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An alternative to thresholding during echo-integration data collection

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Determination of threshold to reduce the amount of noise included in echo-integration data has always been a relatively arbitrary operation. Values selected in the field often are too low and allow noise integration or are too high and bias against low fish-density situations. This paper describes an alternative method for reduction of non-reverberatory (ambient) acoustical noise and electrical interference encountered during echo-integration data collection. Automatic or manual implementation may be easily accomplished.

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Introduction

Analogue data (echo voltages) presented to an echo integrator always include superimposed non-reverberatory noise generated by weather, the vessel, etc. A voltage threshold at the input of the integrator is commonly used to reduce noise contribution to estimated echo intensity and hence, to estimated biomass. The determination of an appropriate threshold has long been a topic of concern and has been discussed at length (Aglen, 1983; Burczynski, 1982; Forbes and Nakken, 1972; Johannesson and Mitson, 1983). This report describes a method for manual or automatic reduction of non-reverberatory acoustical noise and electrical interference from echo-integration data.

Effective noise intensity included in the output of an echo-sounder receiver can be measured directly with an echo integrator by operating it in the usual manner but with the echo-sounder transmitter disabled. Noise integration can then be eliminated from echo-integration data by subtraction. The remainder of this report discusses several possible implementations of the technique as well as advantages and disadvantages.

Implementation of noise cancellation

Non-reverberatory (environmental) noise and echo (backscattered) intensity cannot be measured simultaneously in a manner that allows determination of the effects of either on overall (echo + noise) intensity. The result is that noise cancellation using this technique requires that noise-integration data be collected independently of normal echo-integration data and also be representative of conditions during echo-integration data collection. Average echo intensity ($\bar{I}$) measured with an echo integrator when the echo-sounder transmitter is enabled is:

$$\bar{I} = (K/n) \times \Sigma(V_e + V_{nz})^2$$

where K = scaler,
n = sample size,
V_e = echo voltage,
V_{nz} = noise voltage.

Similarly, average noise intensity ($\bar{I}_{nz}$) measured with the integrator when the transmitter is disabled is:

$$\bar{I}_{nz} = K/n' \times \Sigma(V'_{nz})^2$$

where n' = sample size,
V'_{nz} = noise voltage.

Primes (′) indicate noise and overall intensity are not simultaneous measurements. Average reverberatory intensity ($\bar{I}_{revb}$) can now be estimated by:

$$\bar{I}_{revb} = \bar{I} - \bar{I}_{nz} = (K/n) \times \Sigma(V_e^2 + 2V_eV_{nz} + V_{nz}^2) - (K/n') \times \Sigma V'^2_{nz}.$$

Now, assume that the average noise intensity associated with overall integrated intensity is equal to the independent noise measurement (i.e., $V_{nz}^2 = V'^2_{nz}$). By subtraction:

$$\bar{I}_{revb} = (K/n) \times \Sigma(V_e^2 + 2V_e V_{nz}).$$

Further, assume the noise and echo voltages in the cross product are distributed symmetrically about zero voltage and that $E(V_e V_{nz}) = 0$. The above equation then reduces to:

$$\bar{I}_{revb} = (K/n) \times \Sigma V_e^2,$$

which represents only the portion of the average overall intensity from backscattering the portion of interest.

Various methods for implementation of noise cancellation as described in this report are possible, but three basic levels come quickly to mind. They are: 1) integration of noise during selected times or in survey subareas; 2) during alternate integration time intervals; or 3) after alternate pings. Each method requires that all noise sources (weather, ship speed, etc.) remain constant between associated noise- and echo-integration measurements. Considerable operator intervention may be necessary using option 1 when noise conditions change rapidly (i.e., building weather) but in general it does not require much effort. Options 2 and 3 can be designed into the echo-integration data collection system to operate automatically.

Advantages and disadvantages

The major advantage of this technique is auto-regulation of the effect of noise on integration data. Thresholding can still be used to set minimum echo voltage detectability in order to exclude echo energy from plankton layers, small fish, etc. An appropriate level based on system parameters can be determined at any time before data collection.

The major difficulty in implementation of this technique is that options 2 and 3 both require software and hardware modifications of the echo-integration data collection system. Echo- and noise-integration data must be either collected in separate, parallel files or automatically coded in a manner that is easily identifiable as to content. In addition, the echo-sounder transmitter must automatically be enabled and disabled at appropriate times.

Discussion

The concept of noise cancellation as described in this report is not new. The technique, in various forms, is used routinely in other fields to eliminate noise, offset, and other factors that affect the accuracy of measurements. Noise reduction in echo integration has previously been explored with respect to thresholding, reduction of noise sources such as ship hulls or propellers, and flow noise around transducers mounted on hulls or in towed bodies. The direct measurement of background noise using an echo integrator and subtraction of it from echo-integration data has not been reported.

Implementation of noise reduction in echo-integration data can be accomplished in a number of ways. This report assumes that a number of depth strata are preset in the echo integrator and that the TVG operates during noise integration. In this way, a number of noise measurements can be collected in each integrator output and the effects of occasional (i.e., several per ping; from propeller cavitation, etc.) large noise spikes can be smoothed using curve fitting. Noise integration can then be removed from echo integration by a direct, depth-interval-by-depth-interval subtraction. An equivalent method that has been used is the measurement of average noise within a narrow depth interval well beyond the range where any bottom echo is expected to occur. A curve equal to that of the TVG is then forced through the point to estimate noise at all other depths. Noise subtraction can then be accomplished as described above (Holliday, personal communication). An advantage of this method is that no data collection time is lost during noise measurement. Care must be exercised when using this method to be sure that no residual bottom reverberation or multiple bottom echoes occur during the measurement period. Also, the effect of occasional large noise spikes cannot be detected.

Thresholding of echo voltages to eliminate the detection of unwanted scatterers (plankton layers, small fish, etc.) in the water column should not be confused with reduction of ambient noise. Echo intensity is a function of the operation of the echo sounder and data collection system, while ambient noise sources are independent of the measurement technique. The reduction of undesired echo integration using the two concepts together is complementary but is also somewhat interactive. The result is that when noise reduction as described in this report is used with a threshold, threshold values must be calculated using system parameters and scatterer plus sub-threshold noise intensity. The effect of noise on calculated threshold voltage is greatest when unwanted echo voltages are equal to noise levels. The effect is less when the ratio of threshold voltage to noise voltage deviates from unity. When noise exceeds the threshold, it can be measured and subtracted from echo integration. When the threshold exceeds noise, the proportionate contribution of noise to unwanted echo intensity decreases as the ratio of threshold to noise increases. The effect of echo intensity from unwanted scatterers and sub-threshold noise on echo intensity from scatterers of interest, when all are detected simultaneously, cannot be removed. Detectable voltages derive from the algebraic sum of all simultaneous acoustical energy, and the components are indistinguishable.

This report discusses the concept of noise reduction in echo-integration data collection and offers several suggestions for implementation of this approach. Elimination of much of the effect of noise is possible, and in many cases it is not difficult. Use of the concepts discussed here should be seriously considered for implementation during all routine echo-integration surveys.

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