Implications of a Bi-static Treatment for the Second Echo from a Normal Incidence Sonar

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Abstract A bi-static treatment of the second echo from a normal incidence sonar is required to understand the mechanism by which the second echo includes information that is not available in the first echo. The theory shows that the range dependence of scattering from the sea-bed places the receiver position in the near field of the scattering patch with respect to the effective position of the transmit source. Results from a laboratory tank experiment will be presented to show that sediment discrimination can be achieved.

INTRODUCTION

The first backscatter return from the sea-bed at normal incidence has traditionally been used to measure the depth of water below the transducer or to provide limited information about the seabed whilst the second return is often ignored. Using information contained in both the first and second echo it is possible to discriminate sediment types [1]. This technique has been employed in a commercial system known as ROXANN for a number years. It is not our intention to replicate the details of the ROXANN system but rather to investigate the scattering mechanism that allow additional information to be extracted from the second echo.

THEORY

The second echo geometry is shown in figure 1 and it is clear that this is a bi-static configuration. This is an important factor in the classification mechanism. The relationship between \( R_1 \), \( R_2 \), \( \theta_1 \) and \( \theta_2 \) means that the backscatter intensity can be written in terms of \( \theta_1 \) and \( d\theta_1 \) and this is given in equation 1.

![Figure 1. Unfolded geometry of the source and receiver positions for the second echo](image)

The integral for backscattered intensity (\( I_{bs2} \)) using the bi-static geometry in figure 1 can written as:

\[
I_{bs2} = \frac{I_0}{4} \frac{\theta_1^2}{R_1^2(1+\alpha^2\theta_1^2)} \int_{\theta_1}^{\theta_1+\Delta\theta_1} \exp\left(-\frac{\beta_0 \theta_1^2}{4} (1+\alpha^2)\right) \exp\left(-\frac{\beta_0 \theta_1^2}{4}\right) \theta_1 d\theta_1 \left(1+\frac{\theta_1^2(1+\alpha^2)^2}{4}\right)^2
\]  

(1)
where

\[ \beta_2^2 = \frac{1 + \alpha^2}{\sigma_0^2}, \quad \beta_1^2 = \frac{T^2}{4h^2}, \quad \alpha = \frac{R_1}{R_2} \]

For the second backscatter return (time \( t=0 \) corresponds to its onset at the receiver) from the sea bed the complete envelope is required for the subsequent analysis. The ensemble averaged envelope of the returned intensity is obtained by integrating between appropriate time dependent angular limits. When \( \alpha = 1 \) the source and receiver are coincident and hence equation 1 applies to the first return in which \( \Re^4 \) is replaced by \( \Re^2 \) as there has only been a single insonification of the surface. When the transducer is at the water surface, as shown in figure 1 the value of \( \alpha \) is 3 for the second echo.

Al-Hamdani et al [2] showed for a vertically bistatic source and receiver that as the receiver is placed closer to the sediment it moves into the near-field scattering region. As a consequence the received signal is related to the reflection coefficient rather than the scattering due to the sediment roughness.

**EXPERIMENTS**

Experiments have been conducted in a laboratory tank using a 200 kHz transducer with a -3 dB full beamwidth of 12°. The transducer was placed on a computer controlled gantry so that it could be moved over each of the three sediments which had been placed at the bottom of the tank. The raw data was processed to obtain ensemble average envelopes for first and second backscatter over a range of water surface roughness conditions. Single numbers are obtained from the 1st and 2nd echo ensemble averages by integrating over the tail of the 1st echo (E1) and the whole of the 2nd echo (E2) in a similar manner to the ROXANN procedure. Figure 2 show an example of the tank experiment result with waves on the water surface and using a pulse length of 100μS.

![Figure 2 Plot of E2 against E1 for sand (+), gravel (*) and cobble (△) from the processed tank data](image)

**REFERENCES**
