operator Station (4.5 m length)
- 5 All system software
- 6 Technical manuals covering system installation, operation and maintenance

Options

System options available include:

- Mounting arrangement for over-the-side mounting of 2 by 2 degrees model transducers which may include integrated motion sensor, heading sensor and positioning sensor
- Remote control unit for Transceiver Unit
- Non-standard cable lengths or connectors
- Helmsman Display and/or additional monitors
- Various software options
- Removable disks
- IP65 integrated keyboard and pointing device
- Spare parts

System integration

The EM 710 system as presented in this product description is prepared for integration with other sensors to form a complete seabed mapping and inspection system. Kongsberg Maritime can supply the EM 710 either as a sub-system for integration by the user or other parties, or we can offer complete system solutions tailored to the user's need.

Dual frequency system solutions can be formed by combining the EM 710 with a lower frequency multibeam echo sounder such as the EM 120.

Additionally Kongsberg Maritime may deliver the EM 710 as part of a complete survey system. This may include integration with single beam echo sounders and/or other multibeam echo sounders for seamless coverage of any depth range.

TECHNICAL SPECIFICATIONS

Note

Kongsberg Maritime is engaged in continuous development of its products and reserves the right to alter specifications without prior notice.

Interfaces

- Serial lines with operator adjustable baud rate, parity, data length and stop bit length for:
 - Motion sensor (roll, pitch, heave and optionally heading) in format supported by sensors from Applanix, iXSEA, Kongsberg Seatex and VT TSS
 - Heading (gyrocompass) in either NMEA 0183 HDT, SKR82/LR60 or Sperry Mk39 format
 - Position in either Simrad 90, NMEA 0183 GGA or GPK format
 - External clock in NMEA 0183 ZDA format
 - Sound speed at transducer
 - Sea level height (tide)
 - Single beam echo sounder depths
 - Output of depth straight down in NMEA 0183 DPT format
- Interface for a 1PPS (pulse per second) clock synchronisation signal
- Firewire interface for external data storage device (tape or disk)
- USB 2.0 interfaces for data storage, printing or plotting
- Parallel interface for PostScript colour graphics printer/plotter
- Ethernet interface for input of sound speed profile, tide and echo sounder depths, and output of all data normally logged to disk

Physical specifications

Transducer, 2 degrees version

Length: 490 mm

Width: 224 mm

Height: 118 mm

Weight: 18 kg (nominal without cables)

Transducer, 1 degree version

Length: 970 mm

Width: 224 mm

Height: 118 mm

Weight: 35 kg (nominal without cables)

Transducer, 0.5 degree version (two 1 degree modules)

Length: 1940 mm

Width: 224 mm

Height: 118 mm

Weight: 70 kg (nominal without cables and mounting frame)

Transceiver Unit (version for bulkhead mounting)

Height: 841 mm

Width: 540 mm

Depth: 750 mm (nominal including shock absorbers)

Weight: 106 kg (2 by 2 degrees), 111 kg (1 by 2 degrees), 116 kg (1 by 1 degree) or 127 kg (0.5 by 1 degree)

Power: 115 Vac (60 Hz) and 230 Vac (50 Hz), < 900 W

Note

A smaller Transceiver Unit may be available for the 2 by 2 degrees model.

Operator Station

Height: 127 mm

Width: 427 mm (excluding rack fixing brackets)

Depth: 480 mm (excluding handles and connectors)

Weight: Approximately 20 kg

Power: 115 Vac (60 Hz) and 230 Vac (50 Hz), < 250 W

19 inch LCD monitor

Height: 444 mm (excluding mounting bracket)

Width: 483 mm (excluding mounting bracket)

Depth: 68 mm (excluding mounting bracket)

Weight: 12 kg (approx w/bracket)

Power: 115 Vac (60 Hz) and 230 Vac (50 Hz), 100 W (max)

Environmental and EMC specifications

The system meets all requirements of the IACS E10 specification.

The Transceiver Unit meet the additional stronger requirements of the IEC 60945 specification.

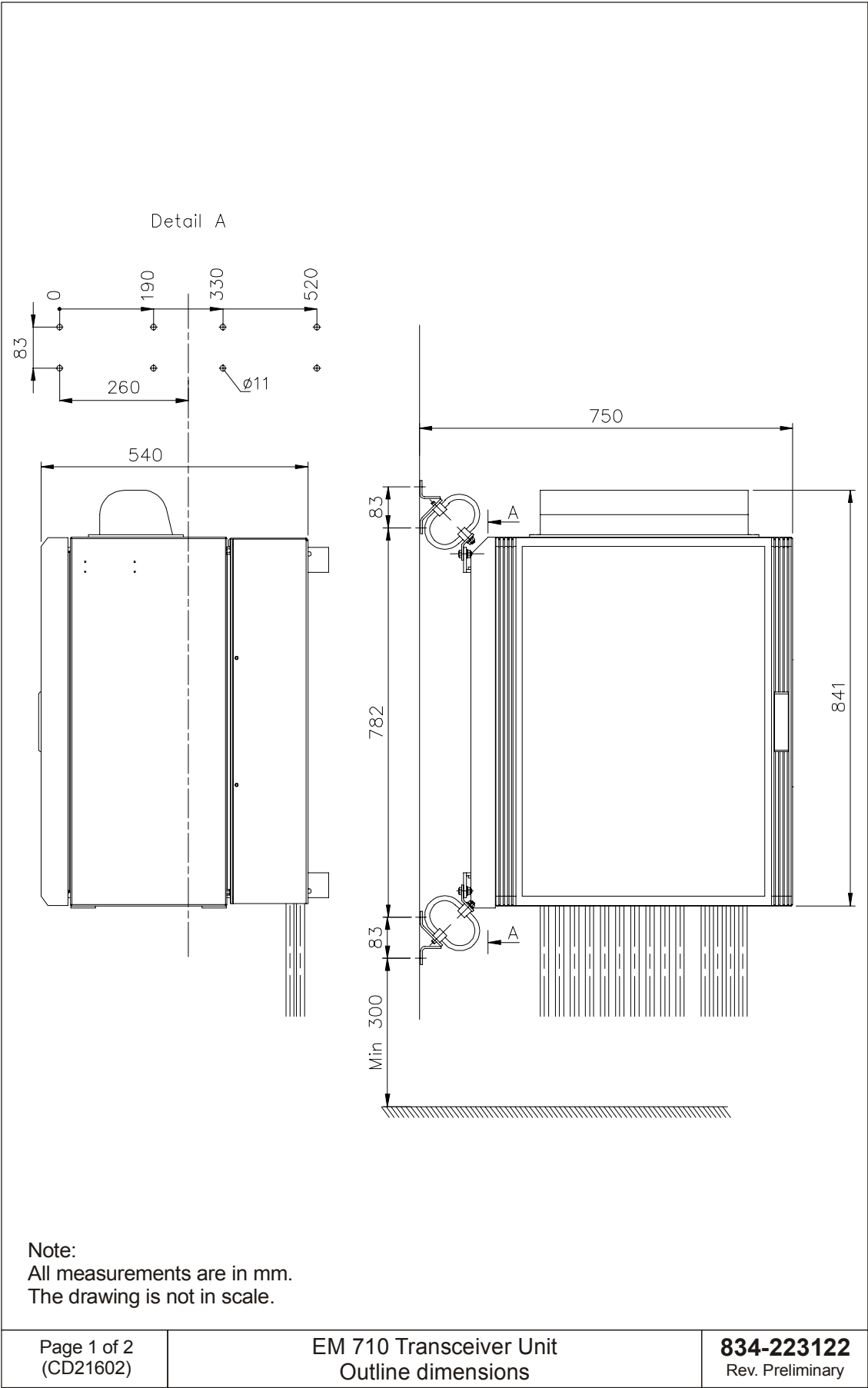
The Operator Station and the LCD monitor are both IP22 rated. The Transceiver Unit is IP54 rated.

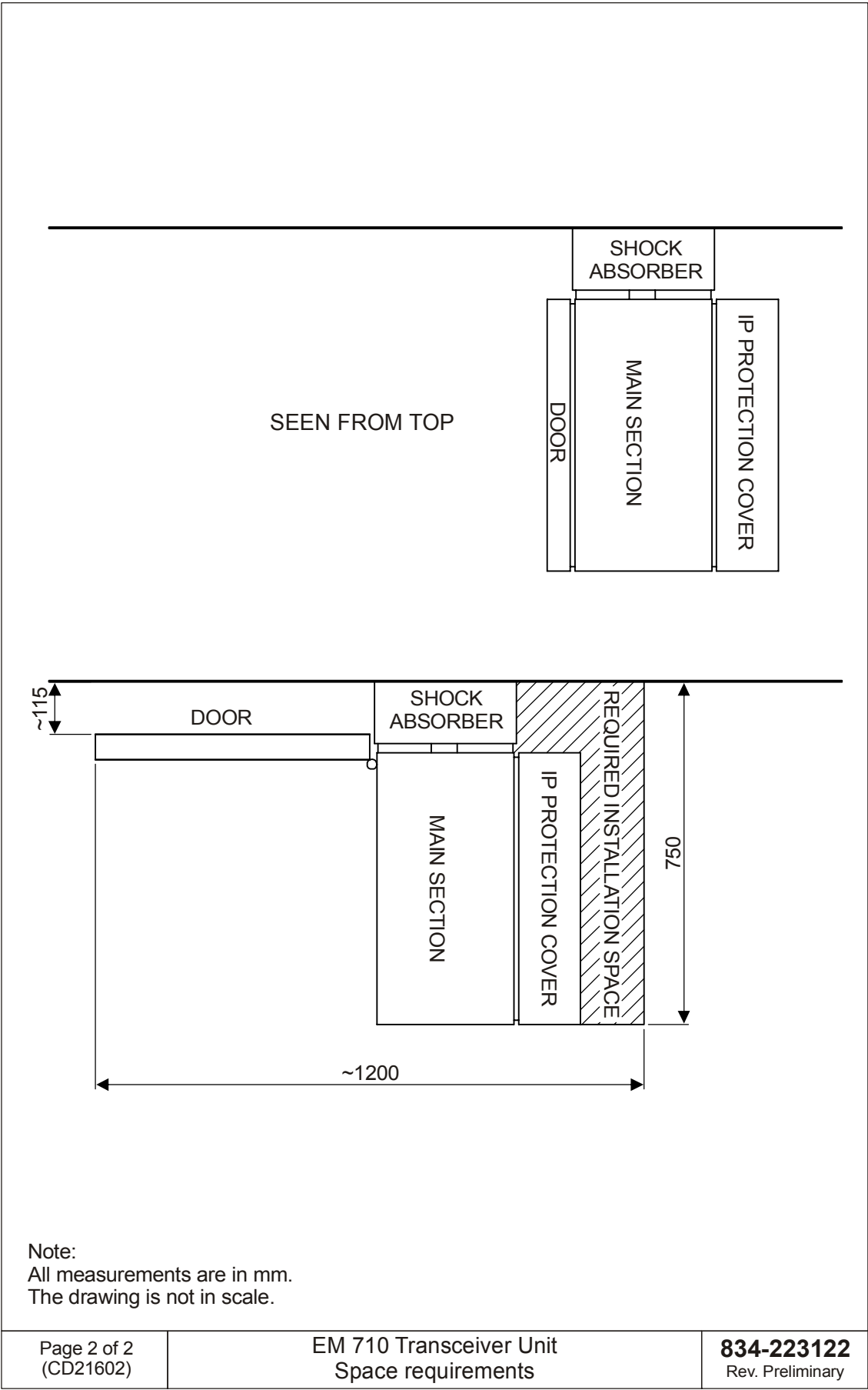
System performance data

- **Maximum ping rate:** More than 25 Hz
- **Number of beams and soundings for each ping:**
 - 1 by 2 and 2 by 2 degrees models: 128 beams with 200 soundings in High Density mode
 - 1 by 1 degree model: 256 beams with 400 soundings in High Density mode
 - 0.5 by 1 degree model: 512 beams with 800 soundings in High Density mode when using two swaths per ping
- **Beamwidths:** 0.5x1, 1x1, 1x2 or 2x2 degrees
- **Beam spacing:** Equidistant, Equiangle, High Density
- **Coverage sector:** Up to 140 degrees
- **Transmit beam steering:** Stabilized for roll, pitch and yaw
- **Receive beam steering:** Stabilized for roll
- **Depth range from transducers:** 3 to approximately 2,000 metres
- **Depth resolution:** 1 cm
- **Pulse lengths:** 0.15, 0.5 and 2 ms CW plus compressible (chirp) up to 200 ms
- **Range sampling rate:** 15 kHz (5 cm) at data output

Restrictions for use - limitations

Currently there may be a limitation in the use of combined long FM sweep and multiping / dual swath mode, due to a limited maximum transmit pulslength.





COMPANY PROFILE

Kongsberg Maritime

Kongsberg Maritime is a leading supplier of advanced maritime automation and instrumentation systems. The company has approximately 2400 employees and an annual turnover of MNOK 3.700 (year 2004). Kongsberg Maritime owns subsidiaries in Canada, Italy, the Netherlands, Germany, Sweden, Singapore, China, Korea, the UK and the USA in addition to four locations in Norway. Decentralisation lets subsidiary company optimise customer relationships while providing maximum flexibility in relation to product design, production and marketing. Kongsberg Maritime currently exports its products to all of the world's major markets.



Figure 25 Kongsberg Maritime's facilities in Horten.

Kongsberg Maritime's main office is situated in Horten, Norway. The **Hydroacoustics** department responsible for the design and production of the EM 710 is also located in Horten, close to the Oslo fjord. Sharing premises with Simrad AS, producer of echo sounder and sonars for the world's fishing fleet, the companies also share more than 50 years of experience in single and multibeam echo sounding, sonar technology and underwater communication and instrumentation.

Kongsberg Maritime's location close to the waterfront provides excellent surroundings for the design, test and manufacturing of the advanced products. Two in-house test tanks, a sea based test station as well as two vessels are available for extensive testing and quality control.



Figure 26 The test and demonstration yacht "M/K Simrad Echo"

The product range provided by Kongsberg Maritime in Horten includes:

- Single and multibeam echo sounders for hydrographic use
- Underwater communication
- Underwater positioning reference systems (including the highly accurate HiPAP® system)
- Naval sonars and echo sounders (hull mounted and towed systems)
- Oil and gas simulator systems

Kongsberg Maritime is fully owned by the **Kongsberg Group**.

Kongsberg Group

Kongsberg Gruppen ASA (the Kongsberg Group) is one of Norway's leading high-technology companies. With an annual turnover of approximately MNOK 6.400 (in 2004), it is listed at the Oslo Stock Exchange. The largest shareholder is the Norwegian Ministry of Industry and Energy holding 51% of the shares. The rest is publicly owned.

The Kongsberg Group operates through two major business areas:

- Kongsberg Defence & Aerospace AS
- Kongsberg Maritime AS

These companies are fully owned by the Kongsberg Group. Kongsberg Defence & Aerospace is engaged in defence activities, while the commercial market activities are allocated within Kongsberg Maritime.

The Kongsberg Group is represented world wide.

For more information, visit www.kongsberg.com

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