UNDERWATER SOUND MEASUREMENTS OF HIGH FREQUENCY SONARS USING A SEABED-MOUNTED RECORDER

Graham Warner[1], Andrew McCrodan[2], Jeff MacDonnell[3], and Eric Lumsden[4]
[1,2]JASCO Applied Sciences, 2305-4464 Markham St., BC, Canada, V8Z 7X8 [1]graham.warner@jasco.com
[3,4]JASCO Applied Sciences, 202-32 Troop Ave., NS, Canada, B3B 1Z1

1. INTRODUCTION

There is concern among regulatory agencies that sonars operating below 180 kHz (upper frequency limit for high frequency marine mammal listeners) could produce sounds causing auditory injury or induce behavioural effects, and that sonars operating above 180 kHz could leak energy into the audible range. The regulatory permit for Statoil USA E&P Inc.'s 2011 marine survey program in the Alaskan Chukchi Sea required underwater sound measurements of high and low frequency sound sources used in the program. We used a seabed-mounted Autonomous Multichannel Acoustic Recorder (AMAR, JASCO Applied Sciences) to accurately measure high frequency sonar sound levels (Warner and McCrodan, 2011).

2. METHODS

2.1 Measurement Equipment

Underwater sound level measurements were made using a seabed-mounted Autonomous Multichannel Acoustic Recorder (AMAR, JASCO Applied Sciences) with a Reson TC4014 hydrophone (nominal sensitivity -186 dB re 1 V/uPa). The AMAR recorded 16 bit samples at 687.5 kHz for 27 hours. The end-to-end sensitivity of the recording system was calculated by adding the factory TC4014 frequency-dependent calibration sensitivity to the calibrated digitization gain of the AMAR.

The AMAR mooring consisted of a 120 lbs single chain link for ballast, an acoustic release, and a float collar surrounding the AMAR. The AMAR was deployed twice, each time in 37 m of water. On deployment, the ballast sank the AMAR with the hydrophone approximately 2 m above the seafloor. On recovery, the acoustic release was triggered to release the mooring from the ballast and the equipment was retrieved once it floated to the surface. The ballast was then retrieved using a grapple.

2.2 Measurement Procedure

Underwater sound measurements were made at Statoil's exploration lease area in the Chukchi Sea (Figure 1, right). The AMAR was deployed at approximately 71.7N, 164.3W in 37 m water. Three sonars were measured: a towed GeoAcoustics 159D side-scan sonar (112.5 kHz), a hull-mounted Kongsberg EM2040 multibeam sonar (205 kHz), and a hull-mounted Kongsberg EA600 single-beam sonar (200 kHz). The sonars were taken past the AMAR along several 1 km long parallel track lines. The lines were offset at horizontal distances between 0 and 400 m from the AMAR (Figure 2).

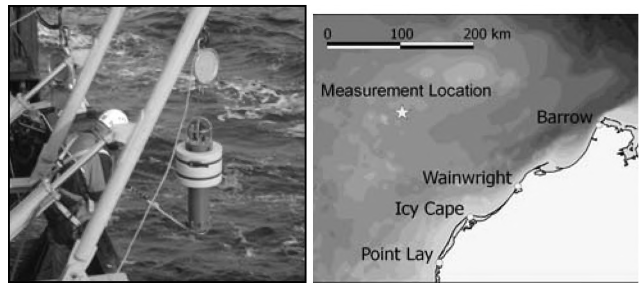

Figure. 1. Photograph of an AMAR with float collar being deployed (left) and map of the measurement location off northwest Alaska (right).

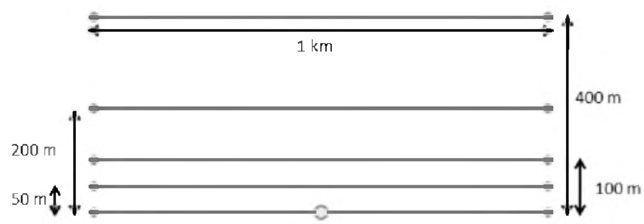

Figure.2. Sonar track lines relative to the AMAR (hollow circle).

2.3 Data Analysis

For each sonar, the acoustic data were band-pass filtered around the operating frequency. Sonar pulse sound levels were calculated using the filtered data and in-beam pulse levels were plotted versus slant range. An empirical equation of the form RL=SL-ALog(r) was fit to the 90% rms SPL data and distances to sound level thresholds were estimated. Sound levels from in- and out-of-beam pulses were then back-propagated using spherical spreading and absorption loss at the centre frequency (Francois and Garrison, 1982). Source levels were plotted versus horizontal or vertical angle.

3. RESULTS

Sonar pulses were detected on all five track lines for the side-scan sonar, lines offset 0, 50, and 100 m for the multibeam sonar, and lines offset 0 and 50 m for the single-beam sonar. The empirical fit equation to the 90% rms SPL in-beam pulse levels was RL=229.3-29.5Log(r) for the side-scan sonar, RL=189.0-27.3Log(r) for the multibeam sonar, and RL=287.6-89.3Log(r) for the single-beam sonar. Table 1 lists the distances to threshold levels for the three sonars.

Table. 1. Threshold distances as determined from the empirical fit equations of the 90% rms SPL in-beam pulse levels.

90% rms SPL threshold (dB re 1 uPa)	Side-scan distance (m)	Multibeam distance (m)	Single-beam distance (m)
190	22		12*
180	47		16*
170	100		21*
160	230		27*
150	490*	27	35*
140	1100*	62	45
130	2400*	140*	58
120	5100*	330*	75

*Extrapolated beyond measurement range.

Received levels were back-propagated to estimate source level versus angle off broadside for the side-scan (Figure 3) and multibeam (Figure 4) sonars and versus angle off vertical for the single-beam sonar (Figure 5).

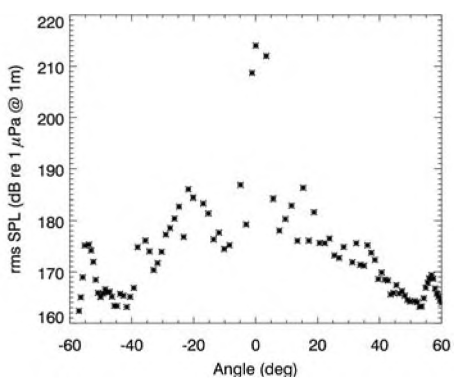

Figure. 3. Source levels as a function of azimuthal angle off broadside for the side-scan sonar.

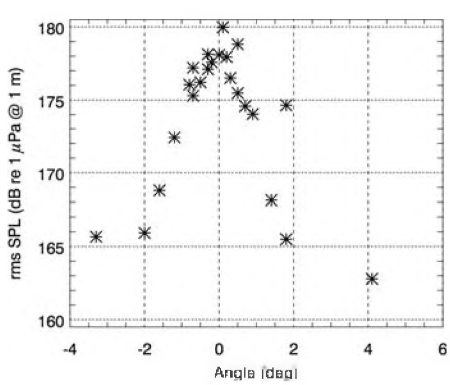

Figure. 4. Source levels as a function of azimuthal angle off broadside for the multibeam sonar.

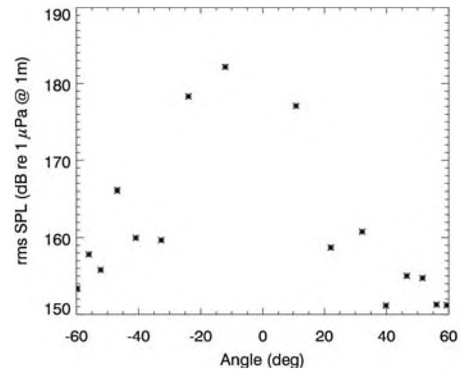

Figure. 5. Source levels as a function of angle off vertical for the single-beam sonar.

4. DISCUSSION

Statoil's regulatory permit for their 2011 Alaskan Chukchi Sea survey program required acoustic measurements of high frequency sonars. We measured underwater sound levels from side-scan, multibeam, and single-beam sonars using a high sample rate seabed-mounted AMAR. The measurement system allowed good control of source-receiver geometry compared to previous measurements using ship-based recorders (e.g. Chorney et al., 2011) and is suitable for both high and low frequency sound source measurements.

REFERENCES

Chorney, N.E., G. Warner, J. MacDonnell, A. McCrodan, T. Deveau, C. McPherson, C. O'Neill, D. Hannay, and B. Rideout. 2011. Underwater Sound Measurements. (Chapter 3) In: Reiser, C.M, D.W. Funk, R. Rodrigues, and D. Hannay. (eds.) 2011. Marine mammal monitoring and mitigation during marine geophysical surveys by Shell Offshore, Inc. in the Alaskan Chukchi and Beaufort seas, July–October 2010: 90-day report. LGL Rep. P1171E–1. Rep. from LGL Alaska Research Associates Inc., Anchorage, AK, and JASCO Applied Sciences, Victoria, BC for Shell Offshore Inc, Houston, TX, Nat. Mar. Fish. Serv., Silver Spring, MD, and U.S. Fish and Wild. Serv., Anchorage, AK. 240 pp, plus appendices.

Francois R.E. and G.R. Garrison. 1982a. Sound absorption based on ocean measurements: Part I: Pure water and magnesium sulfate contributions. JASA 72:896-907.

Francois R.E. and G.R. Garrison. 1982b. Sound absorption based on ocean measurements: Part II: Boric acid contribution and equation for total absorption. JASA 72:1879-1890.

Miller, J.H., A.E. Bowles, B.L. Southall, R.L. Gentry, W.T. Ellison, J.J. Finneran, C.R. Greene Jr., D. Kastak, D.R. Ketten, P.L. Tyack, P.E. Nachtigall, W.J.Richardson, and J.A. Thomas. 2005. Strategies for weighting exposure in the development of acoustic criteria for marine mammals. J. Acoust. Soc. Am. 118:2019 (Abstract).

Warner, G., and A. McCrodan. (2011). Underwater Sound Measurements. (Chapter 3) In: Hartin, K.G., L.N. Bisson, S.A. Case, D.S. Ireland, and D. Hannay. (eds.) 2011. Marine mammal monitoring and mitigation during site clearance and geotechnical surveys by Statoil USA E&P Inc. in the Chukchi Sea, August-October 2011: 90-day report. LGL Rep. P1193. Rep. from LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. For Statoil USA E&P Inc., Nat. Mar. Fish. Serv., and U.S. Fish and Wild. Serv. 202 pp. plus appendices.