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Grazing-Angle Dependent Boundary Reflection Effects on Underwater Acoustic Communication

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1. Introduction

Oceanic environmental parameters such as background noise, sea surface state, bottom sediment property and depth dependent sound speed profile impact the underwater acoustic communication performance. Many studies have been published for the effects of these parameters on acoustic communication and give some successful results qualitatively and quantitatively. However, what is not well known is which parameter gives the strongest effect on acoustic communication.

The multipath reflection at the boundaries is known as an important adverse factor affecting the underwater acoustic communication system performance. In the time domain, the received signal suffers fading, such as time-variant fluctuation, in both amplitude and phase owing to interactions with both time-variant boundary reflection and scattering.

In this study, the average reflection coefficient of a signal scattered by the sea surface is analyzed as a function of subtended angle. The bottom reflection coefficient of a signal reflected on sea bottom is also analyzed as a function of subtended angle which could include critical angle of incidence.

To verify the effects of this, the band limited impulse response in the multipath channel is analyzed since the impulse response gives the acoustic communication channel's coherence bandwidth.

2. Grazing-angle dependent boundary reflection coefficient

In scattering sea surface, the scattered coherent reflection coefficient is given as

$$R_{coh} = e^{-(2kh\cos\theta)^2/2}, \quad (1)$$

where reflection coefficient depends on the Rayleigh parameter, $R = 2kh\cos\theta$, where k is the wave number, h is the effective value of the surface wave height, and θ is the grazing angle. In several tens kHz of high frequency used in acoustic communication, it could be ignored the coherent reflection path from the sea surface since the Rayleigh parameter k is much greater than 1.

For sound going from water to sea bottom, when $C_2>C_1$, total reflection occurs at grazing angle of incidence, $\theta_1< \theta_c$. θ_c is the critical angle defined by

$$\theta_c = \arcsin(c_1 / c_2), \quad (2)$$

where C_1 and C_2 are speed of sound water and the sediment. In the case of $\theta_1> \theta_c$, reflection coefficient R_{12} is given by

$$R_{12} = \frac{\rho_2 c_2 \cos\theta_1 - \rho_1 c_1 \cos\theta_2}{\rho_2 c_2 \cos\theta_1 + \rho_1 c_1 \cos\theta_2}, \quad (3)$$

where ρ_1 and ρ_2 are density of water and sediment.

3. Experimental Result and Discussions

Figure 1 is the experimental configuration for grazing-angle dependent boundary reflection effects on underwater acoustic communication. At each range and depth, four millisecond linear frequency modulated (LFM) from 16 to 24 kHz signal is transmitted to measure the band limited impulse response. Matched filtering is implemented for each range and each receiver depth for measured signals.

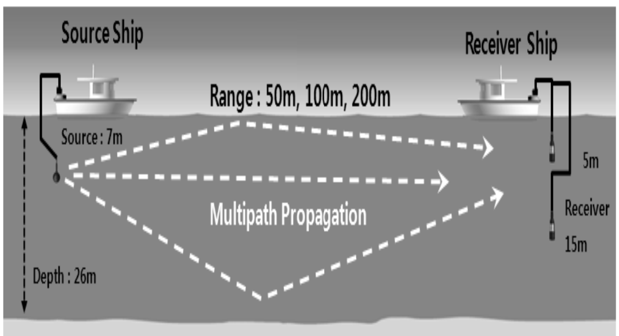

Fig. 1 Experimental configuration.

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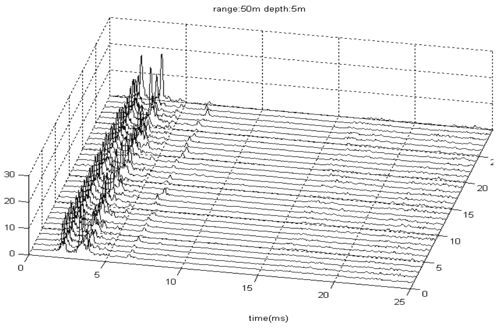
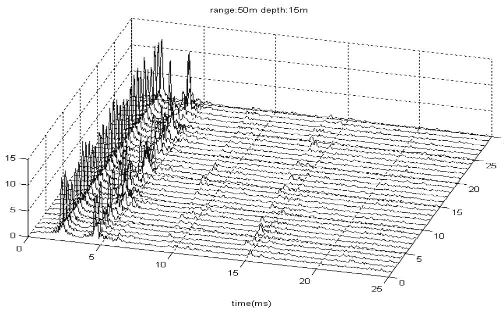
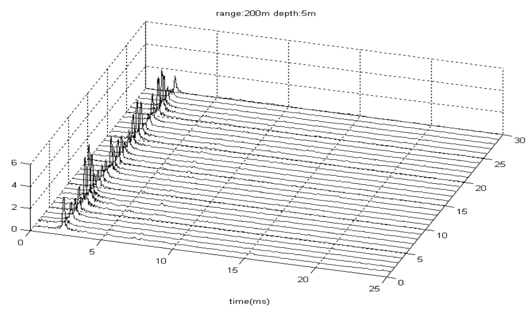
Figure 2 shows the measured impulse response for two different ranges of 50 and 200 m and source depth 7 m and receiver depth 5 and 15m. **Figure 3** shows eigenrays of 50 and 200 m ranges at 15 m receiver depth using the measured CTD data.



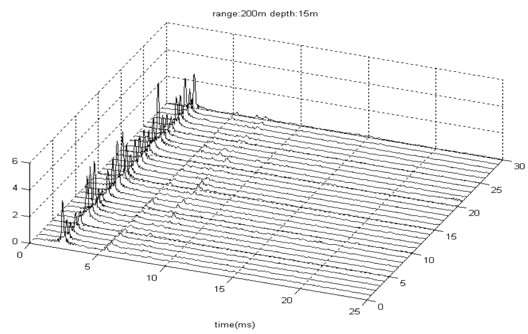
(a) Range: 50 m, receiver depth: 5 m.



(b) Range: 50 m, receiver depth: 15 m

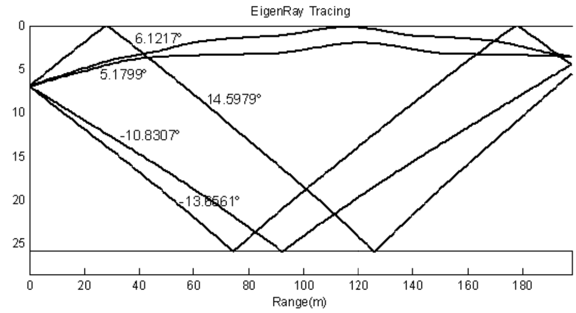


(c) Range: 200 m, receiver depth: 5 m

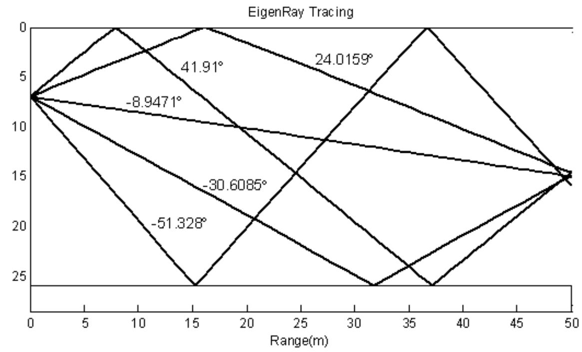


(d) Range: 200 m, receiver depth: 15 m

Fig. 2 Band limited impulse responses for two different ranges and two different receiver depth.



(a) Range: 50 m, receiver depth: 15 m



(b) Range: 200 m, receiver depth: 15 m

Fig. 3 Eigenrays for two different ranges at 15 m receiver depth.

As shown in Fig. 2, at short range of 50 m, amplitude of 1st boundary reflection path from surface is high enough to give an inter symbol interference (ISI) in acoustic communication even though Rayleigh parameter $R >> 1$. At long range of 200 m, only direct path signal is dominant even though a signal path from sea bottom may include critical angle of incidence.

Comparison of the simulated impulse response considering the eigenrays shown in Fig.3 and the measured impulse response in Fig.2 is ongoing and also analyzed statistically using Rayleigh and Rice fading models.

Acknowledgment

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