Fol, 41 B

International Council for the
Exploration of the Sea

C.M. 1990/B:22
Sess. R
Fish Capture Committee

BAD-WEATHER CALIBRATION OF SPLIT-BEAM ECHO SOUNDING SYSTEMS

by

Kenneth G. Foote
Institute of Marine Research
5024 Bergen, Norway

ABSTRACT

A condition for standard-target calibration is stability of the sonar platform and target rig. This condition cannot always be met, nor need it be when the transducer has a split-beam function. Since the position of the target can be known even when it is moving, the beam pattern can thus be removed from the measurement, allowing direct sensing of the target's backscattering cross section whenever the target is in the beam. The calibration can therefore be performed when the target is off-axis or moving.

RESUME: ETALONNAGE DE SONDEUR A FAISCEAU SCINDE PAR MAUVAIS TEMPS

La stabilité de la plateforme sonar et du gréement de la cible est une condition favorable à l'étalonnage sur sphère étalon. Cette condition ne peut être toujours trouvée mais elle n'est plus nécessaire lorsque le transducteur possède une fonction faisceau scindé. La position de la cible étant connue même quand elle bouge, la fonction de directivité peut aussi être déterminée. La mesure peut alors tenir compte de cette fonction de directivité, rendant possible une utilisation immédiate de la rétrodiffusion de la cible dès que celleci se trouve dans le faisceau. L'étalonnage peut ainsi être effectué quand la cible n'est pas sur l'axe d'émission et qu'elle bouge.

INTRODUCTION

The ICES calibration guide (Foote et al. 1987) gives two examples of a standard-target calibration. Both the stationary-sphere method and the moving-sphere method require stability of the sonar platform and target rig. Of course, this condition cannot always be met, even at anchorage in fjords surrounded by high mountains. Calibration is, however, so important sometimes that it cannot be postponed or ignored, hence the need to be able to cope with bad conditions.

Many transducers used in echo integration surveys of fish stocks (MacLennan 1990) are of the split-beam or dual-beam variety (Ehrenberg 1983).

For either of these the position of resolved single targets can be sufficiently well known to permit compensation of the echo energy for the beam pattern. That is, the target strength can be measured directly, as though the target were suspended on-axis or were being moved systematically over the beam cross section. The performance of both echo sounder and echo integrator can thus be measured relative to a known standard, and a calibration can be effected.

A number of measures are used to characterize the performance state of acoustic instruments. One of the most important of these is the echo integrator constant, which is treated here. Other measures, such as the sum of receiver voltage response and source level, used to characterize the echo sounder, can be derived by analogy.

Below, some basic theory is presented. Details of the proposed method are given in one of several possible formulations, and error sources are discussed.

THEORETICAL BACKGROUND

The echo integrator measures a quantity M that is proportional to the mean backscattering cross section $\bar{\sigma}$ of scatterers distributed over the examined depth interval per unit surveyed area:

$$M \propto \rho\bar{\sigma} \quad , \tag{1}$$

where ρ is the area density of scatterers over the particular depth interval. The product $\rho\bar{\sigma}$ is just the area backscattering coefficient s_A, hence

$$s_A = CM \quad , \tag{2}$$

where C is a constant of proportionality. The problem of calibration is that of determining C.

For a standard target on the transducer axis at range r (Knudsen 1989),

$$s_A = 1852^2 \frac{\sigma_1}{r^2 \psi_o} \quad , \tag{3}$$

where σ_1 is the backscattering cross section of the standard target and ψ_o is the nominal equivalent beam angle of the transducer (Simmonds 1984, Foote 1990). Equating this to the product CM_1 in equation (2),

$$C = 1852^2 \frac{\sigma_1}{r^2 \psi_o M_1} \quad , \tag{4}$$

The multiplicative factor 1852^2 expresses s_A in units of square meters of backscattering cross section per square nautical mile.

METHOD

Under stable conditions, the standard target may be positioned and held on the acoustic axis. The calibration constant C is determined immediately from equation (4), since the backscattering cross section σ_1, target range r, and nominal equivalent beam angle of the transducer, ψ_o, are all known a priori, and M_1 is measured.

Under unstable conditions, the standard target may wander in the transducer beam, even leaving the main lobe or, worse, only occasionally entering it. If the beam pattern at any arbitrary position can be linked to the corresponding single-ping value of M_1, then C can be determined in the following way. The single-ping value M_{1j} is derived with the target generally off-axis at range r_j, where the beam pattern has the value b_j. Since M_{1j} is proportional to the echo energy with application of "20 log r" time-varied gain to the received signal, hence to the product of transmit and receive beam patterns b_j^2, the on-axis value at range r_j would be M_{1j}/b_j^2. On axis at range r, this would be $(r_j/r)^2 M_{1j}/b_j^2$. To avoid singularities due to nulls in b, single-ping values of M_1 should be considered only when b_j exceeds some minimum threshold value, for example, 0.1, corresponding to the -10-dB level. If the minimum or threshold value is expressed by b_T, then the echo integral M_{1j} is accepted if $b_j \geq b_T$ and rejected if $b_j < b_T$. This may be indicated through the counting function u, with values 1 and 0 for the respective cases. The calibration constant C is determined thus:

$$C = 1852^2 \frac{\sigma_1}{r^2 \psi_o \hat{M}_1} \quad , \tag{5a}$$

where, for n pings,

$$\hat{M}_1 = \frac{1}{r^2} \sum_{j=1}^{n} u_j (r_j/b_j)^2 M_{1j} \Big/ \sum_{j=1}^{n} u_j \quad . \tag{5b}$$

The divisor normalizes the sum with measured values M_{1j} to the number of values that are counted, namely those for which $u_j = 1$, or $b_j \geq b_T$.

DISCUSSION

Realization of the calibration described through equation (5) is most conveniently done by storing the simultaneous set of measurements (r_j, b_j, M_{1j}) for each ping in a series. Based on comparison of b_j with a minimum or threshold beam pattern value b_T, the value u_j of the counting function u is determined, and the summation in equation (5b) can be performed. Substituting the estimated on-axis value $\hat{M}_1$ in equation (5a) completes the determination of C.

This process is more involved than that of ordinary on-axis calibration, in which C is determined simply by equation (4). It is also more susceptible to measurement error. The particular error source that is, perhaps, most critical is that determining the beam pattern in the target direction. This involves measurement of two angles from four phase signals in the case of the split-beam echo sounder and measurement of two amplitudes from separate sum-beam signals in the case of the dual-beam echo sounder. Deviation of beam patterns from their nominal forms will thus introduce errors into the estimate $\hat{M}_1$, thence into C. While beam patterns may differ from their specified forms because of effects of mounting and housing, for example, adjustment of compensation factors is possible (Degnbol 1988, Kieser 1988, Kieser and Ona 1988, MacLennan and Svellingen 1989).

Additional sources of error may be due to other terms in equation (5b), specifically r_j, u_j, and M_{1j}. The effect of errors in r_j can be estimated. Errors in u_j arise from the use of a comparison value b_T. Since a large number n is desirable for the sake of good statistics, b_T should be set low. This will make the comparison with b_j uncertain due to the influence of noise. The problem is less with high values of b_T. Noise affects the measured value M_{1j} in similar fashion. Experience and consideration of the conditions of the particular calibration exercise will suggest a reasonable value for b_T.

The opportunity to perform a bad-weather calibration is more frequent in the ICES community than the recommended good-weather sort. It is hoped that reports comparing good- and bad-weather calibrations performed on the same echo sounders and integrators will be presented at future statutory meetings.

ACKNOWLEDGEMENT

N. Diner is thanked for rendering this abstract, as well as that of ICES C.M. 1990/B:21.

REFERENCES

Degnbol, P. 1988. A calibration method for split beam echo sounders including calibration of directivity compensation and level. ICES C.M. 1988/B:8. 10 pp. [mimeo]

Ehrenberg, J. E. 1983. A review of in situ target strength estimation techniques. FAO Fish. Rep., 300: 85-90.

Foote, K. G. 1990. Equivalent beam angles for several standard transducers. ICES C.M. 1990/B:21. 6 pp. [mimeo]

Foote, K. G., Knudsen, H. P., Vestnes, G., MacLennan, D. N., and Simmonds, E. J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Coop. Res. Rep., 144. 69 pp.

Kieser, R. 1988. An extension of the dual beam algorithm. ICES C.M. 1988/B:23. 10 pp. [mimeo]

Kieser, R., and Ona, E. 1988. Comparative analysis of split beam data. ICES C.M. 1988/B:44. 8 pp. [mimeo]

Knudsen, H. P. 1989. Bergen Echo Integrator: An introduction. ICES C.M. 1989/B:9. 8 pp. [mimeo] [J. CIEM (in press)]

MacLennan, D. N. 1990. Acoustical measurement of fish abundance. J. acoust. Soc. Am., 87: 1-15.

MacLennan, D. N., and Svellingen, I. 1989. Simple calibration technique for the split-beam echo-sounder. FiskDir. Skr. Ser. HavUnders., 18: 365-379.

Simmonds, E. J. 1984. A comparison between measured and theoretical equivalent beam angles for seven similar transducers. J. Sound Vib., 97: 117-128.