RANGE-DEPENDENT REVERBERATION AND TARGET ECHO CALCULATIONS USING THE DRDC ATLANTIC CLUTTER MODEL

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1. INTRODUCTION

A shallow water reverberation model based on normal modes has been developed and refined at DRDC Atlantic over the years [Ellis, 1985; 1995]. Originally, the model handled range independent boundary reverberation in monostatic or bistatic geometries, including source and receiver beam patterns for comparison with measured data, and was later extended to handle target echo. The formulation was extended to range-dependent environments using adiabatic normal modes [Ellis et al., 2008]. The computations presented at that time used a Matlab/Fortran hybrid model with modes evaluated on a rectangular grid. While the scattering strength and echo at any point on the grid could be arbitrary, a constant water depth was still required. In 2009 a range-dependent Matlab/Fortran code was developed for monostatic reverberation calculations along a single radial [Kwan and Ellis, 2010]. In 2010, a model (implemented in Fortran 95) was developed to handle both sloping bathymetry, and towed array beam patterns in bistatic geometry on a 2-D grid. The model is computationally efficient and its capabilities are evolving. Work is in progress to implement it into jAMI [Brooke et al., 2010], as well as the DRDC Atlantic System Test Bed and Pleiades System which is sometimes used by the Canadian Forces. Model-data comparisons of towed array clutter data obtained on the Malta Plateau are underway, as well as comparisons with several range-dependent problems from the ONR Reverberation Modeling Workshop [Thorsos and Perkins, 2008], and the UK Institute of Acoustics workshop on Validation of Sonar Performance Assessment Tools [Zampoli et al., 2010].

This paper provides a brief description of the model and a few illustrative calculations of its output.

2. METHOD

The model assumes the environment is defined over a rectangular area. At each (x,y) point the required inputs are water depth, sound speed profile, bottom acoustic properties, scattering strength (surface and/or bottom); for the signal excess calculations an omni-directional target echo strength at specified depth z_T is specified. In addition a number of discrete targets can be specified. A source is at location (x_S, y_S, z_S) and towed array receiver at (x_R, y_R, z_R), heading in direction ϕ_R. The source is simply specified by a center frequency, intensity and pulse length, and can have a vertical beam pattern; the towed array can have beams steered in multiple directions (typically a line array of N hydrophones will have N independent beams at the design frequency). The beam steering angles can be specified, as well as the ambient noise on each beam.

The equations for the formulation in terms of normal modes are given in [Ellis et al., 2008]. The implementation requires the input of the environmental parameters on a grid of points. At each point the sound speed, acoustic properties, and scattering strengths can be different. The user can specify a number of computational parameters, including some normal mode computational controls, and the radials on which the towed array beam time series will be calculated. Two main calculations are done and written to data files for display later: (1) reverberation and target echo at the grid points, assuming ideal "wedgie" receiver beam patterns of uniform response over horizontal beam width ϕ_H, and no sidelobes; (2) beam time series for each towed array steering direction. The first calculation is intended primarily for illustrative purposes and at this point a number of short cuts have been made in the coding; the second is for comparison with data, and the intent is to keep improving the fidelity.

3. RESULTS

Figure 1 shows the signal excess (target echo to reverberation level in dB) on a grid generalized from Fig. 2 in Ellis et al. [2008]. The area is 100 km square with (x, y) coordinates between (-50,0) and (50,100). A 50x50 grid is used for the calculations; [a 51 by 51 might have been nicer], so the centre of the grid points range from approximately (-49,1) to (49,99) with increments of 2 km in each direction. The water depth is 100 m, except for two ridges in the y-direction rising to 60 m, and another ridge rising to 70 m in the x-direction; both have gaps near the middle. There is a single seamount of height 50 m near (-40,85). The bottom has Lambert scattering with a strength of -27 dB, except for a +10 dB enhancement along the line (2,2) to (50,50). Similarly the target (at depth 10 m) has echo strength of 8 dB, except for a 7 dB enhancement along the line (-48,52) to (2,2). The source is at (-10,48) at depth 30 m, and the receiver at (10,48) at depth 50 m.

The basic environment is similar to the ONR 3D problems, and described by Zampolli et al. [2010]. It has isospeed water of 1500 m/s over a sand bottom half space of relative density 2.0, sound speed 1750 m/s and attenuation of 0.5 dB/wavelength; the volume absorption in the water is a version of Thorp's formula.

The source is omni-directional with unit energy (10 dB source level for a duration of 0.1 s). The frequency was 250 Hz. The towed array was chosen to give a horizontal beam width of 3.6°; 39 omnidirectional elements at spacing of 2.5 m with Hann weights were used for the beam time series. The CPU time on a 2GHz computer was only 1.5 s, with modes (usually 16) being calculated each of the 2500 grid points.

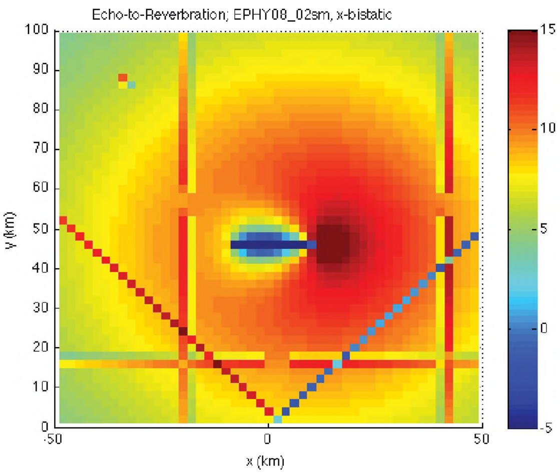

Figure 1. Signal excess on grid using wedgie beam patterns.

In Fig.1 the receiver sees high reverberation (low signal excess) in the direction of the source (west, W); similarly along the high scattering line to the SE. The higher echo along the line to the SW shows up clearly too. Along the 3 ridges, the signal excess first drops (due to the higher reverberation on the up-slope), then increases on the down slope. Beyond the ridges one would expect some shading due to mode cutoff, but perhaps the reverberation and echo are affected similarly. The single point to the northwest affects the signal excess in the adjacent cells.

Figure 2 shows time series with geometry corresponding to Fig. 1, and a selection of beam steering angles relative to the towed array heading of 225°. The predictions have not been checked out thoroughly, but generally seem to make sense. The reverberation on the omni receiver is 10–15 dB above the beam predictions; at short times the reverberation on the 45° and 60° beam are higher since they look in the direction of the source (note the beams have left-right symmetry); the 45° beam also seems to be picking up backscatter from the ridges to the S and W; the 0° and 359° beams are essentially identical; the 90° and 270° beams should be identical, and have the lowest reverberation, except in the region of features; at long ranges the endfire beams (0° and 180°) should have the highest reverberation, and in a uniform environment approach each other.

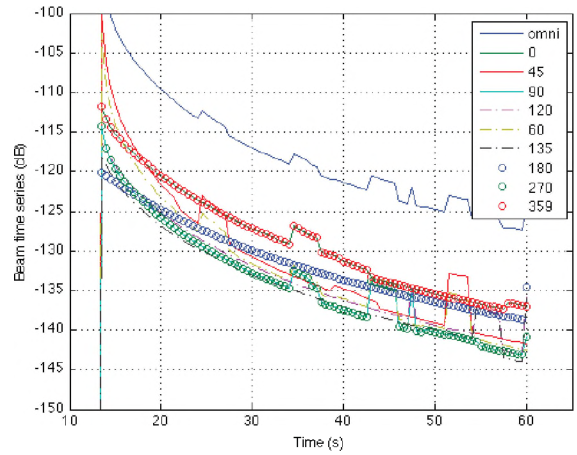

Figure 2. Beam time series of reverb. corresponding to Fig. 1.

4. DISCUSSION

The model continues to evolve. Presently the same sound speed profile and bottom loss are used at all locations. The next step will be to generalize it. For production calculations, it makes sense to pre-calculate the modes on the grid, perhaps interpolating them to a finer scale. Then for other source-receiver geometries and multistatic scenarios they can be re-used for the reverberation and target echo calculations.

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