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Practical calibration of ship-mounted omni-directional fisheries sonars

Gavin J. Macaulay [a,*], Sindre Vatnehol [a], Ole Bernt Gammelsæter [b], Héctor Peña [a], Egil Ona [a]

[a] Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway

[b] Kongsberg Maritime AS, Strandpromenaden 50, 3191, Horten, Norway

HIGHLIGHTS

- Calibration is essential for quantitative use of fisheries sonar backscatter.
- A method for calibration of ship-mounted fisheries sonars is proposed.
- We measured and corrected for the effect of sonar configuration on the calibration.
- The accuracy and stability of sonar calibrations are measured.

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ABSTRACT

Conventional ship-mounted vertically-oriented echosounders are poor at detecting organisms that are close to the sea surface. In contrast, omni-directional sonars can ensonify these near-surface waters unavailable to hull-mounted echosounders. If calibrated, sonars can provide quantitative biomass estimates of pelagic aggregations. However, for sonars that have not been designed as scientific and research instruments, the quantification and verification of the system performance is of heightened importance, and should include how parameters such as the shape and gain of the beams vary with system and operational configurations. We present a practical methodology for absolute calibration of omni-directional sonars when conventionally mounted on a vessel, illustrate the achievable calibration accuracies and precision, and document their variability over time and for a range of operating parameters. This work forms an essential prerequisite to the use of such sonars for quantitative measurement of backscatter, such

* Corresponding author.
E-mail address: gavin.macaulay@imr.no (G.J. Macaulay).

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as for echo-integration surveys and individual school density and biomass estimation.

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1. Introduction

Downward-looking, narrow-beam echosounders are commonly used for quantitative acoustic surveys of fish populations, being relatively simple to operate with well-developed analysis procedures for producing biomass estimates (Simmonds and MacLennan, 2005). However, they are not the ideal tool for detecting organisms that are close to the sea surface because most ship-based installations have the transducers mounted some metres below the surface to avoid the deleterious effects of air bubbles (Dalen and Løvik, 1981). In conjunction with the transducer near-field, transducer ringing, and the increasingly popular use of lowerable keel-mounted transducers, it is common that no echoes can be quantitatively measured in the upper 5–15 m. Also, at typical marine survey speeds (approx. 5 m/s), the probability of detecting small near-surface aggregations is low.

Omni-directional sonars are commonly used in pelagic fisheries, where they aid in finding and assessing fish aggregations, and monitoring the catch process (Ben-Yami, 1994). These sonars form acoustic beams from an array of transducer elements in a range of directions (Sherman and Butler, 2007). The most common arrangement is to form many narrow beams with oval cross-section that are emitted radially in all directions from the transducer, with a configurable tilt angle relative to horizontal, commonly called the horizontal mode. Some systems also form a vertical fan of beams with a configurable azimuth direction, commonly called the vertical mode.

Omni-directional sonars can provide information on schools metrics, speed, and behaviour (Misund, 1990; Misund et al., 1996; Peraltilla and Bertrand, 2014; Stockwell et al., 2013; Trygonis et al., 2016), but in most instances the backscatter amplitude information has not been used in a quantitative manner analogous to the echo-integration method commonly used with narrow-beam echosounders. Lack of access to calibrated quantitative backscatter has restricted most work to the analysis of the sonar's presentation display (Brehmer et al., 2006; Brehmer and Gerlotto, 2001; Trygonis et al., 2009), with compromises in dynamic range, linearity, and backscatter measurement accuracy.

While omni-directional sonars are able to better sample near-surface waters due to the horizontally-oriented beams, and can provide quantitative estimates of pelagic biomass (Brehmer et al., 2006; Misund, 1993, 1990; Smith, 1970), they introduce other complexities. Ensonifying organisms at variable side-aspect angles increases the variation in acoustic reflectivity (Cutter and Demer, 2007; Holmin et al., 2012; Tang et al., 2009), requires a more complicated echo-integration method (Nishimori et al., 2009), and acoustic ray bending (Brehmer et al., 2006; Lichte, 1919) complicates the survey sampling strategy.

Quantitative use of sonar backscatter data requires a known and stable relationship between acoustic and recorded amplitude over the range of sonar operating modes that are used in a study or survey — that is, the sonar should be calibrated. For systems that have not been intended for use as scientific instruments, the quantification and verification of system performance is of heightened importance. This should include knowledge on how parameters such as the shape and gain of the beams vary with system and operational configurations. Most omni-directional sonars provide the ability to set the acoustic frequency, pulse duration, pulse form, beamwidth, and tilt angle. For the sonars considered in this paper the total number of unique combinations of these settings exceeds 98 000. When combined with the 64 beams available in these sonars, there are more than six million potential combinations and is overwhelmingly impractical to calibrate all of them. A better approach is to understand the independent effect of each setting, so that relative adjustments can be applied to a small number of calibrations. Variation in beam characteristics and the associated calibration can be predicted via theoretical considerations of the underlying sonar transmit and receive operations, but the actual performance of individual sonars can vary significantly from the theoretical (Cochrane et al., 2003).

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