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VESSEL HEAVE, AN INDEX FOR AIR BUBBLE ATTENUATION CORRECTIONS

by

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ABSTRACT

The possible use of vessel heave as a correction indicator for air bubble attenuation of acoustic signals from hull mounted transducers is investigated. Vessel heave was monitored along with the echo energy from the air bubble layer close to the transducer surface. Initial comparisons under different weather conditions are presented.

INTRODUCTION

Air bubble attenuation of the transmitted and received signal in bad weather is a major problem when using hull mounted transducers to measure fish abundance (FORBES & NAKKEN, 1972). During the standard acoustic surveys in the Norwegian economic zone and adjacent waters we frequently experience wind force Beaufort 7, or 35 kn. Under these circumstances, attenuation of the acoustic signals from the hull mounted transducer may be total. In general, the only way to avoid the problem is to deploy the transducer below the air bubble layer in a towed body, or on a protruding platform below the keel (ONA & TRAYNOR, 1989). Under low to moderate attenuation levels, however, it is frequently more convenient to use hull mounted systems, in particular when doing combined trawl / acoustic surveys and when oceanographic observations are made along the acoustic transect. The time to set and retrieve the towed body together with the transducer stabilization time may be significant compared to the time between stations on some surveys.
Several index variables for the attenuation level have formerly been used in Norway to correct the integrated fish density under such conditions. These are (1) wind speed and direction (DALEN & LØVIK, 1981), (2) percentage of bottom echoes below a defined signal threshold, (ONA, 1987; ONA & MAMYLOV, 1988), (3) integrated echo energy in a depth layer close to the transducer (ONA, 1987, ONA & TRAYNOR, 1989), and finally, (4) a specifically designed bubble density estimator has also been tested (BERG et al. 1983), but has not yet been installed.

Corrections to the integrated echo energy from fish recorded below an air bubble layer is a job for experienced survey personnel. As for the joint Norwegian - Soviet multispecies survey in the Barents Sea, specific procedures for this work are established. When the goal of the survey is to obtain absolute acoustic estimates for one or several fish stocks, as here, a limit for correction of the data from the hull mounted system is set at 30% . when this level of attenuation is exceeded, the towed body should be deployed, or the survey suspended for vessel equipped with only hull mounted transducers.

On board the new research vessel "JOHAN HJORT", a vessel heave sensor is coupled to the EK-500 echo sounder, compensating for vessel heave on the echogram and in the data. This paper will evaluate vessel heave as a possible new index for air bubble attenuation.

MATERIAL & METHOD

The investigations were made north of North Cape, Norway, from the research vessel "Johan Hjort", (57 m, 3300 HP). The EK-500 echo sounder / echo integrator was coupled to a GPS positioning system, and to a Datawell, Hippy 120 Heave compensator, as well as to the BI500 postprocessing system (KNUDSEN, 1990).
The task of the heave sensor is mainly to feed data on vessel tilt, roll and heave to the Acoustic Doppler Current Profiler (RD-instruments), but can also be used to obtain heave compensated echo recordings on the EK-500.

The following telegrams, or data sequences, were logged over the serial line from the echo sounder, Table 1.

Vessel Motion telegram	-	Identification, time, heave (m),
Position telegram	-	Identification, time, N: deg, min, sec E: deg, min,sec.
Integrator tables	-	Identification, time,date, s_A measurements in 2 m depth channels from 0-50 m and 50 m channels from 51 m to bottom.

COMPUTATIONS

The instantaneous heave in metres, about 60 readings per minute, varying positively and negatively, were squared and accumulated over the integrator report period, Fig.1.

$$H = \int_{1}^{n_h} h_i^2 \, dt \qquad ,$$

where h_i is the individual readings, and n_h is the number of readings over the reporting period, usually 0.5 nautical miles.m (At a survey speed 11 knots, an average of 163 readings of heave were squared and accumulated over this period).

The standard error of the average heave during the period was also calculated:

$$SE(H) = n_h \left[\left(\frac{1}{n_h - 1} \right) \left(\Sigma h_i^4 - \frac{\Sigma h_i^{\;2}}{n_h} \right) n_h^{-1} \right]^{-\frac{1}{2}}$$

The average speed during the report period was calculated directly from the difference between the GPS positions, and the integrated echo energy in the four first cells, 2 to 10 m, after transmission pulse decay, caused by the bubble layer were compared with the accumulated heave over the same period.

RESULTS AND DISCUSSION

A typical example of a comparison between vessel heave and the integrated echo intensity from the air bubble layer beneath of the transducer over a stretch of 36 nautical miles on March 10. 91, is shown in Fig.2. Logging of data started in relatively rough weather, 25 - 30 kn. wind, calming down as the vessel approached the coast, at a survey speed of 11 knots. The variables show a reasonable correlation, r= 0.82, n=72 , Fig. 3, comparable to the relationship between bottom signal strength and integrated air. The standard error of the heave increases with increasing vessel movement. The correlation will improve if the averaging period is increased to one or five nautical miles, and are best in the lower half of the range, where corrections to the data obtained on the hull mounted system may be done. For measurements above about s_A =3000, only data from the towed system are considered acceptable.

Several conclusions can be drawn from this first approach:

(1): Most of the overall error in the echo integral in bad weather is caused by the complete or partial loss of the received signal when total blocking of the transmitted signal occurs. This is not caused by the wind mixed bubble layer, but by the way the vessel meets the waves, traps air at the bow, and the steepness of the hull in front of the transducer platforms. Typically this can be observed when turning the vessel into the wind or wave direction, when a large fraction of the transmissions may be blocked. In this direction, air is trapped at the bow and floats backwards under the transducer platform and also the vertical movement of the transducer inside the bubble layer increase. As the layer has a exponentially increasing bubble density towards the surface, the vertical movement of the transducer up to near surface level will drastically increase the attenuation. At 20 kHz, HALL (1989) found the attenuation to be as low as 1 dB at normal transducer draft, 5 m , but 70 dB at 1 m depth during a wind speed of 15 m/s.

Echo integrators with algorithms to average the signal from all transmissions during such conditions, like the first ones used for fish abundance measurements, will bias its measurements with the full effect of blocking and air bubble attenuation. However, all the transmissions along a track line are rarely needed to reproduce the average fish density on the elementary sampling distance used on surveys. Algorithms to reduce this effect were first implemented successfully in the ND-10 digital integrator at IMR, Bergen (BLINDHEIM et al. 1982), in which the quality of the bottom signal determined if the transmission should be included in the average. Correction factors for attenuation, based on the reported fraction of rejected accepted bottom signals have been used in Norway for some years now (ONA , 1987).

(2): The receiver of new echo sounder, EK-500, has a high dynamic range, 160 dB, and even strong signals from targets near the transducer may be correctly measured. This enables us to measure the average echo intensity of air bubbles in front of the transducer at survey settings of the sounder without saturating the receiver.
In this paper integrated air is compared with vessel heave as an index for air bubbles attenuation. At this point, more data is needed to evaluate which of these indices is preferable, but both contain qualities which should be taken into account. They are vessel dependent, so that small vessels will experience problems at lower wind speeds than large ones. They are also vary with vessel speed and direction, as does the attenuation.

(3) The average integrated heave measurements may provide an objective, qualitative index of survey weather conditions.

(4): The precision of integrator data corrected for attenuation will always be lower than data obtained under calm sea conditions, the error being proportional to the correction. On surveys for absolute fish abundance measurements, a correction of more than 30% to the integration measurements from hull mounted transducers is not recommended (ONA & MAMYLOV, 1988). On some of the Norwegian surveys, this has been defined as the maximum level before the towed system should be deployed.

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Table 1. Section of the raw data file logged from EK-500, with telegrams as indicated in Material and Methods. Only 10 of the narrow, 2 m layers are shown in line no. 8

```
GL,16342746,7118.47,N,02604.26,E
MS,16342611, 0.35,  0.0,  0.0
MS,16342705, 0.43,  0.0,  0.0
MS,16342804, 0.18,  0.0,  0.0
MS,16342897,-0.06,  0.0,  0.0
MS,16342991,-0.19,  0.0,  0.0
A2,16343218,910307,
  253E4, 1883,   22,    1,89E-2,32E-2,78E-3,29E-3,20E-3,11E-3,
      6,
      6,
     23,
     14,
     15,
      1,
      3,
      7,
     12,
MS,16343086,-0.27,  0.0,  0.0
GL,16343358,7118.47,N,02604.28,E
MS,16343182,-0.29,  0.0,  0.0
MS,16343531, 0.15,  0.0,  0.0
MS,16343626, 0.15,  0.0,  0.0
```

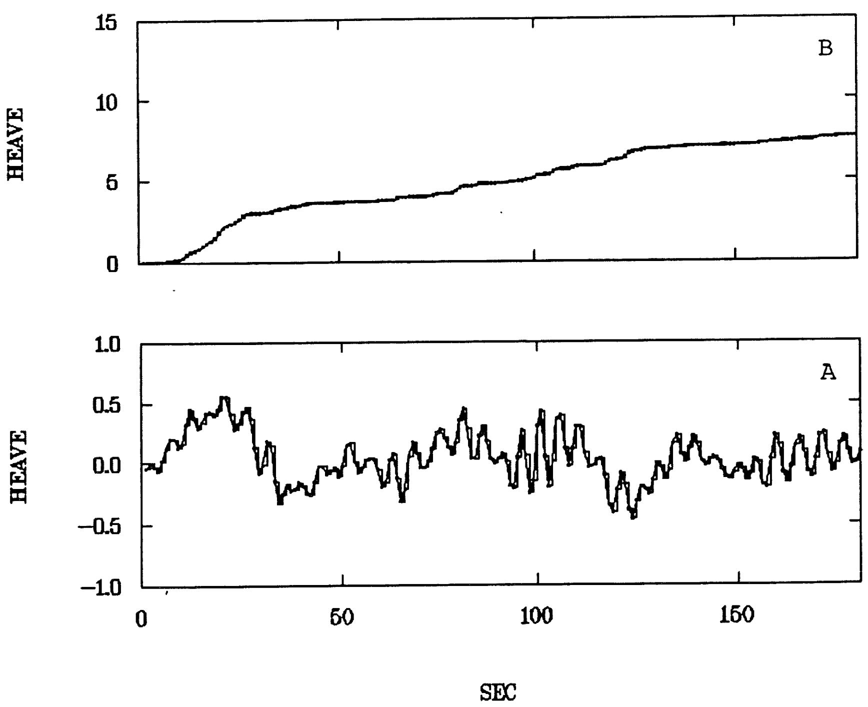

Figure 1. Instantanous vessel heave over a 3 min. period, (A), and the corresponding integrated squared heave, (B).

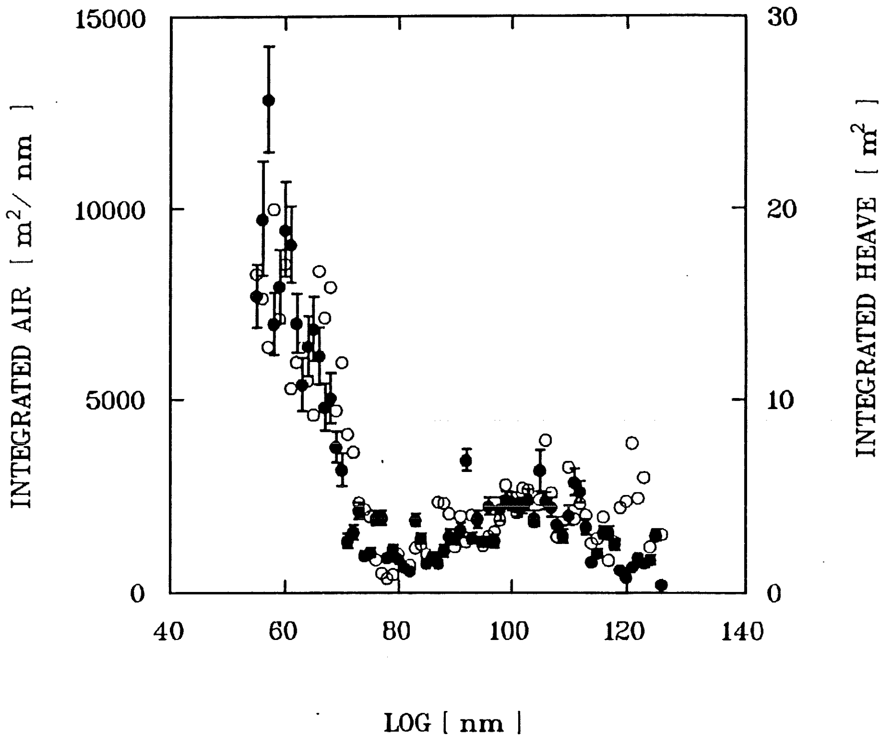

Figure 2. Integrated air, 2-10 m, compared with integrated vessel heave over a stretch of 36 nautical miles. Output interval is 0.5 nautical miles, and standard error of average heave in the report period is shown.

Integrated heave, closed symbol, integrated air, open symbol.

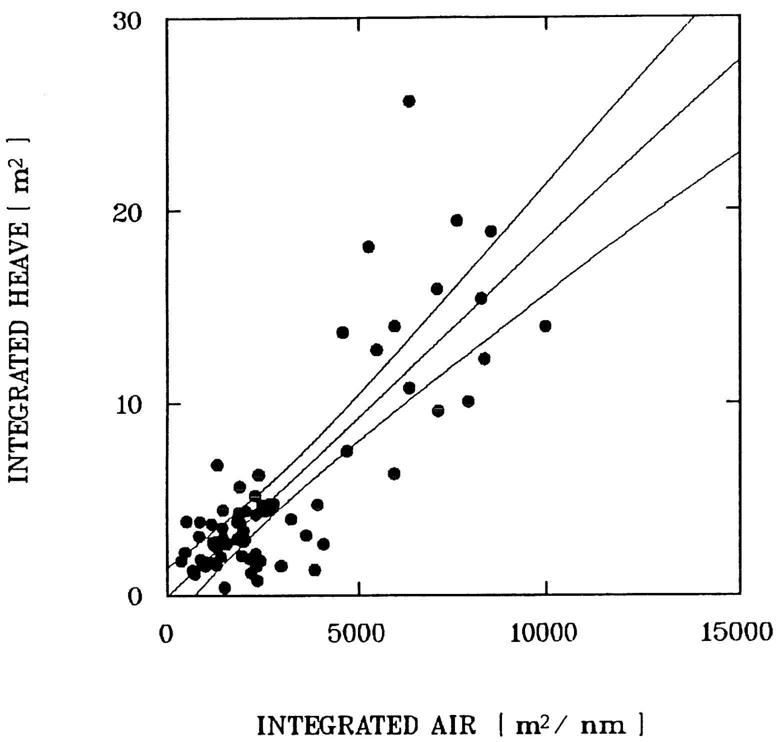

Figure 3. Correlation between integrated vessel heave and the amount of air measured in front of the transducer.
Y = 1.185 E-3 X - 0.039, (r = 0.82, n = 72).