SWAMI AND ASSA FOR GEOACOUSTIC INVERSION

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1. INTRODUCTION

The SWAMI (Shallow Water Active-sonar Modelling Initiative) (Theriault and Ellis 1997) toolset in use at DRDC Atlantic contains modules to produce predictions of transmission loss, reverberation, signal excess, and probability of detection. The toolset includes a capability to consider many source and receiver configurations; from omni directional to line-arrays (horizontal and vertical), and to volumetric arrays. The toolset allows the environment to vary both azimuthally and radially (Nx2D).

Simulated reverberation data can be compared with measured reverberation data and a quantitative measurement can be made that essentially tests the goodness of fit of the modelled data to the “measured” values. This paper briefly presents an overview of the SWAMI toolset, the type of active sonar of interest, the inversion technique, and results. For the purposes of this paper, a reverberation model has generated the “measured” input data.

1.1 SWAMI

SWAMI is an Nx2D active sonar performance prediction toolset based on adiabatic normal-mode theory (Bucker and Morris 1968). The current reverberation model, MONOGO is based on Ellis' OGOPOGO (Ellis 1992 and Ellis 1995) model. The key differences between the models are that OGOPOGO computes reverberation predictions for range-independent environments with bistatic geometries whereas MONOGO computes reverberation predictions for Nx2D environments for the monostatic geometry case. MONOGO, as do all of the SWAMI components, computes its predictions for multiple receiver steering angles in parallel.

1.2 System

The DRDC Atlantic TIAPS (Towed Integrated Active-Passive Sonar) system consists of a two-element vertical source array and two high-dynamic-range towed arrays. One of the arrays (MANTArray) consists of a large set of omni directional hydrophones while the second array (DASM) consists of a set of directional sensors (Theriault and Hood 2004). These towed arrays allow the reverberation environment to be sampled in both range (time) and azimuth (steered beams). It is this type of system that is of interest for the inversion presented in this paper.

The goal of the effort is be able to produce sonar operator decision aids. By inverting reverberation measurements, estimates of geoacoustic parameters, and therefore predicted target echo strength can be obtained. A comparison of predicted target echo strength with the original reverberation data yields a measure of performance.

2. METHOD

The reverberation inversion is performed using an Adaptive Simplex Simulated Annealing (ASSA) technique, where the implementation is essentially the same as that described by Dosso (2001). The ASSA-derived geoacoustic parameter values are used as input to the model MONOGO, which uses them to produce reverberation time series. An energy value E related to a set of model parameters is obtained by calculating the differences between adjacent model time series values, subtracting them from the corresponding differences produced from the measured data, and summing the absolute values of the differences. Both model and measured time series must have the same time origin and increment so that E can be produced by comparing the slopes of the two time series. Slope comparison, as opposed to direct comparison, is used based on an earlier observation by Ellis (1994). Ellis observed that the bottom-loss related parameters seemed to be more sensitive to reverberation decay than overall level. Scattering strength is more sensitive to the overall level. Predicting echo levels is not dependant on scattering strength so the alternative energy value is used in order to generate a potentially faster inversion methodology.

The geoacoustic parameters are found at a number of evenly spaced points along a user-selectable number of fixed-length radials. A feature of the analysis program is that besides specifying the number of points per radial (N_R) to solve for, the user is able to give the program a range of N_R values to use. When this option is used the program produces minimum E results for each N_R value and indicates which N_R produces the overall minimum E. The user can examine the results for all values of N_R before choosing which geoacoustic values to use in later processing. This is done since it may turn out that the results from certain N_R values may produce low E values but conflict with reality in the form of known parameter values, topography, etc.

3. RESULTS

For the purposes of this paper, a three radial environment was generated, with each radial being divided into six segments. For each radial the environment segments started at 0, 12.04, 24.08, 36.12, 48.12 and 60.20 km. The three radials were unequally spaced with bearings of 40°, 90°, and 250° respectively. The center environment (range 0 km) was the same for all radials.

Table 1 shows the values used to represent the seabed characteristics for the simulated environment. MONOGO was used to generate a reverberation time series. The sound speed in the water column was held constant (1500 m/s). The columns of Table 1 show the input radial number, point on the radial, density, compressional sound speed, compressional attenuation, Lambert scattering coefficient, and water depth.

Table 1. Description of Radials

#	Pt	Density g/cm^3	Comp. Sound Speed m/s	Comp. Atten. dB/km	Lambert Scattering Coef. dB/m^2	Depth m
	1	2.07	1782	0.218	-29.3	83
1	2	2.01	1786	0.212	-28.7	78
1	3	1.94	1792	0.207	-27.6	75
1	4	1.86	1799	0.203	-26.8	72
1	5	1.78	1810	0.198	-26.2	68
1	6	1.73	1818	0.193	-25.3	63
2	2	2.05	1788	0.216	-29.3	78
2	3	1.99	1794	0.214	-28.9	67
2	4	1.95	1801	0.213	-28.2	71
2	5	1.91	1807	0.212	-27.4	75
2	6	1.85	1812	0.211	-26.6	68
3	2	2.13	1776	0.221	-29.3	90
3	3	2.18	1771	0.222	-29.0	96
3	4	2.22	1765	0.225	-28.4	85
3	5	2.25	1758	0.227	-27.6	80
3	6	2.28	1753	0.229	-26.9	74

The system assumed for the simulation consisted of omni-directional source and receiver with a depth of 50m. The transmitter projected a 1s CW waveform with a source level of 210 dB re 1μPa @ 1m.

After generating the simulated time series, the ASSA method for the geoacoustic parameters was used to invert the given reverberation. For the purposes of this paper, averages of 10 results from 10 ASSA runs were computed. Each ASSA run required an average of 1683 MONOGO runs. The simulated reverberation data and the results from the inversion are shown in Figure 1. Figure 2 shows the difference between the simulated reverberation time series and the inversion results.

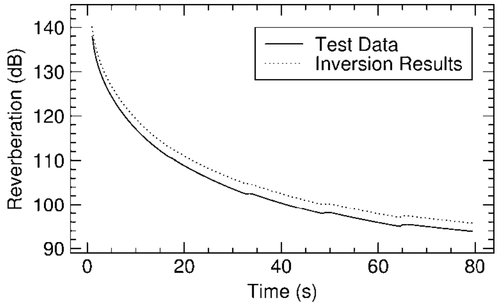

Fig. 1. Reverberation Predictions Using Input and Simulated Geoacoustic Parameters.

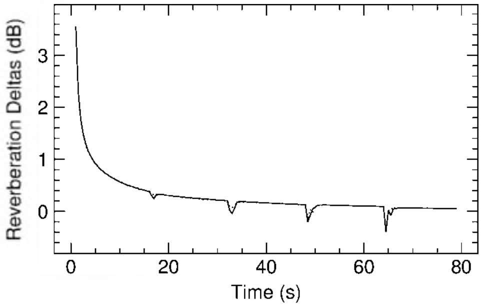

Fig. 2. Difference between Original Simulated Reverberation Levels and Results of Inversion.

4. DISCUSSION

As shown in Figures 1 and 2 the inversion approach is capable of generating geoacoustic parameters that will closely replicate the input time series. The sharp differences occurring at ranges that correspond to radial segments are likely a shortcoming in the MONOGO model rather than the inversion technique.

The approach presented above shows some promise for producing relevant geoacoustic parameters. However, experience with simulated noisy input time series and measured data is required.

REFERENCES

Bucker HP and Morris HE (1968) Normal-mode reverberation in channels or ducts, *J. Acoust. Soc. Am.* **44**, 827-828, 1968.

Dosso SE, Wilmut MJ, and Lapinski A-L.S. (2001) An Adaptive-Hybrid Algorithm for Geoacoustic Inversion, *IEEE J. Ocean Eng.*, **26**, pp. 324-336, July 2001.

Ellis DD (1992) A Shallow-Water Normal-mode Reverberation Model, SACLANTCEN Report 92-196, September 1992.

Ellis DD (1994) Personal Communication.

Ellis DD (1995) A Shallow-Water Normal-Mode Reverberation Model, *J. Acoust. Soc. Am* **97**, 2804-2814, 1995.

Theriault JA and Ellis DD (1997), Shallow-water low-frequency active-sonar modelling issues, in *Oceans '97 MTS/IEEE Conference Proceedings* (IEEE, Piscataway, NY, USA) Vol **1**, pp. 672-678, 1997.

Theriault JA and Hood J (2004) Using Directional Sensors to Enhance the Performance of Towed Receiver Array of Active Sonar, in *Undersea Defence Technology Proceedings*, October 2004.