REVERBERATION-LIMITED SONAR PERFORMANCE PREDICTIONS FROM EXPERIMENTAL VOLUME-SCATTERING-STRENGTH DATA

W.I.RODERICK, R.K.DULLEA, L.C.MAPLES
Special Projects Department
Naval Underwater Systems Center,
New London, CT 06320 U.S.A.

ABSTRACT

Volume reverberation caused by biological scatterers often limits effectiveness of active sonar systems. With sonar system modes that utilize the refractive properties of the ocean, propagation loss and volume scattering strength vary significantly because of the nonuniform and changing vertical distributions of scatterers.

For an accurate prediction of sonar system performance under refractive conditions, both the volume-scattering-strength profile and the propagation-loss profile are required. Actual system performance is compared with (1) measured propagation loss and the integrated scattering strength and (2) measured propagation loss and the complete volume-scattering-strength-versus-depth profile.

INTRODUCTION

Volume reverberation caused by biological scatterers often limits the effectiveness of active sonar systems. For sonar system modes that utilize the refractive properties of the ocean, significant variations in propagation loss and volume scattering strength are experienced because of the nonuniform and changing vertical distribution of scatterers. The layers of biological scatterers migrate and concentrate close to the ocean surface at night, so that the effect of these variations is particularly evident at that time for the surface duct and convergence zone (CZ) modes of sonar operation.

This paper will demonstrate that, for an accurate prediction of sonar system performance under refractive conditions, both the volume-scattering-strength profile and the propagation-loss profile are required. The actual system performance, computed from measured propagation loss and reverberation levels, is compared with system performance predictions for a target at both shallow and moderate depths. The performance predictions were based on (1) measured propagation loss and the integrated scattering strength, and (2) measured propagation loss and the complete volume-scattering-strength-versus-depth profile.

EXPERIMENTAL PROCEDURE

The measurement of CZ propagation loss involved two ships. The source ship was equipped with a mobile sonar system and an expendable bathythermograph (XBT) system. The receiving ship was an oceanographic research vessel equipped with an "upward-looking" transducer mounted in a paraboloidal reflector, a hull-mounted transducer (dome), and a vertical hydrophone string (CZ array) that consisted of 20 hydrophones spaced at 25-ft (7.6-m) intervals, at depths of 60 to 535 ft (18.3 to 163 m), Fig. 1.

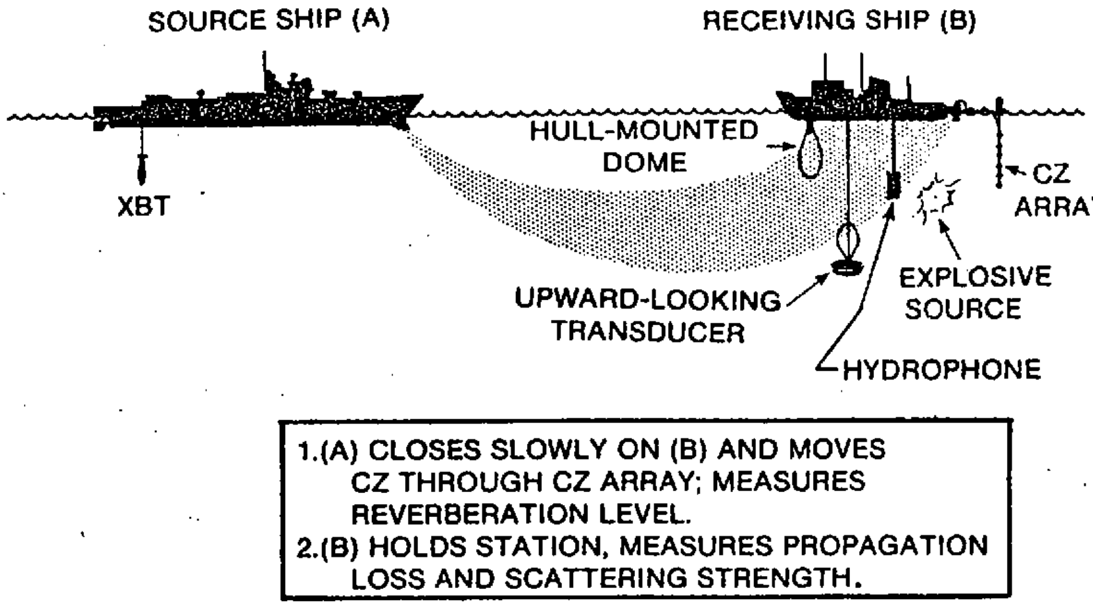

Figure 1. The Experiment

While the receiving ship was acquiring propagation loss and scattering strength data and developing the profiles, the source ship was obtaining the CZ reverberation data measured by the sonar system. The reverberation data were digitally recorded and processed on the receiving ship computer between runs and after the operations to determine reverberation levels for signal-excess computations and for comparisons with CZ reverberation modeling.

To obtain the volume scattering data, three methods were used. The first employed two directional transducers operating with short pulse lengths. One transducer was mounted inside a dome on the hull with its beam directed downward. To obtain the near-surface data, the second transducer was deployed at a depth of 2000 ft (610 m) with its directional beam looking upward. The data from the two transducers were processed to yield values for scattering-strength-versus-depth profiles.

The second set of experimental data was obtained by detonating several explosive charges at a depth of 60 ft, in proximity to a broadband omnidirectional hydrophone. The resulting reverberation data were processed to obtain column integrated scattering strength as function of frequency.

The third method used an explosive technique in which a charge was detonated close to an omnidirectional hydrophone, which was used to monitor the reverberation following the detonation. The measurements were made by using a variable-depth broadband explosive source and a receiving system that could be lowered to a maximum depth of 2500 ft (763 m). The scattering strength was determined as a function of frequency at discrete depths, and scattering strength versus depth profiles were constructed.

Representative propagation-loss and volume-scattering-strength profiles, as measured, are shown in Figure 2. It should be noted that, at the greater receiver depths, propagation loss increases although volume scattering strength decreases. Therefore, the major contributors to the reverberation level are the biological scatterers at the shallow depths.

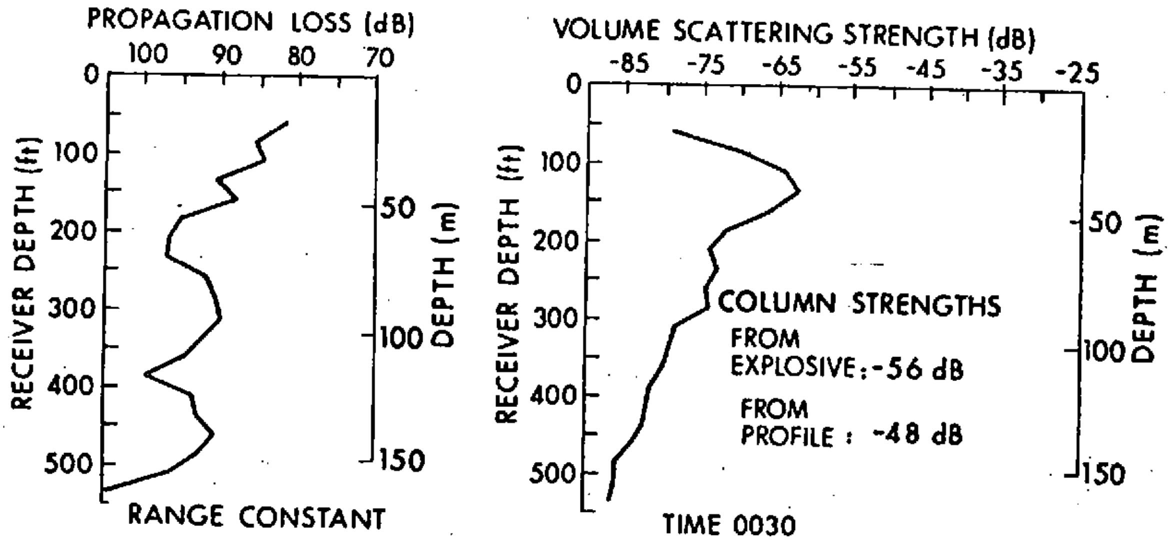

Figure 2. Depth-Dependent Propagation-Loss and Volume-Scattering-Strength Profiles

SONAR SYSTEM PERFORMANCE

The methods used to formulate estimates of sonar system performance are well known. The signal-excess formulation, based on the sonar equations, is used here. Signal excess means signal received in excess of that required for a 50 percent probability of detection and is a measure of the echo-to-background-interference ratio or level. Because the limiting interference background is either noise or reverberation or both, the total signal excess against a background composed of reverberation and noise is found by converting the two "excess" values to intensities and adding in random phase. The propagation-loss input to the signal-excess equation was based on a five-ping moving average of received intensities. Figure 3 shows the average propagation loss, measured across the zone, to the 535-ft hydrophone.

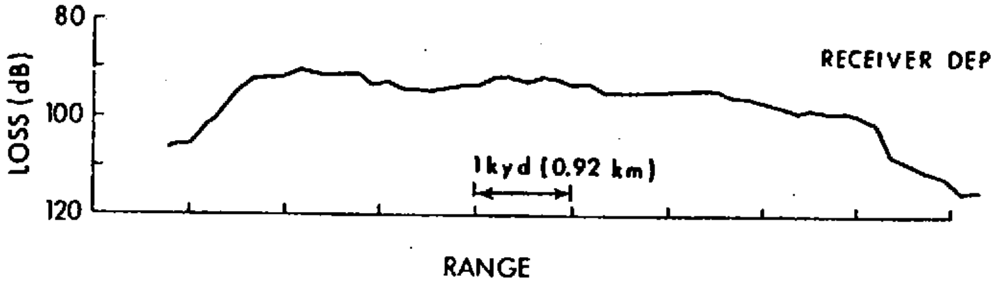

Figure 3. Average Propagation Loss Measured Across the Convergence Zone

The reverberation-level input to the signal-excess equation can be predicted from the volume-scattering-strength profile. Predicted levels were computed and compared with values measured with the sonar system, Fig. 4.

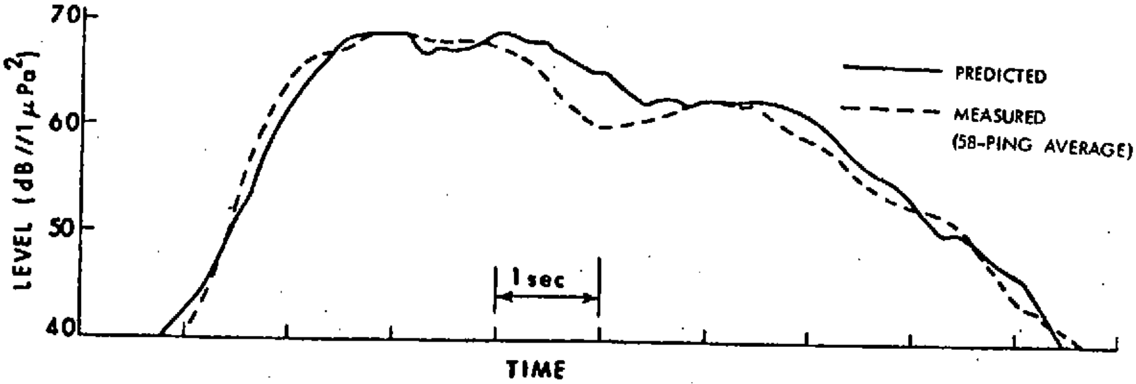

Figure 4. Measured and Predicted CZ Reverberation Levels for One Transmission

A quantitative comparison of the signal-excess predictions based on the volume-scattering-strength profile and on the integrated value obtained from the profile has been made, Fig. 5. It can be seen that there is good agreement, at both target depths, between measured performance and the performance predictions based on the volume-scattering-strength profile.

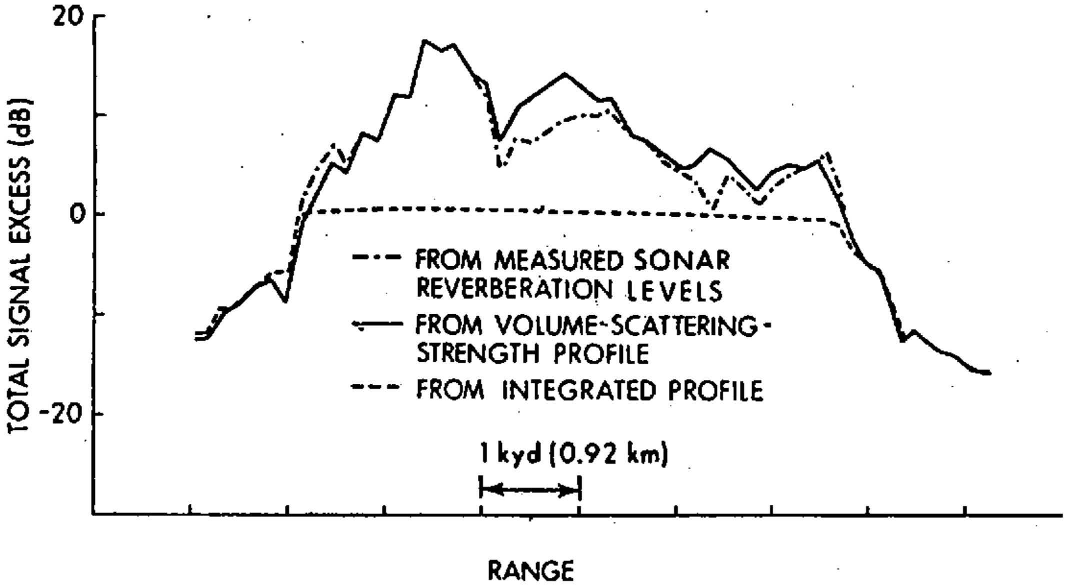

Figure 5. Comparison of Signal-Excess Predictions For a Shallow Target

SUMMARY AND CONCLUSIONS

Prediction of sonar system performance under volume-reverberation-limited conditions has been analyzed. Predictions of signal excess obtained from both depth-dependent volume-scattering-strength profiles and integrated scattering strengths have been compared with signal excess predictions calculated from measured reverberation levels and propagation loss. Significantly better agreement was found with profile-derived than with column-based signal-excess predictions. Errors in predictions based on integrated scattering strength are in large part due to the difference between the propagation loss to the assumed target depth and that to the scatterers' depth. It is concluded, therefore, that for system modes affected by refraction, the volume-scattering-strength profile and the depth-dependent propagation loss must be incorporated into reverberation models to accurately predict sonar system performance.