USCGC *Healy* EM122 Multibeam Echosounder System Review May 16-20, 2017

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Introduction

The USCGC *Healy* is equipped with a Kongsberg Maritime EM122 (12 kHz) deepwater multibeam echosounder utilizing both a Seapath 330+ (primary) and Applanix POS/MV (secondary) positioning and attitude reference systems. This report describes the procedures and results from a review of system geometry, geometric calibrations ('patch tests'), vessel noise testing, swath accuracy assessment, and swath coverage analysis conducted during cruise HE17TA (May 16-20, 2017) off the coast of Washington. These tests were conducted to verify functionality following earlier data collection challenges and shipyard maintenance. Figure 1 depicts the operational areas and track lines for calibration, swath accuracy, and swath coverage data collection.

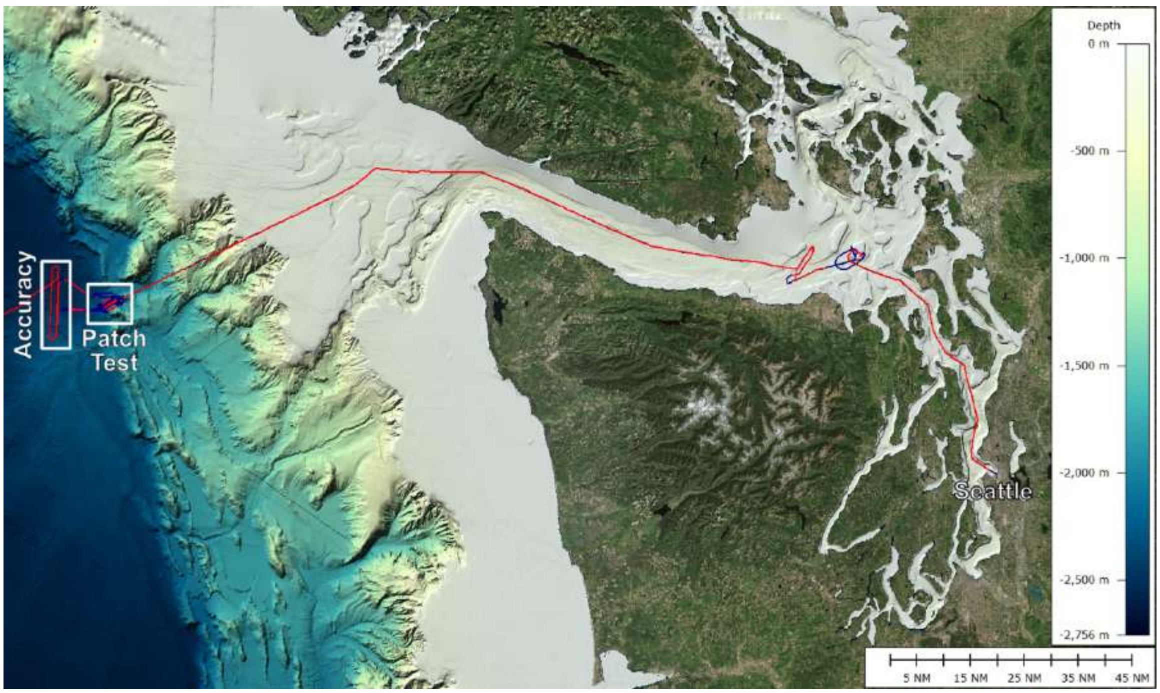


Figure 1. Calibration and accuracy testing sites in the Strait of Juan de Fuca and off the coast of Washington during HE17TA. These sites were selected based on availability of suitable seafloor features in the intended operational depth range for the EM122 multibeam echosounder. Swath coverage (acoustic extinction) data were collected up and down the slope in addition to over these test sites (red ship track).

Overview of System Geometry

In this report, we use the term 'system geometry' to mean the reference frame(s) of the vessel and the linear and angular offsets of the primary components of the multibeam mapping systems, including the following:

1. Master Reference Plate (origin of ship reference frame)
2. Seapath 330+ system:
    a. MRU (motion sensor)
    b. GNSS antennas
3. Applanix POS MV system:
    a. IMU (motion sensor)
    b. GNSS antennas

4. EM122 1° TX array
5. EM122 2° RX array

The system geometry parameters are critical for data collection in an unbiased and repeatable manner.

Pre-HE17TA Geometry Review

Two surveys were conducted by IMTEC to establish the vessel reference frame and determine all linear and angular sensor offsets for the EM122, Seapath, and POS MV systems. The first survey was conducted in January 2010 during initial installation of the EM122 multibeam and motion reference systems (POS MV with 'IMU' located aft, and Seapath with 'MRU' located forward). In 2014, a Seapath 330+ was installed as the primary motion reference system and IMTEC performed a supplemental survey of the MRU and antennas for this system in the original ship reference frame.

Table 1 provides an overview of documentation describing system geometry and an approximate timeline of recent modifications. Note: as of HE17TA, the Seapath antenna locations in use were originally listed as 'IMU GPS Choke Ring Port' and '…Stbd' in the 2010 IMTEC report, and listed as 'POS/MV PORT' and '…STBD' in the 2014 IMTEC supplemental report.

The two IMTEC reports presented all linear offsets in accordance with Kongsberg Maritime (KM) and Applanix conventions, using the Master Reference Plate (MRP) as the origin of a common reference frame for the vessel and all sensors. This common coordinate system is right-handed with its origin at the MRP, with the X axis positive toward the bow, Y axis positive toward starboard, and Z axis positive downward (Figure 2; see also 2010 IMTEC report, p. 9).

Sensor installation angles are described in the 2010 and 2014 reports in degrees-minutes-seconds format with descriptions of the rotation direction (e.g., 'stbd down'), rather than decimal degrees with a common sign convention. During review, the angles reported by IMTEC were converted to decimal degrees using the KM and Applanix sign convention of pitch positive with bow up (right-hand rule about the +Y axis), roll positive with port side up (right-hand rule about the +X axis), and yaw positive with bow movement to starboard (compass convention, right-hand rule about the +Z axis).

After the 2014 IMTEC survey and prior to the 2017 MAC visit, the POS MV GNSS antennas were moved to new 'outriggers' on the antenna masts. The linear offsets from the IMTEC-surveyed original positions to the new locations were surveyed with measuring tapes and factored into the POS MV configuration (personal communication with STARC).

Pre-Calibration Configuration Changes

Review of the survey reports and pre-HE17TA settings for the EM122, Seapath, and POS MV revealed discrepancies in several parameters, probably arising during translation from the IMTEC report to each system's configuration. Most notably, the transducer array installation roll angles in the SIS configuration were opposite in sign from our interpretation of the IMTEC survey reports under the Kongsberg convention. The EM122 TX and RX array installation roll angles were updated in SIS prior to calibration to match our interpretation of the IMTEC survey report. This change was made only after thorough review of the IMTEC reports and consultation among on-board personnel, the MAC team, and Kongsberg engineers. No changes were made to the EM122 array pitch, yaw, or linear offsets in SIS.

Prior to calibration, the Seapath MRU (roll and pitch) installation angles were modified to reflect the IMTEC 2014 supplemental survey results. All POS MV IMU installation angles were set to zero in POSView because the IMU had been removed and reinstalled during maintenance work, and the 2010 IMTEC installation angles were no longer considered applicable. A small change was made to the vertical offsets for the IMU based on this new installation. Linear offsets for the POS MV primary GNSS antenna were verified to reflect the new location on the outrigger, based on hand measurements from the IMTEC survey point by ship personnel. Prior to calibration, a GAMS calibration was performed for the POS MV to determine separation of the primary and secondary antennas.

The EM122 parameters for motion sensor angular offsets in SIS were set to 0.000° prior to calibration and then updated with the calibration results ('residual' angular offsets of the motion sensor) after each test. Tables 2-4 in the Calibration Results section provide summaries of the post-calibration linear and angular offsets for the EM122, Seapath, and POS MV. No change was made to the waterline previously entered, but this is one value that should be addressed by examining draftmarks in the future while the vessel is dockside. If the value is changed, it should be referenced to the MRP for SIS by compensating for the surveyed vertical offset of the transducers, which are considered for this purpose to be mounted flush with the hull.

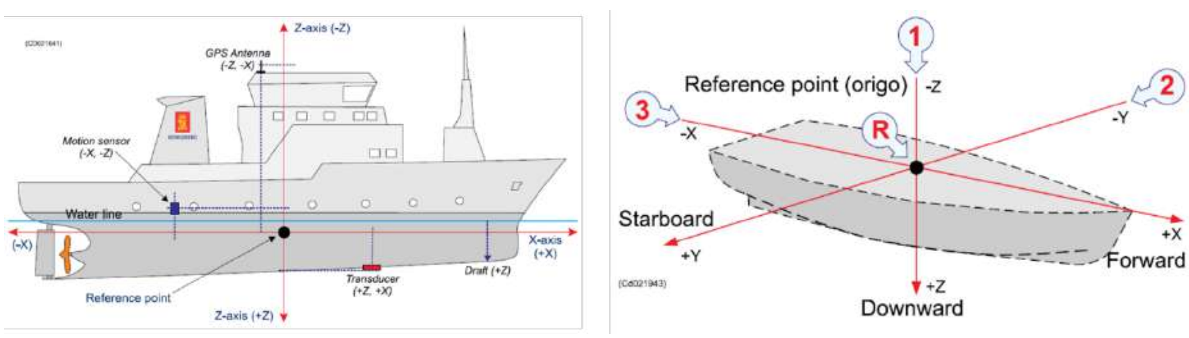


Figure 2. Reference frame axes according to the Kongsberg/Seapath and Applanix conventions and employed for the vessel survey report (images from Kongsberg EM710 manual).

Table 1. Documentation for system geometry

Date	Location	Event	References
2010 Jan 21-29	Seattle, WA	IMTEC survey to establish vessel reference frame and offsets of EM122, POS MV motion sensor (IMU), Seapath motion sensor (MRU), GNSS antennas; survey conducted in IMTEC convention and reported in Kongsberg convention with origin at Master Reference Plate (MRP)	IMTEC survey report (March 1, 2010, Rev. 0) provided by *Healy*
2014 Feb 17	Seattle, WA	Addendum to 2010 IMTEC report; re-establish vessel reference frame and survey new Seapath motion sensor (MRU) and GNSS antennas	IMTEC survey report (February 25, 2014) provided by *Healy*
2014-17	Port Angeles, WA	POS MV antennas relocated on outriggers; offsets from original IMTEC locations measured with tape measure and incorporated into the POS MV configuration	Personal communication with STARC
2017 May 16-20	Seattle, WA	EM122 system performance review; geometric calibration; testing for swath accuracy, platform noise, baseline transducer impedance, and swath coverage	This report

Geometric Calibration

After review and confirmation of the software configuration using offsets available from the survey documentation, the EM122 multibeam systems was calibrated for residual angular offsets using the Seapath and POS MV motion sensors independently, then verified with secondary calibration lines.

Site Selection

Figure 3 shows the calibration areas southeast of the Strait of Juan de Fuca. These were selected based on depths and slopes of prominent features for pitch/yaw calibration (and positioning latency check) and proximity to nearby flat seafloor for roll calibration, and had been used previously for patch tests for the *Healy* and R/V *Sally Ride*. A latency check was conducted prior to calibration, though it is acknowledged that even a significant latency may be very difficult to detect in deep water (e.g., versus shallow water with higher ping rate, data density, and resolution on the seabed). No obvious signs of positioning or attitude latency were observed during HE17TA.

Sound Speed

Expendable bathythermograph (XBT) profiles were acquired with Sippican software and probes, processed in SSP Manager, and applied in SIS prior to the first line for each pair of survey passes for pitch, roll, and heading calibrations / verifications. All XBTs collected throughout HE17TA were processed with SSP Manager to remove spurious sound velocities, apply salinity data from the World Ocean Atlas 2009 (WOA09), and prepare the profile for SIS. Surface sound speed was measured with a flow-through sensor and fed to SIS during data collection.

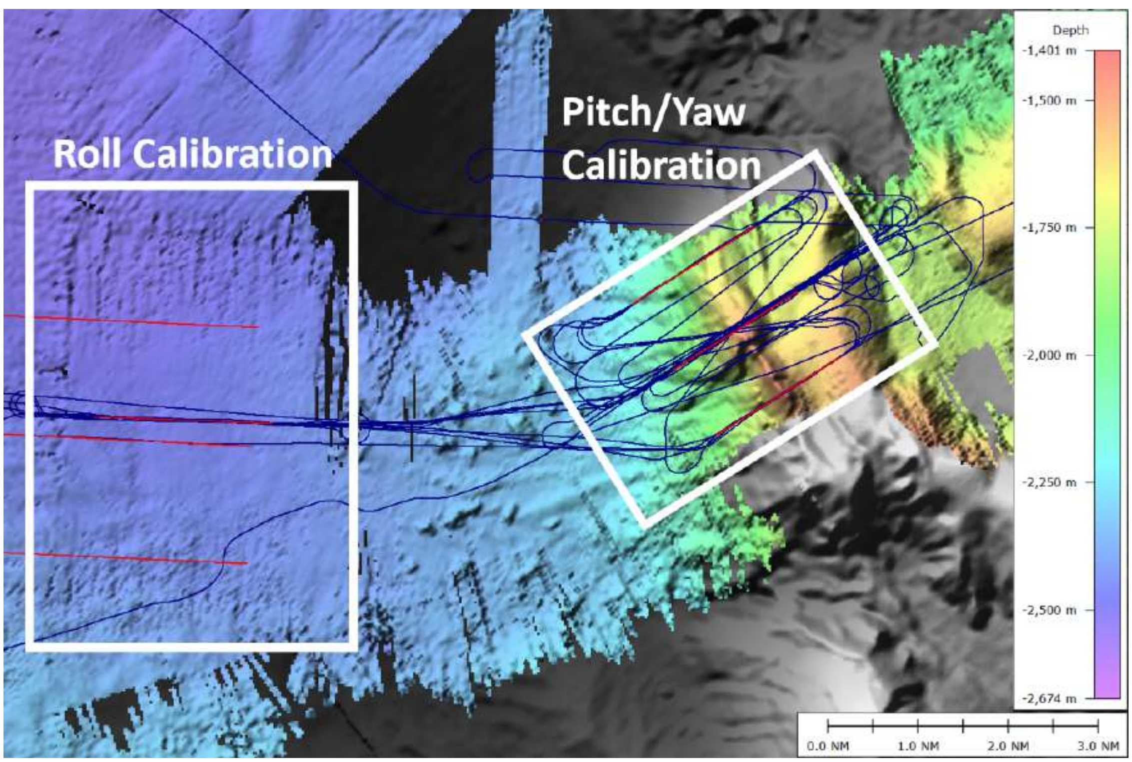


Figure 3. Calibration sites offshore Washington. These sites were selected based on availability of suitable seafloor features in the intended operational depth ranges of the EM122.

Calibration Configuration

To achieve high ping rate and sounding density, while also attempting to reduce bubble sweep, the ship was operated at 7 kts for all calibration lines (5 kts and 10 kts for positioning latency check). The EM122 was configured as follows for each calibration:

Depth mode:	AUTO	
Dual-swath mode:	enabled (dynamic)	
Transmit mode:	FM enabled	
Yaw stabilization:	enabled (rel. mean heading)	
Pitch stabilization:	enabled	
Beam spacing:	High density equidistant	
Swath width:	Pitch:	30°/30° port/stbd
	Roll:	70°/70° port/stbd
	Yaw:	10°/60° and 60°/10° port/stbd

The motion sensor angular offsets in SIS were set to zero prior to calibration. Residual angular offsets were determined in the order of pitch first, roll second, and yaw third. To minimize coupling of angular offsets in the calibration results, each residual angular offset result was updated in SIS after completion of its respective calibration procedure and before the start of survey data collection for the following calibration (e.g., the pitch result was entered in SIS before data collection for roll, and roll before yaw).

Calibration tools in QPS Qimera and SIS were used separately to evaluate each set of calibration lines for both echosounders. Results from independent examinations of each set of calibration lines by MAC, Kongsberg, and ship personnel typically fell within 0.05° of each other and frequently agreed to within 0.02°; final values were agreed upon after additional scrutiny before modification in SIS.

All calibration results for each motion sensor were verified by examining additional survey lines for pitch, roll, and yaw artifacts after application of the initial results in SIS. In some cases, very small remaining residual offsets were detected during the verification and updated in SIS. Offsets for the Seapath (primary) system were verified prior to starting the calibration and verification for the POS MV (secondary) system.

Calibration Results and Current Configuration

Tables 2-4 summarize the post-HE17TA configurations for the multibeam echosounder and motion reference systems. For parameters with any changes made during HE17TA, the pre-cruise value is included in parentheses. These results are based on careful review of the survey documentation and calibration datasets and are to be used until sensors are modified or another calibration becomes necessary. To demonstrate the calibration results, Figures 4-11 depict transects of the latency check and roll, pitch, and yaw verification data sets in the QPS Qimera calibration tool with the final adjustments for each offset applied (note that the value applied in the calibration tool is only the final adjustment made in the course of calibration, not the offset recorded in the corresponding table of offsets; see caption for additional information on each test).

Table 2. EM122 sensor offsets recorded in SIS after system geometry review and calibration during HE17TA. Pre-HE17TA values are shown in parentheses, if changed during review and calibration. Position and attitude data from the Seapath and POS MV are valid at the Master Reference Plate, which is considered the origin of the multibeam system reference frame on Healy. Note that the primary Seapath is fed to Attitude 2, COM3, and the secondary POS MV is fed to Attitude 1, COM2.

EM122 Origin at Granite Block	X	Y	Z	Roll	Pitch	Yaw
	BOW +	STBD +	DOWN +	PORT UP +	BOW UP +	COMPASS +
EM122 TX	-18.404	-1.909	8.919	0.016 (-0.015)	-0.020	0.00
EM122 RX	-7.66	0.009	9.023	0.012 (-0.012)	-0.143	0.024
Pos, COM1 (POS MV)	0.00	0.00	0.00			
Pos, COM3 (Seapath)	0.00	0.00	0.00			
Attitude 1, COM2/UDP5 (POS MV)	0.00	0.00	0.00	-0.22 (0.41)	0.23 (-0.96)	0.29 (0.80)
Attitude 2, COM3/UDP6 (Seapath)	0.00	0.00	0.00	-0.04 (-0.25)	0.13 (0.50)	0.05 (0.00)
Waterline			0.533			
Standalone Heading						0.00 (0.80)

Table 3. Antenna and MRU offsets recorded in the Seapath configuration after system geometry review during HE17TA. Pre-HE17TA values are shown in parentheses, if changed during review and calibration. Seapath GNSS antennas are installed at the locations listed in the survey reports as 'IMU Choke Ring' in 2010 and 'POS MV' in 2014. The Master Reference Plate (MRP) is the origin of the vessel, SIS, Seapath, and POS MV reference frames. Position and attitude data fed to SIS are valid at the origin. NOTE: the Seapath is considered the 'primary' motion system (Seapath data are received by the EM122 on COM3, typically used for the 'secondary' system, due to the order of installation of these systems). It is noted also that MRU installation angle modifications on the order of 0.001° are likely due to rounding differences in converting from DMS format, and do not appreciably affect the data.

Seapath Origin at MRP	X	Y	Z	Roll	Pitch	Yaw
	BOW +	STBD +	DOWN +	PORT UP +	BOW UP +	COMPASS +
GNSS Ant. 1 (Port)	-52.557	-2.209	-22.100			
GNSS Ant. 2 (Stbd)	-52.576	2.291 (2.288)	-22.107 (-22.113)			
MRU	-2.047	-0.296	-0.603	-179.739 (-179.742)	-0.146 (-0.151)	1.206

Table 4. Antenna and IMU offsets recorded in the POS MV configuration after system geometry review during HE17TA. Pre-HE17TA values are shown in parentheses, if changed during review and calibration. Linear offsets presented here differ from the IMTEC survey reports due to relocation of the GNSS antennas onto outriggers (measured by hand from the IMTEC survey locations), and removal/reinstallation of the IMU. IMU installation angles were set to zero after removal/reinstallation during maintenance. Position and attitude data fed to SIS are valid at the origin. NOTE: The Master Reference Plate (MRP) is the origin of the vessel, SIS, Seapath, and POS MV reference frames; all POS MV data feeds are valid at the MRP. The POS MV is configured as the 'secondary' motion system (POS MV data are received by the EM122 on COM1, typically used for the 'primary' system, due to the order of installation of these systems).

POS MV Origin at MRP	X	Y	Z	Roll	Pitch	Yaw
	BOW +	STBD +	DOWN +	PORT UP +	BOW UP +	COMPASS +
Ref to Prim. GPS Lever Arm (Port)	-51.808	-2.057	-22.163 (-22.251)			
Ref to IMU Target	-49.954	1.615	-16.892 (-16.851)	0.00	0.00	0.00

EM122 with Seapath

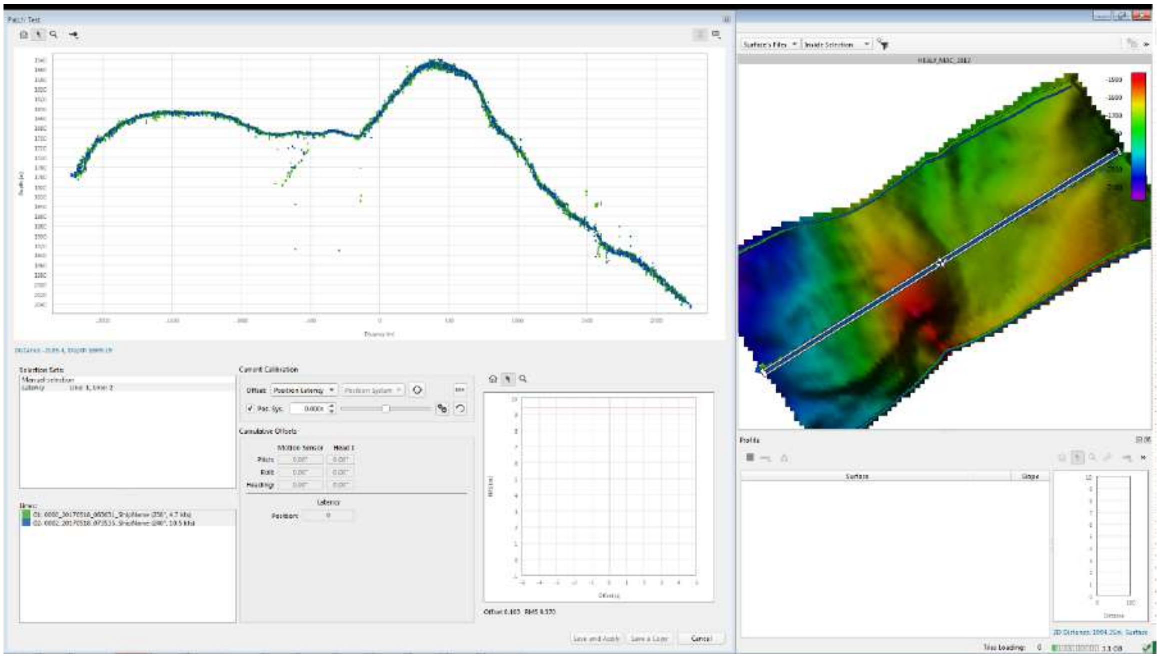


Figure 4. EM122 / Seapath positioning latency checking in Qimera, applying 0.00 s position timing adjustment.

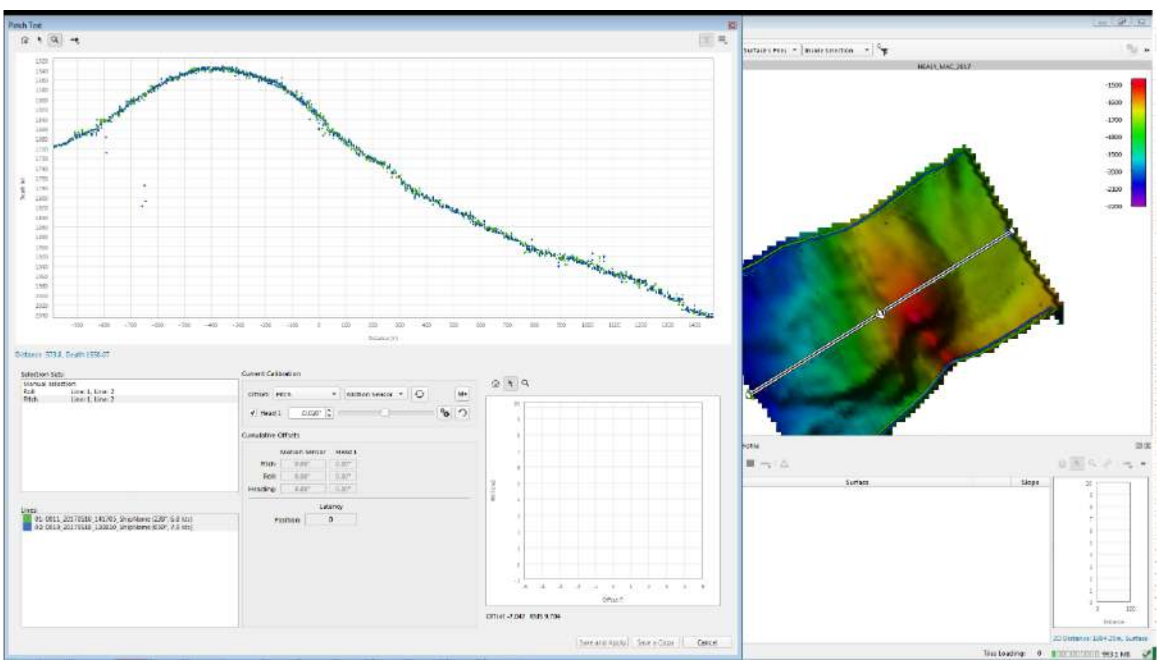


Figure 5. EM122 / Seapath pitch verification in Qimera, applying an adjustment of -0.02° to the initial value of 0.15° for a final offset of 0.13° in SIS.

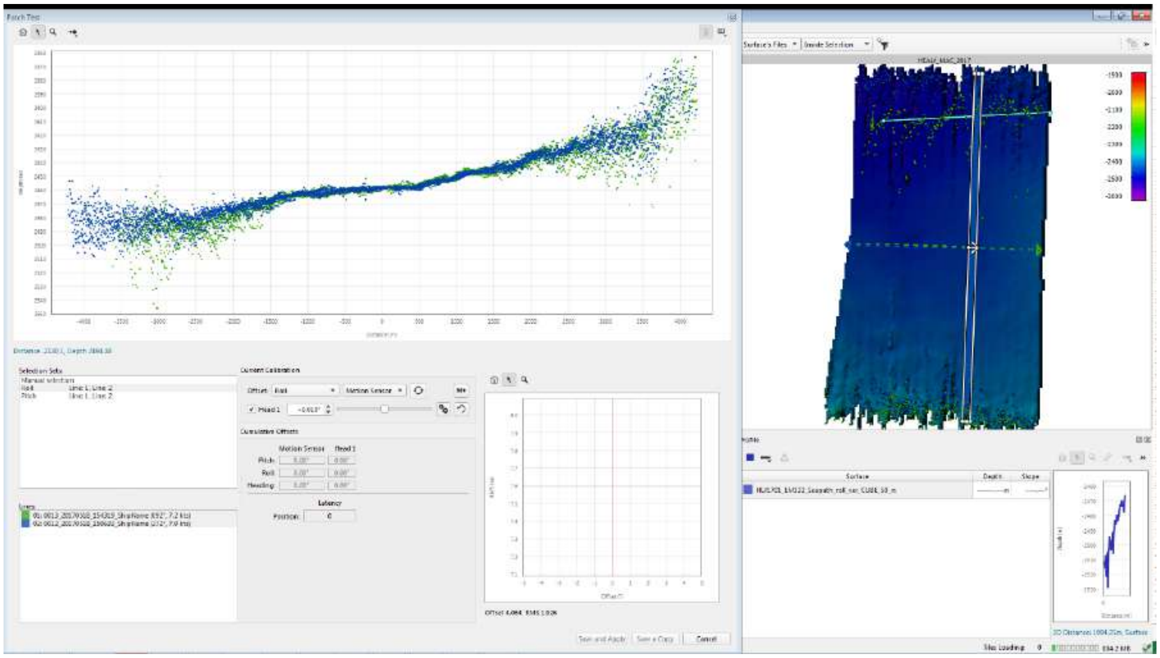


Figure 6. EM122 / Seapath roll verification in Qimera, applying an adjustment of 0.01° to the initial value of -0.05° for a final offset of -0.04° in SIS.

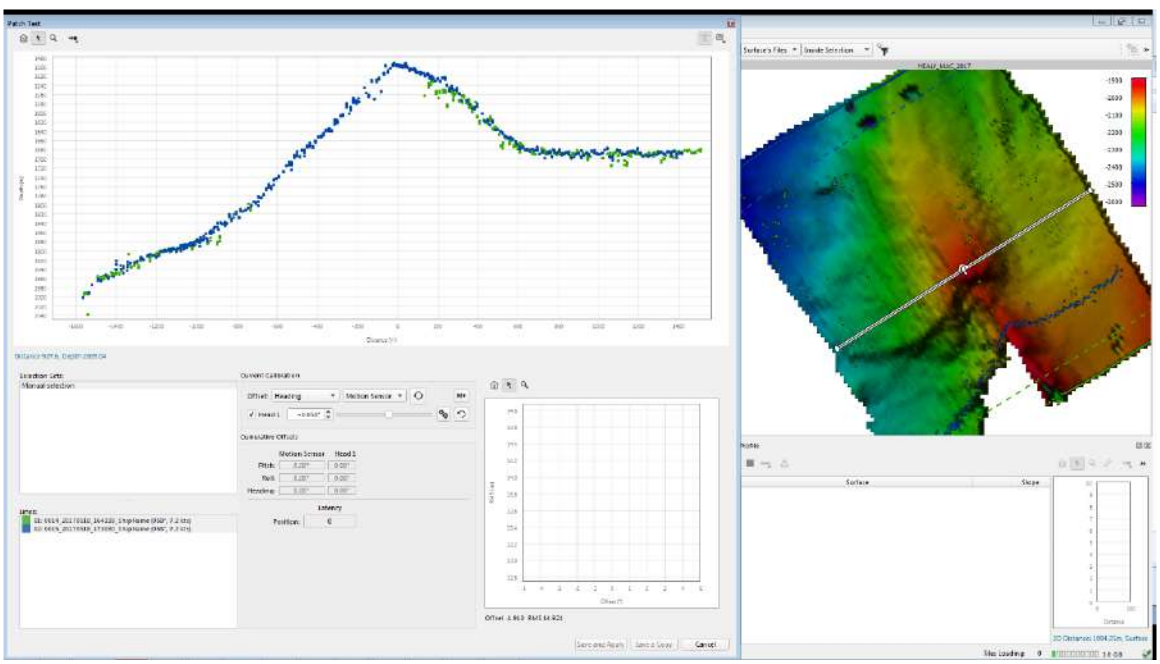


Figure 7. EM122 / Seapath heading verification in Qimera, applying an adjustment of 0.05° to the initial value of 0.00° (initial data were inconclusive) for a final offset of 0.05° in SIS.

EM122 with POS MV

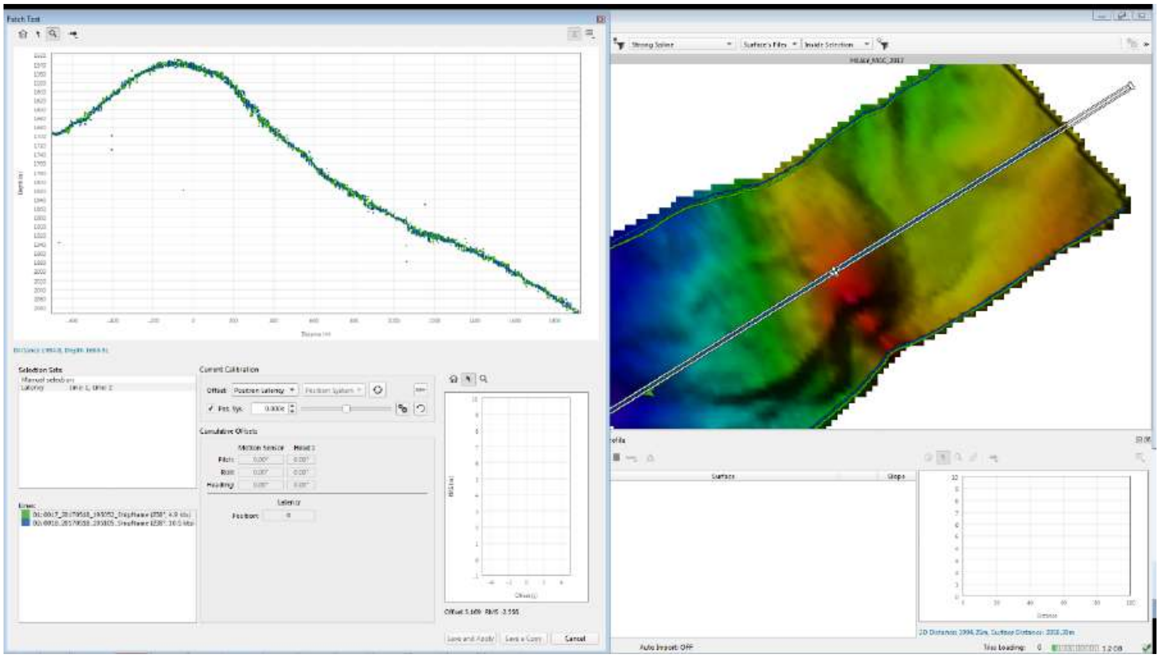


Figure 8. EM122 / POS MV positioning latency checking in Qimera, applying 0.00 s position timing adjustment.

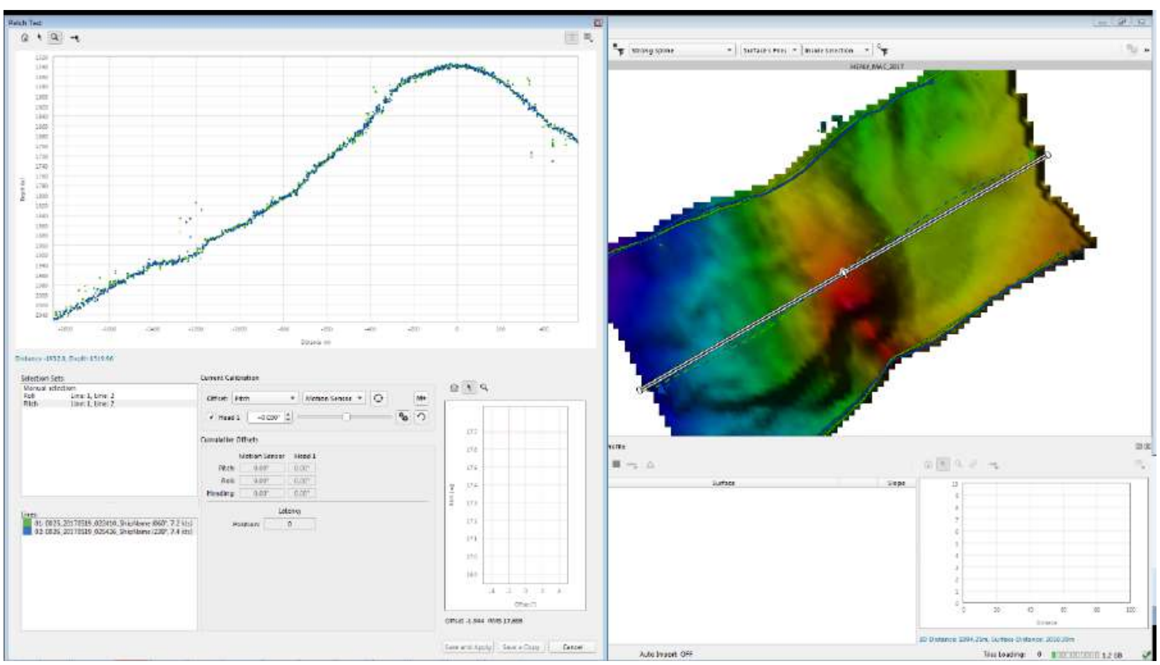


Figure 9. EM122 / POS MV pitch verification in Qimera, applying an adjustment of 0.03° to the initial value of 0.20° for a final offset of 0.23° in SIS.

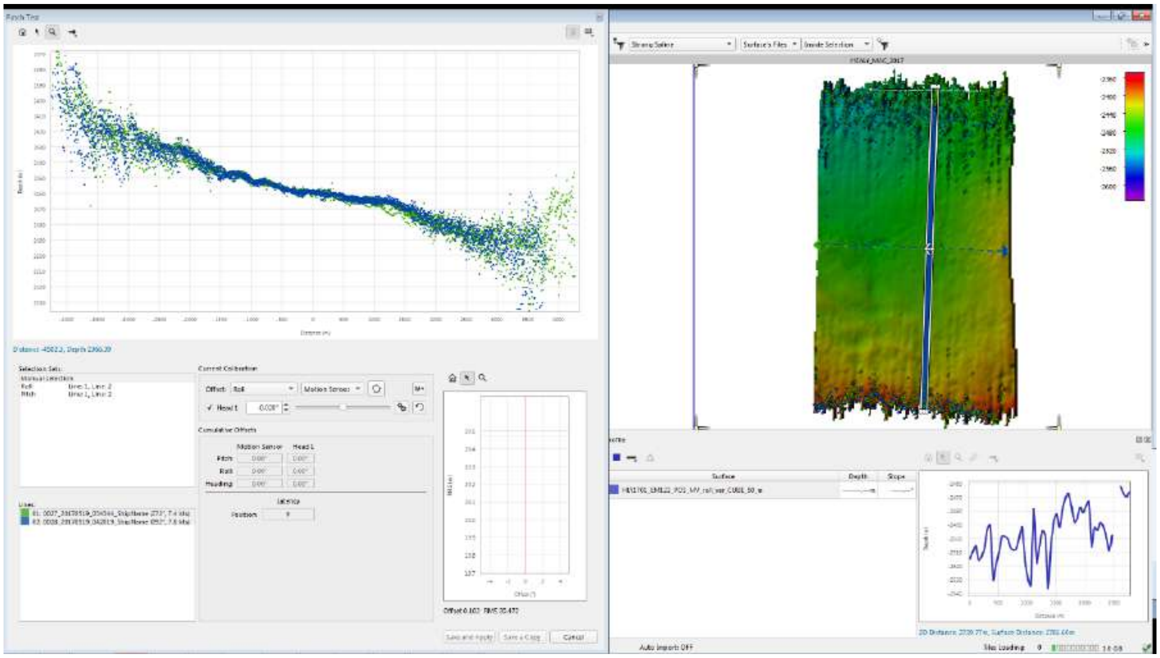


Figure 10. EM122 / POS MV roll verification in Qimera, applying an adjustment of -0.02° to the initial value of -0.20° for a final offset of -0.22° in SIS.

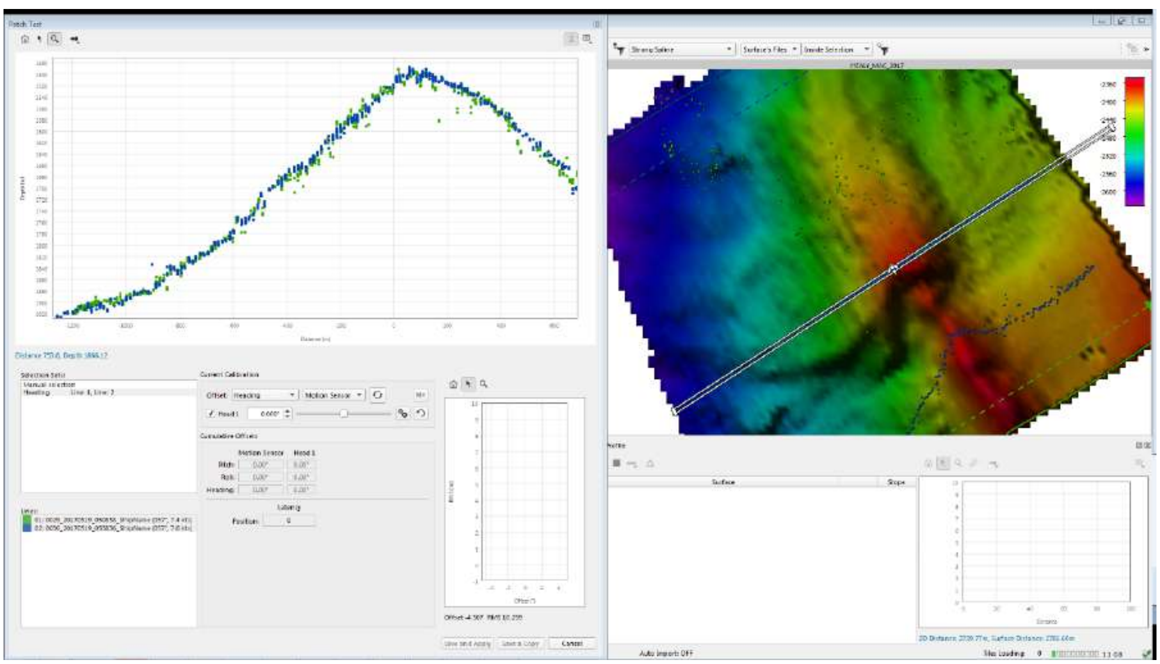


Figure 11. EM122 / POS MV yaw verification in Qimera, applying an adjustment of 0.00° to the initial value of 0.29° for a final offset of 0.29° in SIS.

Transducer and System Health

A full Built-In Self-Test (BIST) diagnostic routine was run through the SIS acquisition software prior to departure and also during HE17TA to verify that the EM122 was functioning correctly. Additionally, EM122 transmitter element impedance BIST tests were run through a telnet session at sea. These tests are useful in establishing a proxy for the health of the array elements, which have been observed among other installations to degrade with time under normal use. It is, however, important to note that the BIST impedance measurements do not provide a full characterization of transducer properties as a function of frequency (e.g., as performed by Kongsberg or Ifremer). That said, the BISTs do provide useful indicators of overall transducer health over their lifetime, especially when conducted on a routine basis. Figure 12 presents the EM122 TX channel impedance BIST results, showing one element (slot 9, channel 5) that appears to have low impedance outside the range of factory tolerances. Very small numbers of isolated elements outside the expected range of impedance do not have an appreciable effect on transmitter performance. Aside from this single outlier, the BIST levels shown do not indicate significant degradation for the transmitter array. However, after discussion with the Kongsberg representatives, the decrease in acoustic impendence at the elements at the edge of the modules (bordering channels 0, 11 and 12, 22 and 23, and 35), might indicate the start of potential water infiltration into the modules and should be monitored by conducting more RX channel BISTs in the future.

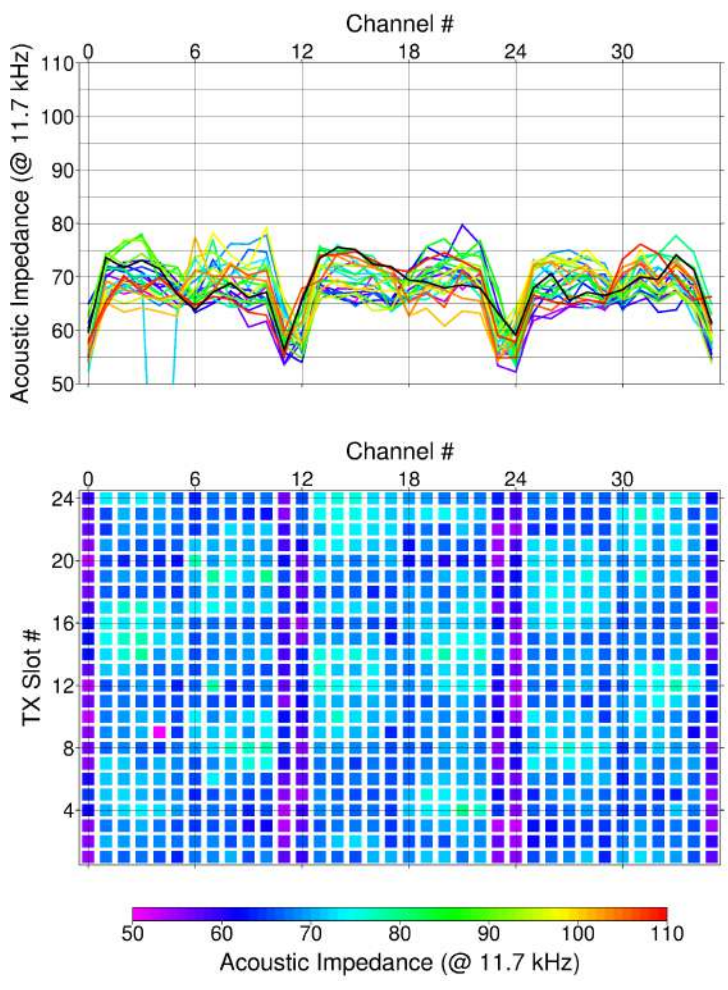


Figure 12. EM122 transmitter channel impedance, as measured by BIST through the system electronics.

Noise Levels

A potentially significant limiting factor in multibeam performance and swath coverage is the effect of ship self-noise, either mechanical or electrical, which confounds the system's ability to detect and track the acoustic signal returning from the seafloor. Gates Acoustic Services (GAS) performed a series of tests aboard *Healy* in 2014 to characterize vessel noise perceived by the EM122 receiver under different speeds and machinery configurations. In order to compare the results of the previous tests with the results collected during HE17TA, similar systems configurations were run to look for differences between 2014 and 2017. This was done after discussions with the *Healy* engineering crew to determine whether any new potential noise sources had been added to the ship since 2014. Data were collected using ten iterations of the RX Noise and RX Spectrum BIST functions in SIS for each machinery and speed test. A selection of noise test results summaries for the 2017 and 2014 tests are presented below in Figure 13-18, with individual test results included in Appendices 4-5.

Machinery Noise Testing

A selection of machinery configurations were tested while the vessel maintained steerageway with a shaft speed of 50 RPM. Machinery tests included the following configurations (with all other pumps secured) to better characterize individual systems' contributions to the vessel noise environment:

1. Boiler feed pumps
    a. Pump 1 ON, Pump 2 OFF
    b. Pump 1 OFF, Pump 2 ON
    c. Pump 1 OFF, Pump 2 OFF

2. Potable water pumps
    a. All pumps OFF

3. Main sea water pumps
    a. Pump 2 OFF

4. Aux generator pumps
    a. Primary cooling pump OFF
    b. Seawater cooling pump ON

5. Fire pumps
    a. Pump #2 ON

In general, the results show a relatively narrow distribution of noise levels as was seen in 2014 under most of the test configurations, though all levels are high relative to the noise levels observed on other mapping vessels. One notable machinery noise result from HE17TA is Fire Pump #2, which showed significantly elevated noise levels under operation. This is not considered to be a concern for routine mapping operations, given the emergency purpose and infrequent use of the pump.

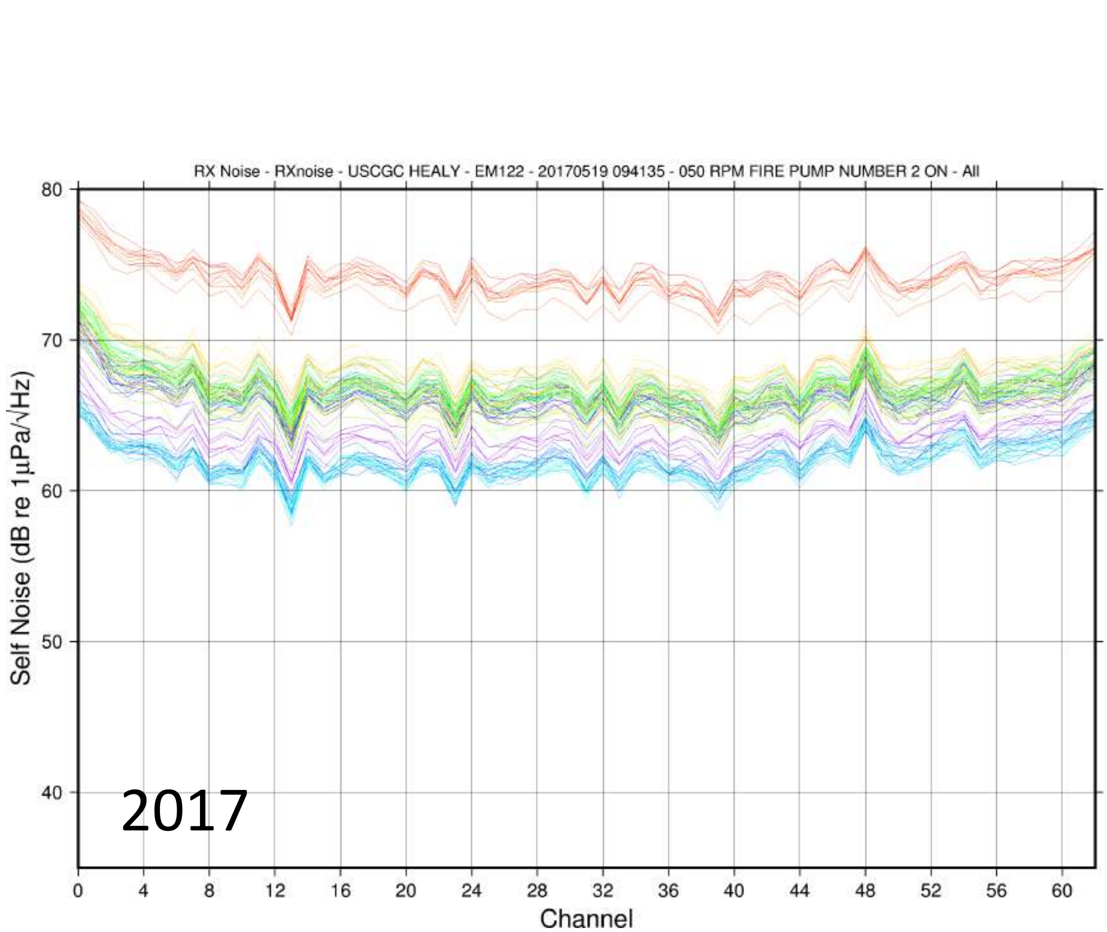


Figure 13. Noise levels perceived by the EM122 receiver under different machinery configurations. Individual test results are presented in Appendix 4.

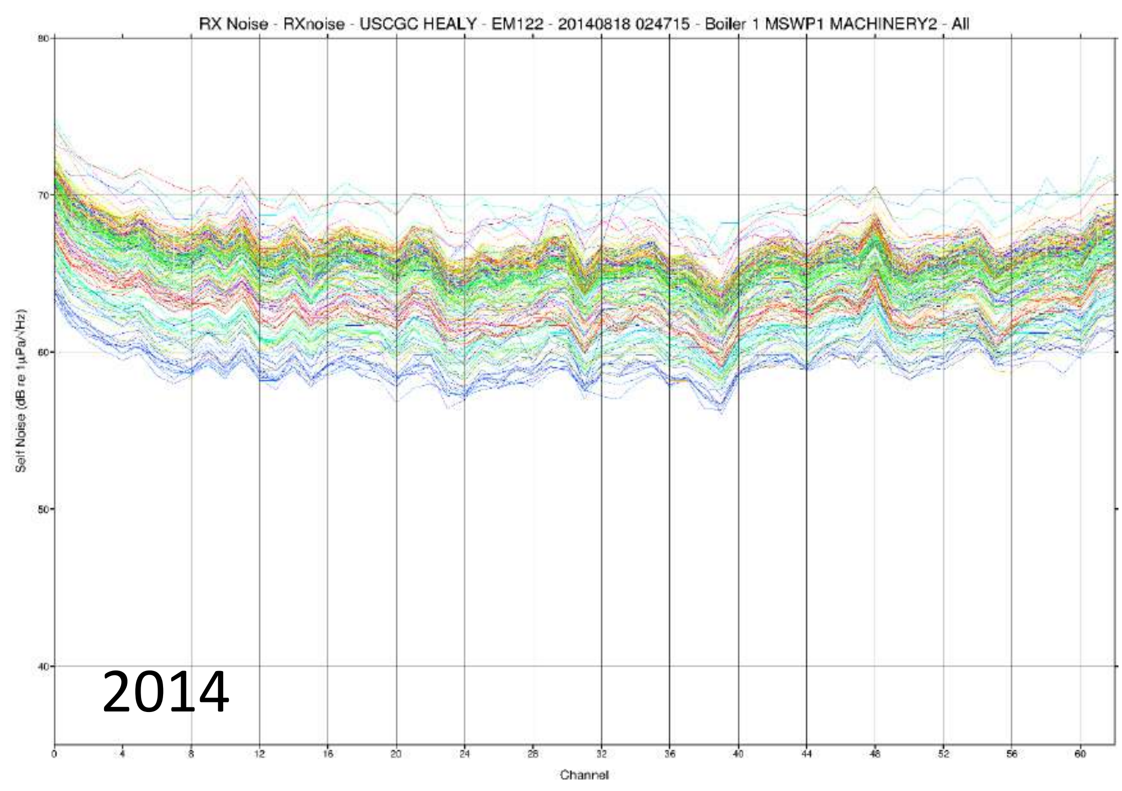


Figure 14. Noise levels perceived by the EM122 receiver under different machinery configurations. This data was collected in 2014 by Gates Acoustic. Individual test results are presented in Appendix 4.

Vessel Speed Noise Testing

A series of RX Noise and RX Spectrum BISTs were collected with the vessel operating at different speeds in order to characterize the combined effects of machinery (primarily main engine) and flow noise on the EM122 receiver noise environment. Figure 15 shows the trends in noise versus shaft speed; notably, the slope of the plot is relatively flat until 120 RPM, indicating the dominance of machinery noise over flow noise over most of the speed range. Figure 16 shows the results of the 2014 testing, which exhibits a comparable range of noise values at similar RPM. These data are also presented versus RX module in Figure 17 and 18. As noted during previous evaluations with Gates Acoustic Services, the *Healy* exhibits a higher noise profile in the frequency bands of interest for the EM122 compared to other vessels with similar systems, possibly negatively affecting swath coverage and accuracy performance.

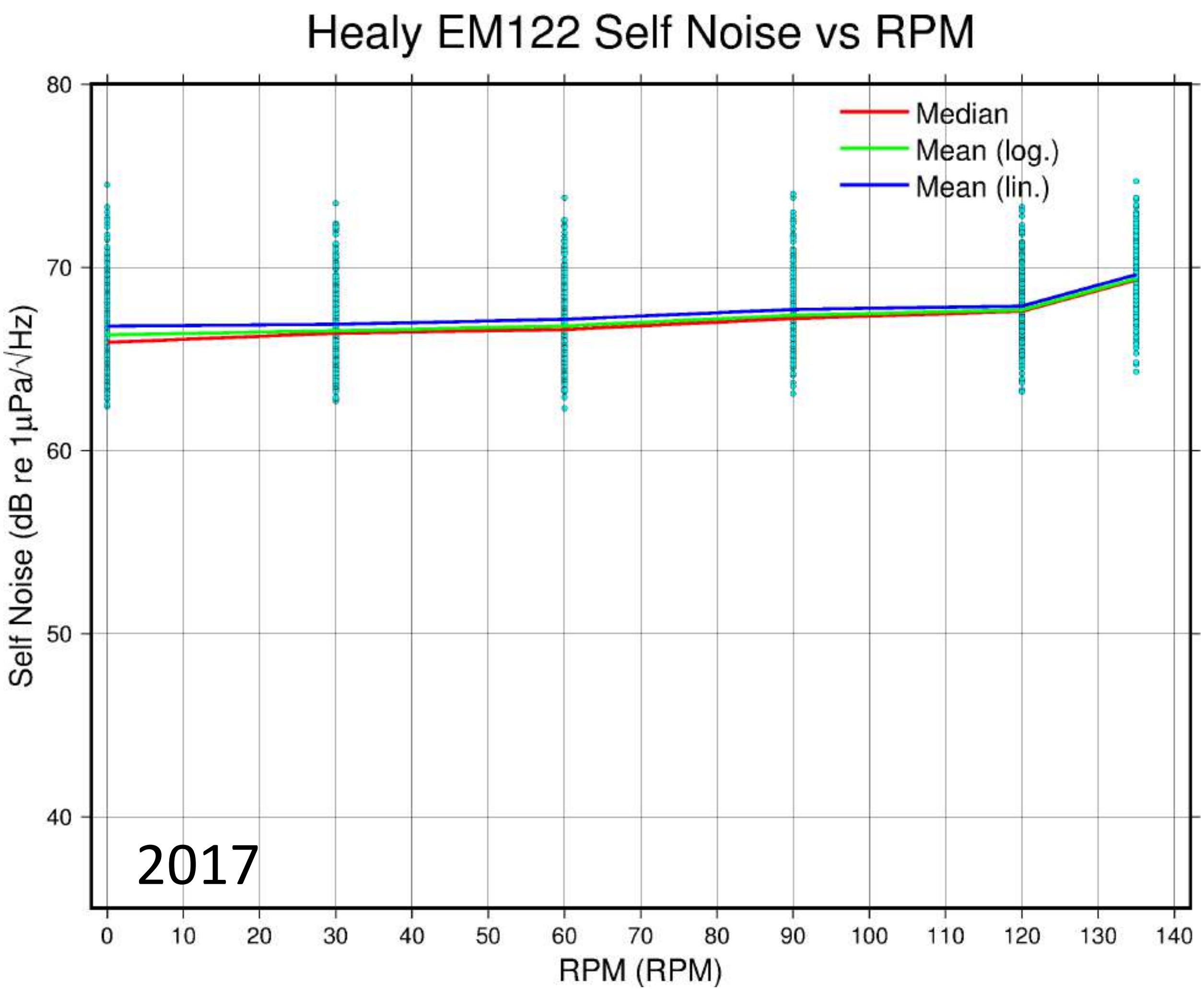


Figure 15. Mean and median EM122 RX Noise BIST results collected at multiple shaft speeds during HE17TA.

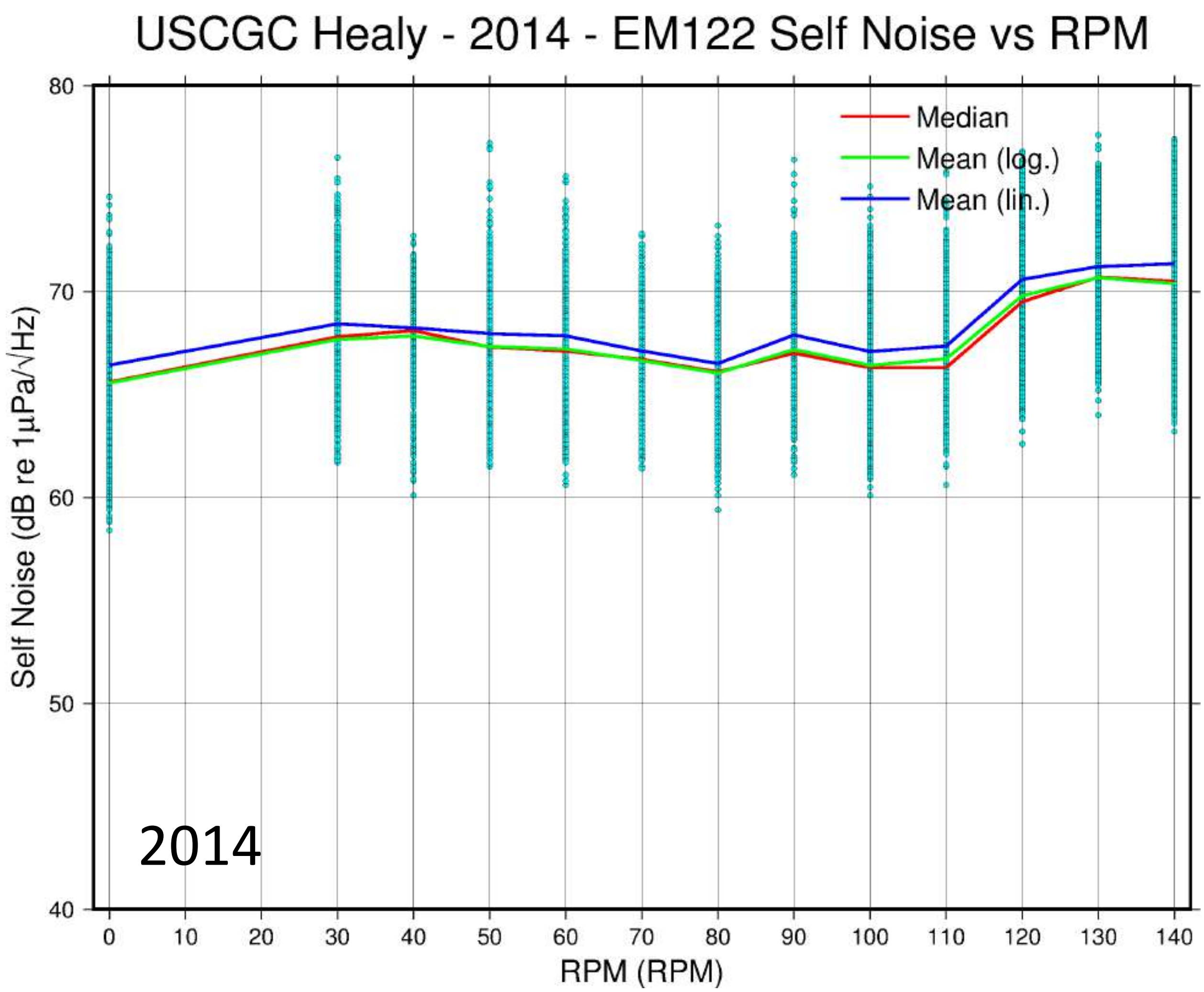


Figure 16. Mean and median EM122 RX Noise BIST results collected at multiple shaft speeds by Gates Acoustics in 2014.

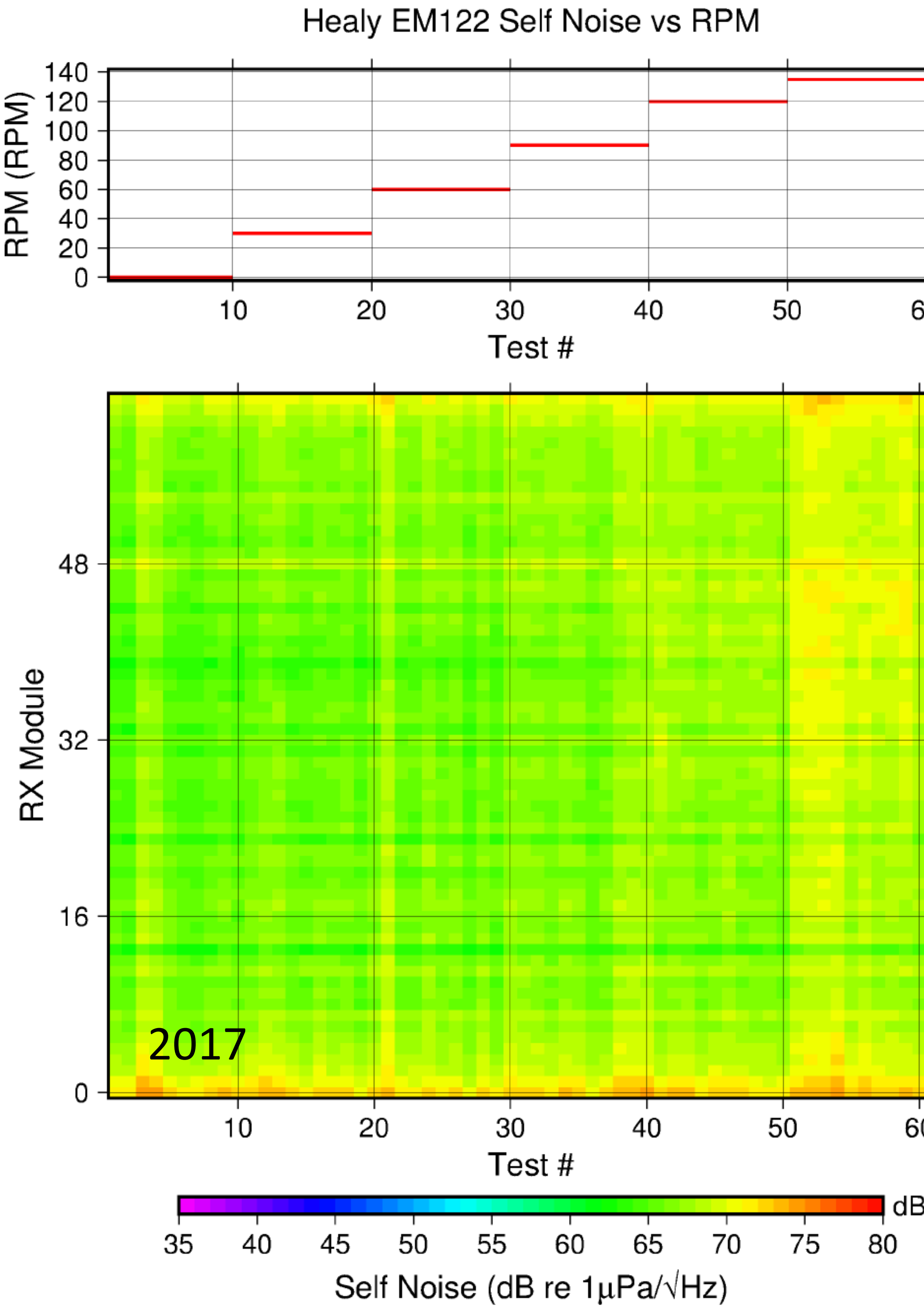


Figure 17. EM122 RX Noise results plotted versus RX module for each shaft speed test during HE17TA.

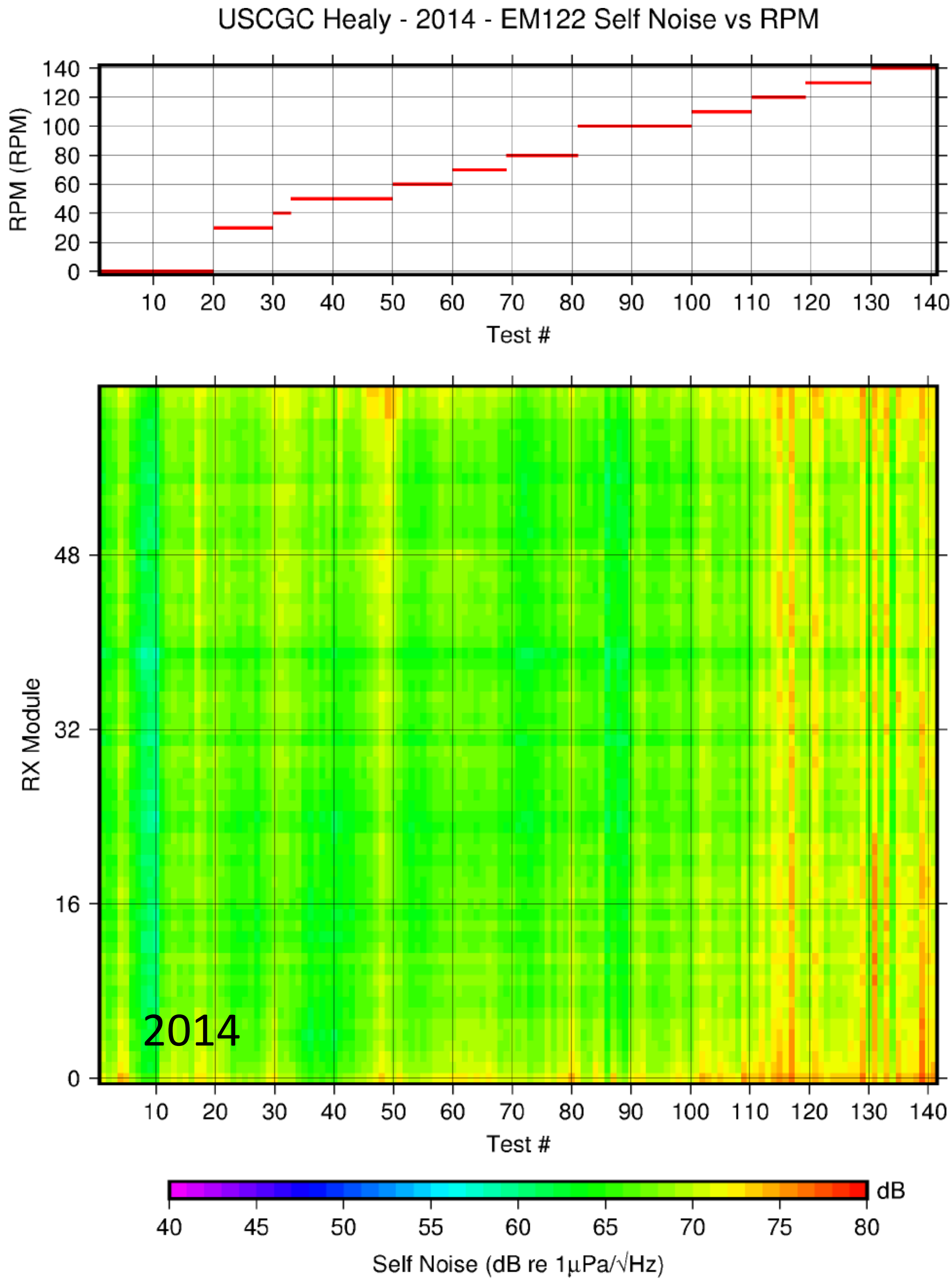


Figure 18. EM122 RX Noise results plotted versus RX module for each shaft speed test in 2014 by Gates Acoustics.

Accuracy Testing

Overview

After calibration, swath accuracy testing was conducted over an existing reference surface in depths of 2250-2550 m (adjacent to the calibration site). The reference surface was collected with the EM122 aboard R/V *Sally Ride* in July 2016, consisting of three survey lines with line lengths at least eight times the water depth (e.g., sufficient to ensure ample 'buffer' on each side for the maximum crossline swath width expected). Multiple sound speed profiles were collected throughout the reference surface survey in 2016 and prior to the accuracy crosslines during HE17TA.

All sounding data in the reference surfaces and accuracy cross lines were corrected for tide using the Oregon State University global tide model ([http://volkov.oce.orst.edu/tides/otps.html)](http://volkov.oce.orst.edu/tides/otps.html) and had outliers removed using QPS's Qimera software. Surfaces were then masked to exclude grid cells with low sounding density (depending on survey configuration). Furthermore, bathymetric slopes were computed for the reference surfaces and used as a mask to exclude areas of significant topography (>5°) from the crossline analysis (Figure 19).

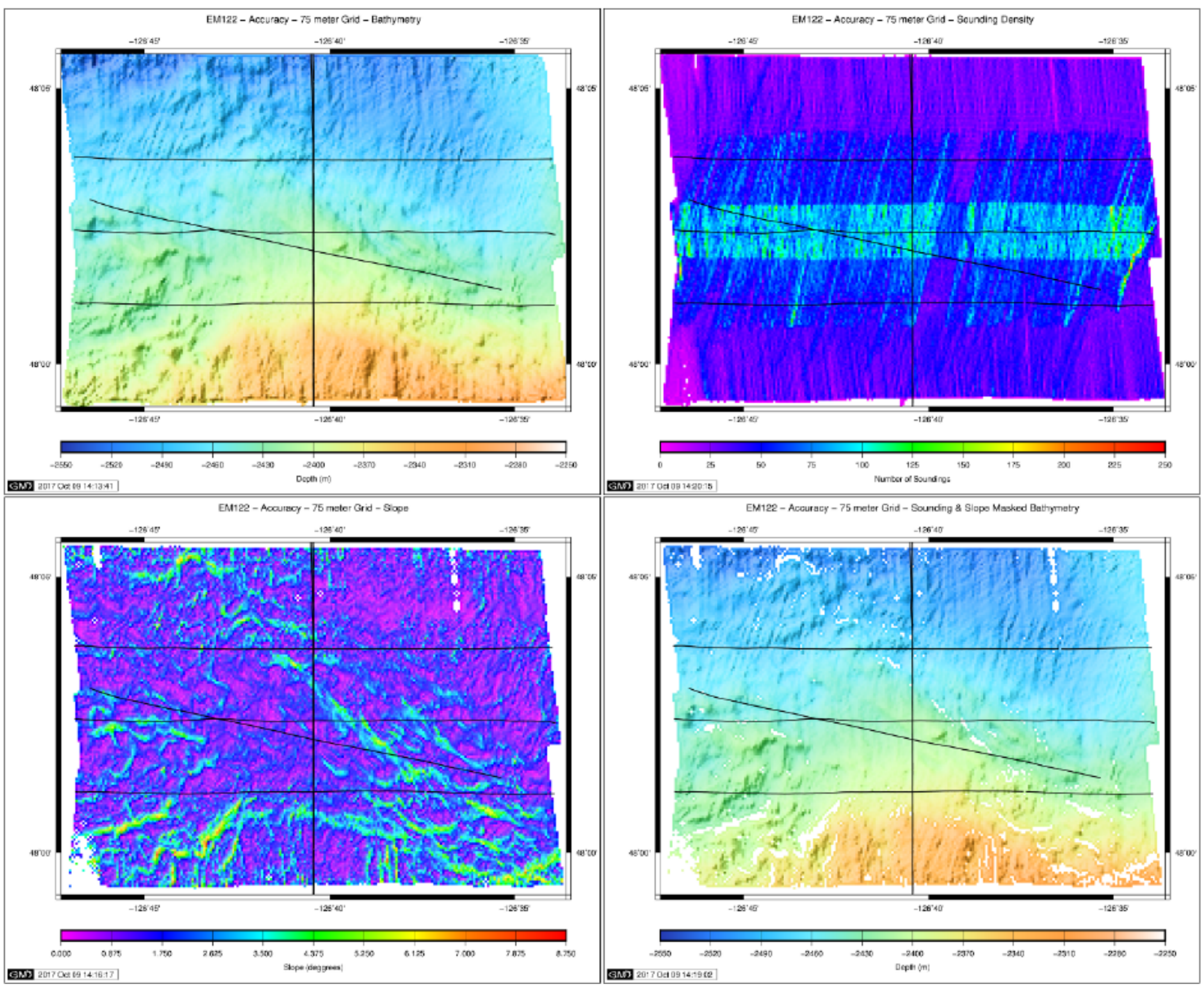


Figure 19. EM122 reference surface in depths of 2250-2550 m. Top left: all soundings gridded at 75 m cell size. Top right: sounding density. Bottom left: slopes of the reference surface after masking for grid cells with fewer than 10 soundings per grid cell. Bottom right: final reference surface after masking for sounding density and slopes greater than 5°.

All cross lines were run orthogonally to the reference surface main lines to reduce the effects of any biases compounding or cancelling across the swath. To reduce refraction artifacts, an XBT profile was collected, processed with SSP Manager, and loaded into SIS for each echosounder prior to cross line data collection for each settings configuration.

Major outliers (such as bottom detections at constant range across the swath due to interference) were removed from the accuracy analysis, as these would clearly be edited during normal bathymetric processing. For each configuration, the mean depth bias and depth bias standard deviations were computed as a percentage of water depth in 1° angular bins across the swath. EM122 configurations and accuracy results are presented below.

Accuracy Crossline Results

The EM122 reference surface and crossline settings represent an intended depth range and typical configuration for this system. Table 5 presents the settings used for accuracy crosslines at this site and Figure 20-21 present the accuracy results.

Table 5. EM122 accuracy cross line settings. DEEP mode uses a mixed FM/CW pulse form in this depth range when FM is enabled. Note that the swath width was limited to 66° based on coverage observed prior to accuracy testing.

Sector Coverage	**Cross Line Settings 1**
Max. angle (port)	66
Max. angle (sbtd)	66
Max. coverage (port)	30000
Max. coverage (stbd)	30000
Angular coverage	Auto
Beam spacing	HIDENS EQDIST

Depth Settings	**Cross Line Settings 1**
Force depth	n/a
Min. depth (m)	2200
Max. depth (m)	2650
Dual swath mode	DYNAMIC
Ping mode	DEEP
FM disable	*Unchecked (MIX)*

Transmit Control	**Cross Line Settings 1**
Pitch stabilization	ENABLED
Along. direction	0
Auto tilt	OFF
Yaw stab. mode	REL. MEAN HDG
Heading	n/a
Heading filter	MEDIUM
Min. swath dist.	0
Enable scanning	Off

As shown in Figure 20, the EM122 exhibited difficulty tracking bottom near nadir and around +/- 15°, near TX sector boundaries, leading to significantly higher sounding standard deviations compared to trends across the rest of the swath. These bottom tracking issues likely result in part from the vessel's relatively high noise levels. Outlier sounding data near nadir and the TX sector transitions were removed (Figure 21) in order to mitigate the effects of major bottom detection errors and provide a clearer assessment of soundings across the swath that would typically be retained for routine bathymetry processing.

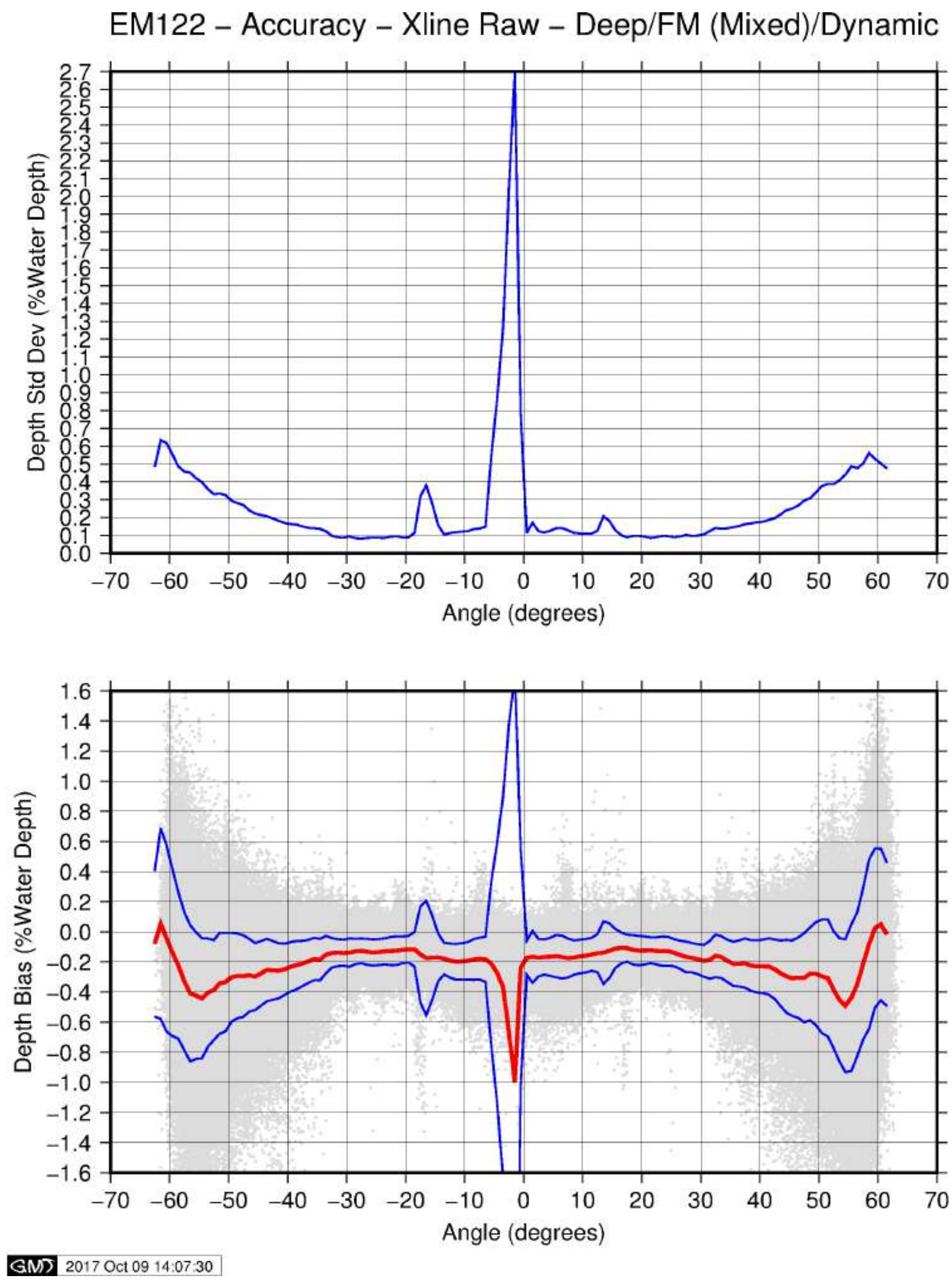


Figure 20. EM122 accuracy crossline results using all data (no outlier removal).

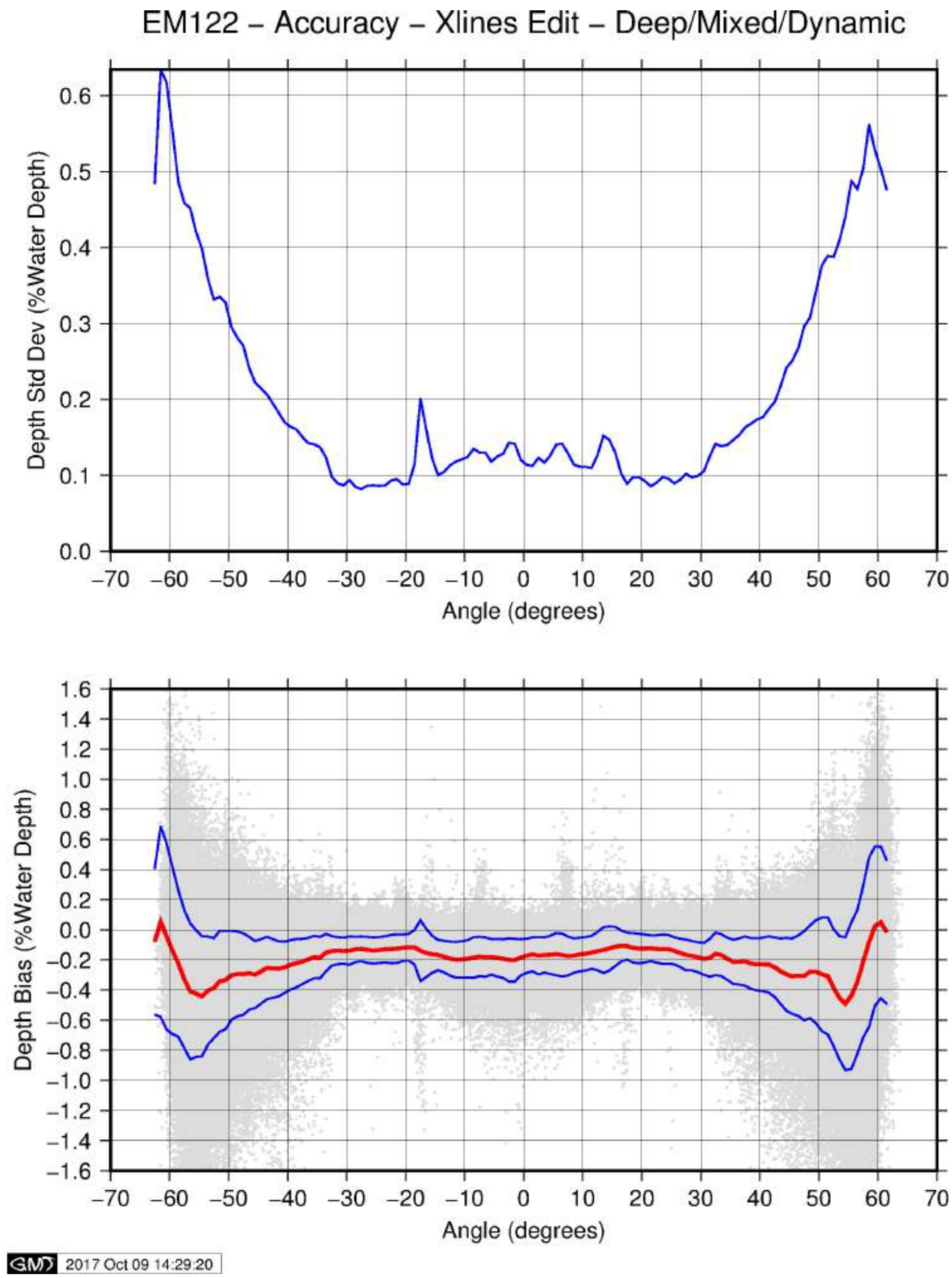


Figure 21. EM122 accuracy crossline results after removal of bottom-tracking artifacts and outliers near nadir (soundings that would typically be removed during routine bathymetry processing).

In general, these results show an expected increase in depth bias standard deviation toward outer beam angles, due to reduced SNR stemming from larger ranges and shallower angles of incidence on the seafloor. The shape of the accuracy curve falls within +/- 0.2% from its mean out to 50-55°, which is within the range of accuracy variability seen among other EM122 installations. However, the mean bias of approximately -0.2% to -0.4% across the swath requires additional scrutiny. Possible complicating factors include tide model error, elevated noise levels, sea state and bubble interference, attenuation and reduced SNR due to the ice protection window, and uncertainty regarding waterline. The accuracy test results translate to a consistent, shoal depth bias of roughly 5-10 m at the reference site.

Aside from the nonzero mean bias, both sides of the swath showed similar behavior with increasing beam angle, suggesting no systemic issues in the receiver hardware or attitude configuration that could lead to asymmetrical accuracy results. Data beyond 60° was sparse, representing a reduction of 5-10° on each side of the swath compared to typical EM122 coverage in this depth range (see swath coverage analysis below).

Swath Coverage Testing

Overview

The noise and impedance evaluations help in assessing some of the primary factors controlling the swath coverage performance of a multibeam sonar. The net effects of these and other factors on achievable swath coverage may be assessed over a range of depths at various points throughout the life cycle of the echosounder.

This is sometimes a straightforward comparison; for example, when a ship always returns to the same home port, it is possible to build up a long time series of coverage performance as it leaves and returns to port over the same track line. Elsewhere, coverage can be compared from differing areas of similar water depths; however, one must recall that environmental conditions can affect the achievable coverage and caution must be exercised when interpreting or comparing results from areas with different oceanographic regimes, seafloor compositions, and terrain features.

To establish a baseline for swath coverage performance, transits during HE17TA were run in an orientation as close to perpendicular to the depth contours as feasible, given the time constraints of the cruise and test locations. The EM122 was run in automatic ping modes during transits, allowing the system to choose its appropriate transmission mode based on observed depths while traversing up and down the continental slope. Other runtime parameters were set to maximum angular coverage and to maximum swath width. Figure 22 presents the tracklines and effective depth ranges included for swath coverage assessment.

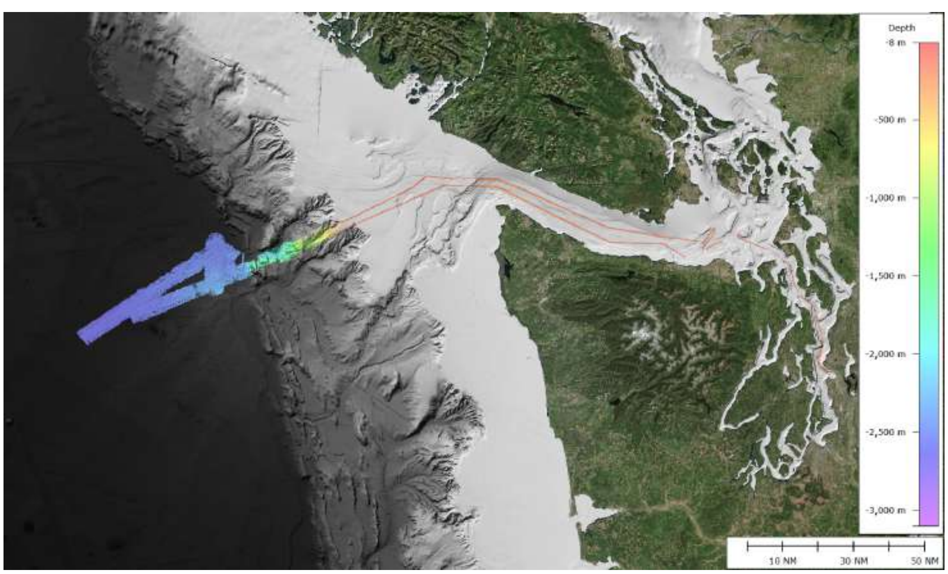


Figure 22. Track lines for EM122 data contributing to the swath coverage assessment in depths of ~15-2600 m.

EM122 Swath Coverage

The EM122 swath coverage over the depth ranges surveyed during HE17TA (Figure 23) shows less than expected performance, maintaining swath width of roughly five times water depth (5 x w.d.) to ~750 m and reducing to 4 times water depths at depths of ~2600 m. Interestingly, the 2012 data consistently shows wider swath widths for data collected shallower than 1500 m (grey points). While some of this may be attributed to difference in bottom type, sea conditions, and other environmental factors, between the 2012 and 2017 data collections sites, it is concerning that there is such a significant difference between the two years' swath performance. Additional data has been collected by the *Healy* in deeper waters and this report will be amended when that data has been analyzed.

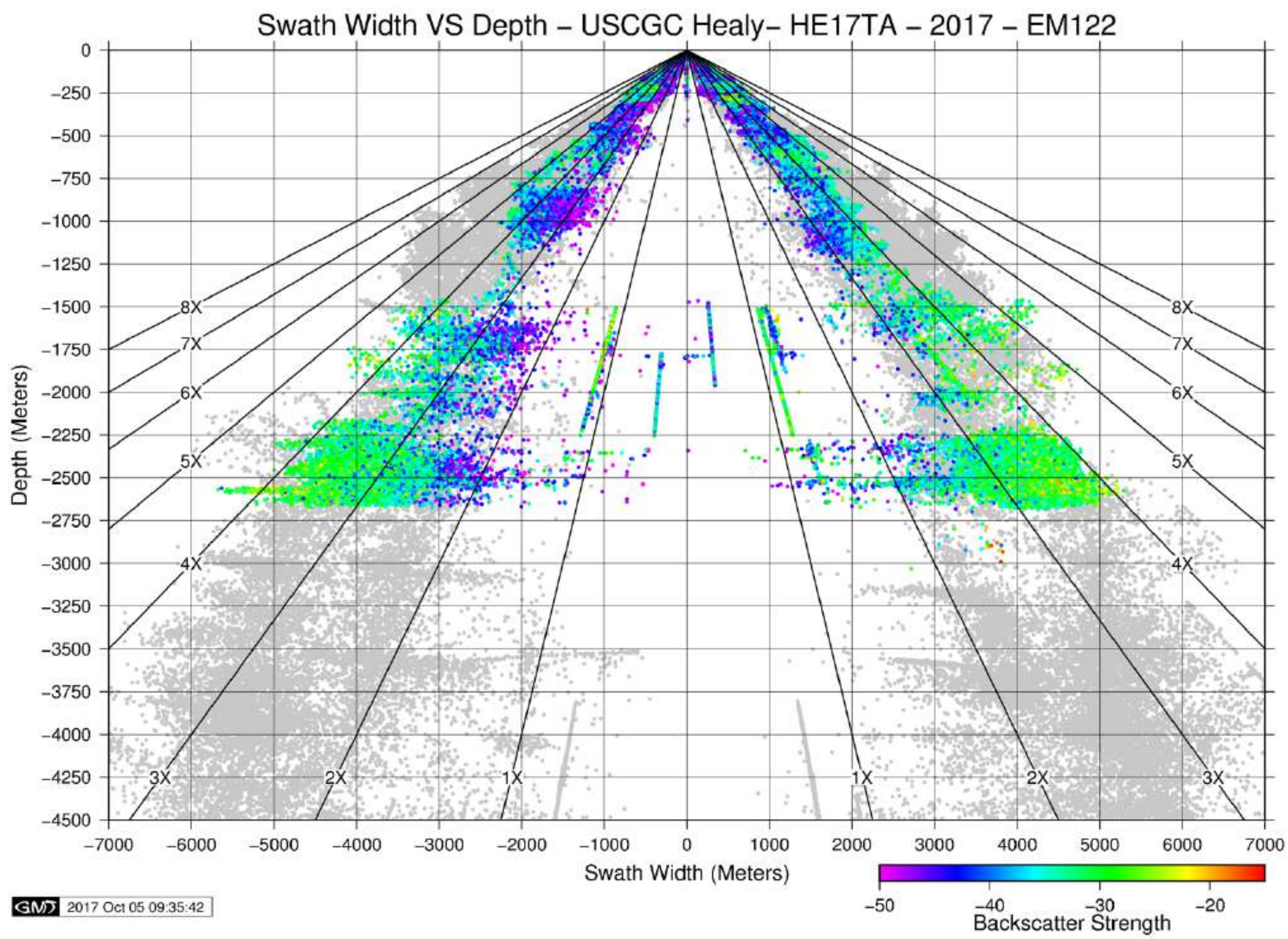


Figure 23. EM122 swath coverage performance during HE17TA (colored by backscatter strength, dB) as compared to data collected in 2012 during the system's initial shipboard acceptance testing (grey points)).

Undetermined Transit Noise Issues

Following completion of the deep water accuracy test, the EM122 was secured in order for the *Healy* to conduct non-mapping activities. Once these undertakings were completed, the ship began the final return transit to Seattle. During this transit, the plan was to collect additional swath performance data up the continental slope in order to better define the swath extinction curve. However, when the data collection began it was noticed that the quality of the data was severely impacted (Figure 24 and 25) with outliers predominantly on the starboard side, with excursions greater than 700 meters. As the ship approached the slope break, the speed was reduced and the apparent source of interference vanished, after which data quality returned to normal. We contacted the engineering staff and attempted to determine what changes had been made in the plant configuration that may have caused such a significant reduction in data quality, but were unable to determine what had been changed. We did question if the bridge 12 kHz sonar was active, but were informed at the time that it was not. Further investigation is warranted to determine if this issue, which unfortunately occurred at the end of the cruise, was related to an engineering configuration change or was from another sonar causing interference on the EM122.

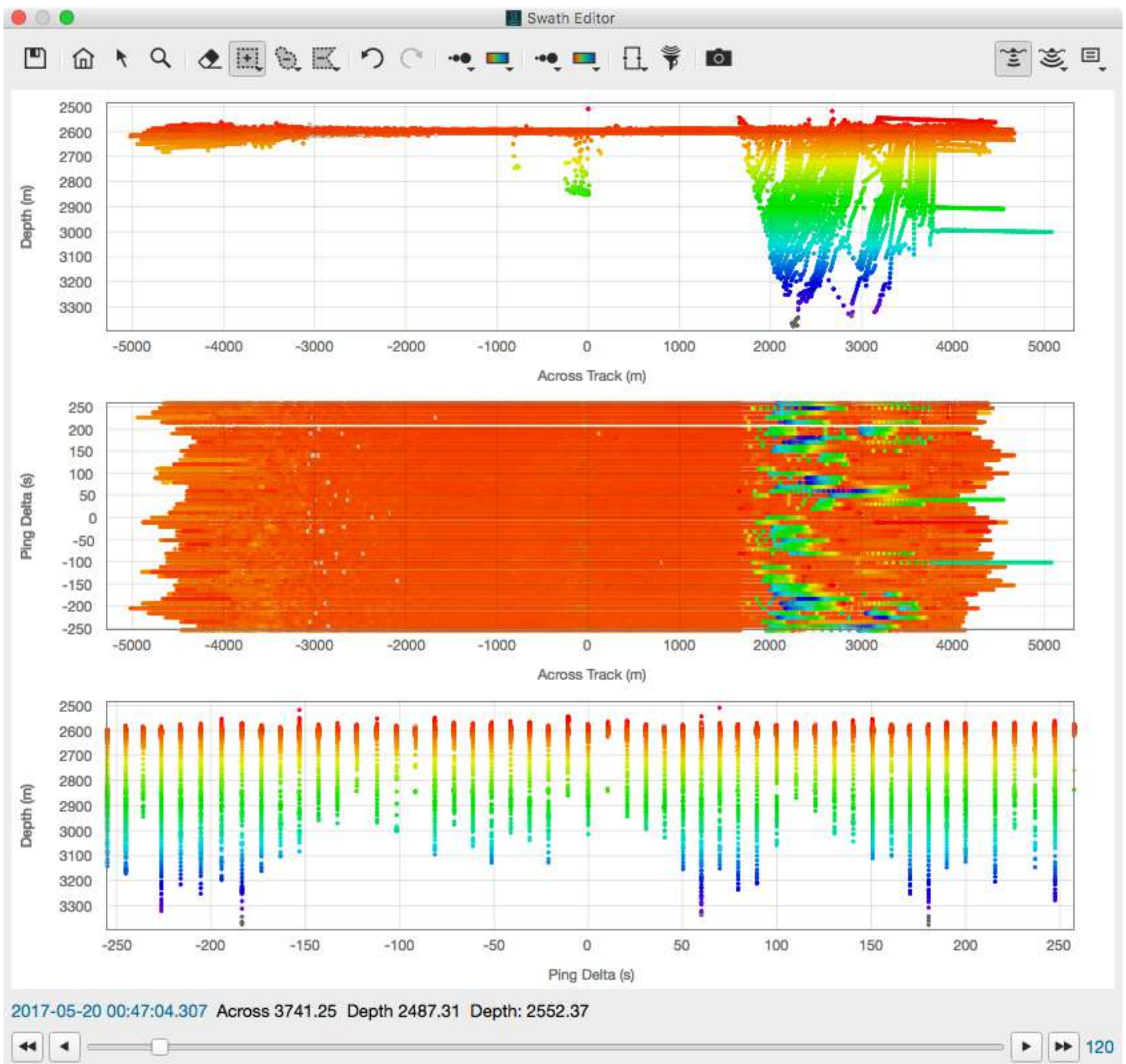


Figure 24. Example of noise seen in transit.

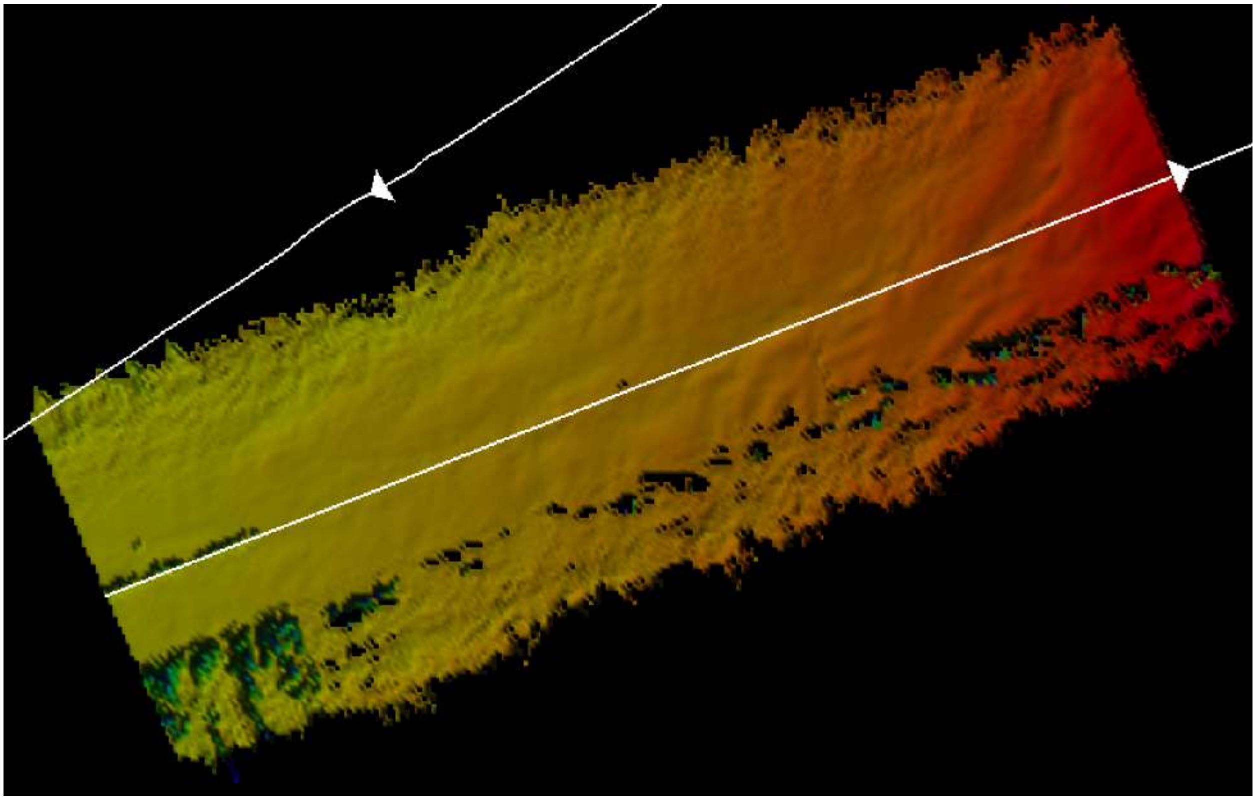


Figure 25. Results of gridding data with undetermined noise.

Principal Findings & Recommendations

1. Review of the available vessel survey documentation and existing configuration revealed small discrepancies in array installation angles (namely, sign conventions) that were corrected prior to HE17TA data collection.

2. Calibrations of the EM122 with the Seapath and POS MV presented no extraordinary or unexpected challenges, and the MAC has a high degree of confidence in the results. Magnitudes of the angular adjustments applied in SIS fall within normal ranges seen aboard other installations. No obvious signs of latency were observed during HE17TA.

3. Any modification to the Seapath MRU, POS MV IMU, or antennas should be carefully documented and followed immediately by another calibration. The MAC can assist with these steps as requested.

4. The new bridge echosounder operates at 12 kHz, the same frequency that the EM122 operates at, and should not be used when quality multibeam data needs to be collected due to interference between the two systems.

5. Swath accuracy testing showed the expected behavior of standard deviation across the swath, but revealed a mean bias of -0.2% to -0.4% of water depth. Additional scrutiny is required.

6. The EM122 produced a large number of seafloor penetration outliers near nadir during the reference surface crosslines. This is likely a consequence of elevated noise levels, as this artifact has not been noted so severely on other EM122 installations at the same site.

7. Vessel noise levels are higher than seen aboard other EM122-equipped ships, which likely contributes to reduced swath width and increased standard deviation of soundings. Any reduction in vessel noise (perceived by the EM122 receiver) would have multiple positive impacts on the multibeam data and mapping operations. That said, there are no significant changes in the noise characteristics of the ship from those observed in 2014 by Gates Acoustics.

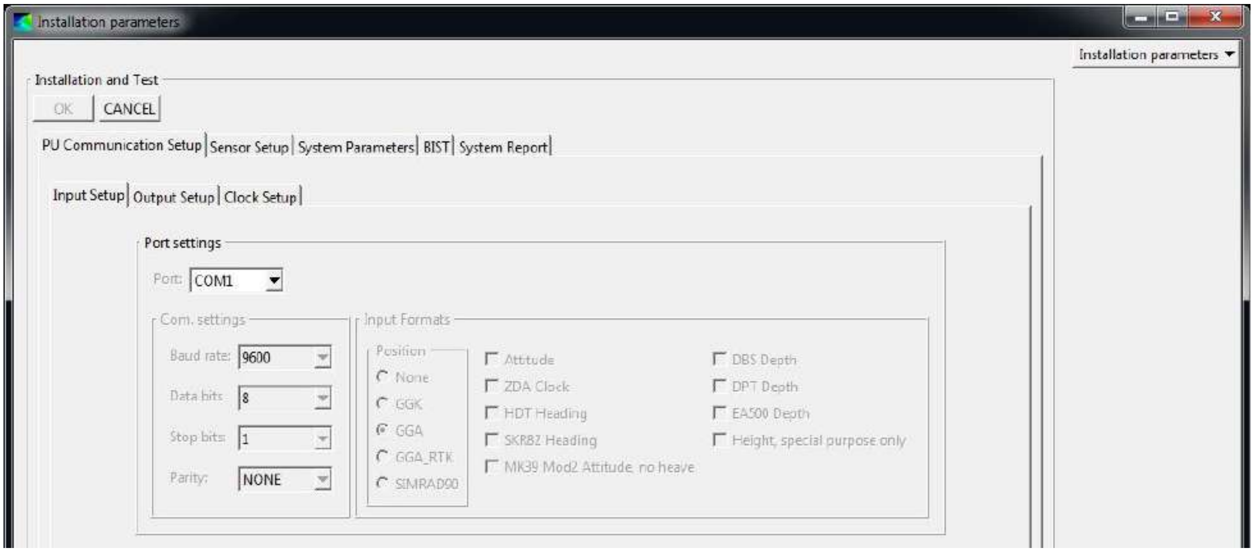
8. The TX transducer element impedance values, as measured through the transceivers using BIST routines, show acceptable levels across the array with only one element appearing to fall outside the expected range (low impedance). These data provide an important proxy for baseline EM122 transmitter array health and should be examined annually (at a minimum) to identify possible degradation as early as possible. There is a hint that potential water infiltration is occurring at the edges of the array and this should be checked routinely with additional TX channel BISTs.

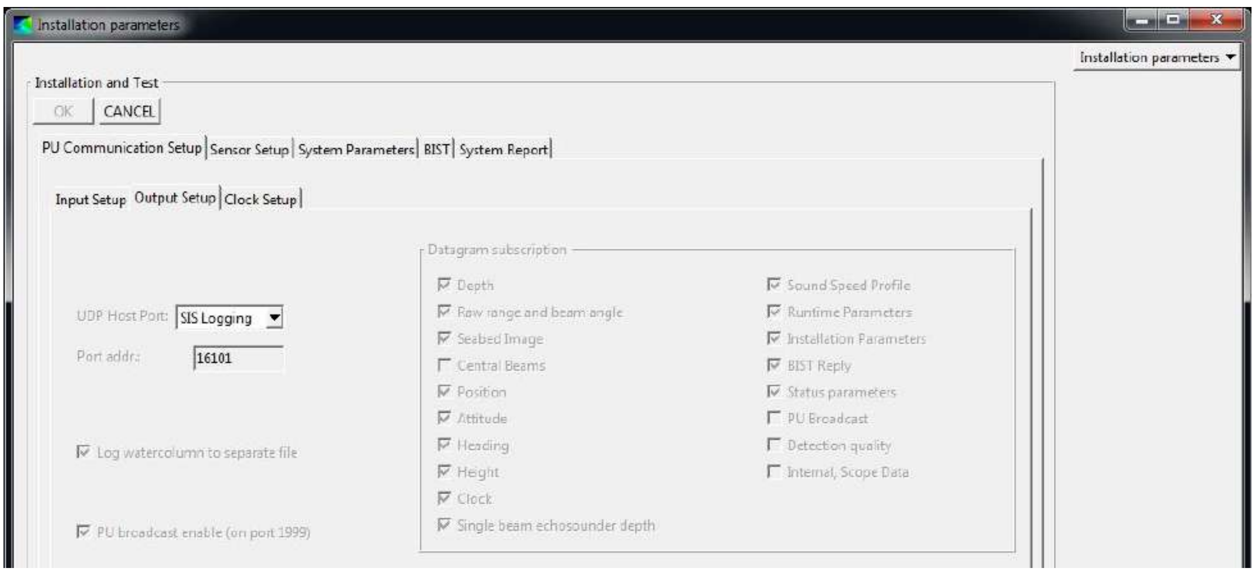
9. Deep water data has been collected for swath performance testing and will be analyzed and amended to the report as soon as possible.

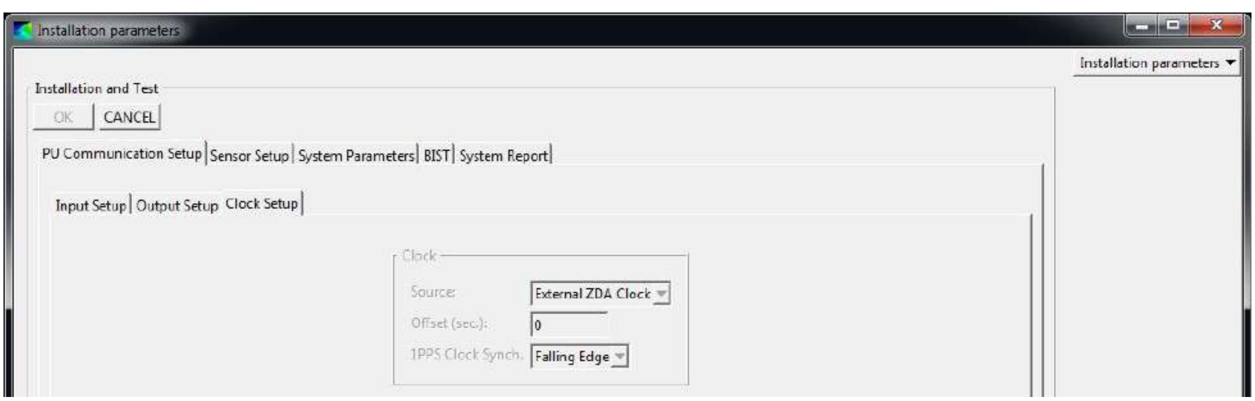
10. The survey reports documenting system offsets and angles should be maintained and updated carefully whenever any sensor is modified, in tandem with documentation for future patch tests and SIS modifications. Screenshots of all sensor configurations (e.g., Appendices 1-3) should be collected at the start of each mapping leg. These reports, coupled with routine text file exports of the SIS PU Parameters, are extremely valuable for tracking the system geometry and verifying the applied offsets in survey data over the service lives of the EM122, Seapath, and POS MV.

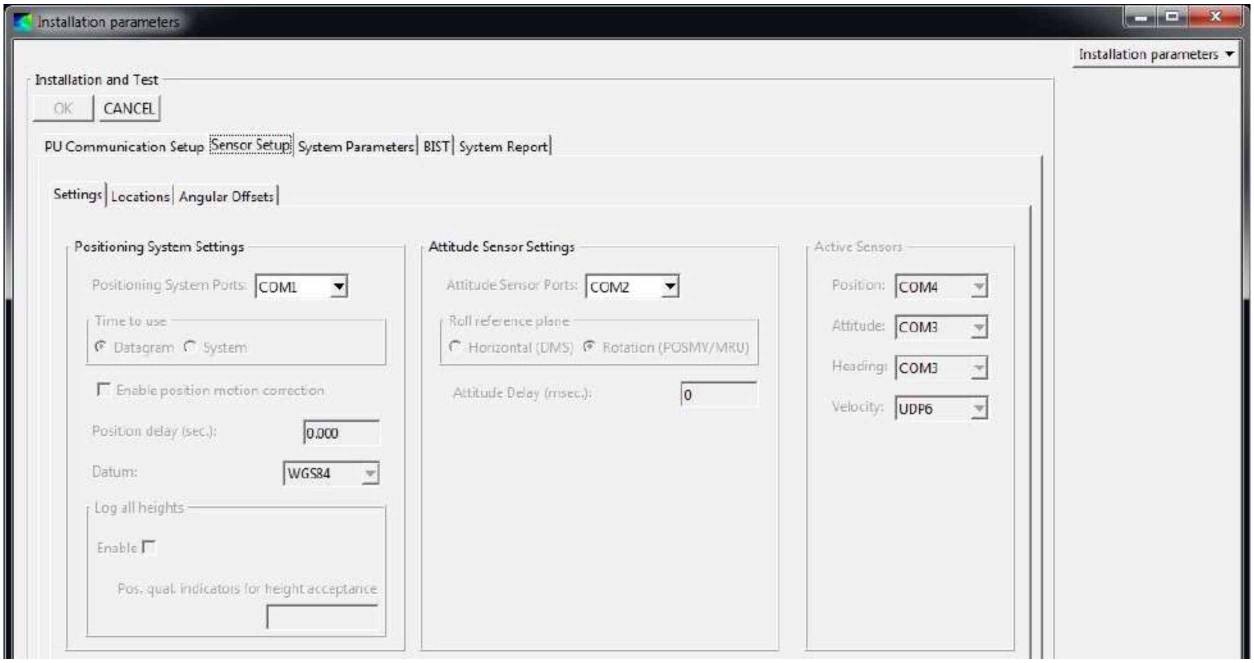
11. During the final transit returning to port the ship's engineering plant was configured in a way that caused significant degradation in the quality of the EM122 data (mostly on the starboard side of the swath). In talking with the engineering staff, we were unable to determine what change was made; once the ship slowed down, the noise disappeared and data quality returned to normal. Determining the engineering change that was made during this period should be considered a priority, as quality EM122 data cannot be collected when the ship is underway with that configuration.

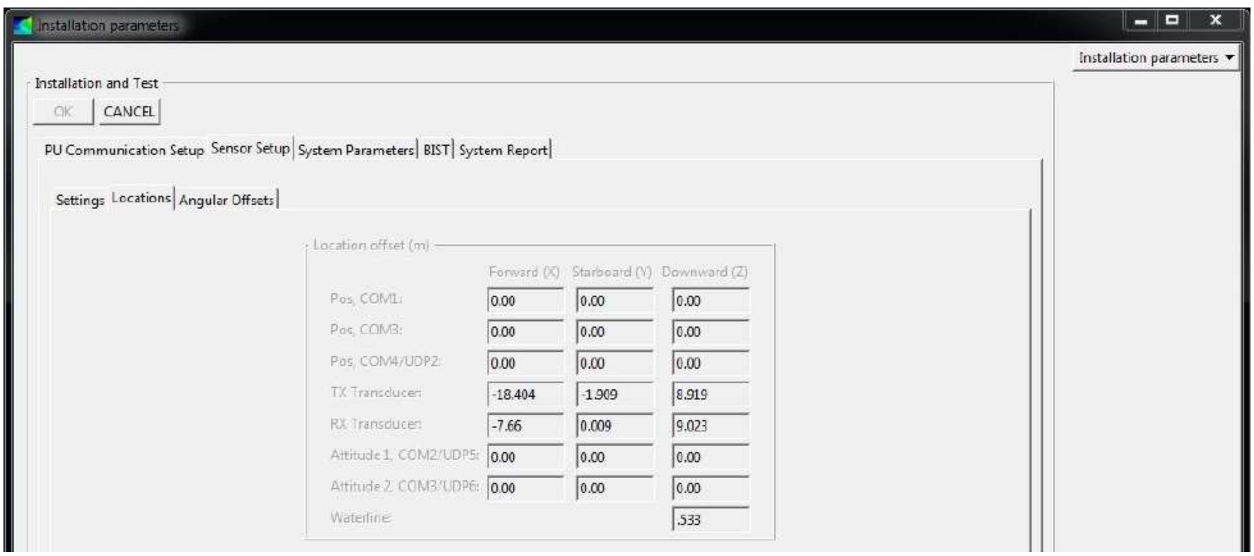
Appendix 1: EM122 Configuration

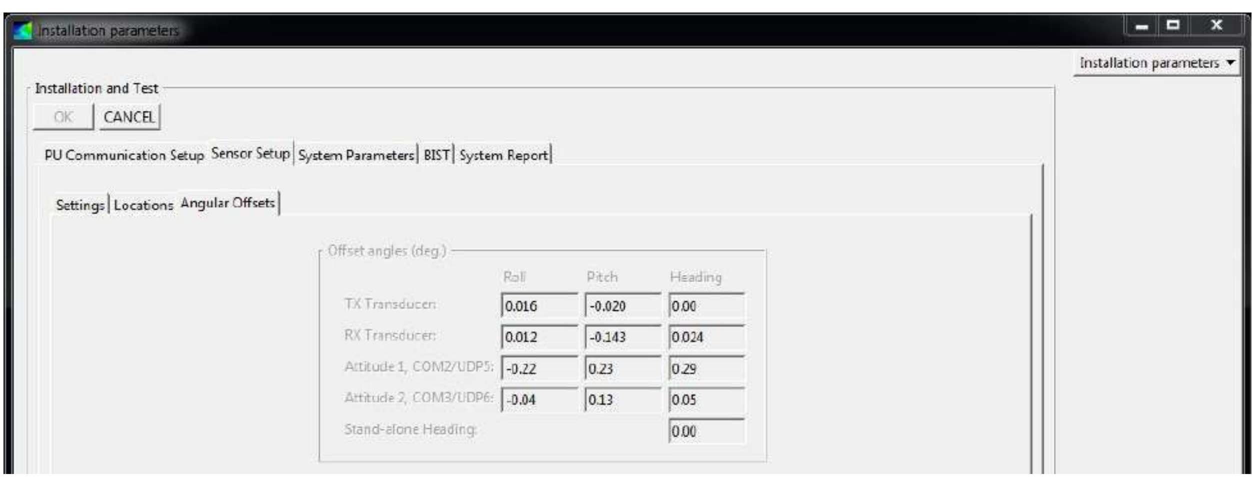


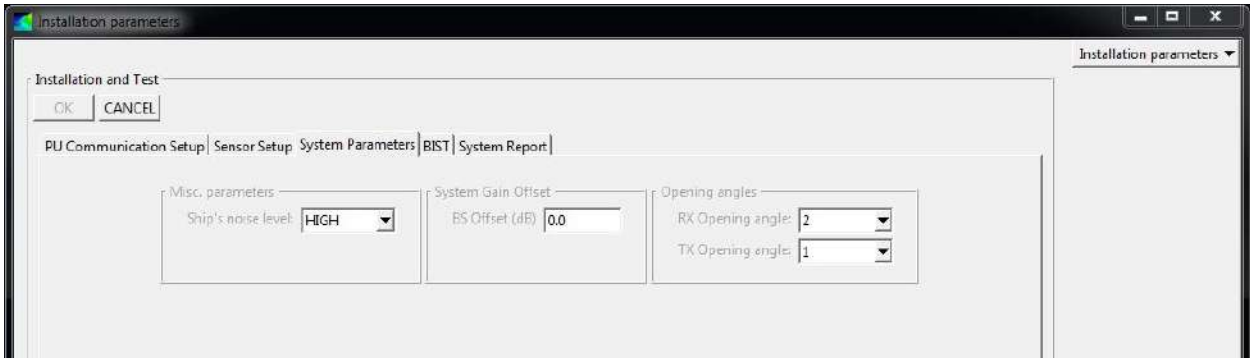




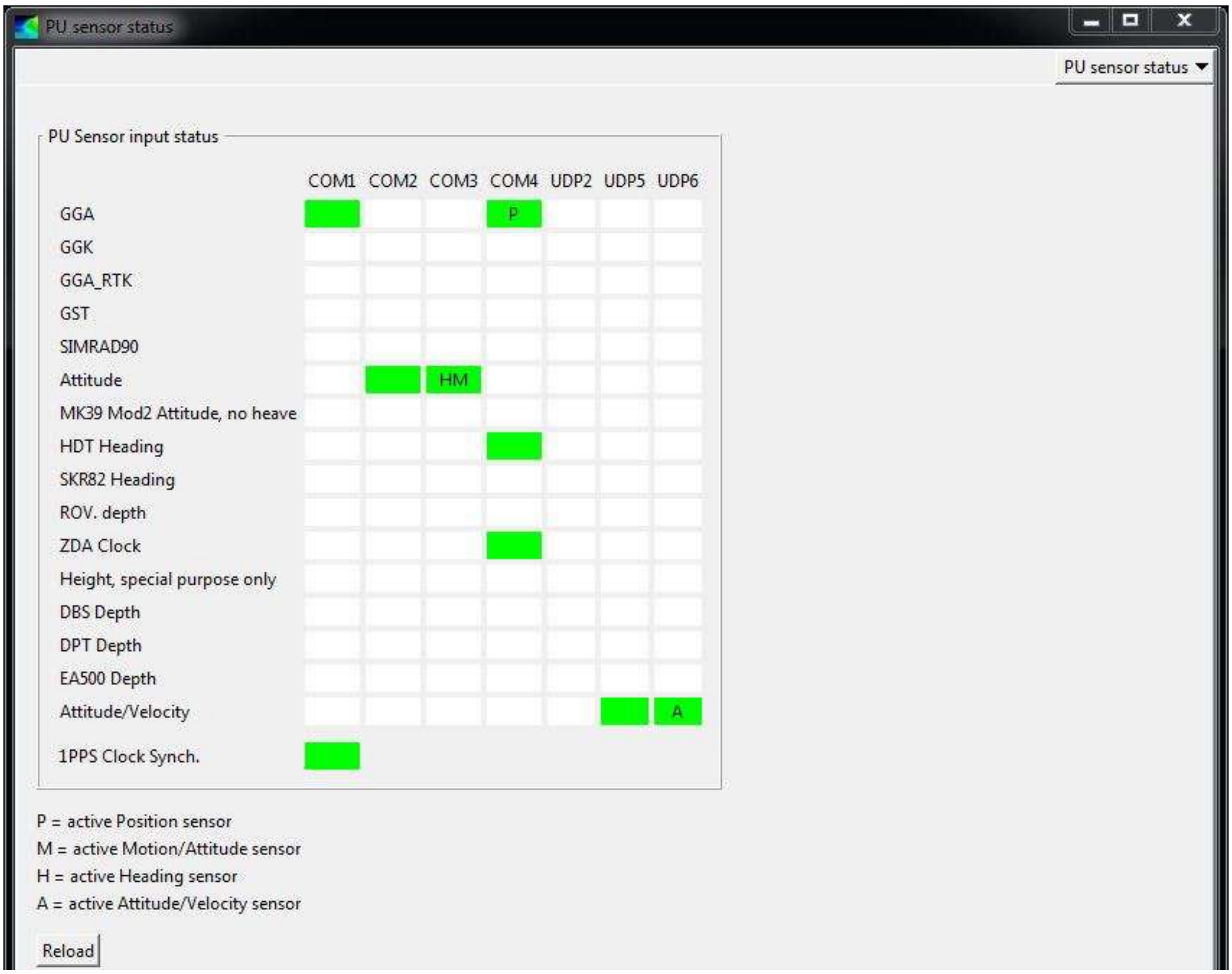

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
Positioning System Settings
Positioning System Ports:
COM1
Time to use
Datagram
System
Enable position motion correction
Position delay (sec.):
0.000
Datum:
WGS84
Log all heights
Enable
Pos. qual. indicators for height acceptance
Attitude Sensor Settings
Attitude Sensor Ports:
COM2
Roll reference plane
Horizontal (DMS)
Rotation (POSMV/MRU)
Attitude Delay (msec.):
0
Active Sensors
Position:
COM4
Attitude:
COM3
Heading:
COM3
Velocity:
UDP6


Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
Location offset (m)
Forward (X)
Starboard (Y)
Downward (Z)
Pos, COM1:
0.00
0.00
0.00
Pos, COM3:
0.00
0.00
0.00
Pos, COM4/UDP2:
0.00
0.00
0.00
TX Transducer:
-18.404
-1.909
8.919
RX Transducer:
-7.66
0.009
9.023
Attitude 1, COM2/UDP5:
0.00
0.00
0.00
Attitude 2, COM3/UDP6:
0.00
0.00
0.00
Waterline:
.533

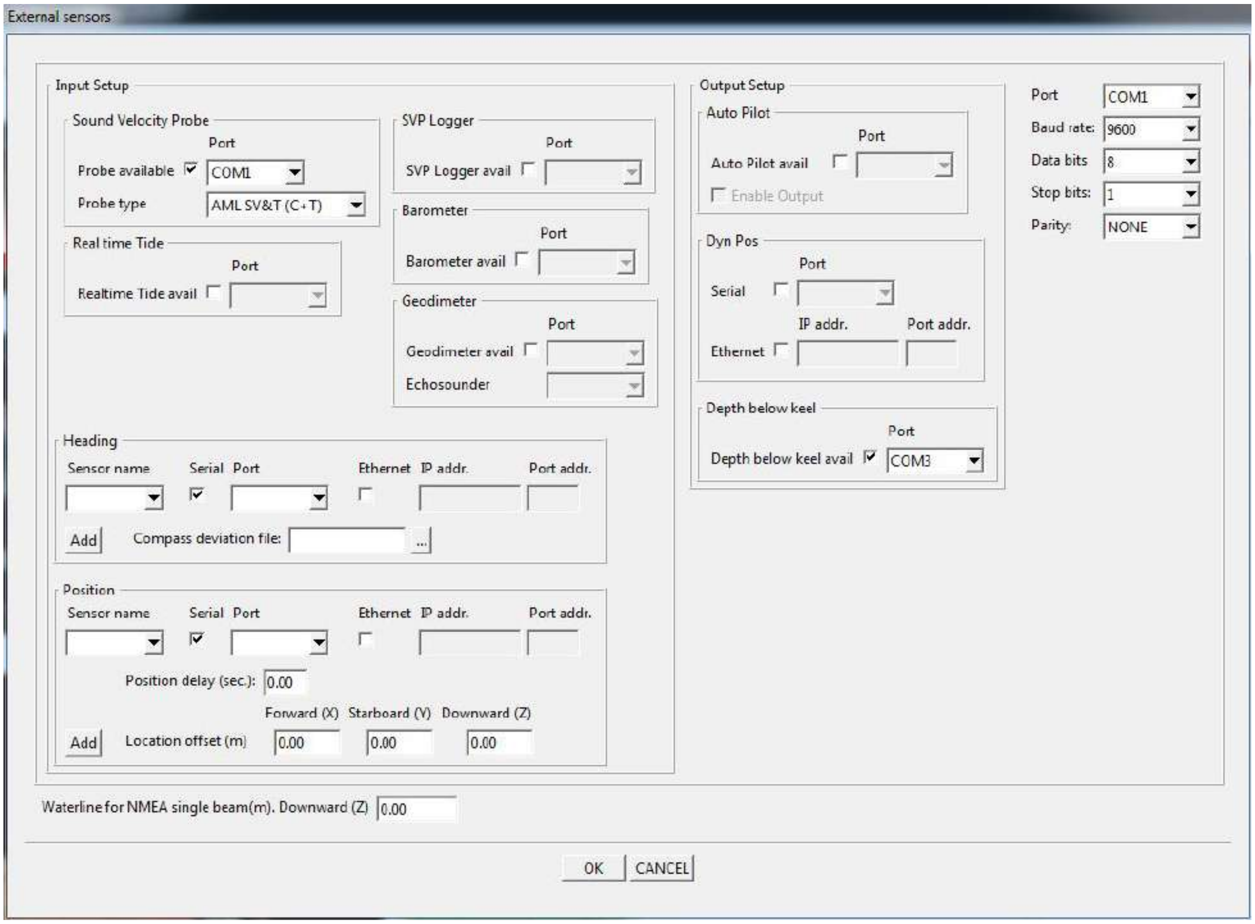

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
Offset angles (deg.)
Roll
Pitch
Heading
TX Transducer:
0.016
-0.020
0.00
RX Transducer:
0.012
-0.143
0.024
Attitude 1, COM2/UDP5:
-0.22
0.23
0.29
Attitude 2, COM3/UDP6:
-0.04
0.13
0.05
Stand-alone Heading:
0.00

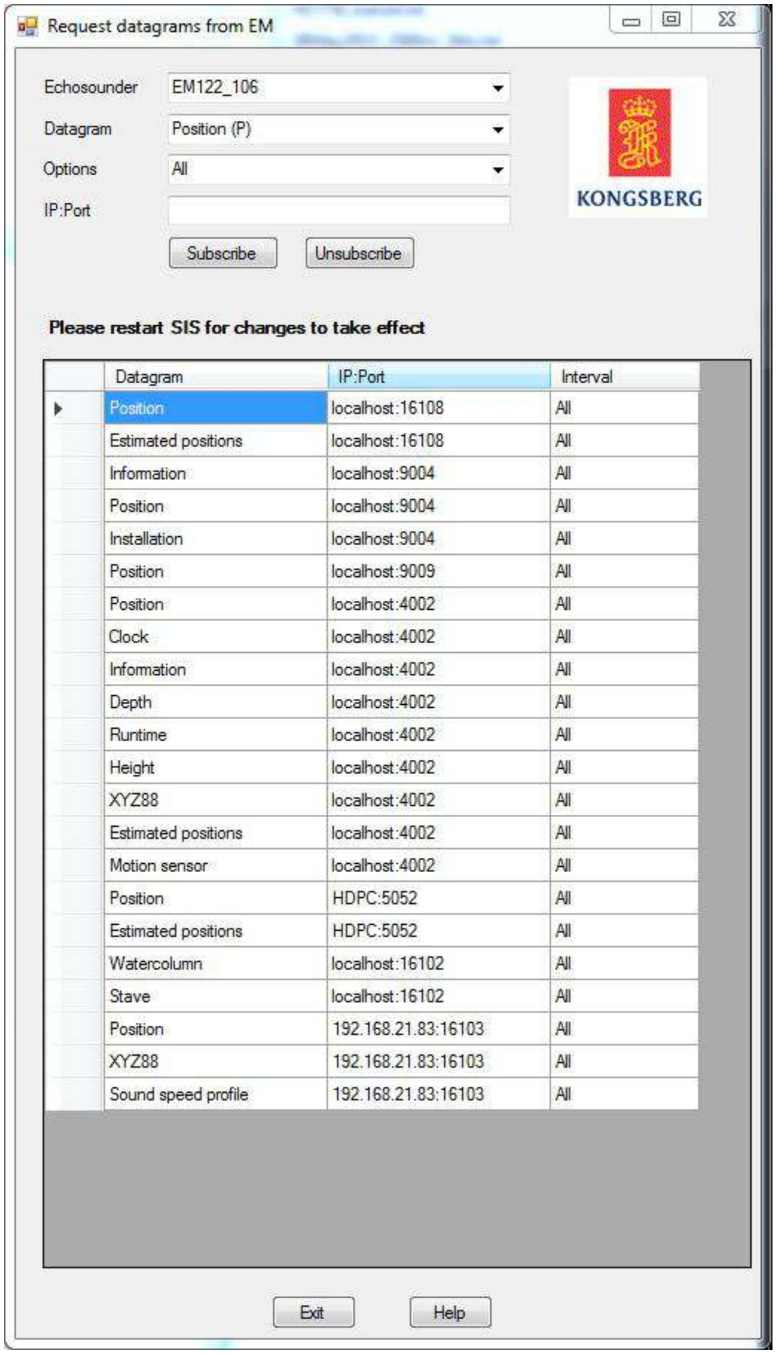


Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Misc. parameters
Ship's noise level:
HIGH
System Gain Offset
BS Offset (dB)
0.0
Opening angles
RX Opening angle:
2
TX Opening angle:
1

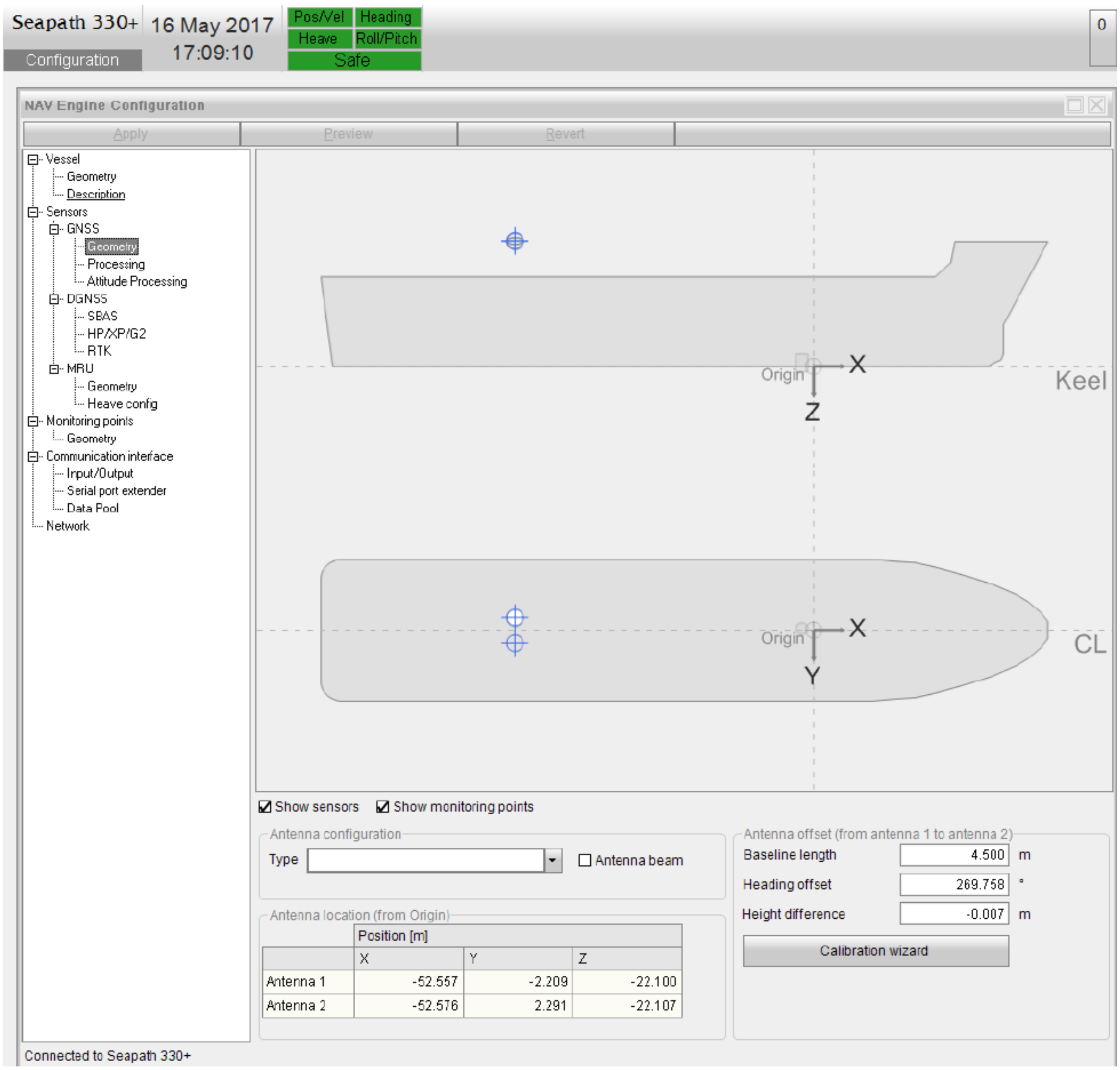


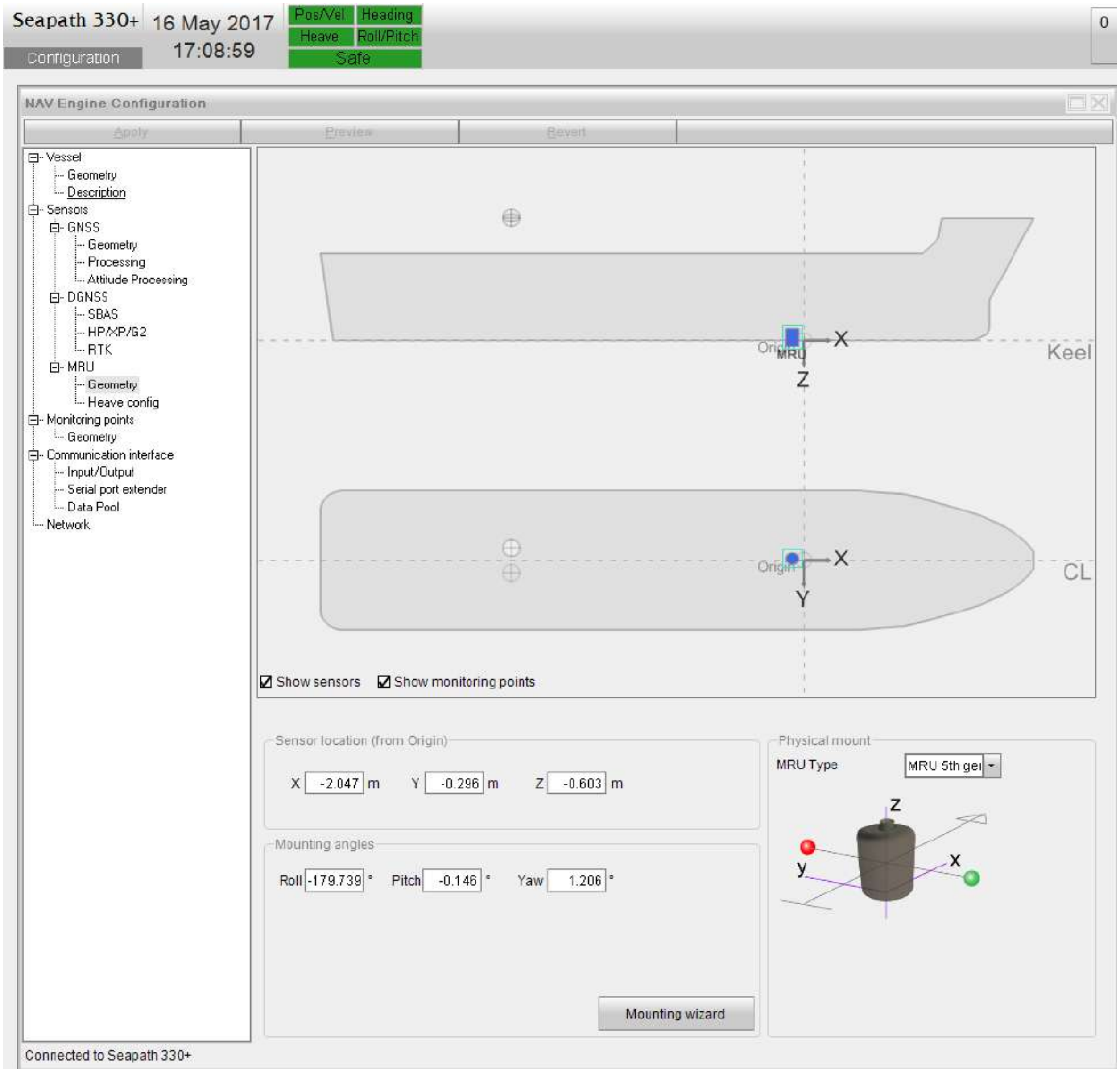
PU sensor status
PU sensor status
PU Sensor input status
COM1 COM2 COM3 COM4 UDP2 UDP5 UDP6
GGA
P
GGK
GGA_RTK
GST
SIMRAD90
Attitude
HM
MK39 Mod2 Attitude, no heave
HDT Heading
SKR82 Heading
ROV. depth
ZDA Clock
Height, special purpose only
DBS Depth
DPT Depth
EA500 Depth
Attitude/Velocity
A
1PPS Clock Synch.
P = active Position sensor
M = active Motion/Attitude sensor
H = active Heading sensor
A = active Attitude/Velocity sensor
Reload


External sensors
Input Setup
Sound Velocity Probe
Port
Probe available
COM1
Probe type
AML SV&T (C+T)
SVP Logger
Port
SVP Logger avail
Barometer
Port
Barometer avail
Real time Tide
Port
Realtime Tide avail
Geodimeter
Port
Geodimeter avail
Echosounder
Heading
Sensor name
Serial
Port
Ethernet
IP addr.
Port addr.
Add
Compass deviation file:
Position
Sensor name
Serial
Port
Ethernet
IP addr.
Port addr.
Position delay (sec.):
0.00
Forward (X)
Starboard (Y)
Downward (Z)
Add
Location offset (m)
0.00
0.00
0.00
Output Setup
Auto Pilot
Port
Auto Pilot avail
Enable Output
Dyn Pos
Port
Serial
IP addr.
Port addr.
Ethernet
Depth below keel
Port
Depth below keel avail
COM3
Port
COM1
Baud rate:
9600
Data bits
8
Stop bits:
1
Parity:
NONE
Waterline for NMEA single beam(m). Downward (Z)
0.00
OK
CANCEL


Request datagrams from EM
Echosounder
EM122_106
Datagram
Position (P)
Options
All
IP:Port
Subscribe
Unsubscribe
KONGSBERG
Please restart SIS for changes to take effect
Datagram
IP:Port
Interval
Position
localhost:16108
All
Estimated positions
localhost:16108
All
Information
localhost:9004
All
Position
localhost:9004
All
Installation
localhost:9004
All
Position
localhost:9009
All
Position
localhost:4002
All
Clock
localhost:4002
All
Information
localhost:4002
All
Depth
localhost:4002
All
Runtime
localhost:4002
All
Height
localhost:4002
All
XYZ88
localhost:4002
All
Estimated positions
localhost:4002
All
Motion sensor
localhost:4002
All
Position
HDPC:5052
All
Estimated positions
HDPC:5052
All
Watercolumn
localhost:16102
All
Stave
localhost:16102
All
Position
192.168.21.83:16103
All
XYZ88
192.168.21.83:16103
All
Sound speed profile
192.168.21.83:16103
All
Exit
Help

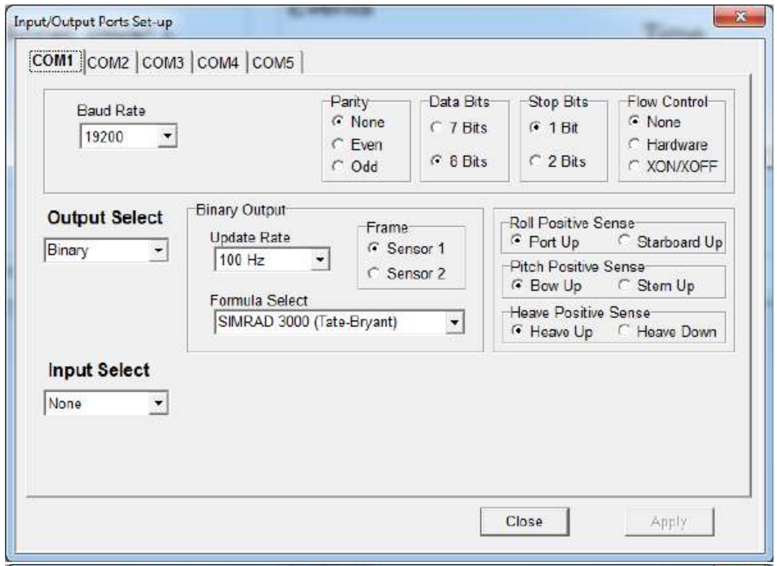
Appendix 2: Seapath 330+ Configuration

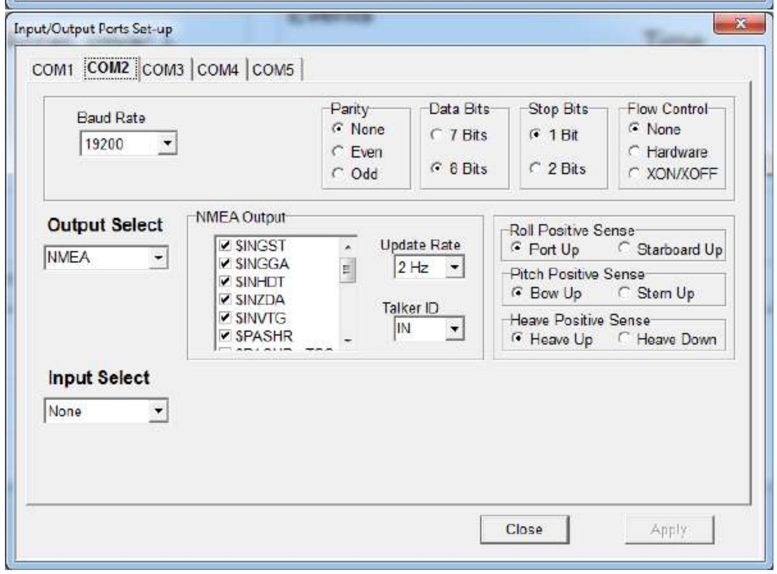


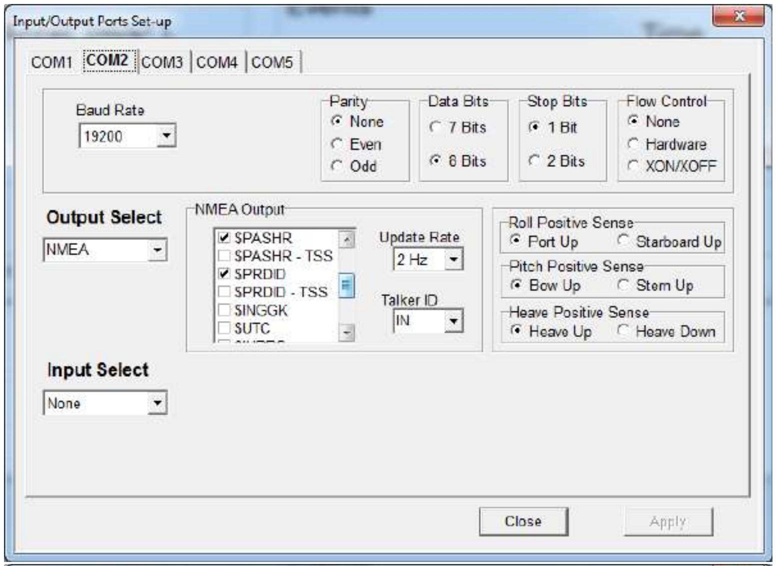


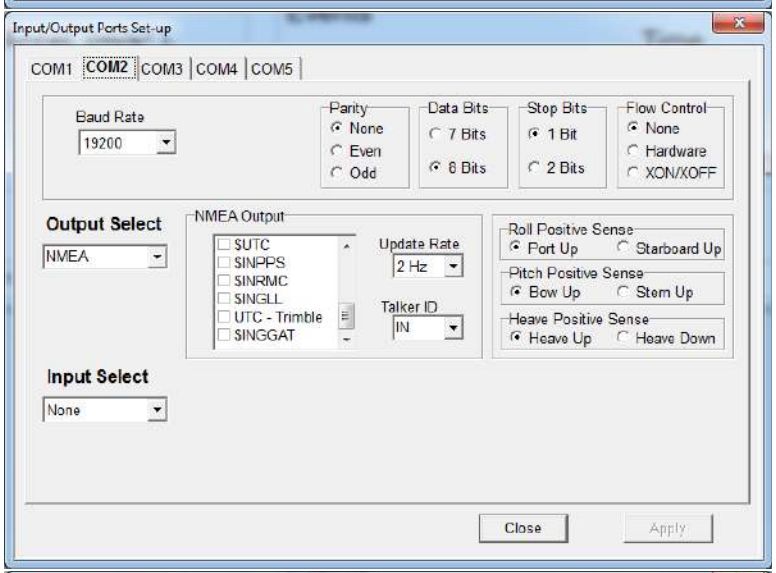
Seapath 330+
16 May 2017
17:08:59
Configuration
Pos/Vel
Heading
Heave
Roll/Pitch
Safe
NAV Engine Configuration
Apply
Preview
Revert
Vessel
Geometry
Description
Sensors
GNSS
Geometry
Processing
Attitude Processing
DGNSS
SBAS
HP/XP/G2
RTK
MRU
Geometry
Heave config
Monitoring points
Geometry
Communication interface
Input/Output
Serial port extender
Data Pool
Network
Keel
CL
Show sensors
Show monitoring points
Sensor location (from Origin)
X -2.047 m
Y -0.296 m
Z -0.603 m
Mounting angles
Roll -179.739 °
Pitch -0.146 °
Yaw 1.206 °
Mounting wizard
Physical mount
MRU Type
Connected to Seapath 330+

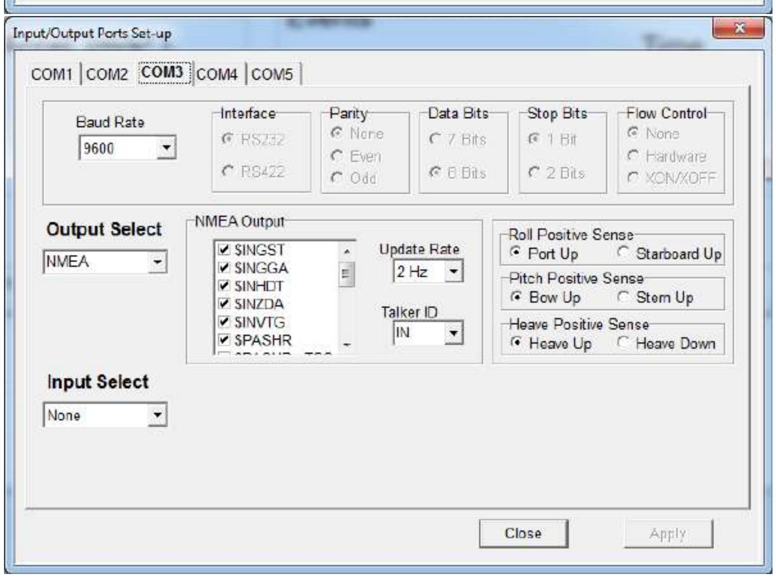
Appendix 3: Applanix POS MV Configuration

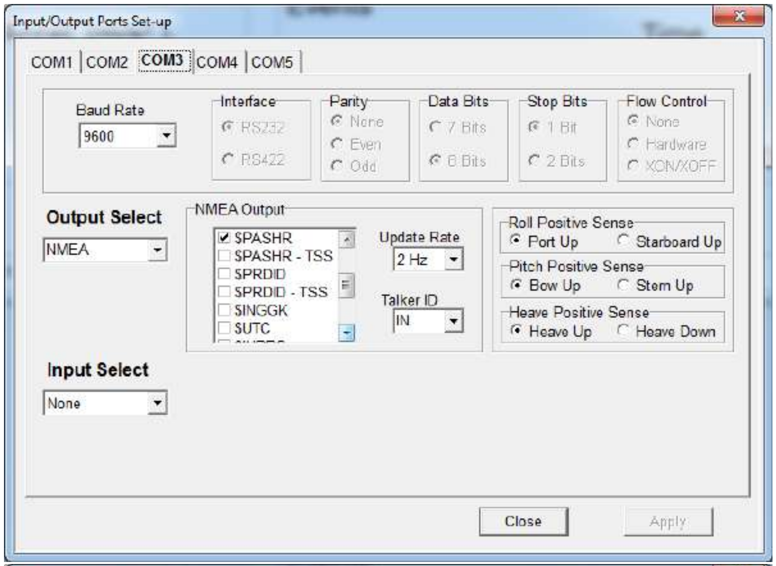





Input/Output Ports Set-up
COM1 COM2 COM3 COM4 COM5
Baud Rate
19200
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$PASHR
$PASHR - TSS
$PRDID
$PRDID - TSS
$INGGK
$UTC
Update Rate
2 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

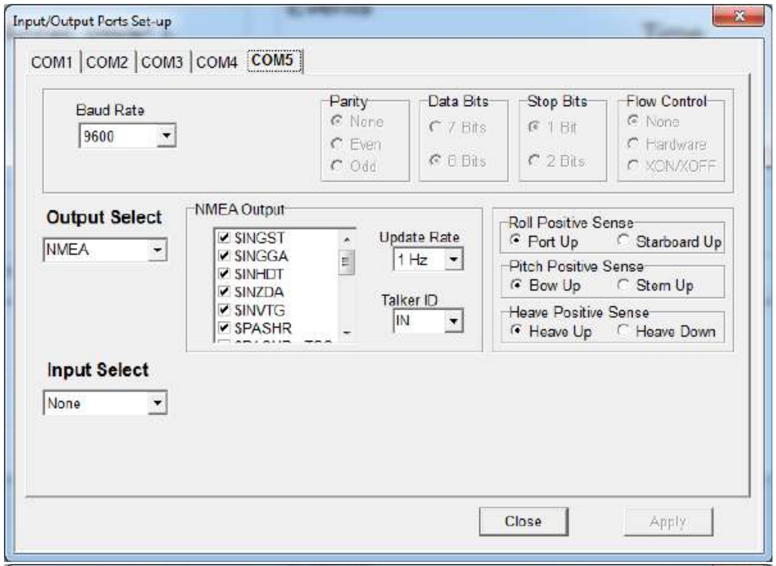

Input/Output Ports Set-up
COM1 COM2 COM3 COM4 COM5
Baud Rate
19200
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$UTC
$INPPS
$INRMC
$INGLL
UTC - Trimble
$INGGAT
Update Rate
2 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

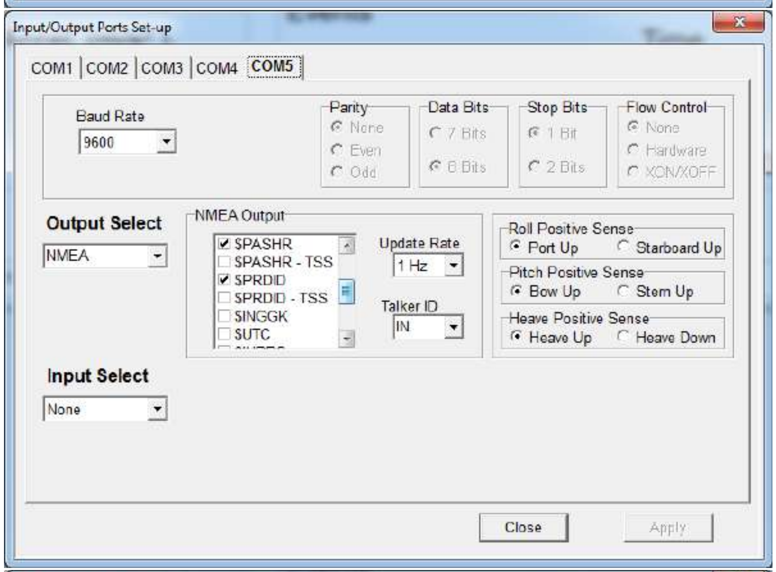

Input/Output Ports Set-up
COM1 COM2 COM3 COM4 COM5
Baud Rate
9600
Interface
RS232
RS422
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$INGST
$INGGA
$INHDT
$INZDA
$INVTG
$PASHR
Update Rate
2 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

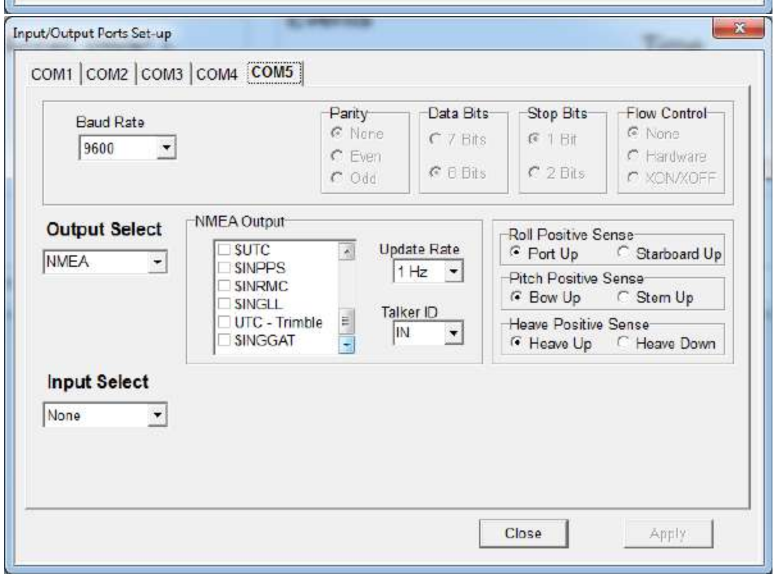

Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
9600
Interface
RS232
RS422
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$PASHR
$PASHR - TSS
$PRDID
$PRDID - TSS
$INGGK
$UTC
Update Rate
2 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

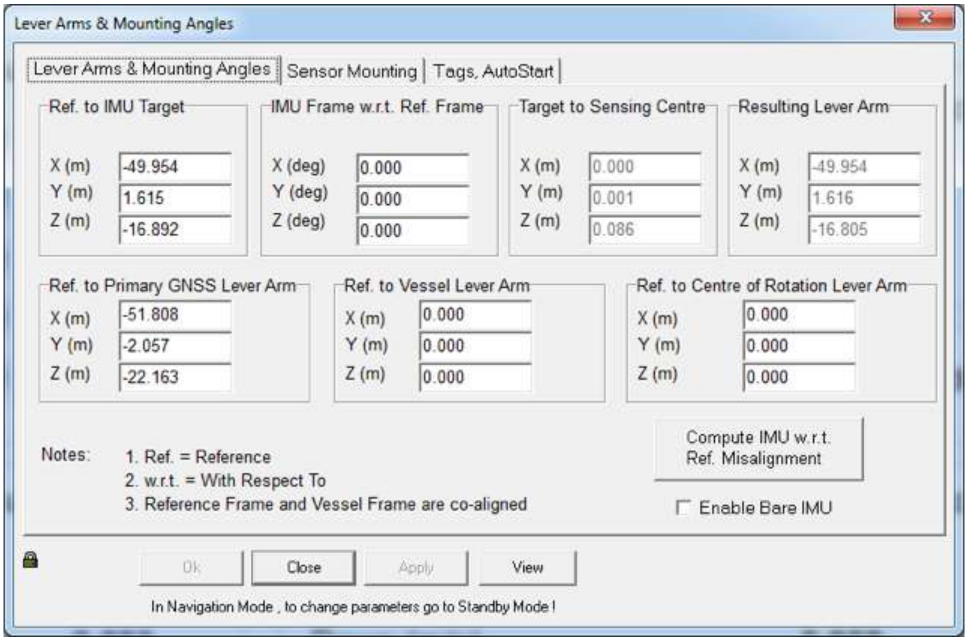

Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
9600
Interface
RS232
RS422
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$UTC
$INPPS
$INRMC
$INGLL
UTC - Trimble
$INGGAT
Update Rate
2 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply


Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
4800
Interface
RS232
RS422
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
None
Input Select
Base 1 GPS
Base GPS Input
Input Type
RTCM 1 or 9
Datum
WGS84
Line
Serial
Modem
Modem Settings
Close
Apply


Input/Output Ports Set-up
COM1 | COM2 | COM3 | COM4 | COM5
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$INGST
$INGGA
$INHDT
$INZDA
$INVTG
$PASHR
Update Rate
1 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

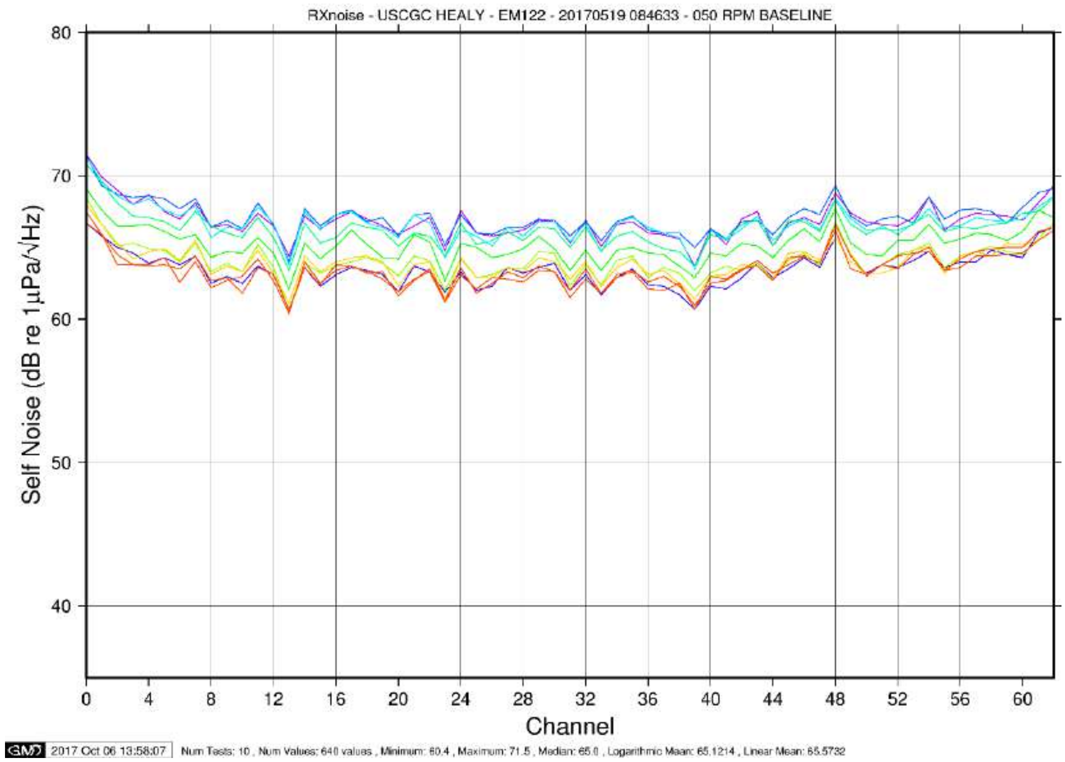

Input/Output Ports Set-up
COM1 | COM2 | COM3 | COM4 | COM5
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$PASHR
$PASHR - TSS
$PRDID
$PRDID - TSS
$INGGK
$UTC
Update Rate
1 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

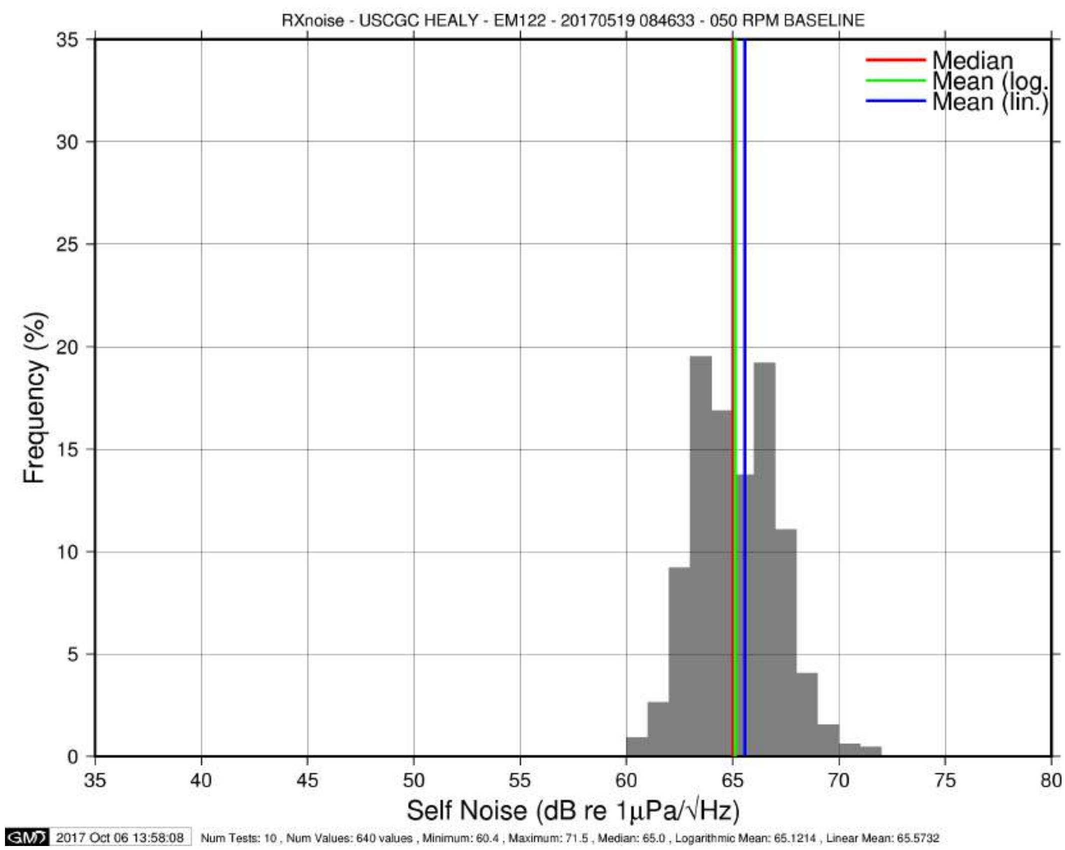

Input/Output Ports Set-up
COM1 | COM2 | COM3 | COM4 | COM5
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$UTC
$INPPS
$INRMC
$INGLL
UTC - Trimble
$INGGAT
Update Rate
1 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

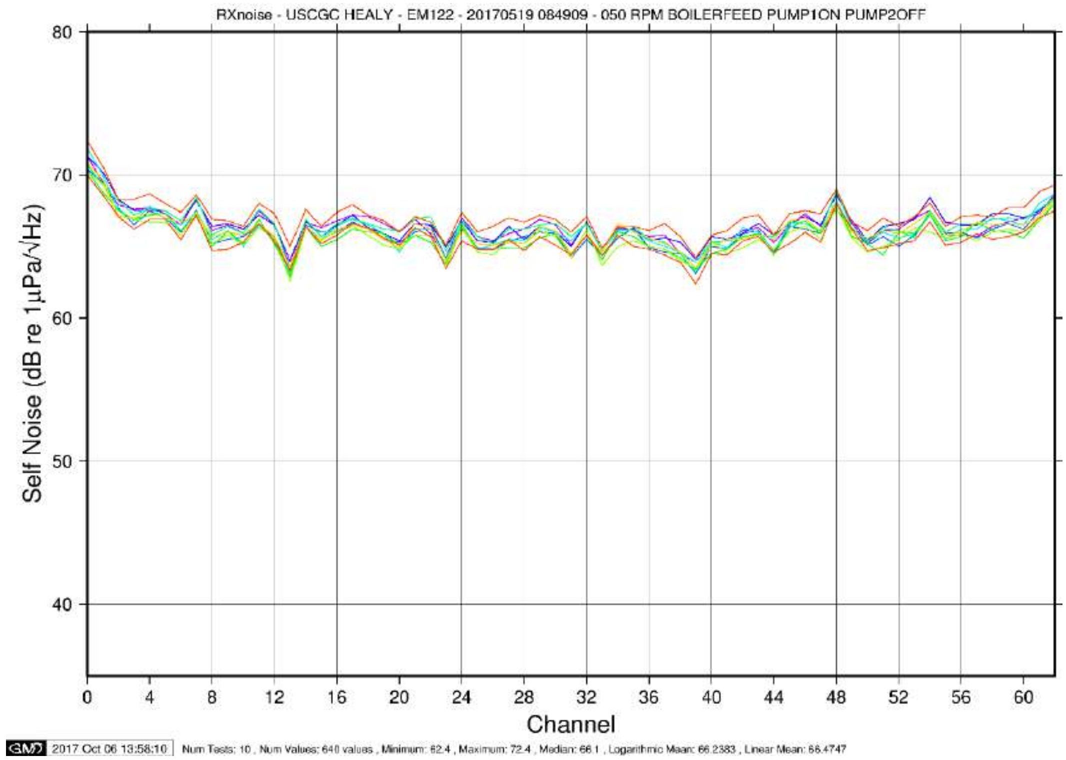


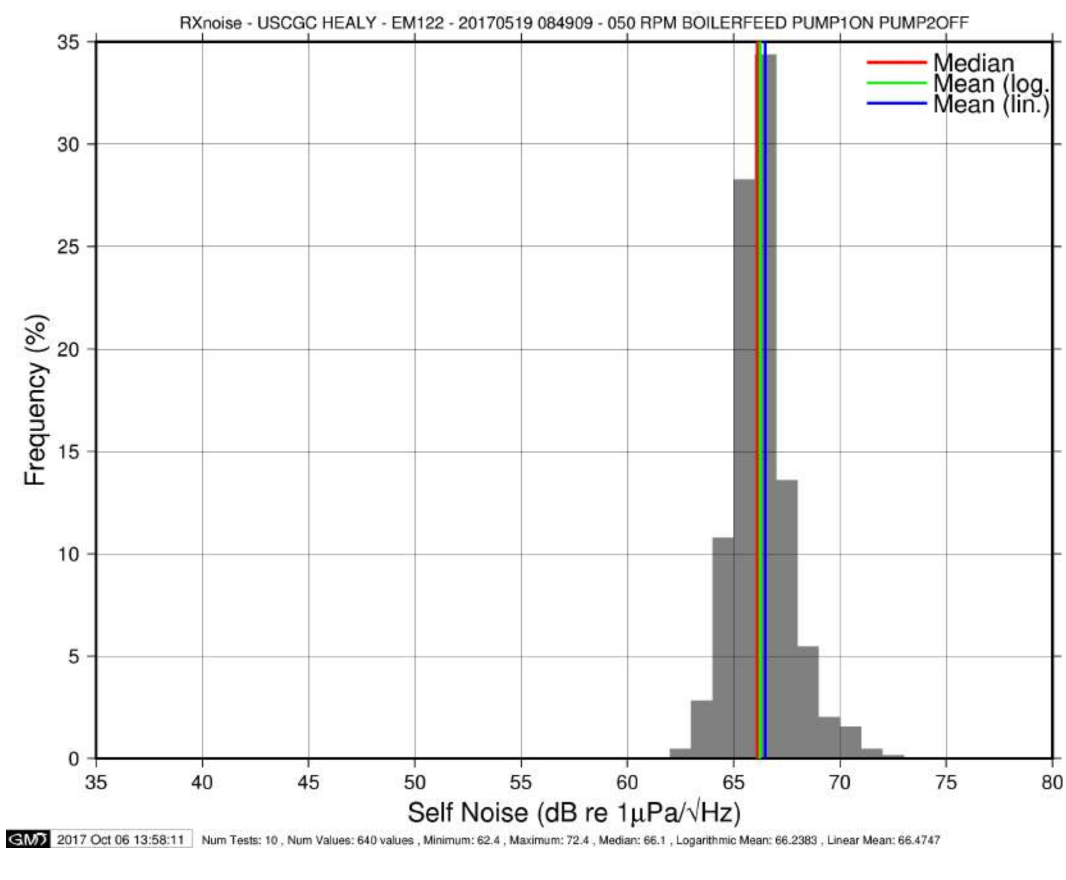
Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, AutoStart
Ref. to IMU Target
X (m) -49.954
Y (m) 1.615
Z (m) -16.892
IMU Frame w.r.t. Ref. Frame
X (deg) 0.000
Y (deg) 0.000
Z (deg) 0.000
Target to Sensing Centre
X (m) 0.000
Y (m) 0.001
Z (m) 0.086
Resulting Lever Arm
X (m) -49.954
Y (m) 1.616
Z (m) -16.805
Ref. to Primary GNSS Lever Arm
X (m) -51.808
Y (m) -2.057
Z (m) -22.163
Ref. to Vessel Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Centre of Rotation Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Notes:
1. Ref. = Reference
2. w.r.t. = With Respect To
3. Reference Frame and Vessel Frame are co-aligned
Compute IMU w.r.t. Ref. Misalignment
Enable Bare IMU
Ok
Close
Apply
View
In Navigation Mode , to change parameters go to Standby Mode !

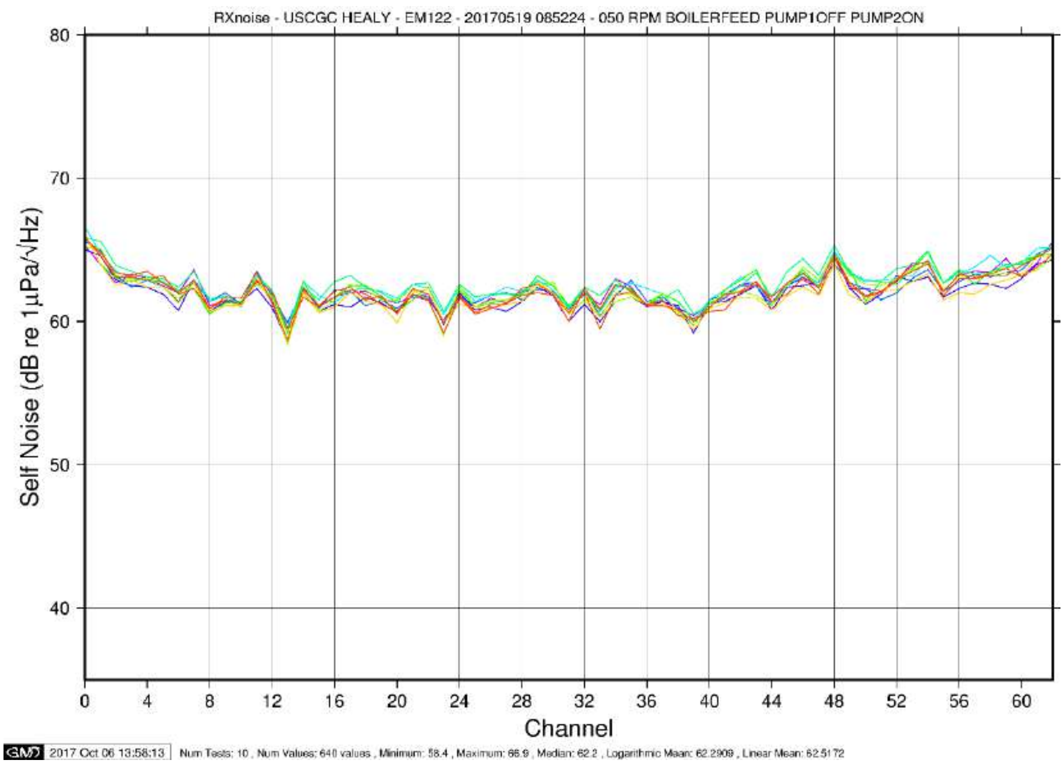
Appendix 4: 2017 RX Noise BIST Tests – Machinery

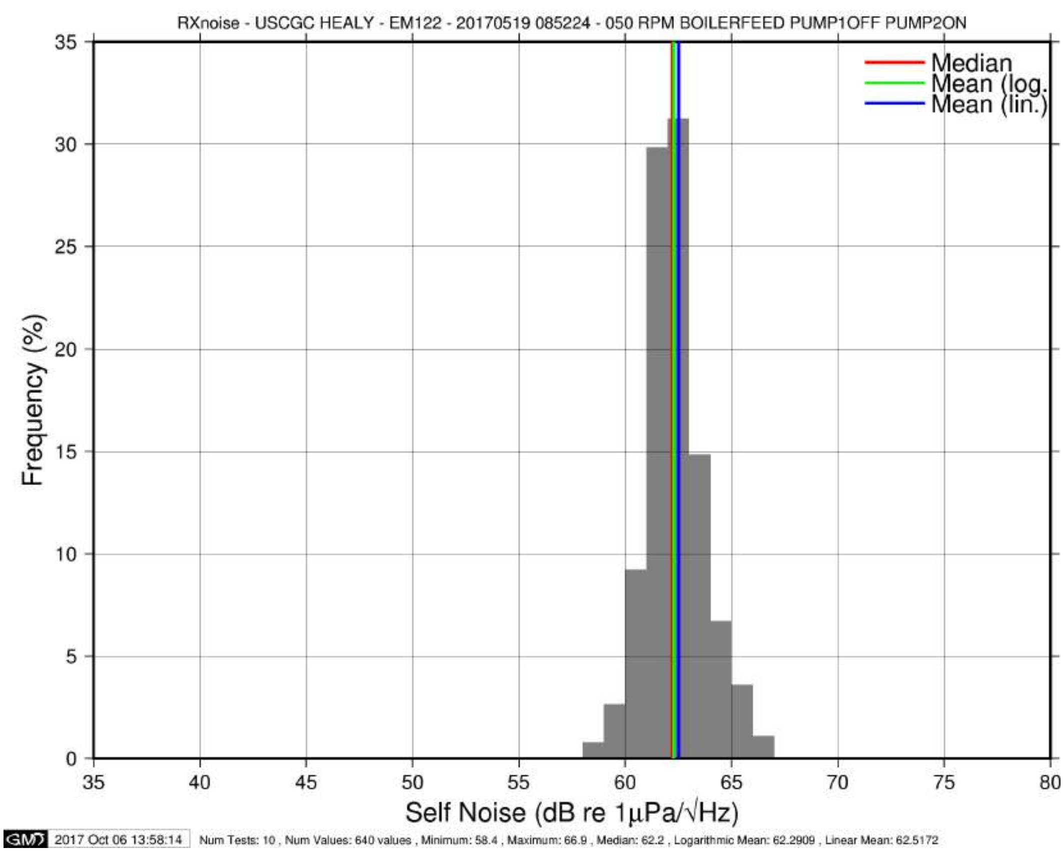


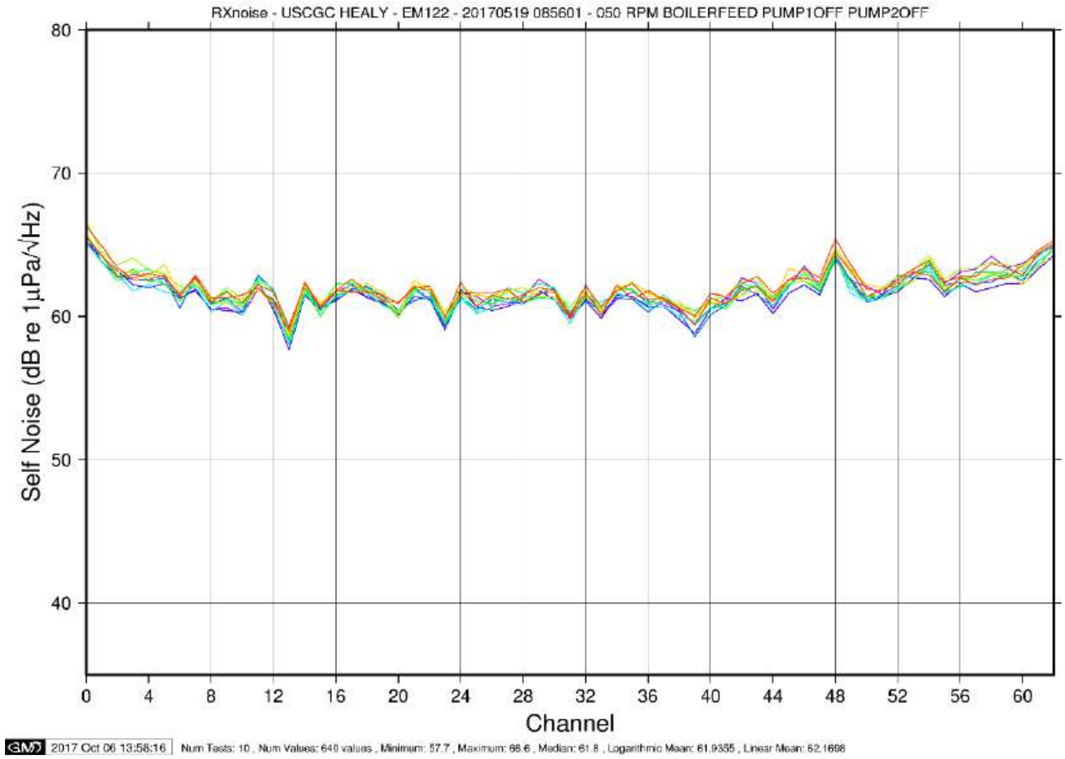


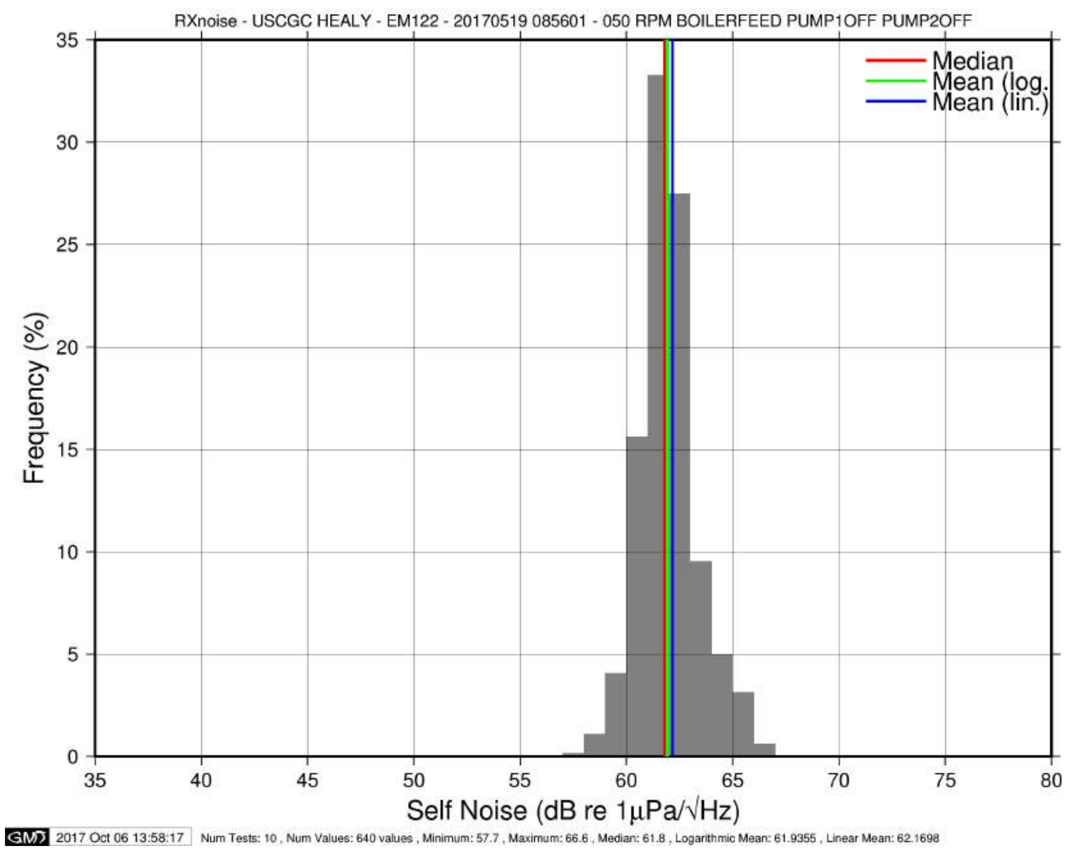

RXnoise - USCGC HEALY - EM122 - 20170519 084909 - 050 RPM BOILERFEED PUMP1ON PUMP2OFF
Self Noise (dB re 1µPa/√Hz)
80
70
60
50
40
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
Channel
2017 Oct 06 13:58:10
Num Tests: 10 , Num Values: 640 values , Minimum: 62.4 , Maximum: 72.4 , Median: 66.1 , Logarithmic Mean: 66.2383 , Linear Mean: 66.4747

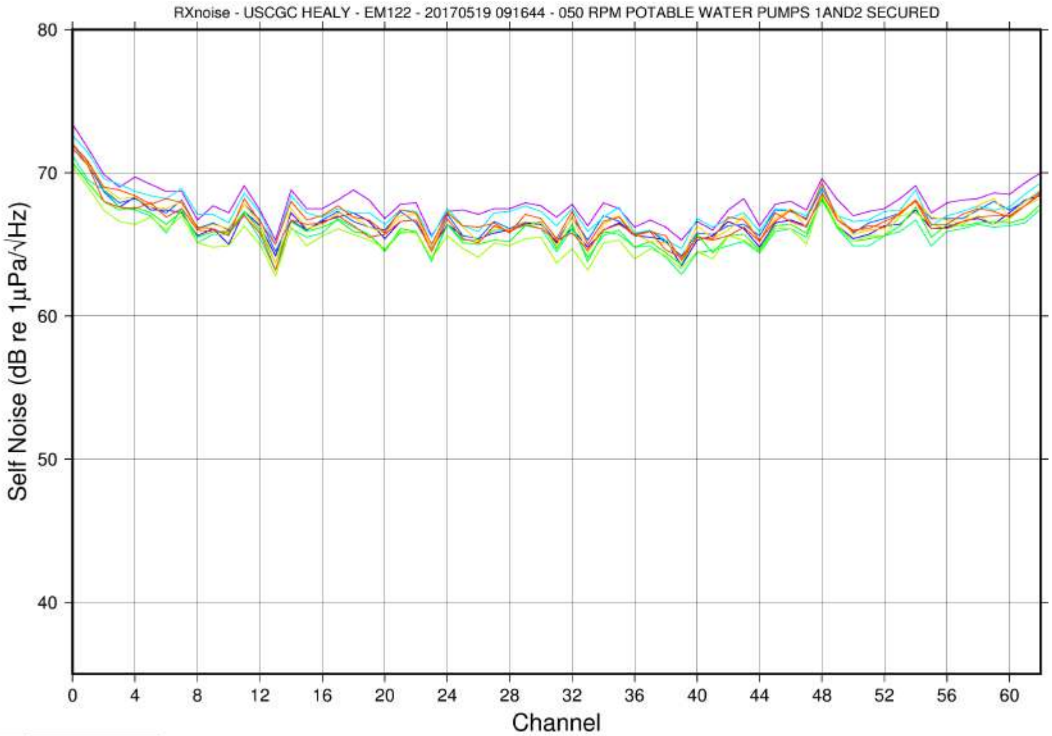

RXnoise - USCGC HEALY - EM122 - 20170519 084909 - 050 RPM BOILERFEED PUMP1ON PUMP2OFF
Median
Mean (log.
Mean (lin.)
Frequency (%)
35
30
25
20
15
10
5
0
35
40
45
50
55
60
65
70
75
80
Self Noise (dB re 1µPa/√Hz)
2017 Oct 06 13:58:11
Num Tests: 10 , Num Values: 640 values , Minimum: 62.4 , Maximum: 72.4 , Median: 66.1 , Logarithmic Mean: 66.2383 , Linear Mean: 66.4747


RXnoise - USCGC HEALY - EM122 - 20170519 085224 - 050 RPM BOILERFEED PUMP1OFF PUMP2ON
Self Noise (dB re 1µPa/√Hz)
Channel
2017 Oct 06 13:58:13
Num Tests: 10 , Num Values: 640 values , Minimum: 58.4 , Maximum: 66.9 , Median: 62.2 , Logarithmic Mean: 62.2909 , Linear Mean: 62.5172

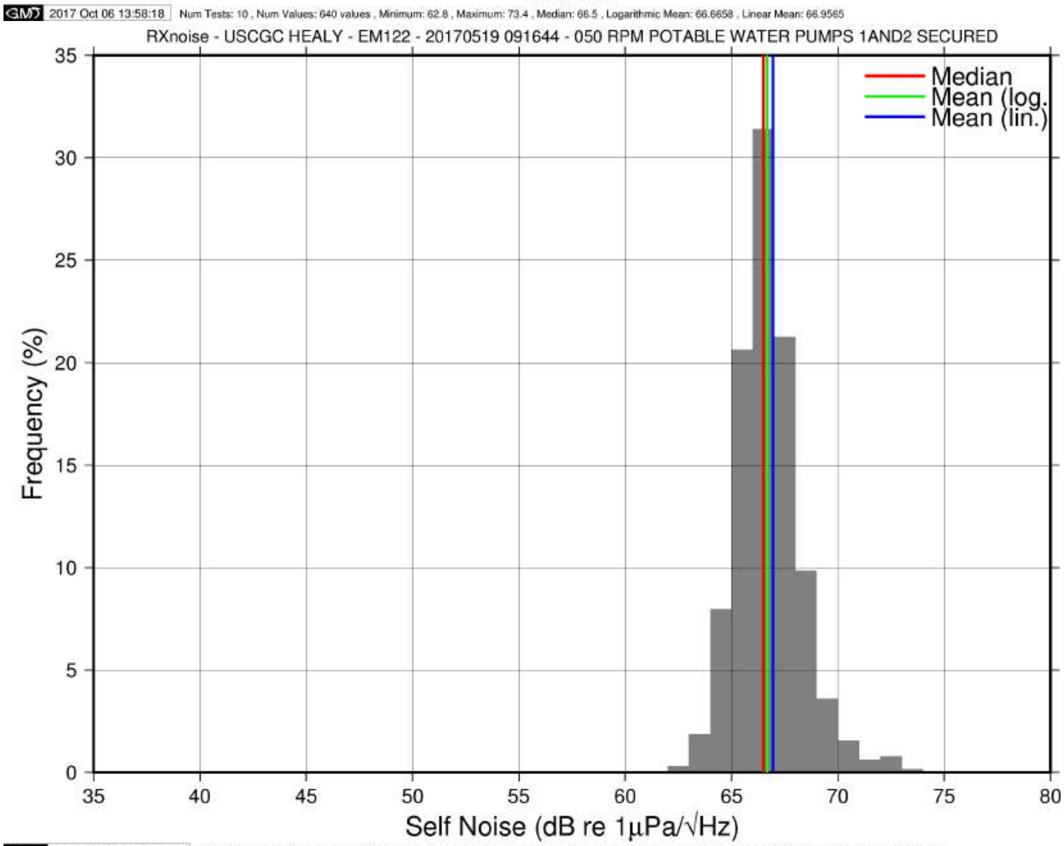

RXnoise - USCGC HEALY - EM122 - 20170519 085224 - 050 RPM BOILERFEED PUMP1OFF PUMP2ON
Median
Mean (log.)
Mean (lin.)
Frequency (%)
Self Noise (dB re 1µPa/√Hz)
2017 Oct 06 13:58:14
Num Tests: 10 , Num Values: 640 values , Minimum: 58.4 , Maximum: 66.9 , Median: 62.2 , Logarithmic Mean: 62.2909 , Linear Mean: 62.5172


RXnoise - USCGC HEALY - EM122 - 20170519 085601 - 050 RPM BOILERFEED PUMP1OFF PUMP2OFF
Self Noise (dB re 1µPa/√Hz)
80
70
60
50
40
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
Channel
2017 Oct 06 13:58:16
Num Tests: 10 , Num Values: 640 values , Minimum: 57.7 , Maximum: 66.6 , Median: 61.8 , Logarithmic Mean: 61.9355 , Linear Mean: 62.1698

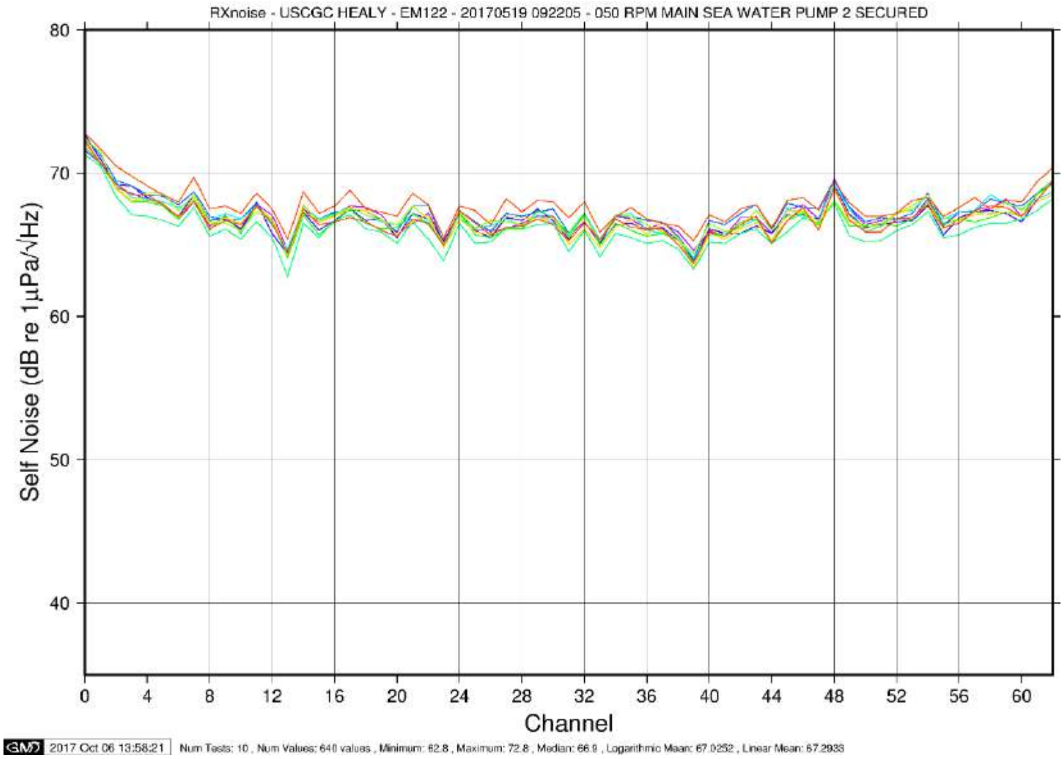

RXnoise - USCGC HEALY - EM122 - 20170519 085601 - 050 RPM BOILERFEED PUMP1OFF PUMP2OFF
Median
Mean (log.)
Mean (lin.)
Frequency (%)
35
30
25
20
15
10
5
0
35
40
45
50
55
60
65
70
75
80
Self Noise (dB re 1µPa/√Hz)
2017 Oct 06 13:58:17
Num Tests: 10 , Num Values: 640 values , Minimum: 57.7 , Maximum: 66.6 , Median: 61.8 , Logarithmic Mean: 61.9355 , Linear Mean: 62.1698



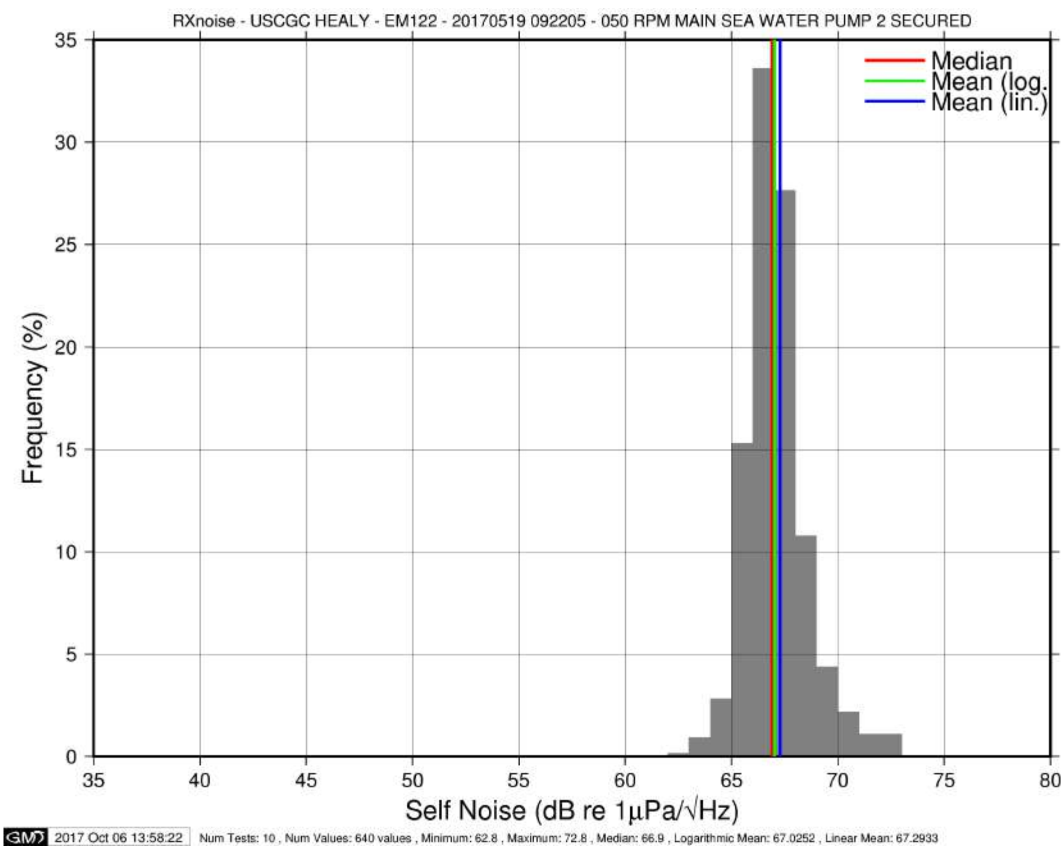
GMT 2017 Oct 06 13:58:18 Num Tests: 10 , Num Values: 640 values , Minimum: 62.8 , Maximum: 73.4 , Median: 66.5 , Logarithmic Mean: 66.6658 , Linear Mean: 66.9565



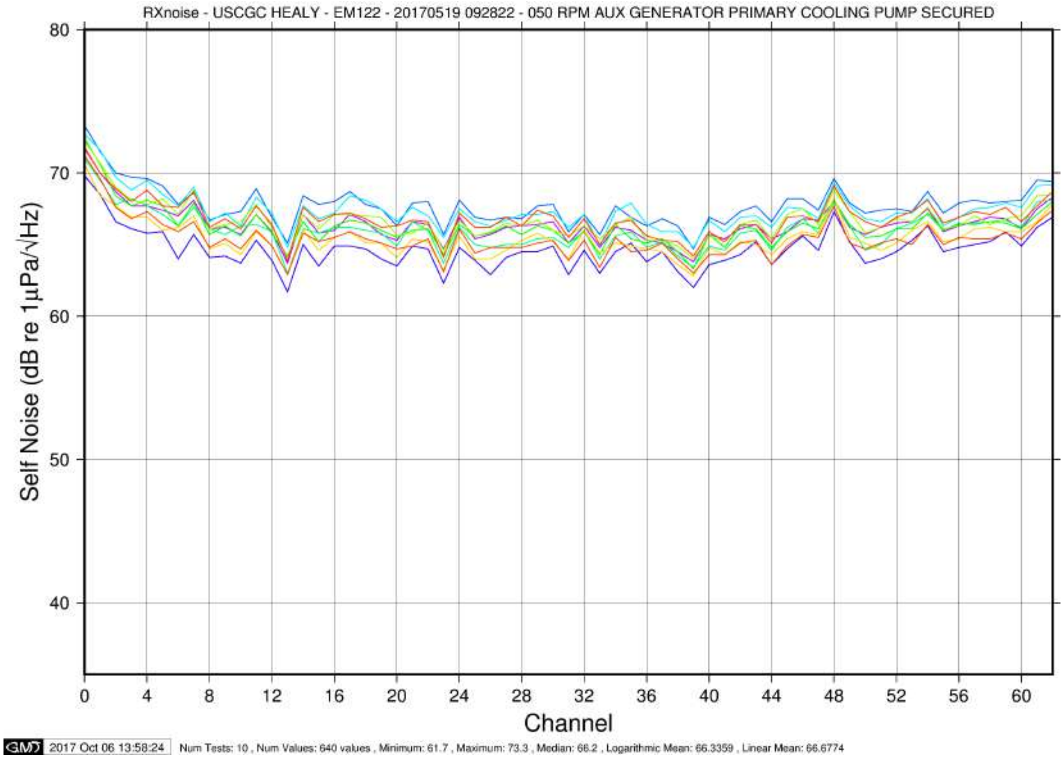
GMT 2017 Oct 06 13:58:20 Num Tests: 10 , Num Values: 640 values , Minimum: 62.8 , Maximum: 73.4 , Median: 66.5 , Logarithmic Mean: 66.6658 , Linear Mean: 66.9565

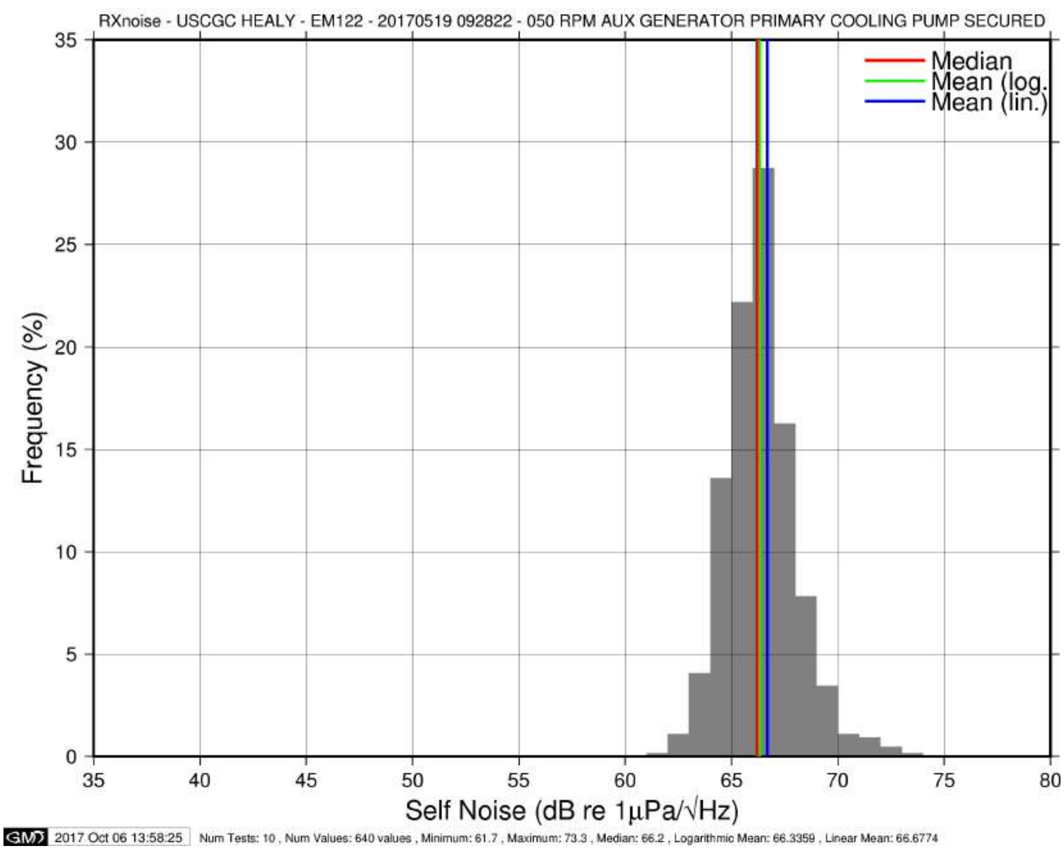


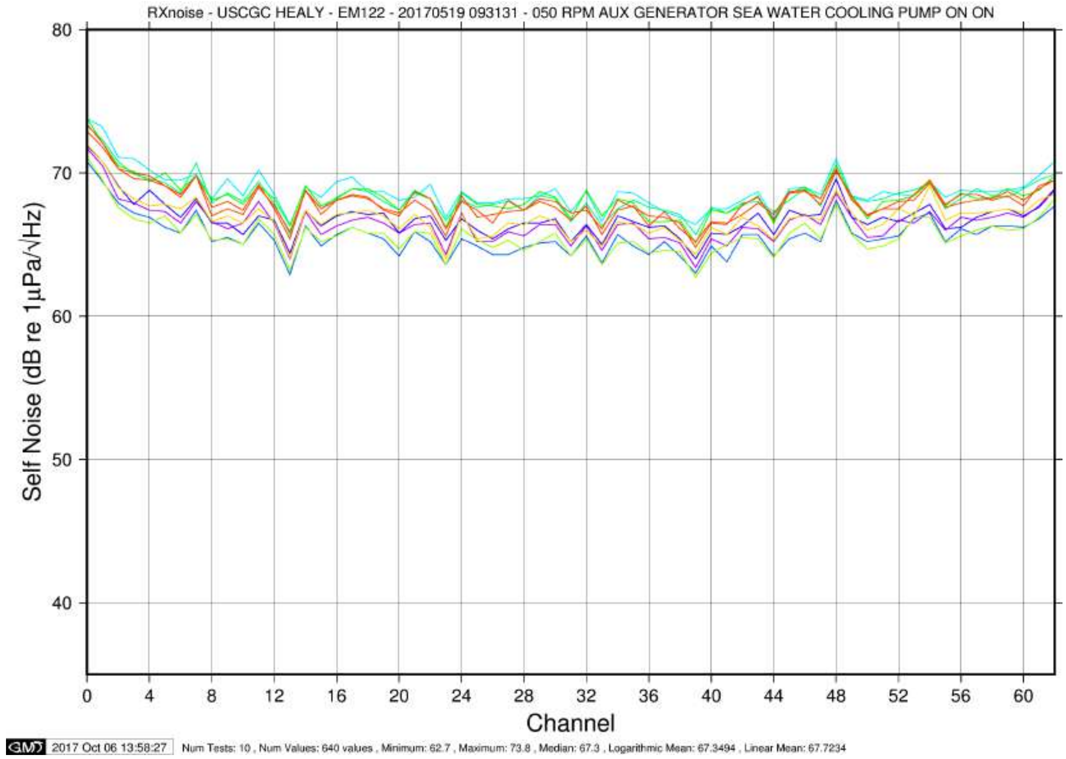
RXnoise - USCGC HEALY - EM122 - 20170519 092205 - 050 RPM MAIN SEA WATER PUMP 2 SECURED
Self Noise (dB re 1µPa/√Hz)
Channel
2017 Oct 06 13:58:21
Num Tests: 10 , Num Values: 640 values , Minimum: 62.8 , Maximum: 72.8 , Median: 66.9 , Logarithmic Mean: 67.0252 , Linear Mean: 67.2933

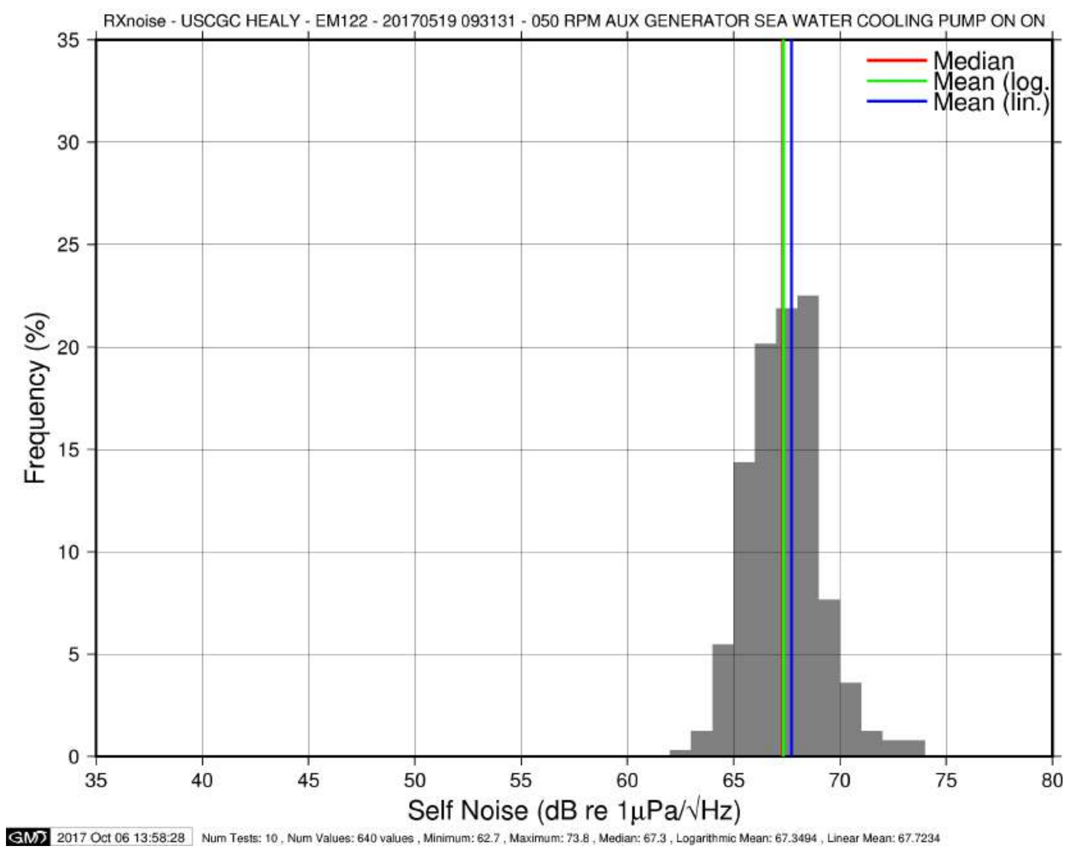


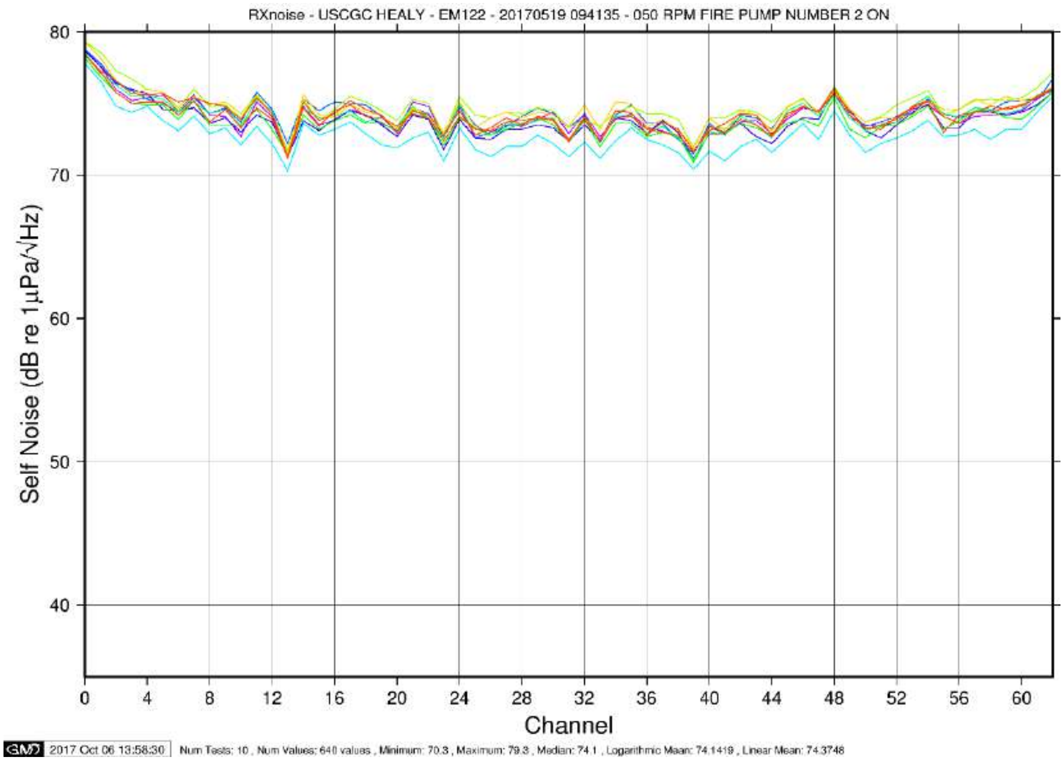
RXnoise - USCGC HEALY - EM122 - 20170519 092205 - 050 RPM MAIN SEA WATER PUMP 2 SECURED
Median
Mean (log.)
Mean (lin.)
Frequency (%)
Self Noise (dB re 1µPa/√Hz)
2017 Oct 06 13:58:22
Num Tests: 10 , Num Values: 640 values , Minimum: 62.8 , Maximum: 72.8 , Median: 66.9 , Logarithmic Mean: 67.0252 , Linear Mean: 67.2933

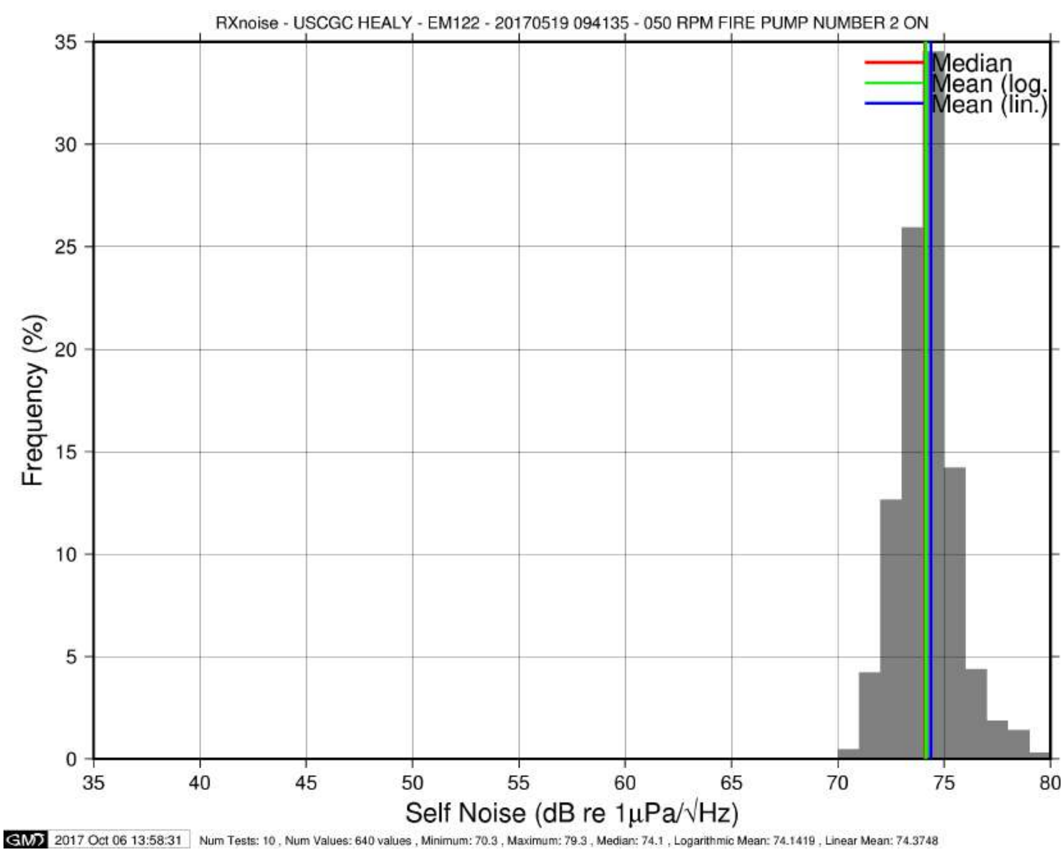

RXnoise - USCGC HEALY - EM122 - 20170519 092822 - 050 RPM AUX GENERATOR PRIMARY COOLING PUMP SECURED
Self Noise (dB re 1μPa/√Hz)
Channel
2017 Oct 06 13:58:24
Num Tests: 10 , Num Values: 640 values , Minimum: 61.7 , Maximum: 73.3 , Median: 66.2 , Logarithmic Mean: 66.3359 , Linear Mean: 66.6774


RXnoise - USCGC HEALY - EM122 - 20170519 092822 - 050 RPM AUX GENERATOR PRIMARY COOLING PUMP SECURED
Median
Mean (log.
Mean (lin.)
Frequency (%)
Self Noise (dB re 1μPa/√Hz)
2017 Oct 06 13:58:25
Num Tests: 10 , Num Values: 640 values , Minimum: 61.7 , Maximum: 73.3 , Median: 66.2 , Logarithmic Mean: 66.3359 , Linear Mean: 66.6774

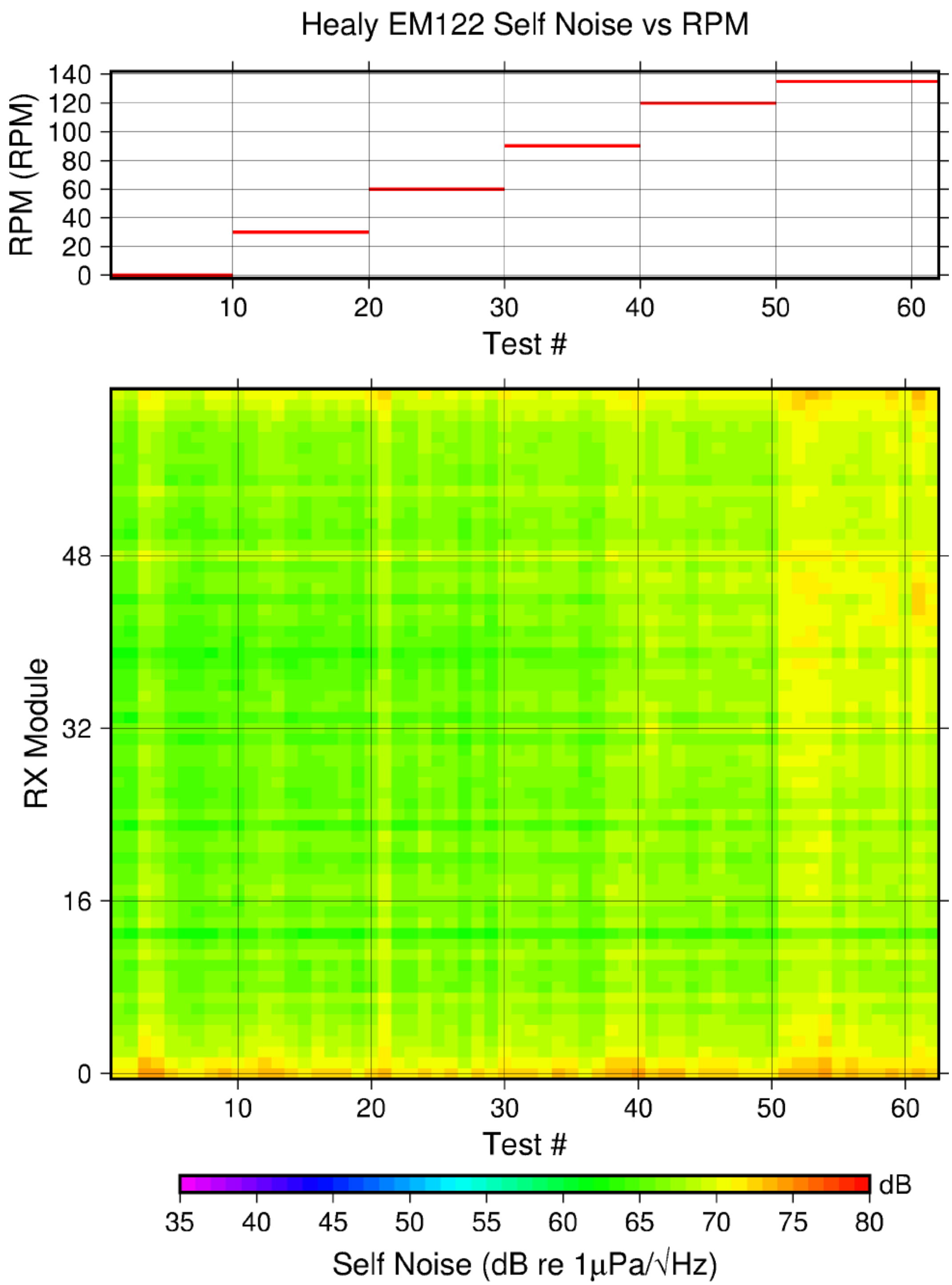

RXnoise - USCGC HEALY - EM122 - 20170519 093131 - 050 RPM AUX GENERATOR SEA WATER COOLING PUMP ON ON
Self Noise (dB re 1μPa/√Hz)
Channel
2017 Oct 06 13:58:27
Num Tests: 10 , Num Values: 640 values , Minimum: 62.7 , Maximum: 73.8 , Median: 67.3 , Logarithmic Mean: 67.3494 , Linear Mean: 67.7234

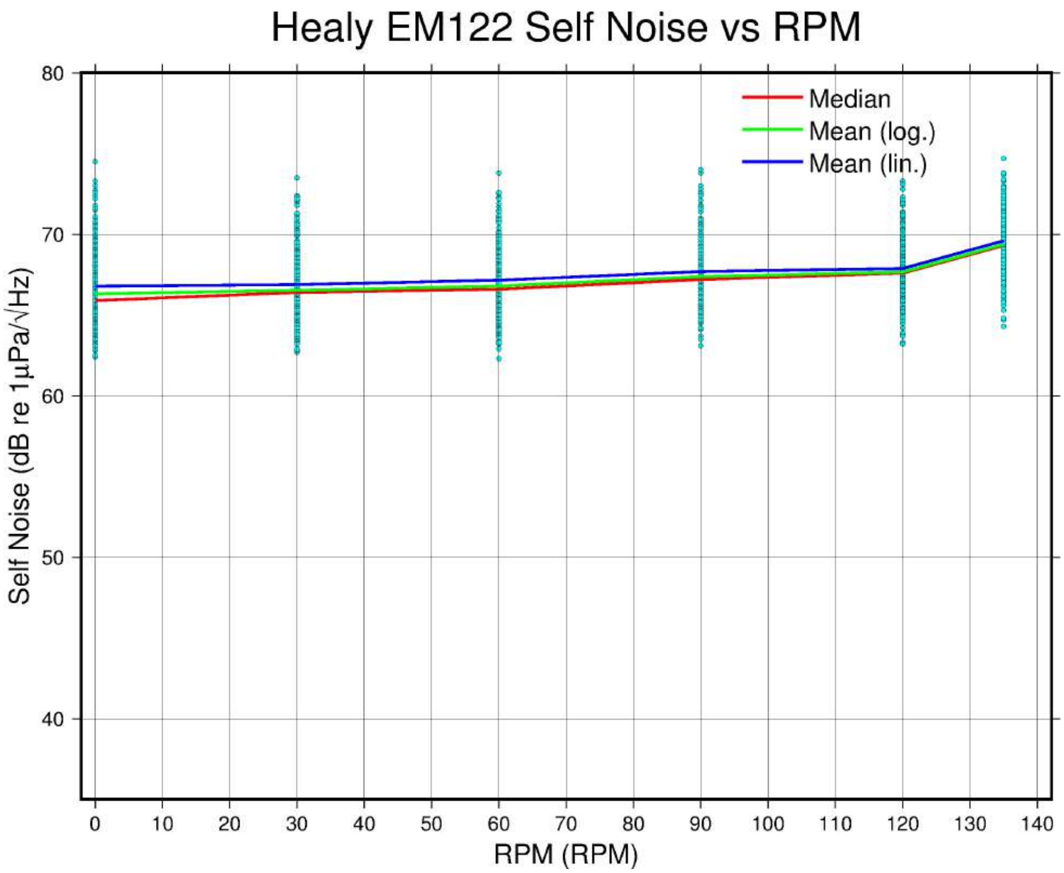

RXnoise - USCGC HEALY - EM122 - 20170519 093131 - 050 RPM AUX GENERATOR SEA WATER COOLING PUMP ON ON
Median
Mean (log.
Mean (lin.)
Frequency (%)
Self Noise (dB re 1μPa/√Hz)
2017 Oct 06 13:58:28
Num Tests: 10 , Num Values: 640 values , Minimum: 62.7 , Maximum: 73.8 , Median: 67.3 , Logarithmic Mean: 67.3494 , Linear Mean: 67.7234


RXnoise - USCGC HEALY - EM122 - 20170519 094135 - 050 RPM FIRE PUMP NUMBER 2 ON
Self Noise (dB re 1μPa/√Hz)
80
70
60
50
40
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
Channel
GMT 2017 Oct 06 13:58:30
Num Tests: 10 , Num Values: 640 values , Minimum: 70.3 , Maximum: 79.3 , Median: 74.1 , Logarithmic Mean: 74.1419 , Linear Mean: 74.3748

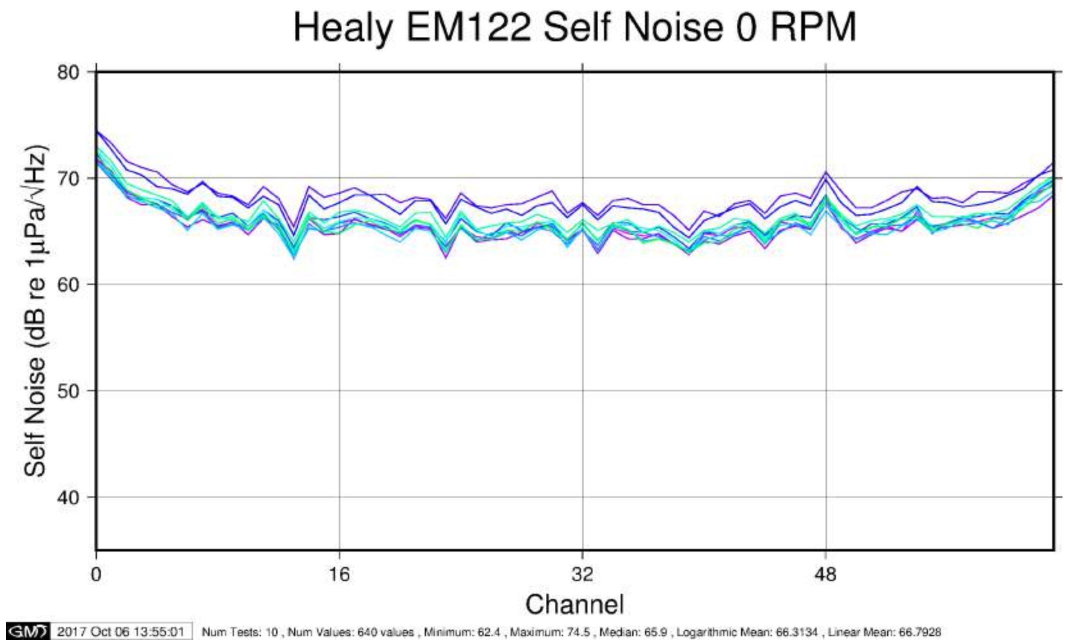

RXnoise - USCGC HEALY - EM122 - 20170519 094135 - 050 RPM FIRE PUMP NUMBER 2 ON
Median
Mean (log.
Mean (lin.)
Frequency (%)
35
30
25
20
15
10
5
0
35
40
45
50
55
60
65
70
75
80
Self Noise (dB re 1μPa/√Hz)
GMT 2017 Oct 06 13:58:31
Num Tests: 10 , Num Values: 640 values , Minimum: 70.3 , Maximum: 79.3 , Median: 74.1 , Logarithmic Mean: 74.1419 , Linear Mean: 74.3748

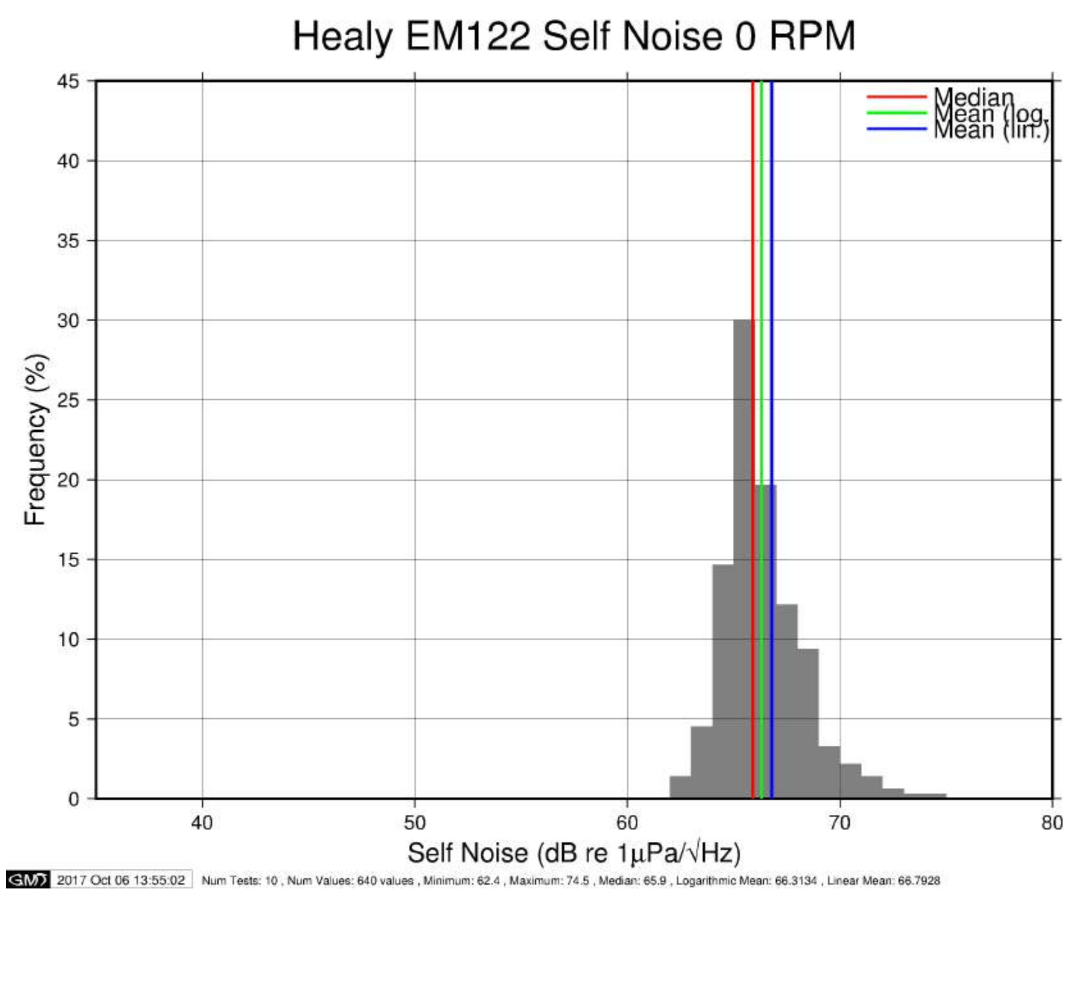
Appendix 5: 2017 RX Noise BIST Tests – Shaft Speed

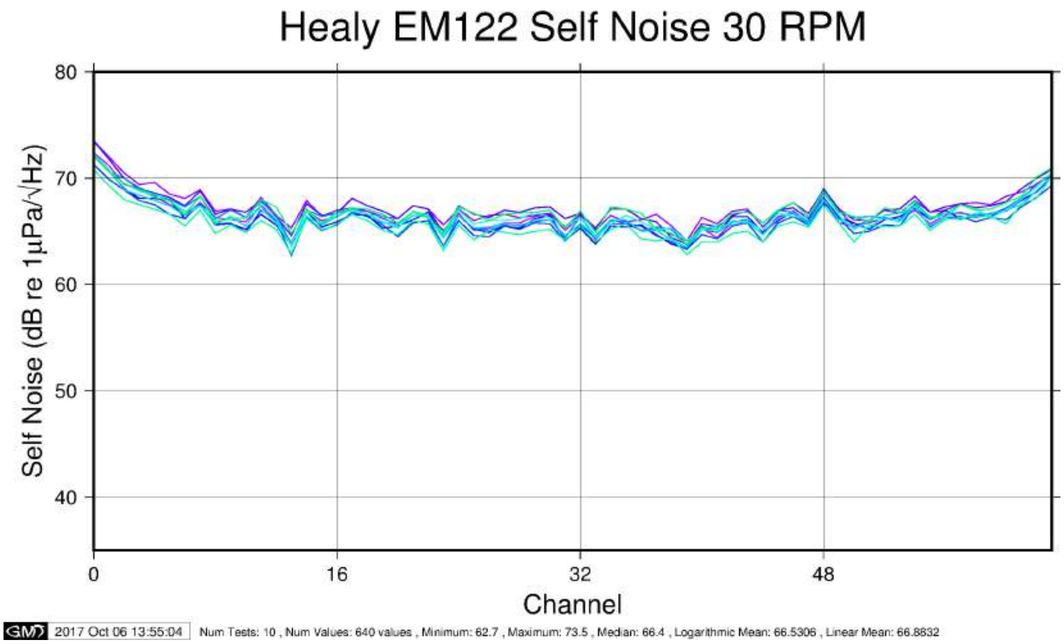


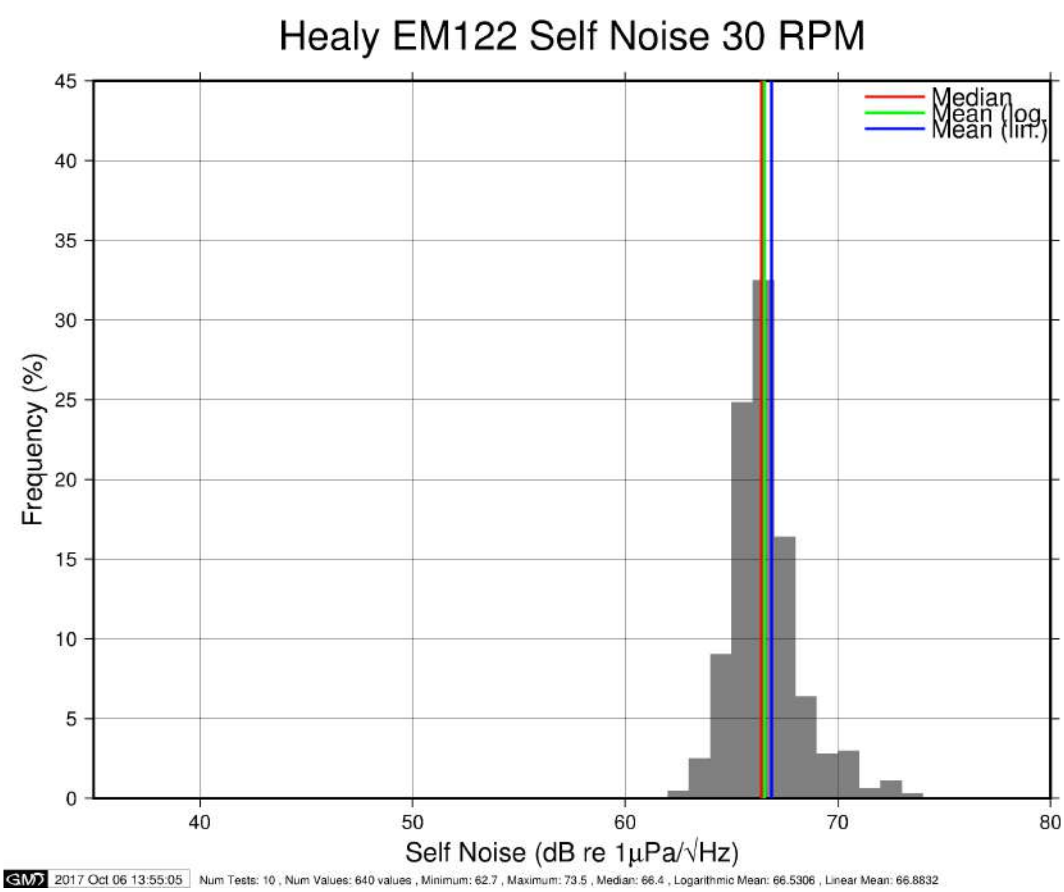


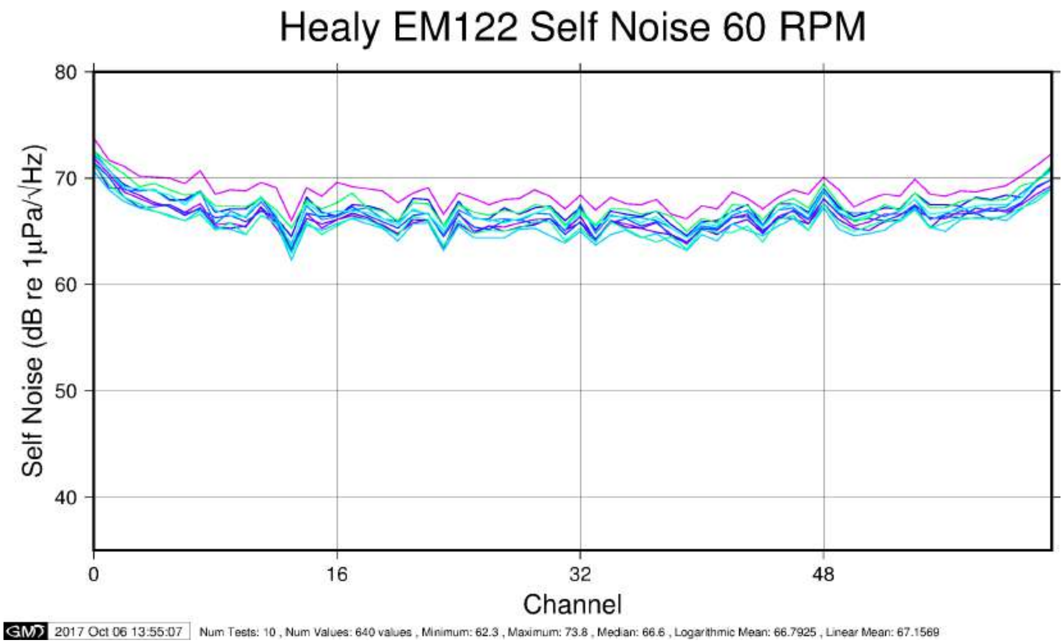
Healy EM122 Self Noise vs RPM
Median
Mean (log.)
Mean (lin.)
Self Noise (dB re 1µPa/√Hz)
RPM (RPM)
80
70
60
50
40
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140

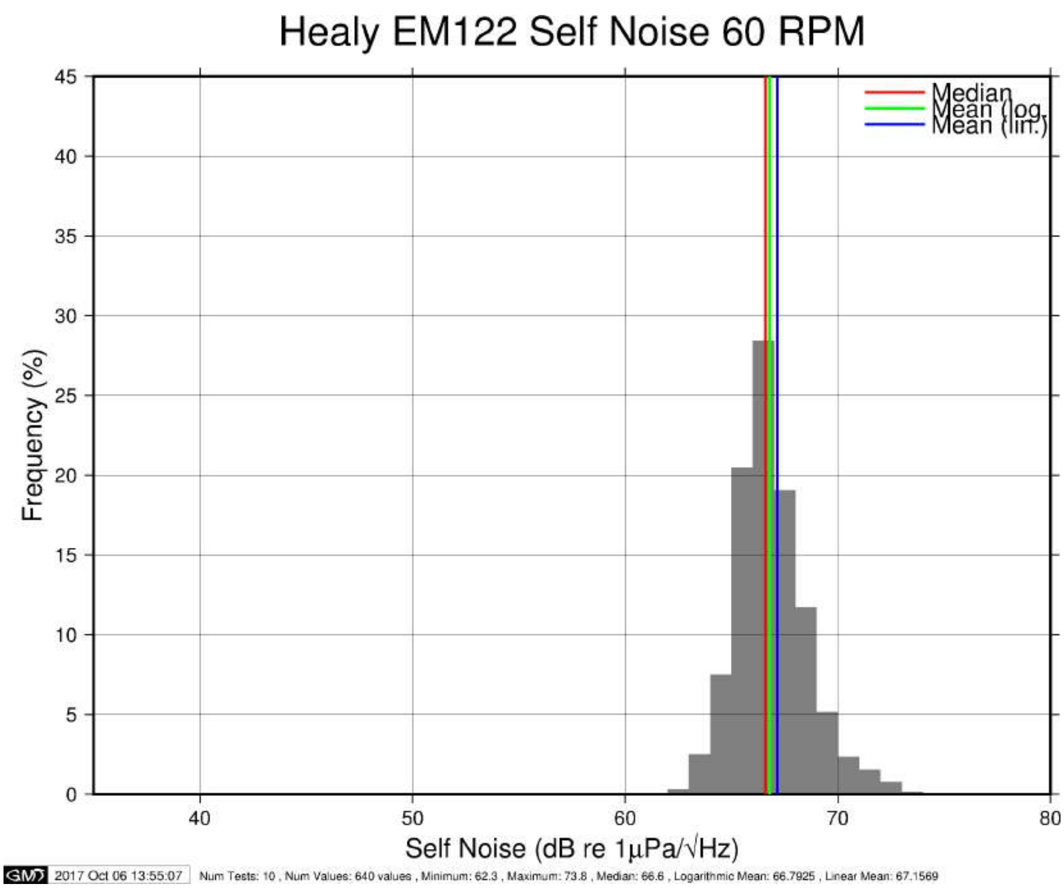

Healy EM122 Self Noise 0 RPM
80
70
60
50
40
Self Noise (dB re 1μPa/√Hz)
0
16
32
48
Channel
2017 Oct 06 13:55:01
Num Tests: 10 , Num Values: 640 values , Minimum: 62.4 , Maximum: 74.5 , Median: 65.9 , Logarithmic Mean: 66.3134 , Linear Mean: 66.7928

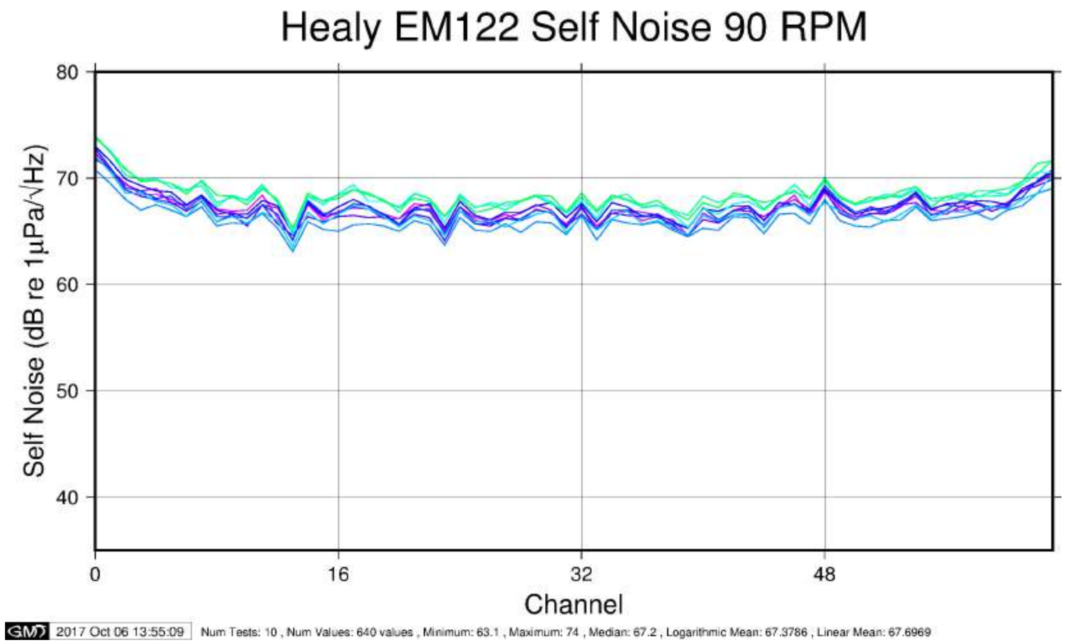

Healy EM122 Self Noise 0 RPM
Median
Mean (log.)
Mean (lin.)
45
40
35
30
25
20
15
10
5
0
Frequency (%)
40
50
60
70
80
Self Noise (dB re 1μPa/√Hz)
2017 Oct 06 13:55:02
Num Tests: 10 , Num Values: 640 values , Minimum: 62.4 , Maximum: 74.5 , Median: 65.9 , Logarithmic Mean: 66.3134 , Linear Mean: 66.7928

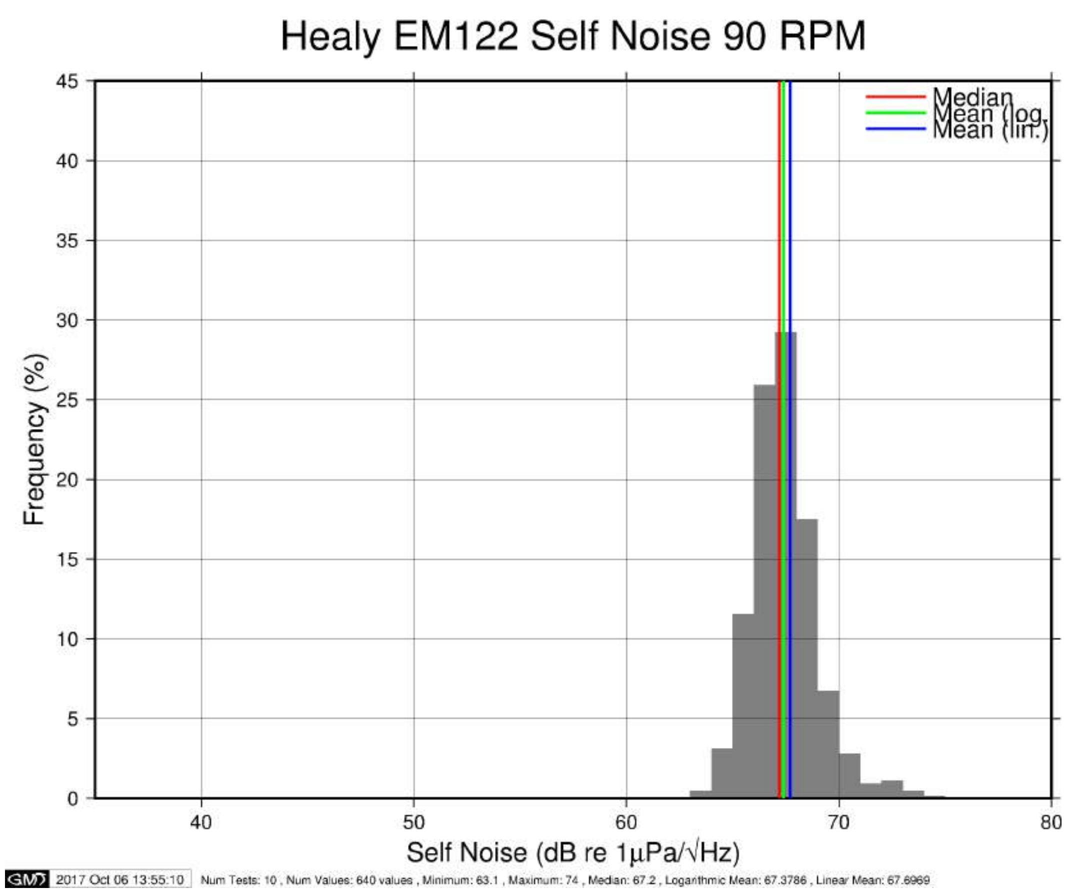

Healy EM122 Self Noise 30 RPM
Self Noise (dB re 1μPa/√Hz)
Channel
2017 Oct 06 13:55:04
Num Tests: 10 , Num Values: 640 values , Minimum: 62.7 , Maximum: 73.5 , Median: 66.4 , Logarithmic Mean: 66.5306 , Linear Mean: 66.8832

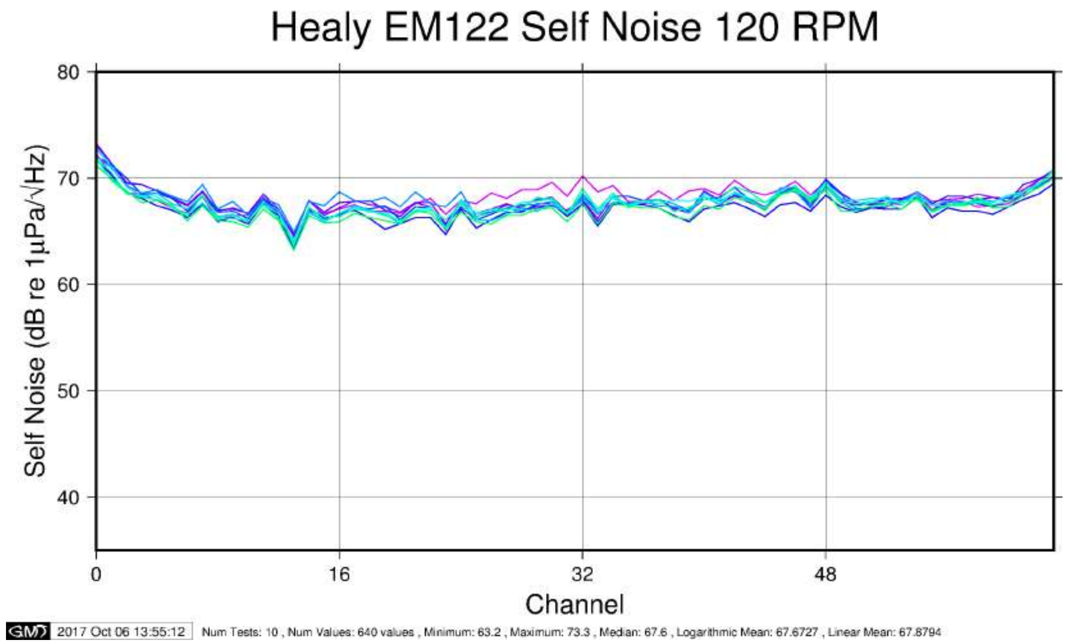

Healy EM122 Self Noise 30 RPM
Median
Mean (log.)
Mean (lin.)
Frequency (%)
Self Noise (dB re 1μPa/√Hz)
2017 Oct 06 13:55:05
Num Tests: 10 , Num Values: 640 values , Minimum: 62.7 , Maximum: 73.5 , Median: 66.4 , Logarithmic Mean: 66.5306 , Linear Mean: 66.8832

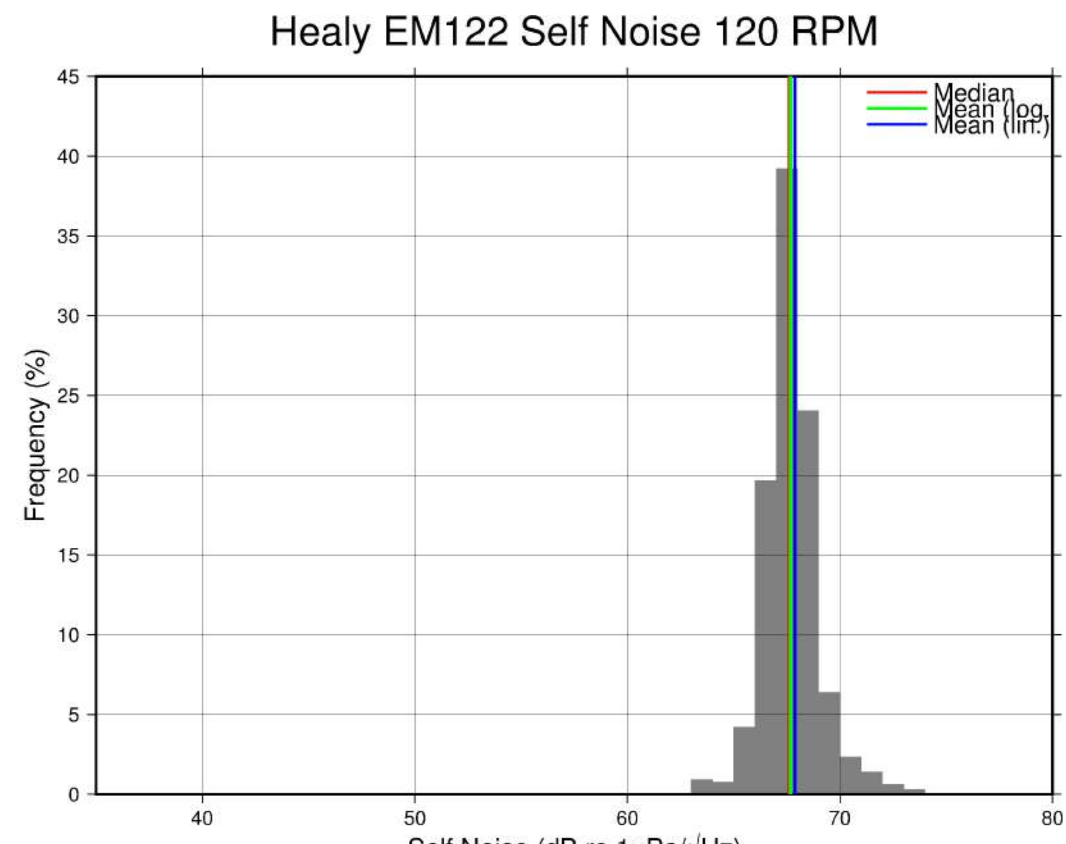

Healy EM122 Self Noise 60 RPM
Self Noise (dB re 1μPa/√Hz)
80
70
60
50
40
0
16
32
48
Channel
2017 Oct 06 13:55:07
Num Tests: 10 , Num Values: 640 values , Minimum: 62.3 , Maximum: 73.8 , Median: 66.6 , Logarithmic Mean: 66.7925 , Linear Mean: 67.1569

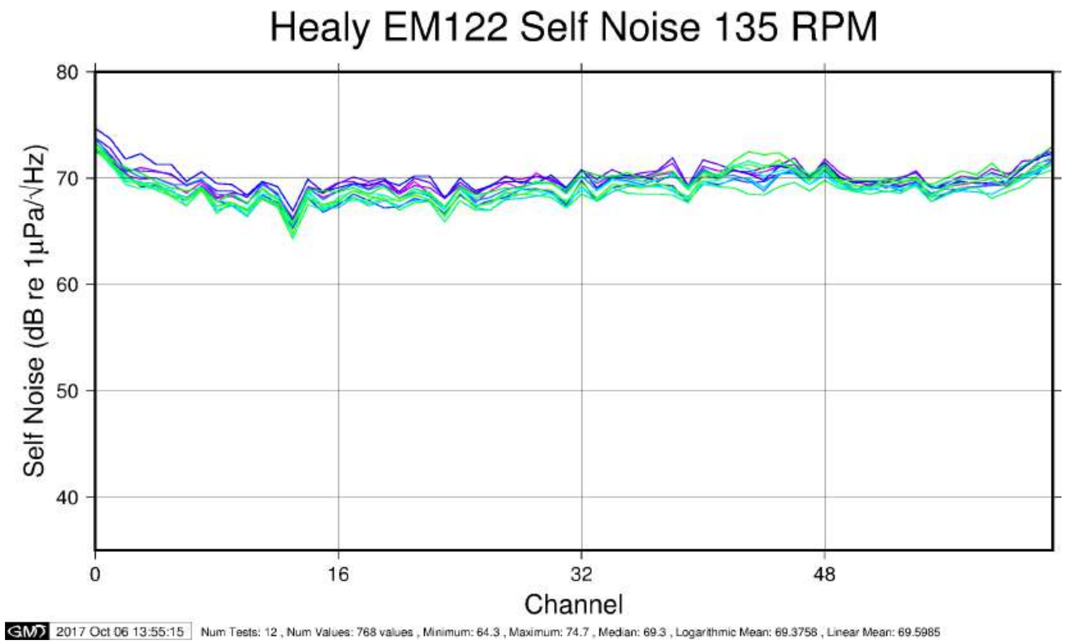

Healy EM122 Self Noise 60 RPM
Median
Mean (log.)
Mean (lin.)
Frequency (%)
45
40
35
30
25
20
15
10
5
0
40
50
60
70
80
Self Noise (dB re 1μPa/√Hz)
2017 Oct 06 13:55:07
Num Tests: 10 , Num Values: 640 values , Minimum: 62.3 , Maximum: 73.8 , Median: 66.6 , Logarithmic Mean: 66.7925 , Linear Mean: 67.1569

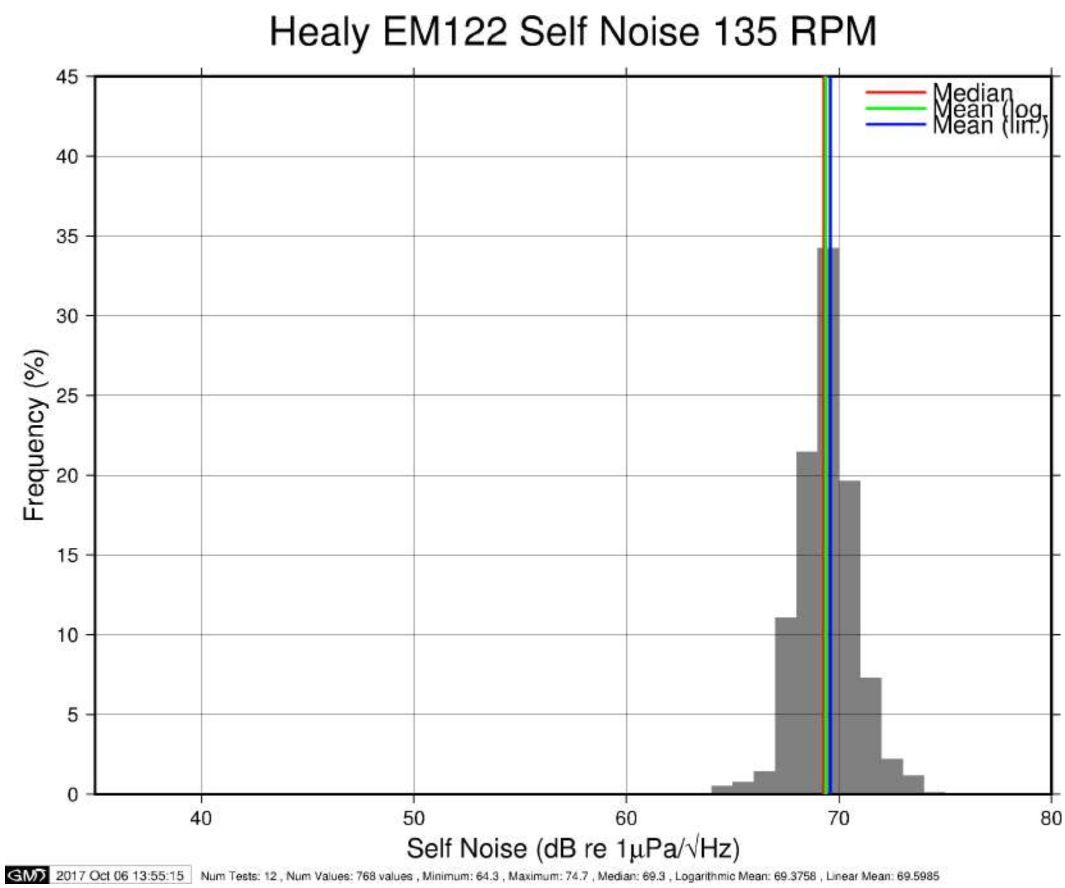

Healy EM122 Self Noise 90 RPM
80
70
60
50
40
Self Noise (dB re 1µPa/√Hz)
0
16
32
48
Channel
2017 Oct 06 13:55:09
Num Tests: 10 , Num Values: 640 values , Minimum: 63.1 , Maximum: 74 , Median: 67.2 , Logarithmic Mean: 67.3786 , Linear Mean: 67.6969


Healy EM122 Self Noise 90 RPM
Median
Mean (log.)
Mean (lin.)
45
40
35
30
25
20
15
10
5
0
Frequency (%)
40
50
60
70
80
Self Noise (dB re 1µPa/√Hz)
2017 Oct 06 13:55:10
Num Tests: 10 , Num Values: 640 values , Minimum: 63.1 , Maximum: 74 , Median: 67.2 , Logarithmic Mean: 67.3786 , Linear Mean: 67.6969


Healy EM122 Self Noise 120 RPM
Self Noise (dB re 1μPa/√Hz)
80
70
60
50
40
0
16
32
48
Channel
2017 Oct 06 13:55:12
Num Tests: 10 , Num Values: 640 values , Minimum: 63.2 , Maximum: 73.3 , Median: 67.6 , Logarithmic Mean: 67.6727 , Linear Mean: 67.8794


Healy EM122 Self Noise 120 RPM
Median
Mean (log.
Mean (lin.)
Frequency (%)
45
40
35
30
25
20
15
10
5
0
40
50
60
70
80
Self Noise (dB re 1μPa/√Hz)
2017 Oct 06 13:55:13
Num Tests: 10 , Num Values: 640 values , Minimum: 63.2 , Maximum: 73.3 , Median: 67.6 , Logarithmic Mean: 67.6727 , Linear Mean: 67.8794


Healy EM122 Self Noise 135 RPM
80
70
60
50
40
Self Noise (dB re 1μPa/√Hz)
0
16
32
48
Channel
GMT 2017 Oct 06 13:55:15
Num Tests: 12 , Num Values: 768 values , Minimum: 64.3 , Maximum: 74.7 , Median: 69.3 , Logarithmic Mean: 69.3758 , Linear Mean: 69.5985


Healy EM122 Self Noise 135 RPM
Median
Mean (log.)
Mean (lin.)
45
40
35
30
25
20
15
10
5
0
Frequency (%)
40
50
60
70
80
Self Noise (dB re 1μPa/√Hz)
GMT 2017 Oct 06 13:55:15
Num Tests: 12 , Num Values: 768 values , Minimum: 64.3 , Maximum: 74.7 , Median: 69.3 , Logarithmic Mean: 69.3758 , Linear Mean: 69.5985