Advanced Broadband Acoustic Clutter

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ABSTRACT

The performance of active sonar systems in littoral environments is often limited by discrete clutter and diffuse bottom reverberation. Discrete clutter tends to be nearly ubiquitous, but its characteristics have been difficult to predict. It has also been difficult to predict the frequency and angular dependence of the seabed scattering strength, which is important for predicting the time dependence of the background reverberation upon which the clutter highlights are distributed. New measurement techniques were developed that have promising possibilities for use in the survey community including quantifying scattering strength frequency and angular dependence, localizing/quantifying clutter discrete scattering, and quantifying seabed reflection which is important for prediction of reverberation, clutter and target echo structure. In addition to measurement techniques modeling advances were made for rapid calculation of clutter and target echo, and a deeper understanding of the impact of seabed range dependence on propagation and clutter.

LONG TERM GOALS

The long term goal is to improve performance of low-mid frequency active sonar systems against clutter.

OBJECTIVES

The objectives are to identify/understand the mechanisms that lead to clutter and develop models that predict the temporal/spatial/frequency dependence of the observed clutter and background diffuse reverberation.

APPROACH

The experimental approach was based upon exploiting both long-range observations of clutter and short-range, or direct-path observations (seabed scattering and reflection) of the features that give rise to the clutter. Direct path observations offer two significant advantages: a) the uncertainties associated with propagation (through a generally sparsely sampled ocean) are minimized, and b) the measurement

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14. ABSTRACT
The performance of active sonar systems in littoral environments is often limited by discrete clutter and diffuse bottom reverberation. Discrete clutter tends to be nearly ubiquitous, but its characteristics have been difficult to predict. It has also been difficult to predict the frequency and angular dependence of the seabed scattering strength, which is important for predicting the time dependence of the background reverberation upon which the clutter highlights are distributed. New measurement techniques were developed that have promising possibilities for use in the survey community including quantifying scattering strength frequency and angular dependence, localizing/quantifying clutter discrete scattering, and quantifying seabed reflection which is important for prediction of reverberation, clutter and target echo structure. In addition to measurement techniques modeling advances were made for rapid calculation of clutter and target echo, and a deeper understanding of the impact of seabed range dependence on propagation and clutter.

15. SUBJECT TERMS
reverberation, clutter, seabed scattering, acoustic modeling, measurements

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geometries are favorable to producing data from which hypotheses about the scattering mechanisms can be directly tested. The theoretical approach for reverberation, clutter and target echo structure was based in part on energy flux methods.

RESULTS

The results have been extensively reported in the peer-reviewed literature and in conferences and symposia (see references below). A summary of key advances are listed below.

Modeling/analysis:

- Developed a simple theory for propagation in a waveguide with range-dependent seabed properties (Refs [1,12]). The importance of the theory is that it provides some deep insights into the effects of range-dependence on propagation. This in turn has lead to some deep insights into seabed variability on clutter (late in the project and hence to date unpublished).
- Developed high-fidelity clutter and target echo model that is computationally very efficient, faster than rays or normal modes (Ref [13]). The efficiency makes it attractive for potential use in simulation.
- Advanced the understanding (with modeling and measurements) of reverberation and clutter from sub-bottom interfaces (Refs [2, 7, 18]). Key result: despite some claims to the contrary in the ocean acoustics community, sub-bottom clutter can and does occur in shallow water environments. Detailed analyses illuminates the relation between the frequency and angle dependence of reflection, scattering, reverberation, propagation, and clutter in both theory and measurements. This is important because in some shallow water areas (especially those with significant riverine deposition) the reverberation and clutter may be controlled by sub-bottom mechanisms.
- Analyzed clutter data from bottomed shipwreck (with Doug Abraham, data from Clutter'07 Experiment) to examine dependence of clutter statistics on multipath (Ref [8]). Key result: in the shallow water environment on the Malta Plateau both modeled and measured statistics showed weak dependence on multipath. This can potentially simplify statistical approaches to clutter modeling .
- Quantified the uncertainties associated with geoacoustic inversion of reverberation data (Refs [3, 20]). Key result: reverberation predictions have large bias errors (order 10 dB+) even when there has been an REA or survey reverberation measurement and inversion in that same area. Also developed methods for mitigating those errors using one additional observation. This is important because it provides the basis to advance/improve survey reverberation measurements.
- Collaborated with University of Victoria (Jan Dettmer and Stan Dosso) to develop inversion methods for quantifying geoacoustic properties and their uncertainties (Ref [4]). This is important for a) measurement of sediment structures that lead to clutter and b) providing required inputs to validate clutter models.
- Analyzed seabed reflection coherence to estimate sediment geoacoustic properties that are important for modeling reflection and scattering from the seabed (Refs [4, 6]) (with Laurent Guillon, Ecole Navale and PhD student Samuel Pinson)

Measurements:

- Developed measurement method for sediment sound speed lateral variability from seabed bi-static scattering measurements (Ref [16])

- In collaboration with NURC, DRDC-A, NRL, and another PI at ARL-PSU, planned and conducted the highly successful Clutter09 experiment in the Straits of Sicily.
- Developed engineering design parameters in collaboration with Peter Nielsen (NURC) for emasurements of seabed reflection from an AUV. Also used system to measure seabed scattering strength and isolate individual clutter features, confirming hypotheses about the mechamism leading to clutter in areas of submarine mud volcanoes. The clutter mechanism is not the mud volcanoes themselves (of order 100m in lateral spatial extent), but rather small carbonate accretions (of order 1-10m in lateral extent and a few meters high) disetributed on the flanks of the mud volcano.

Other:

- Helped organize, with NATO Undersea Research Centre as lead, the International Symposium on Underwater Reverberation and Clutter Conference, Lerici Italy, 9-12 September 2008. This resulted in a conference proceeding with 43 published papers.
- Served on Data Definition Committee for the ONR-PMW/120 Reverberation Workshop II and participated in the workshop (Austin, TX, May 2008) including generating energy flux model results for many test cases. The energy flux solutions compare very well with more sophisticated (i.e., computationally intensive) models, e.g., coupled mode.

IMPACT/APPLICATIONS

The impact of individual accomplishments are listed above. Here, they are placed in a broader context. Some of the modeling developments appear to be useful for transition to the HiFAST/SAST programs inasmuch as they are extremely computationally efficient. One specific example is the clutter or target echo modeling in which realistic fluctuations in the echo structure could be very useful for simulation and training with little computational overhead. Another example is the new theory for propagation in a waveguide with range-dependent boundaries [3], which has potential to speed up point-to-point calculations by replacing a range-dependent marching solution with a range-independent solution using the geometric mean of the reflection coefficient and the arithmetic mean of the cycle distance. For incoherent models (e.g., ASPM) this could further enhance speed of computation, without loss of accuracy.

The AUV measurements have a promising potential for transition to the survey community to provide seabed reflection and scattering using a much reduced source level (compared to current use), reduction in ship time, reduction in sensitivity to water column dynamics and also biologics at a much higher spatial density.

TRANSITIONS

The seabed scattering data from this program have been transitioned to the PMW-120 Ocean Bottom Characterization Initiative (OBCI, Marcus Speckhahn, program manager) for development of a seabed scattering database for the Naval Oceanographic Office. The scattering data have already been key to the determination of which modeling approach to use for database construction.

RELATED PROJECTS

This project was part of the Broadband Clutter Initiative Joint Research Project (JRP) including ARL-PSU (USA), DRDC-A (CAN), the NATO Undersea Research Centre (Italy) and NRL-DC (USA). The PI served as leader for the JRP (external to NURC) in collaboration with Peter Nielsen who lead the project within NURC.

PMW-120 OBCI Program: Measurement results and analysis/modeling techniques developed in this program are being transitioned to the design of the first generation Naval Oceanographic Office bottom scattering database.

ONR Applied Reverberation and Modeling Board: that board seeks to enhance transitions of basic research in reverberation modeling to the applied community. Some of the modeling advances developed in this program may transition through the HiFAST FNC to the SAST simulation program.

ONR Quantifying Predicting and Exploiting (QPE) Uncertainty: seabed reflection data measured in this program are being leveraged to QPE for developing/validating methods for quantifying geoacoustic variability and uncertainty.

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