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Geoacoustic inversion using mid-frequency bottom loss data in shallow water off the East Coast of Korea

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1. Introduction

When sound propagates through shallow water waveguide, acoustic waves interact with sea surface and bottom. Especially, for the downward refracting sound speed profile (SSP) which is a typical characteristic of shallow water, acoustic propagation is greatly influenced by bottom interacting paths. It is thus important to investigate the information of geoacoustic parameters and sediment layer structure to understand sound propagation in shallow water. This paper presents the result of bottom loss measurements as a function of grazing angle using 6, 8, and 10 kHz, and geoacoustic inversion result produced by genetic algorithm [1].

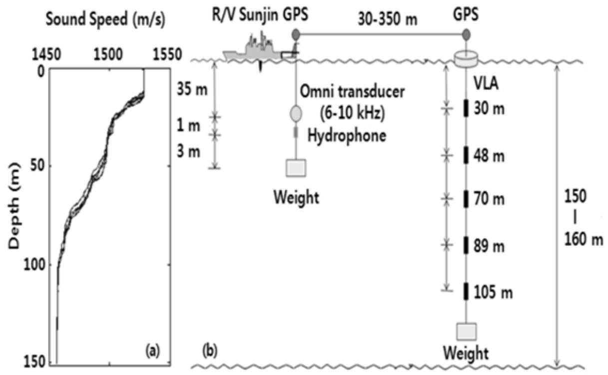

Fig. 1 Experimental geometry for bottom loss measurements.

2. Field Measurements

Acoustic field experiment to measure the bottom loss as a function of grazing angle was conducted in the east coast of Korea in October 2008 in nominal water depth of 150 m. Continuous waves (CW) with a pulse length of 2 *ms* and center frequencies of 6, 8, and 10 kHz were transmitted from D-17 transducer (NEPTUNE), which was deployed from the stern of the R/V *Sunjin* (**Fig. 1**).

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The signals were received by 5-elemets, 75 m long, drift vertical line array (VLA) covering water depths of about 30 to 105 m. Bottom loss data were measured at source-receiver ranges of about 30 to 350 m. SSP was monitored with expendable bathythermograph (XBT) during the acoustic measurements which was stable during the acoustic measurements and has a negative sound speed gradient (about 0.8 m/s per meter) from water depth of about 12 to 100 m, showing strong thermocline. Bottom topography for the experimental area was surveyed from a depth sounder, and the result showed that seafloor was almost flat, showing a slope less than about 1°. Piston core analysis showed very fine sand having grain size of 3 to 5 ϕ, which accounted for 75 % of total sediment components.

3. Results

The sonar equation for estimating the bottom loss is given by

$$BL(\theta) = RL_B - SL - TL_B \ ,$$

where $BL(\theta)$ is the bottom loss in dB, SL is the source level (dB re 1 μPa). RL_B and TL_B are the received level (dB re 1 μPa) and the transmission loss (in dB) from the source to the receiver for the bottom reflected path, respectively. SL was estimated from the received levels for direct paths of the data sets measured at source-receiver ranges 32 and 52 m to reduce the error caused by refracted effect. Transmission losses for direct path and bottom reflected path and seabed grazing angle were estimated by a ray-based propagation model using the measured SSP.

A genetic algorithm was used to estimate the geoacoustic parameters with an objective function to be minimized for the inversion defined by [2]

$$E = (X_i - M_i)^T W (X_i - M_i)$$

where, X_i is the measured bottom loss (in dB), and M_i is model prediction obtained from the two layered fluid sediment reflection model. W is a diagonal weight matrix to consider the measurement variance for each bottom loss.

Inversion results show that a relatively lower sound speed surficial layer having a thickness of about 0.4 m overlies a higher sound speed layer (**Table I**). Note that the bottom loss data cannot apply to geoacoustic inversion for the deeper sediment layer due to sediment attenuation for the frequencies higher than 6 kHz.

Table I. Inversion results of geoacoustic parameters

	Sound speed (m/s)	Density (kg/m³)
1st layer	1545 ± 7	1773 ± 43
2nd layer	1624 ± 11	1754 ± 62
	Attenuation (dB/m/kHz)	**Thickness (m)**
1st layer	0.31 ± 0.10	0.38 ± 0.01
2nd layer	0.28 ± 0.12	∞

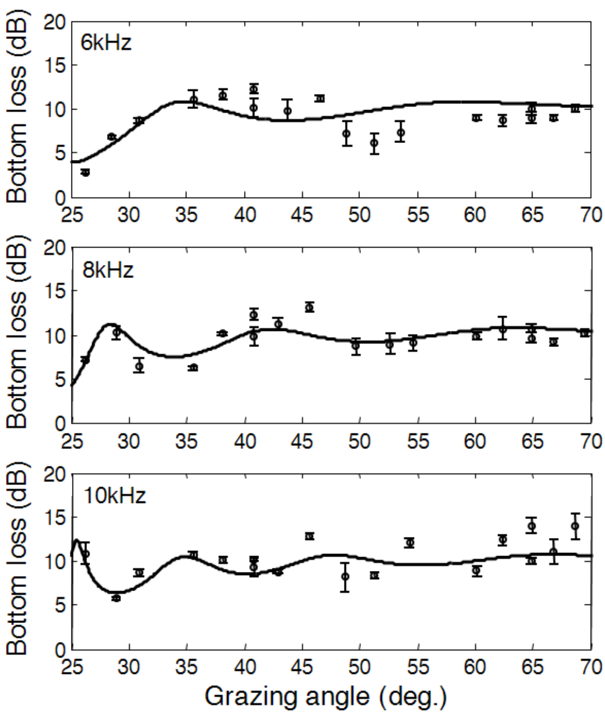

Fig. 2 Measured bottom loss data as a function of grazing angle and the comparison to the two-layered sediment reflection coefficient model predicted using inversed geoacoustic parameters.

Fig. 2 shows a comparison between the measured bottom loss and the model predictions using the inversion results shown in Table I. The measured bottom loss data are in good agreement with model predictions obtained from the two-layered sediment reflection coefficient model.

Surficial sediment structure estimated from this study is very consistent with air gun survey results [3], for which one profile line overlapped the experimental site. Critical angles of the water-surficial sediment interface and the second sediment layer interface are estimated to be 18.2° and 25.3°, respectively, which were given by $\arccos(c_w/c_s)$ where c_w and c_s are the sound speeds of water and sediment, respectively. Although the measurements do not include the data at the lower critical angle, the significant oscillations as a function of grazing angle are seen near the higher critical angle and the model predictions reflect well these oscillations.

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