TITLE

SHALLOW WATER IN-PLANE BISTATIC SCATTERING EXPERIMENT

Shallow Water In-plane Bistatic Scattering Experiment

D. Vance Crowe, Paul C. Hines and Patrick J. Barry
Defence Research Establishment Atlantic, P.O. Box 1012, Dartmouth, Nova Scotia, Canada
crowe@drea.dnd.ca, hines@drea.dnd.ca, barry@drea.dnd.ca

Abstract: A simple array consisting of a pair of free-flooding-ring projectors and an omnidirectional hydrophone was used to measure monostatic and in-plane bistatic scatter in 100 m of water on the Scotia Shelf. Linear FM (LFM) pulses were transmitted in four frequency bands over the range 900 to 2100 Hz. In this paper, an estimate of the bistatic scattering strength at 2 kHz is presented for a limited set of grazing angles.

INTRODUCTION

Every reverberation experiment done in shallow water is, by its nature, bistatic at long ranges. That is to say, in addition to simple monostatic returns, the received signal is composed of energy arriving along bottom-bounce paths for which incident and scattered angles are different. Therefore, it is possible to measure in-plane bistatic scattering strength using a monostatic geometry (1). Noting this, a simple array consisting of a pair of free-flooding-ring projectors and an omnidirectional hydrophone was used to measure monostatic and bistatic scatter in 100 m of water on the Scotia Shelf. Data arriving after the first-bottom-first-surface interaction provided estimates of in-plane bistatic scattering strength for pairs of incident and scattered grazing angles (ϕ_i, ϕ_s) down to (7°, 54°). In this paper, the experiment and data are described in light of the monostatic and bistatic arrivals.

THE EXPERIMENT

The experimental geometry is depicted in Fig. 1. The array was deployed approximately 15 m above a flat seabed and linear FM pulses were transmitted in 4 frequency bands over the range 0.9 to 2.0 kHz. Pulse lengths of 10, 100 and 250 ms were used. Measurements were taken in calm seas with the research vessel drifting.

RESULTS AND SUMMARY

Fig. 2 shows a schematic of the two bottom-bistatic scattered paths, BB1 and BB2 as well as the surface reflection, S1. The bistatic paths are composed of up-and down-going components, due to the nature of the transmitter beam pattern. However, since the receive and transmit beam patterns are not identical, the up-going and down-going paths are not equal in amplitude.

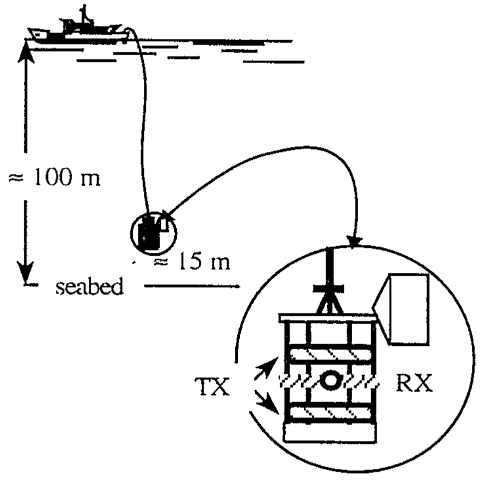

FIGURE. 1: Experimental geometry.

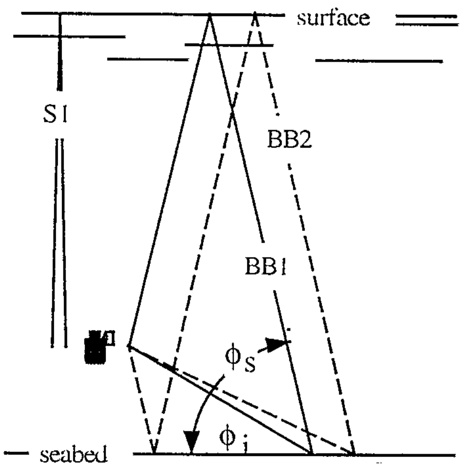

FIGURE 2: The bottom bistatic paths.

The solid line in Figure 3 is the total measured intensity, in decibels. The arrival time of S1 and the onsets of Paths BB1 and BB2 are labeled. To compute the bistatic scattering strength (BISS), one must extract the contribution due to a single path, from that of the total reverberation. We begin by noting that although the first arrivals on Path BB2 lag those of Path BB1, the relationship of (ϕ_i, ϕ_s) for both paths is almost identical for the experiment. This means that we can use the intensity of arrivals on Path BB1 to estimate the intensity of Path BB2 arrivals at some later time. We write,

$$BI_{BB2}(t+\delta t, \phi_i, \phi_s) \approx BI_{BB1}(t, \phi_i, \phi_s) - BL - \Delta PL_{BB}(\phi_i, \phi_s) + \Delta A_{BB}(\phi_i, \phi_s) \qquad (1)$$

where BI_{BB1} and BI_{BB2} are the bottom bistatic intensities from Paths BB1 and BB2, respectively, BL is the bottom loss estimated from the fathometer returns, and ΔPL_{BB} and ΔA_{BB} account for the difference in propagation loss and insonified area between Paths BB1 and BB2 (ΔPL_{BB}, $\Delta A_{BB} > 0$). The arguments t and t+δt in the bistatic intensity terms serve to highlight the fact that although the angle pairs are the same for both paths, the arrival times corresponding to those angles are different. Implicit in Equation (1) is the assumption that the BL is approximately constant for steep grazing angles. This reduces the intensity to that resulting from Path BB1. Finally, if one subtracts out the up-going component of BB1 by including the effect of the transmit beam pattern on the up-and down-going components, we are left with an estimate of the down-going component of Path BB1, given by the dashed curve of Fig. 3. In this algorithm we have neglected contributions from surface scatter, a reasonable assumption for the current experimental conditions. The procedure to account for the effect of surface scatter is contained in Ref. 1.

Fig. 4 shows the measured grazing angle dependence of the bistatic scattering strength (BISS) at 2 kHz. The down-going bistatic scattered intensity from Path BB1, I_d, was converted to the BISS employing the definition

$$BISS = 10 \log_{10}(I_d \, r_i^2 r_s^2 / I_0 \, A), \qquad (2)$$

where I_d is the scattered intensity measured at the receiver, I_0 is the intensity of the incident wave measured at the transmitter, r_i is the path length from transmitter to the scattering patch of area A, and r_s is the return path length from the scattering patch to the receiver. The measured sound-speed profile was used in conjunction with the Generic Sonar Model (2) to convert arrival time to path length and grazing angle as well as compute the transmission loss along contributing paths.

Although not reported on in this paper, the reverberation data between the first bottom return and the first surface return can be used to provide estimates of monostatic backscatter strength for grazing angles down to 10 degrees. The backscatter data can then be compared to the in-plane bistatic returns to examine the validity of the half-angle and separable approximations (1).

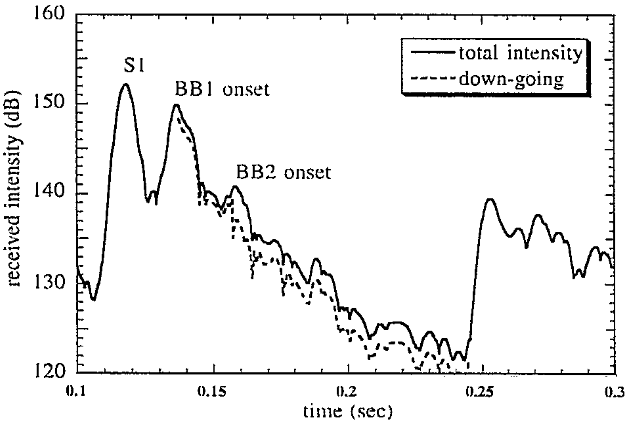

FIGURE 3: The scattered intensity.

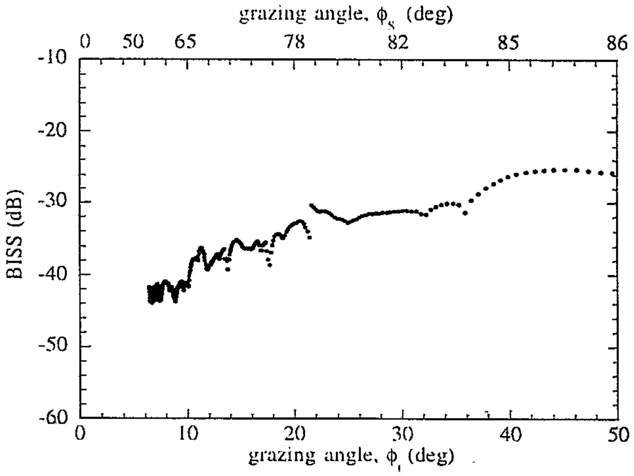

FIGURE 4: Bottom bistatic scattering strength.

REFERENCES

1. Paul C. Hines, D. Vance Crowe, Dale D. Ellis, "Extracting Bistatic Scattering Information From a Monostatic Experiment," *J. Acoust. Soc. Am.*, (in review).

2. H. Weinberg, "The Generic Sonar Model," Naval Underwater Systems Center, New London, CT, Technical Document 5971D, (1985).

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