SKQ202203S Planning Overview

• The University of Alaska’s UNOLS vessel R/V *Sikuliaq (SKQ)* is equipped with Kongsberg Maritime EM302 and EM710 multibeam echosounders and a Seapath 320 positioning / attitude system

• During the 2021-22 winter maintenance period in Portland, OR, the Seapath MRU was calibrated by Kongsberg / Seatex in Norway and re-installed shortly before the shakedown; no Seapath or SIS installation angles or other configurations were changed

• The Multibeam Advisory Committee (MAC) was asked to assist with Quality Assurance Testing (QAT) of the ship’s EM302 and EM710 ahead of the 2022 field season; due to scheduling constraints, MAC personnel provided remote support for line planning and data analysis from shore

• MAC communication with *SKQ* personnel (Ethan Roth) commenced in winter 2021-22 with planning for calibrations (‘patch tests’) for both systems off Oregon

• The *SKQ* reoccupied two proven calibration sites:
  • EM302 at a site used by R/V *Thomas G. Thompson* (2018), R/V *Sikuliaq* (2021), E/V *Nautilus*, and others
  • EM710 at a site used by R/V *Falkor* (2017), R/V *Kilo Moana* (2020) south of the Columbia River

• The MAC appreciates UAF / Ethan Roth’s early and clear communication regarding the vessel’s schedule and working areas, as well as efforts to thoroughly document and organize the data throughout these tests

• This report describes the calibration results and implementation in SIS, as well as Built-In Self-Test results for tracking hardware health
SKQ202203S Planning Overview

- EM302 / EM710 calibration lines have been used previously for testing aboard R/V Sikuliaq and other vessels; these were initially planned over features selected from the Global Multi-Resolution Topography Synthesis (gmrt.org) and SAT/QAT data from R/V Thomas G. Thompson.
 SKQ202203S Planning Overview: EM710

- EM710 calibration lines were planned at a site used previously for R/V *Kilo Moana* and other vessels (background bathymetry from GMRT; depth color scale corresponds to 2022 *Sikuliaq* EM710 data)

<table>
<thead>
<tr>
<th>EM710</th>
<th>Waypoint</th>
<th>Decimal Degrees</th>
<th>Degrees Decimal Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch</td>
<td>A</td>
<td>45.605985</td>
<td>-125.096199</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>45.587981</td>
<td>-125.221780</td>
</tr>
<tr>
<td>Roll</td>
<td>C</td>
<td>45.617994</td>
<td>-124.680537</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>45.582006</td>
<td>-124.679463</td>
</tr>
<tr>
<td>Heading 1</td>
<td>E</td>
<td>45.611717</td>
<td>-125.097860</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>45.593710</td>
<td>-125.223453</td>
</tr>
<tr>
<td>Heading 2</td>
<td>G</td>
<td>45.600254</td>
<td>-125.094538</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>45.582251</td>
<td>-125.220107</td>
</tr>
</tbody>
</table>
EM302 calibration lines were planned at a site used previously for R/V *Thomas G. Thompson* and other vessels (background bathymetry from GMRT; depth color scale corresponds to 2022 *Sikuliaq* EM302 data).

<table>
<thead>
<tr>
<th>EM302</th>
<th>Waypoint</th>
<th>Decimal Degrees</th>
<th>Degrees Decimal Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch</td>
<td>A</td>
<td>47.635439</td>
<td>-126.017656</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>47.574553</td>
<td>-126.074311</td>
</tr>
<tr>
<td>Roll</td>
<td>C</td>
<td>47.536378</td>
<td>-125.980898</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>47.493611</td>
<td>-126.049074</td>
</tr>
<tr>
<td>Heading 1</td>
<td>E</td>
<td>47.630406</td>
<td>-126.005837</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>47.569527</td>
<td>-126.062500</td>
</tr>
<tr>
<td>Heading 2</td>
<td>G</td>
<td>47.640470</td>
<td>-126.029477</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>47.579579</td>
<td>-126.086124</td>
</tr>
</tbody>
</table>
System Geometry Review

Overview: Vessel Survey

• The granite block remains the origin for all sensor reference frames; Seapath output is valid at the granite block.

• Following the 2021 calibration (SKQ202102S), no changes were made to Seapath, EM302, or EM710 installation offsets prior to calibration data collection during SKQ202203S.

• Refer to MAC reports (mac.unols.org) for a more complete history of the vessel and sensor geometry:
  - 2014 SAT (SKQ201400L3)
  - 2016 QAT (SKQ201602S)
  - 2018 QAT (SKQ201802T)
  - 2019 QAT (SKQ201907T)
  - 2020 calibration (SKQ202008S)
  - 2021 calibration (SKQ202102S)
The Seapath MRU is the only mapping system component to have undergone any modification since the 2016 QAT.

In early 2018 and late 2021, the MRU ‘bottle’ was removed and shipped to Kongsberg for a factory calibration, then reinstalled in its mounting bracket (prior to SKQ201802T and SKQ202203S, respectively).

Because the MRU bottle is a reasonably tight fit in the bracket (expected to be repeatable to within a few hundredths of a degree), and the bracket was not altered, MAC and SKQ personnel agreed in 2018 and 2022 to maintain the existing MRU installation angles in the Seapath Nav Engine (MRU Geometry) ahead of the respective calibrations.

Likewise, no changes were made prior to the 2019-21 calibrations.

Screenshot at left shows MRU geometry as configured through SKQ202203S.
Seapath 320 Configuration

Antenna Lever Arms

Seapath GNSS antenna offsets are based on the original vessel survey and an updated survey after antenna relocation in 2016.

See the SKQ201602S QAT report for more details of the antenna geometry.

No changes have been made to antenna offsets after SK201602S.

Screenshot at left shows Seapath GNSS antenna geometry as configured through SKQ202203S.
1. A CTD profile was collected at each calibration site, processed in Sound Speed Manager, and applied in SIS during data collection; profiles were applied with ‘nearest in time’ scheduling for post-processing in Qimera.

2. Swath quality was moderately impacted by sea state during both calibrations, resulting in ‘noisy’ soundings (e.g., left image, alongtrack view; rejected soundings shown in red) and bubble sweep / washdown events (e.g., right image, plan view; blue swath is lost and recovered); fortunately, the systems seemed to achieve more uniform sounding distribution compared to when the yaw stabilization limits were reached in 2021.

3. The data were carefully edited in QPS Qimera to remove outliers and mis-tracking, and reduce these data sets down to soundings that appeared suitable for calibration purposes.
EM302 / EM710 Calibration

Pre-Calibration Configuration

1. All Attitude 1 angular offsets were left unchanged in SIS Installation Parameters prior to data collection.

2. Calibration data were examined on shore with patch test tools in QPS Qimera; results were agreed upon by multiple personnel before communication to SKQ.

3. During analysis on shore, results from each test were applied in the Qimera vessel configuration for each system prior to subsequent tests, then reviewed in an iterative process to minimize the effects of coupling between offsets.

4. Results were updated in the SIS Installation Parameters for Attitude 1 on 2022 Feb 27.

5. A latency check was performed for the EM302, which did not indicate an obvious positioning latency error; it is unlikely that a small positioning latency (< 1 s) would be clearly evident in deep water; no latency-related bathymetric artifacts were noted, under the circumstances / caveat of heavy seas and noisy data.
Latency check lines shown at left in the Qimera Patch Test Tool; results were inconclusive in deep water and no obvious signs of latency were observed in other test data.
EM302 Calibration

Results: Pitch

Pitch calibration lines shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: -0.13°
2. Calibration adjustment: +0.02°
3. Final pitch offset: -0.11° in SIS
EM302 Calibration

Results: Roll

Roll calibration lines shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: +0.08°
2. Calibration adjustment: +0.02°
3. Final roll offset: +0.10° in SIS

Note: results varied slightly for different subsets of the roll data; the adjustment recommended here is based on an average of results from small subsets throughout the test area and a large subset using nearly all data in the ‘flat’ region; additional roll tests can be planned opportunistically during the 2022 season to verify this offset, if mapping data indicates a bias
Heading calibration lines shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: 0.00°
2. Calibration adjustment: 0.00°
3. Final hdg. offset: 0.00° in SIS
1. The small *Attitude 1* adjustments (pitch and roll) determined during the 2022 EM302 calibration are well within the typical range of yearly calibration results, especially after factory calibration and reinstallation of the MRU.

2. These results indicate a high-quality vessel offset survey, consistent integration, and no significant changes across the Seapath and EM302.

3. If possible, further roll verification testing is recommended for calm conditions in deep water during the 2021 field season.

4. The *Installation Parameters: Angular Offsets* shown at left should be maintained until any modification is made to the Seapath 320 or EM302 arrays, or a new calibration becomes necessary for other reasons.
EM710 Calibration

Results: Pitch

Pitch calibration lines shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: -0.14°
2. Calibration adjustment: 0.00°
3. Final pitch offset: -0.14° in SIS
EM710 Calibration

Results: Roll

Roll calibration lines shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: +0.13°
2. Calibration adjustment: 0.00°
3. **Final roll offset: +0.13° in SIS**

Note: as with the EM302, roll calibration results were varied for different subsets; the final result is based on the mean of results with multiple subsets throughout the survey area, as well as a large subset using all cleaned data (left)
EM710 Calibration

Results: Heading

Heading verification lines shown at left in the Qimera Patch Test Tool

1. Attitude 1 initial setting: +0.03°
2. Calibration adjustment: 0.00°
3. Final hdg. offset: +0.03° in SIS
As with the EM302, the small adjustments for *Attitude 1* determined from the EM710 calibration indicate a high-quality vessel offset survey, consistent integration, and no significant changes across the Seapath and EM710 since 2020.

These results for pitch and roll fall within the typical range of year-to-year adjustments, with the pitch adjustment showing similar magnitude and direction as that applied for the EM302.

The *Installation Parameters: Angular Offsets* shown at left should be maintained until any modification is made to the Seapath 320 or EM710 arrays, or another calibration becomes necessary for other reasons.
EM302 Hardware Health

TX / RX Channels

- A history of available BISTs since 2014 suggests no recent changes in EM302 RX Z (plot limits are equal to factory spec)
- The causes of increases in 2015-17 are not known
- Although no TX Channels BISTs were collected in 2022, the SKQ team conducts direct impedance measurements to monitor hardware health; the plot of available TX Channels BISTs shows no major changes through 2018
EM710 Hardware Health

TX / RX Channels

- The EM710 BIST history shows a gently increasing trend in RX Z (remaining within factory spec.); *this is being evaluated in tandem with the direct impedance measurements, which may show other modes of degradation (e.g., admittance trends)*

- Although no TX Channels BISTs were run during SKQ202203S, the direct impedance measurements will be assessed; the BIST history plot shows no major changes as of 2018