SCHMIDT OCEAN INSTITUTE

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Falkor (too) Multibeam Guide

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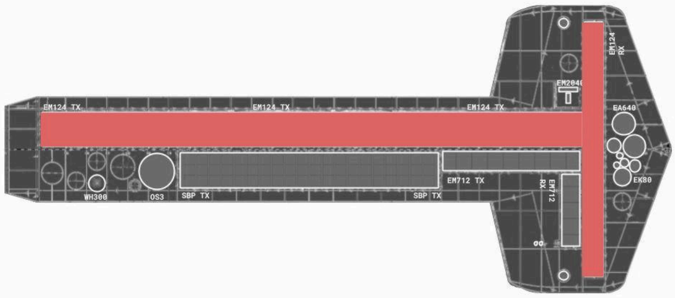
Our Mission

Mapping serves as the backbone of all of our research and is one of SOI's key focus areas for the next decade of research. As a partner of the Nippon-Foundation GEBCO Seabed 2030 Project, an international program to get a high-resolution map of the entire seafloor by 2030, we aim to contribute to the global databases of high resolution multibeam bathymetric data, as well as producing important maps for expansion of protected areas. We strive to map in remote regions, fostering a better understanding of these unknown ecosystems and how to best protect them. To achieve this, Falkor (too)'s suite of multibeam sonars was designed to cover the full range of ocean depth at high resolution: from shallow coastlines to the deepest trenches. This mapping guide is intended as an aid for future science parties you prepare for your expedition aboard Falkor (too).

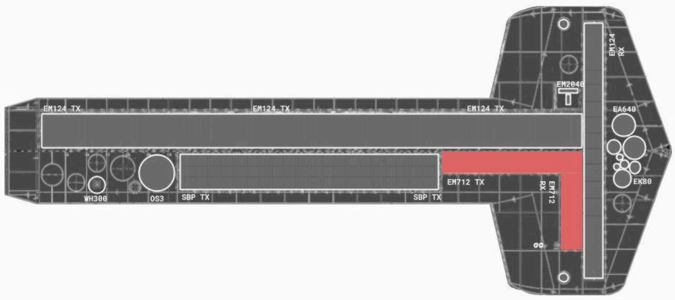
Multibeam Echosounder Overview

EM124



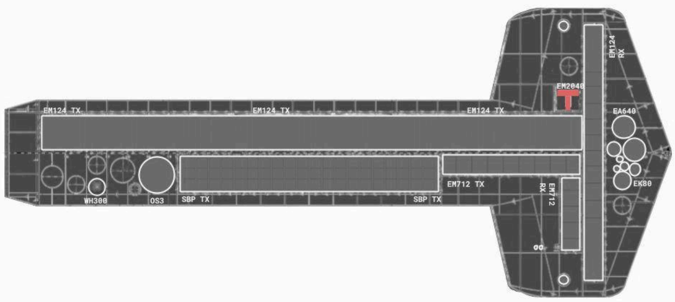
- Specifications: Full ocean depth (11,000m) multibeam echosounder with 12kHz nominal operating frequency (FM pulses and Tx sectors typically span 10.5-13.5 kHz).
- Beamwidth 0.5° Tx with 1° Rx
- Depth Range 20m to 11,000m
- FKt Typical Operational Range: 1000m - 6,000m
- Swath Width: up to 6 times the depth

EM712



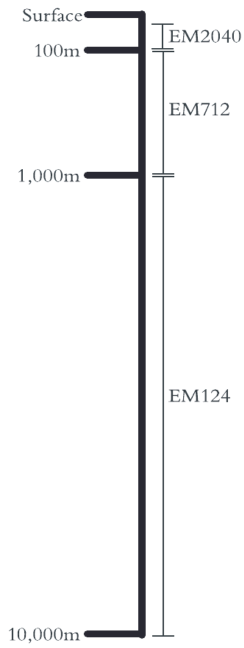
- Specifications: High resolution mid range multibeam echosounder with an operational frequency of 40-100kHz.
- Beamwidth: 0.25° Tx with 0.5° Rx
- Depth Range: 3m - 3,600m
- FKt Typical Operational Range: 50m - 1,000m
- Swath Width: up to 5.5 times the depth

EM2040



- Specifications: High resolution and multi-frequency shallow water multibeam echosounder with an operational frequency band of 200- 700 kHz).
- Beamwidth: 0.4° Tx with 0.75° Rx
- Depth Range: <1m - 635m
- FKt Typical Operational Range: 40m- 100m

Which Multibeam Should I Use?



- In general, the best multibeam to use is dependent on depth and survey goals. An easy rule of thumb is:
  - **<100m : EM2040**
  - **100m - 1,000m : EM712**
  - **~1,000m : EM712 and EM124 sync'd**
  - **>1,000m : EM124**
- Each multibeam's highest data quality will be achieved at the center of its operational range. However, while operating at the same depth, one multibeam may have a higher resolution of data while the other may have a larger swath width. We see this most often with EM712 and EM124 at 1,000m where EM712 achieves the higher resolution while EM124 achieves a larger swath. Running both multibeams simultaneously, will reduce the ping density of both echosounders, which we discuss more below.

Interference

When multiple echosounders are operating simultaneously, their pings can potentially interfere with the other echosounders that are running, making it so that neither echosounder can get clean data. Ksync, a Kongsberg product, works with the echosounder to stagger their transmission timing, allowing us to operate echosounders that would normally interfere with each other simultaneously. A word of caution: by staggering the transmissions, Ksync also increases the standby periods of each echosounder, ultimately reducing the ping density while running multiple echosounders.

Ksync

List of Syncable Echosounders:

Currently, the following echosounders can be synchronized via our Ksync software:

- EM124- Deep Water Multibeam
- EM712- Medium Range Multibeam
- EM2040- Shallow Water Multibeam
- SU90- Collision Avoidance Forward Facing Sonar
- SBP29- Sub Bottom Profiler
- EK80- Mid Water Echosounder
- OS38- Deep Range ADCP
- EA640- Full Range Single Beam Echosounder

Common Combinations

Different survey goals call for different combinations of echosounders. Below are some common combinations that work well together with Ksync.

Very Shallow Water Mapping

- <100m
  - EM2040 and SU90
  - All other echosounders secured.

Shallow Water Mapping

- 50m - 300m
  - EM2040, EM712 and SU90
  - Can also sync SBP29
  - All other echosounders secured.

Shallow - Mid Water Mapping

- 100m - 1,000m
  - EM712 and SU90
  - Can also sync SBP29
  - All other echosounders secured.

Mid Water Mapping

- 800m - 1200m
  - EM712 and EM124
  - Can sync EM124 with SBP29 via EM Trigger

Deep Water Mapping

- 1,000m - 11,000m
  - EM124, SBP29, WH300 and OS38
  - Can also sync EK80

Environmental Considerations to Surveys

The design of Falkor (too) makes our echosounder data susceptible to environmental conditions, most notably from bubble sweeps during moderate- heavy weather. These bubble sweeps occur most often at high speeds when the ship is headed into the weather.

Survey Recommendations

The following steps can be taken to minimize the effect of weather on the echosounder data quality.

- Reduce vessel speed: normal survey speeds for FKt are ~6 knots, reducing to 4 kts can reduce the bubble sweeps down the hull, which interrupts the echosounder transmission.
- Change survey direction so the ship does not have to survey into weather: the greatest amount of bubble sweeps occur when the ship is heading into weather , which can be reduced by adjusting the survey direction so the weather is either at our beam or quarter.
- Reduce angular coverage: In heavy weather, the outside beams generally suffer the most, so bringing the beams in to reduce the overall angular coverage can improve data quality to a certain extent.

Multibeam Coverage

Multibeam coverage is dependent on the echosounder used, depth of the seabed, angular coverage and environmental conditions. Generally shallow topography= less coverage and higher resolution, deeper topography= more coverage and less resolution.

Image: Norbit

Swath Width

Knowing the swath width of a echosounder will help in determining line spacing and survey coverage. The table on page 7 shows the approximate swath coverage between the different echosounders within different depth ranges that you can use to guide line plans for your cruise.

Overlap Suggestions

Swath coverage constantly shifts larger and smaller during a survey as a result of rugged terrain. Occasionally, terrain at the edges of swaths can cause shadowing or holes, which can cause your observed swath distance to be smaller than expected. In addition, the edges of the swaths are generally noisy and subject to holes. Therefore, we suggest planning for 20-25% overlap between each line to achieve a good multibeam product.

Edge Mapping Surveys

The marine technicians on Falkor (too) work closely with the bridge officers to achieve the highest data quality for the survey. It is a fairly routine practice to edge-map under the deck officer and marine technicians' direction, using the line plan as a guide. The bridge officers have a real time display of the multibeam giving them an active role to maneuver the ship with the changing terrain. This allows us to weave in and out as the topography allows, maximizing swath coverage without risking holes to achieve the highest coverage survey data.

Approximate multibeam total swath width and recommended line spacing of 25% overlap for each echosounder at different depths.						
	EM2040		EM712		EM124	
Depth (m)	Swath Width (m)	Line Spacing (m)	Swath Width (m)	Line Spacing (m)	Swath Width (m)	Line Spacing (m)
50	200	150	-	-	-	-
100	560	420	-	-	-	-
150	560	420	-	-	-	-
200	400	300	-	-	-	-
250	360	270	1200	900	2000	1500
300	320	240	1600	1200	2100	1575
350	240	180	1700	1275	2200	1650
400	160	120	1850	1387.5	2300	1725
450	160	120	1900	1425	2400	1800
500	100	75	2000	1500	2500	1875
750	-	-	2600	1950	3600	2700
1000	-	-	2800	2100	5000	3750
1250	-	-	3000	2250	6000	4500
1500	-	-	3000	2250	8000	6000
1750	-	-	3200	2400	9000	6750
2000	-	-	2800	2100	10000	7500
2250	-	-	2000	1500	11250	8437.5
2500	-	-	2000	1500	12500	9375
2750	-	-	2400	1800	12500	9375
3000	-	-	2400	1800	12500	9375
3500	-	-	-	-	14000	10500
4000	-	-	-	-	18000	13500
4500	-	-	-	-	19000	14250
5000	-	-	-	-	20000	15000
6000	-	-	-	-	22000	16500
7000	-	-	-	-	24000	18000
8000	-	-	-	-	18000	13500

This data was collected during FKt's 2022 Sea Trials with the NSF-UNOLS Multibeam Advisory Committee.

Multibeam Resolution

The resolution of the multibeam data can be described by the sounding density along track and across track.

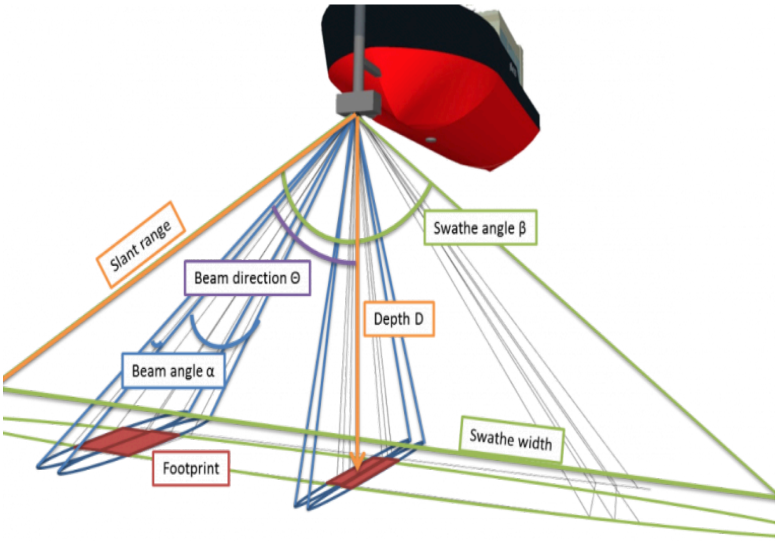


Image: https://www.hydro-international.com/content/article/state-of-the-art-in-multibeam-echosounders

Resolution is dependent on several factors:

- Water Depth
- Physical Characteristics of the Echosounder
- Angular Coverage
- Ship's Speed
- Conditions that Affect the Echosounder's Signal to Noise Ratio
    - Ship Noise
    - Environmental Conditions
    - Echosounder Performance

Along Track

The distance between soundings in the direction the ship is moving. This is generally dependent specifically on depth and speed. The deeper the seafloor, the amount of time it takes for sound to travel to the seabed and back. The faster the ship's speed, the more distance is covered between each ping.

Across Track

The distance between soundings across the swath and perpendicular to the vessel's motion. This is dependent on a multitude of factors including a echosounder's physical characteristics, the set angular coverage, and depth.

How do I increase the resolution of my survey?

1. Reduce speed
2. Decrease angular coverage
3. Increase swath overlap / multiple passes over the same area
4. Utilize dual swath mode (*dual swath mode has been known to cause issues with bottom tracking)

Does Resolution = Object Detection?

It's important to note that resolution does not directly equate to object detection. Just because you can grid your survey to a resolution of 25 meters, does not mean you can detect a 25m object. See Object Detection section for more information.

Multibeam Resolution Table

Minimum Griddable Resolution (m) at different Depths for Each Multibeam (at least 1 sounding per grid cell)			
	Multibeam Echosounder		
Depth (m)	**EM2040**	**EM712**	**EM124**
50	0.5	-	-
100	1	1	-
150	1.5	1.5	-
200	2	2	-
250	2.5	2.5	-
300	3	3	-
400	-	4	-
500	-	5	6
600	-	6	7
700	-	7	9
800	-	8	10
900	-	9	12
1000	-	10	15
2000	-	-	30
3000	-	-	40
4000	-	-	50
5000	-	-	55
6000	-	-	60

Data based on EM Calculator with adjustments from MT Technicians.

Object Detection

Resolution Principles

Sounding density, although closely related to resolution, is a better gauge of what size object is detectable by the multibeam. To be able to detect an object, you generally need at least 3-6 soundings to hit the target.

Different Variables that affect Object Detection

The same variables that affect resolution also contribute to object detection. The higher resolution data you can achieve, the higher the likelihood of detecting objects with a multibeam echosounder.

- *Depth- shallower depths, mean more concentrated beams, higher chance of detection*
- *Speed - slower survey speeds means more concentrated along track pings, higher chance of detection*
- *Angular Coverage - smaller beam angles provide more concentrated beams across track, higher chance of detection*
- *Beam Width - is a characteristic of the sounder. Narrower beams detect smaller targets. Higher frequencies produce narrower beams. Use the best sounder available to match your needs.*
- *Echosounder Settings - settings like dual swath mode can increase the quantity of beams within a given swath.*

Target Detection Principles

To achieve target detection, you need to have a high enough sounding density so that a few soundings hit your target. In general, speed, angular coverage, depth, echosounder mode and target size will all affect what a multibeam can detect. However, it's important to understand that despite a multibeam technically detecting a target, this doesn't mean that target will be able to be distinguished from other noise/ terrain by the human eye. Some factors that can affect human detection include target shape and material, height from seabed, surrounding topography, and more- but this is out of the scope of this document and can be discussed further with the ship's Marine Technicians. Some steps that can be taken to help recognize a target include: slowing down, reducing angular coverage, or conducting multiple passes in different directions/ place in the swath. The backscatter/seabed display is also a powerful tool to help recognize a target, as it can aid in distinguishing harder, more reflective surfaces.

AUVs and Target Detection

Multibeams are not target detection echosounders. We often rely on luck and optimal conditions when a target is detected with a multibeam. AUV's are the better option as they can survey at shallow heights above the seafloor with multibeams, synthetic aperture sonars (SAS) and cameras.

The tables below are calculated w/ Kongsberg's EM Calculator and indicate the smallest size object under certain conditions the multibeam could technically detect returns off the target. This does not mean the target is detectable by the human eye.

EM2040 Chart for Target Detection

Based on survey settings: 6 knot speed, 120 degree swath width, and dual swath mode.

EM2040 Target Detection				
Depth (m)	**Frequency (kHz)**	**Hits Along Track**	**Hits Across Track**	**Minimum Target Size(m)**
50	400	4.2	3.2	.8x.8
75	400	4.2	3.1	1.2x1.2
100	300	4.1	3	1.6x1.6
125	200	4	3	2x2
150	200	3.9	3	2.4x2.4
175	200	3.9	3	2.9x2.9
200	200	3.9	3	3.3x3.3
225	200	3.9	3	3.7x3.7
250	200	4	3	3.9x3.9
275	200	4	3	3.9x3.9
300	200	3.8	3	3.8x3.8

Calculations based on Kongsberg's EM Calculator

EM712 Chart for Target Detection

Based on survey settings: 6 knot speed, 120 degree swath width, and dual swath mode.

EM712 Target Detection			
Depth (m)	**Hits Along Track**	**Hits Across Track**	**Minimum Target Size(m)**
100	3	3.5	1x1
250	3.3	3.9	3x3
500	3.1	3.8	6x6
750	3	6.3	17x17
1000	3	6.2	20x20
1250	3	6.6	22x22
1500	3	7.2	23x23
1750	3	7.7	26x26
2000	3	8.6	27x27

Calculations based on Kongsberg's EM Calculator

EM124 Chart for Target Detection

Based on survey settings: 6 knot speed, 120 degree swath width, and dual swath mode.

EM124 Target Detection, 6 knots			
Depth (m)	**Hits Along Track**	**Hits Across Track**	**Minimum Target Size(m)**
500	3	3.7	5.7x5.7
1000	3	3.6	11x11
1500	3.1	3.8	18x18
2000	3	3.7	23x23
2500	3	3.6	28x28
3000	3	3.7	35x35
3500	3	3.6	40x40
4000	3	3.6	45x45
4500	3	3.6	50x50
5000	3	3.5	55x55
5500	3	3.5	60x60

Calculations based on Kongsberg's EM Calculator

Falkor (too) Mapping Principles

Mapping Plan

The marine technicians will assist the science party with planning their upcoming survey. This will include discussing areas of interest, survey priorities, survey lines and speed, preferred echosounder combination, weather conditions and even echosounder settings. The appendix contains an example of a Mapping Plan which will prompt you for common information needed to conduct a survey.

Normal Practices

With a detailed and well thought out mapping plan, the marine technicians will be able to carry out the survey, however, we always recommend having someone from the science party on watch with the survey goals in mind to help make decisions on the fly and as conditions change. Marine Technicians are available to provide enough multibeam processing to produce dive maps, but anything past that will be the responsibility of the science party to organize.

Appendix

Gondola Technical Drawing

Gondola Outreach Drawing

Antenna Plan

Swath Extinction + Tables

Mapping Plan Template Info