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The Effect of Ray Focusing Gain in Shallow Water

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1. Introduction

While analyzing mid frequency acoustic data that were taken in a continental shelf off the east coast of Korea, we observed frequency dependence of acoustic signal in receiver ranges. Underwater acoustic propagation is strongly affected by a vertical sound speed profile, and ocean boundary characteristics, especially bottom properties due to its frequent interactions in bottom limited propagation environment[1)]. Major factors affecting bottom limited propagation include water depth, angle of incidence, frequency, and bottom composition. The effect of bottom reflection is to return to the depth of the propagation sound that has been carried downward by the depression angle of the transmitted acoustic sound[2)]. Reflections from the ocean bottom can extend propagation ranges. In recent years, the ocean bottom interaction at a mid frequency of underwater acoustic sound has attracted much interest for active detection using bottom reflected signals[3)].

2. Sea Experiment

On September 18-19, 2013, the sea experiment was performed in continental shelf area bounded by 35.80°N to 36.10°N and 129.50°E to 129.90°E. The experiment area was located 21 km offshore from the harbor Pohang. The water depth was approximately 1100 m and the bottom was described in a geologic survey of the area as consisting of sandy-mud. Figure 1 shows the area map of the experiment.

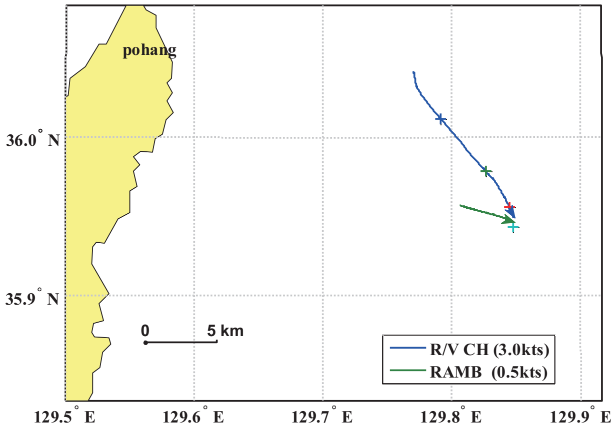

Fig. 1 Area map of the experiment off the east coast of Korea

For acoustic data acquisition, sound source was towed by research vessel ChungHae (R/V CH, blue line on fig. 1) and as a receiver, vertical line array (RAMB, green line on fig. 1) was floated in the experiment area. The acoustic signal was composed of 4 narrow band continuous waves at a frequency of 1000, 2490, 3990, and 5490 Hz. The source level of each tonal was 182 dB and set at a depth of 9 m and a hydrophone was set at a depth of 70 m. The acoustic signal was recorded from 12:54 and the duration time was about 90 min. The vertical sound speed profile (SSP) is calculated from averaged XBT measurements by using Meckenzie formula.

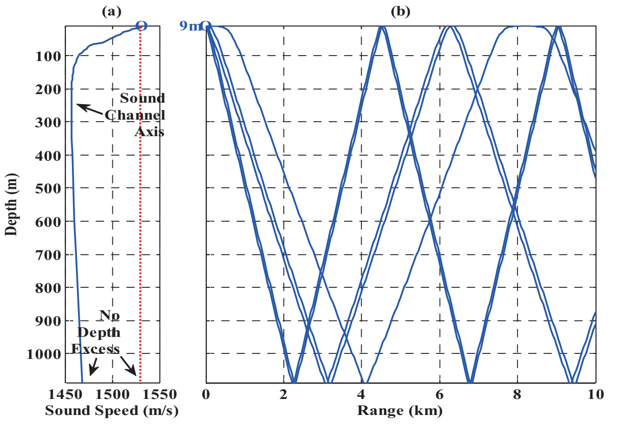

Fig. 2. (a)Measured sound speed profile, (b) Ray trace of measured SSP (source depth 9m)

Figure 2(a) shows the vertical SSP. The sound speed decreases with depth to 1457 m/s at 250 m which is sound channel axis and increases to 1467 m/s at bottom. The negative sound speed gradient at a source depth produce ray curvature that bends downward toward bottom. Due to the water depth is less than conjugate depth, no depth excess exist, so it is obvious that bottom limited propagation environment. Figure 2(b) shows ray trace of measured SSP. 5 rays are traced between -20 to 20 degrees in vertical angle. All ray paths interact with to bottom. This type of ray paths is very common in the summer season in east sea of Korea.

3. Analysis

The analysis method used in this study uses the pressure level as a function of frequency. The acoustic signal from the hydrophone is preamplified, filtered in the frequency band of 0–32 kHz, transformed to a digital signal, and stored in an

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internal memory of the receiver system. In signal postprocessing, the calculations of pressure in stored signals are conducted taking into account the hydrophone sensitivity, preamplifier gain, and transfer function of the filter. The stored signals are decimated by a factor of 2, and the number of fast Fourier transforms (FFTs) is 16384 without an overlap in the window. Figure 3 shows the received sound pressure level at 4 frequencies.

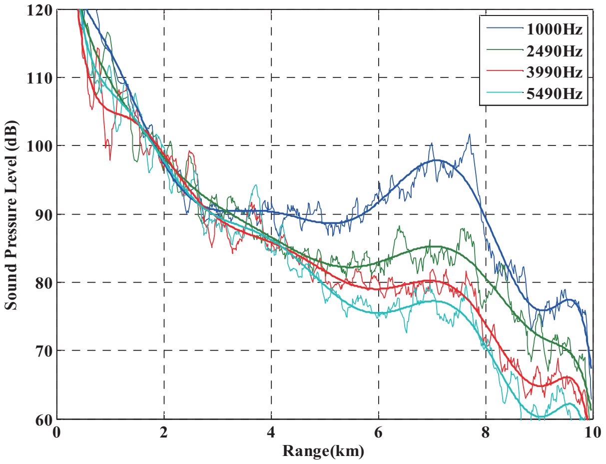

Fig. 3 Received sound pressure levels at frequencies of 1000, 2490, 3900, and 5490 Hz (receiver depth 70m)

The received level depends on the factors of spreading, absorption and bottom loss of the transmitting signal in the experiment environment. The trend of the sound pressure level fluctuation is that as the range increases, sound pressure level decreases steady by 90 dB to the range of 3.4 km. At a range between 3.4 to 6 km, pressure levels also decreases but not as steep as before. However, at a range between 6 to 7 km, sound pressure levels increases and decreases rapidly by 9 km. At a range of 6 km, the sound pressure levels are 91.8, 83.2, 78.4, and 74.9 dB at frequencies of 1000, 2490, 3990, and 5490 Hz, respectively. Meanwhile at a range of 7 km, those are 97.2, 85.1, 80.1, and 76.6 dB. Sound pressure levels increases as range increases between 6 to 7 km by 5.4, 1.9, 1.7, and 1.5 dB at 4 frequencies. Color figure shows bottom reflection focusing gain at a range of 6 to 7 km range.

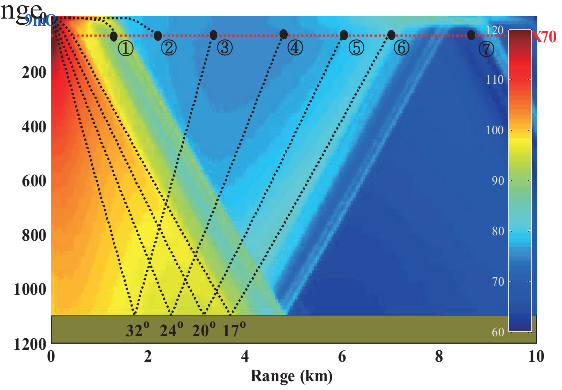

Fig. 4 7 eigenray tracing between source and receiver position using ray based model

To analyze the arrival structure of transmitted signal to the receiver, acoustic model BELLHOP6) is used which is ray theory based model and adequate for mid frequency transmission. As environmental input parameters for the simulation, measured data were used which were described above such as SSP and sediment type. 7 engenrays are traced at a range of 1.4, 2.3, 3.4, 4.8, 6.0, 7.0, and 8.7 km. Figure 4 shows 7 eigenrays between source and receiver position and the grazing angles of each eigenrays are listed on the bottom. It is possible there are more than one eigenray which travel different ray path but only strongest eigenray is used in the simulation. At ranges of 1.4 and 2.3 km, direct path contribute more than bottom reflected path in received signal amplitude. Bottom reflected paths for these ray paths, leading to decreased sound pressure because the steeper paths to the bottom experience greater reflection loss, so little frequency dependence of amplitude exist. Even though the simulation result shows the bottom reflected path are strongest path at ranges of 3.4 and 4.8 km, it is not so strong to excess the direct path as shown in fig. 3 (no local peak at the ranges). However at ranges of 6.0, and 7.0 km, the sound pressure levels are dominated by paths involving a single bottom reflection. Corresponding grazing angles are 20 and 17 degree, respectively. As grazing angle of the each eigenrays is changed, it may cause amplitude difference of received acoustic signals. At a range of 8.7 km, only paths suffering two or more bottom reflections cannot reach the receiver.

4. Results

In this study, we analyze frequency dependence of underwater acoustic sound in bottom limited propagation environment. We observed frequency dependence in bottom reflected signal from the result of experiment. It is very important to determine the transmitter frequency and range of active sonar for detection of bottom reflected target signal. This study presents the simple method to estimate optimum frequency and detection range in bottom limited propagation environment in sandy-mud bottom. Further planned work includes additional measurements aimed at investigating different type of bottom such as mud, sand or rock.

References

1. D. Tielburger, S. Finette, and S. Wolf, J. Acoust. Soc. Am. 101 789 (1997).
2. J. Hahn: Jpn. J. Appl. Phys. 50 07HG03 (2011).
3. R. J. Urick, Principles of Underwater Sound (McGraw-hill, New York, 1983) p.386.
4. Mackenzie, K. V., J. Acoust. Soc. Am. 70(3) 807(1981).