# BISTATIC SCATTERING AT SHALLOW GRAZING ANGLES

**Shawn A. Stewart & Paul C. Hines**
Defence R&D Canada - Atlantic, P.O. Box 1012, Dartmouth, Nova Scotia
Canada B2Y 3Z7

## 1. INTRODUCTION

In recent years there has been a growing interest in bistatic sonar systems. That is to say, systems for which the source and receiver are not co-located. Measurements of acoustic scatter at bistatic angles is required for performance modeling of these systems. DRDC Atlantic has developed a pair of sea going research systems for measuring bistatic scatter from the seabed in shallow water environments. The first system  the Wide Band Sonar (WBS)  is a bottom mounted parametric transmitter with a 6 channel superdirective line array receiver. The second system  the Underwater Acoustic Target  consists of a vertical line array of 8 hydrophones and 2 transmitters [1]. These two systems have been used to make preliminary measurements of low-angle bistatic scattering from the seabed. The bistatic geometry substantially complicates both the collection and the interpretation of these measurements. For these reasons, a computer simulation was developed to compute the pathlengths and the arrival times for the various bistatic arrivals. The simulation is used to help select experimental geometries and to interpret the results in terms of the bistatic arrivals. In this paper the experimental geometry is described and a sample of the data is presented and compared to the results of the numerical simulation.

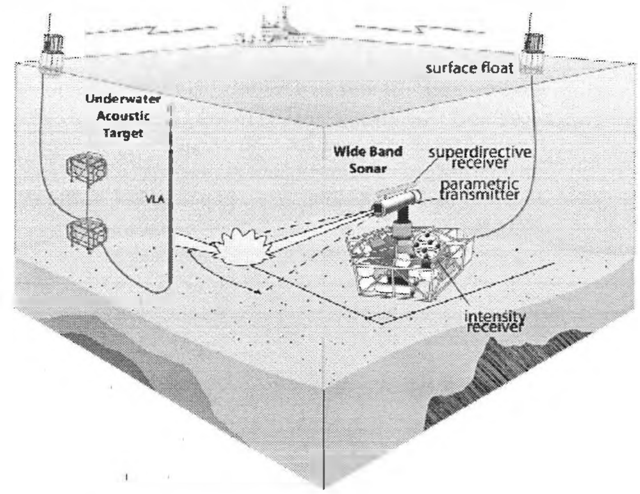


Figure 1: Experimental geometry.

## 2. RESULTS AND DISCUSSION

Figure 1 contains an illustration of the experimental geometry. The UAT hydrophones were positioned at 4.2 m spacings from approximately 10 m to 40 m above the seabed. The parametric array was 2.7 m above the seabed and was pointed at a grazing angle such that the specular reflection insonified approximately the vertical center of the UAT receive array. This corresponded to grazing angles ranging from 9° 2° depending on the separation of the two systems, which in turn ranged from 160 m up to 900 m. At each azimuth a series of 50 pulses, 2 ms long was transmitted by the WBS at 2, 4 and 8 kHz and the bistatic scatter was recorded on the UAT. The parametric array transmitter was rotated 2° in azimuth and the sequence was repeated. This was done from 15° to +15° relative azimuth.

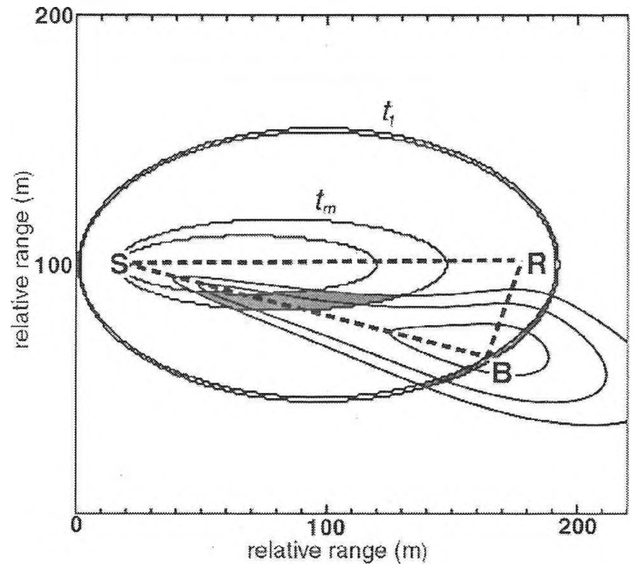


Figure 2: Simulation for a 2 ms pulse and a relative azimuth of 15°.

Figure 2 shows a plan view of the simulation results for a grazing angle of 9°, a relative azimuth of 15° and a separation of 164 m. The normalized contours (plotted in 3 dB increments from 3 dB down to 9 dB) represent the energy received at the hydrophone and include the effect of the parametric array beam pattern and the geometric spreading from source–to scattering point–to receiver. The annulus in the figure labeled $t_m$ corresponds to the time coincident arrivals from the water-seabed interface that occur at the energy maximum of the received signal. It's thickness is proportional to the pulselength and the grazing angle. Note that the sharp focusing of the parametric array and the absence of sidelobes results in a reasonably small, well-defined footprint for the scattering patch rather than the entire annulus. This simplifies the interpretation of the bistatic scattering angles considerably. Note that the annulus is not elliptical and its thickness varies around the circumference because the source and receiver are at different heights above the bottom. For comparison purposes, a second annulus labeled $t_1$ is shown that corresponds to time coincident arrivals occurring at 20 ms. As the range increases the annulus begins to approximate an ellipse and at long ranges is tends toward a circle. Note that including the effects of the parametric array beam pattern and the geometric spreading, results in the asymmetric shape of the contours and draws the maximum of the bistatic arrival (for example, path SBR for annulus $t_1$) in toward specular path SR reducing the mean azimuthal angle from 15° to 12°.

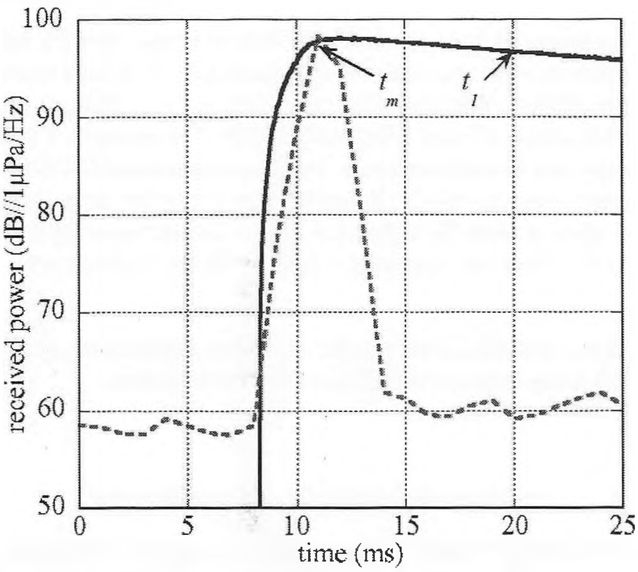


Figure 3: Simulation-data comparison of received energy for a 2 ms pulse duration at 4 kHz, a relative azimuth of 15°, and 9° grazing. Note that the level of the simulation curve has been offset to align it with the peak in the data.

Figure 3 compares the received power at a hydrophone located approximately 23 m above the seabed (dashed line) to the results from the simulation (solid line). The simulation is run assuming that each point on the seabed acts as a perfect reflector from the source to the receiver. This explains the slow energy decay in the simulation. The difference between the simulation and the data can then be used to obtain the scattering strength of the seabed. The times marked $t_m$ and $t_1$ correspond to the arrivals denoted by the annuli in Figure 2.

Figure 4 shows simulations of the relative energy levels vs. arrival times for azimuthal angles of 0°, 10°, and 24°(dashed lines). The remaining parameters are as for Figures 2 and 3. The delay in the onset of the peak as azimuth increases results from the increased bistatic path length. Comparing the arrival times predicted at various azimuths with the corresponding data will ensure that the specular path from the edge of the source beam is not dominating the received energy. That is to say, if the onset time is not changing with azimuth it implies that the received energy is dominated by contributions along the specular path (recall path SR in Figure 2) rather than along the bistatic path.

Returning to Figure 4, the change in arrival time with angle shown in the simulation is relatively small because the source array is so close to the seabed. Increasing the height of the source to 23 m (the same height as the receiver) increases the time separation. This is shown by the solid lines in the figure.

Comparing the arrival times for the experimental data requires time synchronization between the data streams on the transmit and receive systems. This was achieved during a sea trial in June 2002. Unfortunately, analysis of the data was incomplete at the time of publication of this paper.

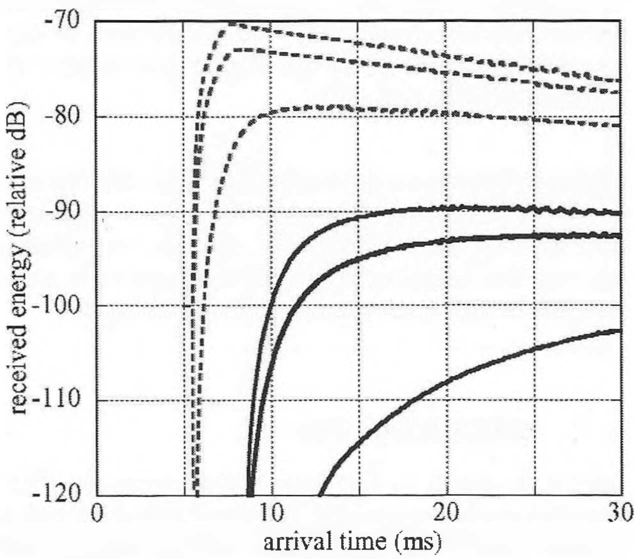


Figure 4: Relative energy vs. arrival times for a range of azimuthal angles for a 2 ms pulse.

# 4. REFERENCES:

1. Paul C. Hines, John C. Osler, and Daniel L. Hutt "The Environmental Acoustics Group's Seagoing Measurement Systems," DREA TM, 2001-173.