Directionality and effects of maneuvering on ship-radiated underwater noise

Mark V. Trevorrow, Boris Vasiliev, and Svein Vagle

I. Introduction

For a variety of environmental acoustic and naval applications, it is important to understand the radiated underwater acoustic signature of surface ships. Although the measurement of broadband acoustic noise from ships is straightforward in principle, the directionality of vessel radiated noise and effects of aggressive turning maneuvers are often overlooked. In current practice, ship radiated noise is usually measured at fixed, shallow-water sound ranges. While acceptable for static measurements, these facilities generally do not allow the vessel to maneuver freely at greater speeds. In this work, a set of Broadband Underwater Recording Buoys (BURB) were developed to facilitate deep-water measurements on a freely maneuvering ship. The BURBs were developed in 2004–05 through a collaboration between Defence R&D Canada Atlantic and Fisheries and Oceans Canada, Institute of Ocean Sciences. The BURBs were designed to provide continuous recording of two calibrated hydrophones at 20-kHz bandwidth. This work describes the first major sea-trial of the BURBs using a small oceanographic vessel.

II. Instrumentation and field trials

BURBs are a set of four, identical self-contained buoys (see [1] for detailed description). Each buoy supports two independent hydrophone channels, each digitized at 40,000 samples per second with 16-bit resolution, and a differential GPS receiver, providing position data at 1-s intervals. Electronics and batteries are contained within a 20.3-cm diameter by 92-cm long pressure housing, with a 60-cm diameter foam floatation collar. The BURB hydrophones are omni-directional, broad-band (10 Hz to >20 kHz) receivers, suspended at depths of 5 and 15 m. After the trials, each BURB hydrophone was acoustically calibrated.

The ship radiated noise tests were conducted in Saanich Inlet (near Sidney), B.C. in mid-April 2005. This location featured relatively deep water (>180 m) while being sheltered from wind and wave action. The target ship, CCGS *Vector* (40 m LOA, 550 ton displacement), was outfitted with GPS receivers at the bow and stern, recorded at 1-s intervals. The CCGS *Vector* has a single 1.8-m diameter, variable-pitch, three-bladed propeller, operating near 300 rpm at maximum speed. The four BURBs were deployed from the CCGS *Vector* in the morning and recovered at the end of the day. Small launches were used to occasionally reposition the BURBs for different measurements. A variety of ship runs were made past the BURBs, with CPA typically 30 to 50 m. A series of straight-line passes at speeds up to 12 knots established a baseline and radiated noise directionality. After that a number of 90° and 180° turning maneuvers were conducted.

III. Results

Ship radiated noise was recorded continuously as the ship transited the BURB field. This work will focus on the 100-Hz to 5-kHz frequency band. The basic data analysis consisted of computing 1-s averaged, calibrated noise spectra, which were then converted to Source Level Spectra (SLS) through spherical spreading corrections using the GPS positions of the ship and BURB. The range calculation assumed that the effective acoustic center of the ship was located 10 m aft of the ship geometric center. The effects of seawater absorption can be ignored at these short ranges and low frequencies. Each 1-s averaged SLS had an associated transmission aspect angle relative to the ship axis (0° at bow, assumed port-starboard symmetric). Thus while the ship transited past the BURB field, source directionality patterns could be extracted.

Fig. 1 shows the resulting ship source level directionality at four different frequencies. Note two general characteristics of the ship SLS: firstly there was a relatively monotonic decrease in SL with increasing frequency, as much as 20 dB from 500 Hz to

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M. Trevorrow and B. Vasiliev are with Defence R&D Canada Atlantic, PO Box 1012 Dartmouth, N.S. B2Y 3Z7 Canada (corresponding author phone 902-426-3100 x315; e-mail: mark.trevorrow@drdc-rddc.gc.ca).

S. Vagle is with Fisheries and Oceans Canada, Institute of Ocean Sciences, 9860 W. Saanich Rd., Sidney, B.C. V8L 4B2 Canada (e-mail: vagles@dfo-mpo.gc.ca.).

4 kHz near broadside aspect, and secondly there was a significant broadside maxima at all frequencies. This non-uniform directionality was stronger at low -frequencies, with approximately 12 dB variation between bow and beam aspect at 500 Hz.

Fig. 2 shows the effects of maneuvering. During the in-run phase the SLS showed similar levels to the near-bow aspect straight-line runs. After the start of the turn (near 272 s) there was a strong increase in source level, reaching as much as 15 dB above the straight-line levels, at the equivalent aspect angle, at the lower frequencies. Note that there was a general increase in source level through the turn, despite variations in aspect angle. Near the end of the turn this source level excess dropped significantly after 320 s as the rudder angle was reduced and the ship began to straighten out and accelerate. Additionally, a significant reduction in SLS level at 4 to 5 kHz was observed in the early middle part of the turn. This higher-frequency drop-out is hypothesized to be due to bubble absorption.

IV. Conclusions

A set of self-contained, continuously recording hydrophone buoys were built, which allowed high temporal resolution measurement of radiated noise from a maneuvering ship. GPS positioning of the ship and buoys allowed precise correction for range and assessment of the effects of ship aspect angle, speed, and turning rate. In straight-line runs the ship source level spectrum showed a 20 dB decrease from 500 Hz to 4 kHz, with peak source levels near 140 dB re 1 μPa at 1 m. The ship source directionality showed a broad maximum near beam aspect, with up to 12 dB variation from bow to beam aspect at lower frequencies. During 180° turning maneuvers at 11 knots, increases up to 15 dB relative to the straight-line runs were observed, with some suggestion of bubble absorption effects at higher frequencies (near 5 kHz).

References

[1] Trevorrow, M., S. Vagle, and N. Hall-Patch, 2005. Description and Field Evaluation of the Broad-Band Underwater Recording Buoy System, DRDC Atlantic TM 2005-231.

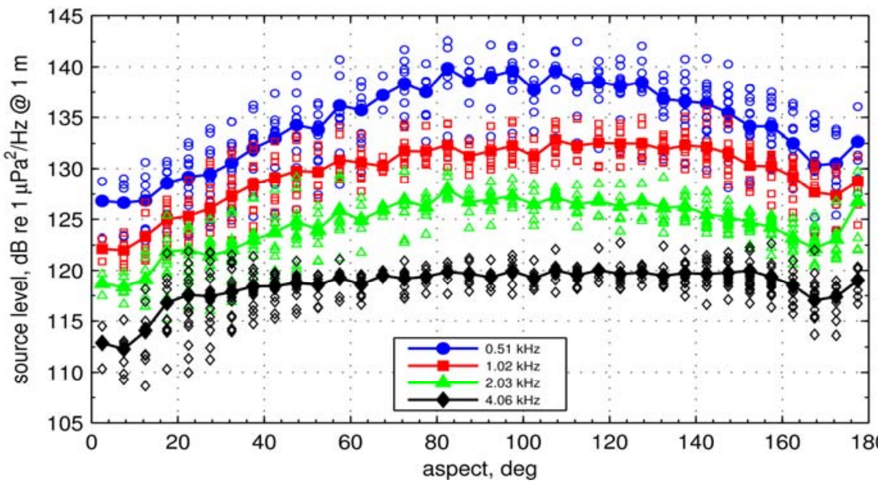

Fig. 1. One-third octave averaged SLS vs. aspect angle (0° bow, 90° beam, 180° stern) at four frequencies from straight-line transits at 10 knots, composite of three separate runs and data from four BURBs. Open symbols are individual measurements and solid symbols are average values in 5° bins.

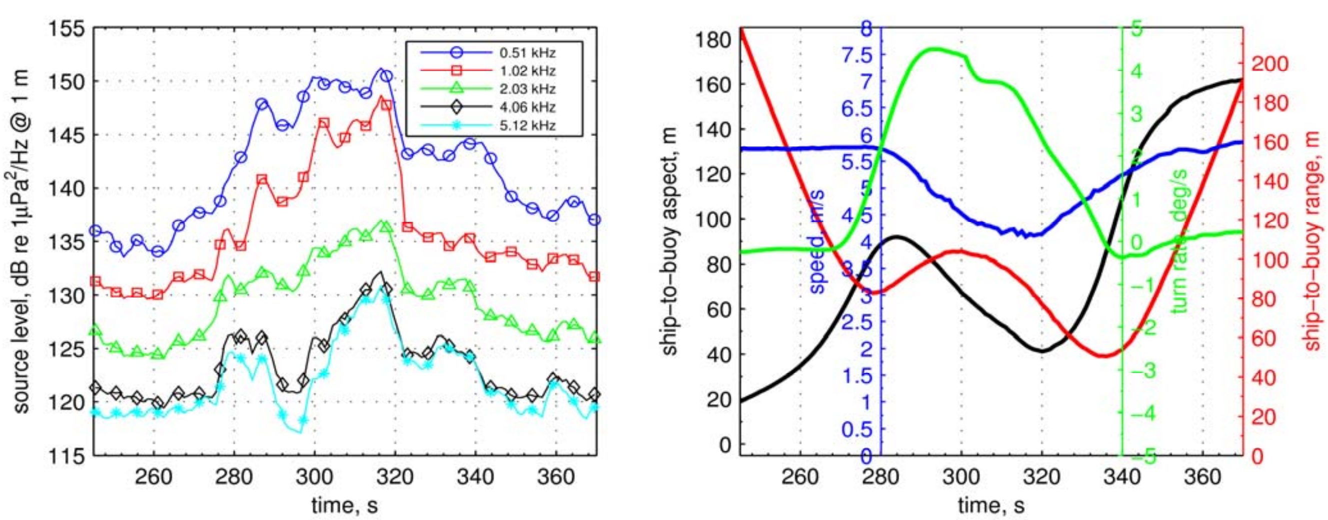

Fig. 2. (Left) One-third octave averaged SLS vs. time at five frequencies for a 180° turning maneuver at 11 knots. (Right) Corresponding ship-to-BURB range (red), aspect angle (black), speed (blue), and turn rate (green) through the maneuver.