SONAR ACOUSTIC WAVE REVERBERATION FROM SCATTERED INTERNAL WAVES AT OCEAN BOTTOM

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1. INTRODUCTION

Sonar acoustic wave reverberation from rough ocean bottoms had been studied for a long time. A study on a component of reverberation caused by a random ocean bottom roughness scattering was first reported by Kuo [1]. In recent years, a sub-bottom inhomogeneity volumetric scattering, attracted attentions of many researchers, (for example, Mourad, et al [2] and Kuo [3]). Kuo [3] predicted the ocean bottom reverberation caused by the interacting volumetric and roughness scattering by perturbation, the Joint Perturbation Scattering (JPS) theory. The idea of JPS theory was first presented at NATO Ocean Reverberation Symposium in 1992 and then was applied for the first time to a study of high sea state ocean surface reverberation [4]. The application succeeded in predicting most of the observed reverberation phenomena.

Study of internal wave effect on sonar acoustic waves have been mainly on forward propagation spread in arriving time and depth over a very long range in deep waters. The spreads is due to variation in sound velocity profiles caused by the internal wave vertical mixing of the stratified medium (see for example Colosi et al [5]).

In general, internal waves and their vertical mixing effects on sound velocity profiles are of a very low wave number phenomenon. As such, internal wave mixing is a poor candidate for sonar acoustic wave reverberation, especially in a backscattering direction. However, a recent finding of internal wave number escalation due to ocean bottom roughness scattering, points to yet another potential component of sonar acoustic wave reverberation. This paper describes approaches to be taken in the on-going study of assessing the effects of the bottom scattered internal waves on the sonar acoustic wave reverberation - a new component in the bottom reverberation.

2. INTERNAL WAVE SCATTERING AT A ROUGH OCEAN BOTTOM

Scattering of internal waves from a randomly rough ocean bottom was first reported by Muller and Xu [6]. They have found that the roughness scattering process produced internal waves of wave numbers shifted by the roughness wave numbers - higher wave number internal waves. Together with incident internal waves, the reflected (or scattered) internal waves have to satisfy a classical zero normal velocity boundary condition at the randomly rough boundary. Thus, the scattered internal waves can be solved from this boundary condition in terms of the incident internal waves and the boundary roughness. Unfortunately, the boundary condition is non-linear and needs a method of linearization not only for an easier solution but also for a meaningful statistical processing that can yield physically meaningful results. Muller and Xu utilized a perturbation with a Taylor's expansion in random height only.

This perturbation method resembles that utilized in many past studies of acoustic wave scattering from rough ocean boundaries. Historically, there were two independent perturbation methods. One was originated by Bass [7] and the other by Marsh [8]. Bass used Taylor's expansion. Marsh expanded reflected field amplitude in terms of statistical parameters appeared in the boundary condition. Since he dealt with pressure release boundary condition at the ocean surface, the random roughness (ocean wave height) was the only statistical parameter. Kuo [1] extended Marsh's method to a transmitting rough surface such as ocean bottom. There, the boundary conditions requiring the continuity in pressure and normal velocity contained both random height and slope. Therefore, the reflected field amplitude was expanded in terms of both random height and slope.

The zero normal velocity boundary condition for internal wave scattering also contain both random height and random slope. Therefore, an improved solution can be obtained by including both statistical properties of height and slope as in perturbation approach of Kuo [1]. Comparisons of the new results with those of Muller and Xu will be presented in the future.

3. THE ACOUSTIC JOINT PERTURBATION SCATTERING THEORY

Since the fractional variation in acoustic velocity is proportional to the vertical internal wave velocity (Colosi et al [5]), the scattered internal wave solution described in the previous section can be utilized to estimate the high wave number random fractional variation in acoustic velocity. The random fractional sound velocity variation causes an incident sonar acoustic wave to be volumetrically scattered before it is roughness scattered. The JPS theory [3], [4] approximates the interacting volumetric and roughness scattering effects on reverberation by alternating single volumetric and roughness scattering processes.

To simplify the study, the volumetric scattering effects of sub-bottom as treated by Kuo [3] will not be included. The sub-bottom volumetric scattering will not be as effective as that of the above-bottom volumetric scattering due to a transmission loss at the bottom interface.

Both volumetric and roughness scattered fields are dependent on the bottom roughness and slope statistics. Therefore, they are expected to be strongly correlated in a statistical analysis.

4. EXPECTED EFFECTS ON SONAR ACOUSTIC WAVES

From the solution of the scattered internal wave field, wave number spectrum of the fractional sound velocity flutuation can be obtained.

This wave number spectrum can be utilized in an acoustic propagation model to predict, as Colosi et al [5] did, the spread in arrival time and depth over a range. The scattered acoustic field to be obtained by JPS Theory will consist of specular and off-specular components. The specular component estimate forward specular bottom loss.

The off-specular component estimates scattering strength in all directions. Together they can be inputs to a propagation model in estimating transmission loss and reverberation strength over a range.

5. References

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