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Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)
16-18 November, 2016

Acoustic Channel Characterization in Shallow water Acoustic Communication

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1. Introduction

Underwater acoustic communication systems are used in broad range of application such as underwater acoustic communication networks, autonomous underwater vehicles, environment monitoring and naval underwater warfare. However, the objective performances of the systems are very much influenced by an acoustical channel conditions between a source and a receiver which varies with time and spatial variant physical nature of medium and boundary condition. In addition, motion of a source and a receiver induces also the acoustical channel conditions for a given physical nature of medium and boundary conditions.

The acouctic channel is characterized as several parameters such as an impuse response, a delay spread, a multipath interference, a channel coherence bandwidth, a temporal coherence time, Doppler spread, and a fading statistics[1]. Here, principle acoustic channel parameters are a delay spread, Doppler spread and a fading statistics. Other parameters are deduced or related to principle parameters. Many studies have been conducted to overcome adverse effects of these acoustic channel parameters on an underwater acoustic communication system performance. Unfortunately, various acoustic channel parameters are mixed together and cannot be analyzed separately on system performance.

In this study, each acoustic channel parameter in shallow water is characterized on the basis of acoustical physics between a source and a receiver and its effect on an digital underwater acoustic communication. The results[2,3] in this study are already used in our previous publication but reanalyzed to give more insight for an digital underwater acoustic communication design.

2. Received Signal Variation in Shallow Water

Physical and boundary conditions which characterize the acoustic channel parameters are temperature profile of medium, medium property, surface roughness and bottom property. Under these condition, transmitting acoustic wave will be spreaded, refracted, absorbed and scattered. Fig. 1(a) and 1(b) show typical acoustic multipath channels.

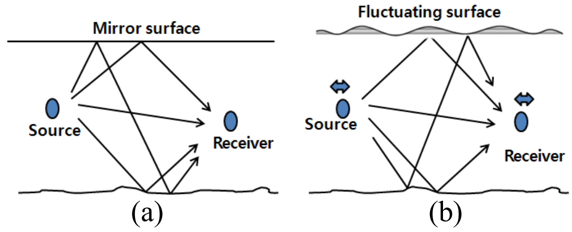

Fig. 1 Two typical multipath shallow water channel.

In medium, all multi-paths will be scattered due to medium inhomogenity such as plancton. Therefore, signal at receiver consists of a coherent and an incoherent scattering components. Amplitude of the incoherent scattering component depends on frequency and medium inhomogenity.

At surface, the incident path will be reflected with scattering in rough surface except in the case of a mirror surface. Amplitudes of a coherent specular and an incoherent scattering component depend on surface roughness, frequency and grazing angle, and change with surface fluctuation[4].

At bottom, the incident path will be reflected with scattering in rough bottom. Amplitudes of a coherent specular and an incoherent scattering component depend on surface roughness, frequency and grazing angle. However, the amplitudes do not change except source-to-receiver geometry change. The reflected path at bottom will be ignored at short range since the property of bottom is mud or sandy mud in littoral shallow water. However, the signal reflected from bottom will survive in the case of long source-to-receiver range.

Amplitude at receiver also depends on frequency dependent interference of multi-paths. Amplitude has a fading owing to surface fluctuation. The received signal also shows Doppler spread owing to relative motion of source and receiver. The magnitude of Doppler spread changes with a relative motion speed and a source-to-receiver range.

3. Receiver Signal Model and Results

Figure 2 shows phase digrams of signal at receiver. As shown in Fig. 2(a), the ith path coherent component r_i is given as

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$$C = \alpha_i e^{j2\pi f_c \tau_i} \quad , \tag{1}$$

Here, f_c is a carrier frequency and α_i and τ_i denote a magnitude and a time delay. α_i depends on frequency and medium inhomogeneity for a direct path, but depends also on surface roughness, and grazing angle for a path reflected at surface.

Figure 2(b) shows the *i*th path incoherent component and is given as

$$I(t) = \beta_i(t) e^{j\Phi(t)} \quad , \tag{2}$$

Here, $\beta_i(t)$ and $\Phi(t)$ denote a magnitude and a phase. $\beta_i(t)$ depends on frequency and medium inhomogeneity for a direct path, but depends also on surface roughness, and grazing angle for a path reflected at surface.

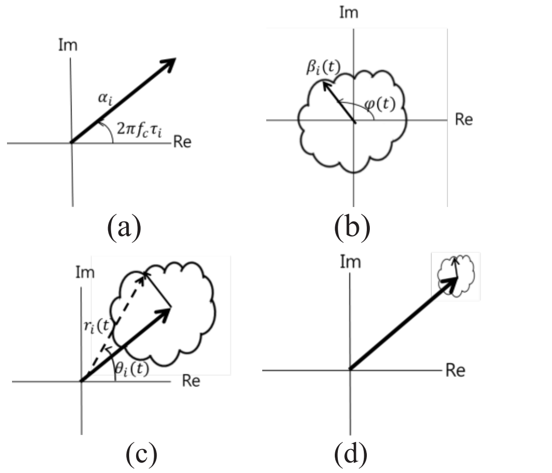

Fig. 2 Phasor diagrams of signal; (a) coherent component, (b) incoherent component, (c) sum of two components, (d) sum of two components(relative magnitude of two components changed).

At receiver, a phasor of *i*th path signal is sum of two components as shown in Fig. 2(c) and is given as

$$R_i(t) = \alpha_i e^{j2\pi f_c \tau_i} + \beta_i(t) e^{j\Phi(t)} = r_i(t) e^{j\theta_i(t)} \tag{3}$$

A phasor of each path signal will be different since α_i, τ_i, $\beta_i(t)$, and phase are different each other. At receiver, the coherent components of multi-paths are summed and interfere each other. The magnitude time varying $r_i(t)$ is analyzed by its stastical distribution and related to signal-to-noise ratio and bit-error-rate in a digital underwater acoustic communication.

Figure 3 shows received signal waveforms in shallow water. If the coherent components of multi-paths interfere destructively then the received signal phase corresponds to that of Fig. 2(b). The waveform and statistics of envelope or $r_i(t)$ becomes to Rayleigh distribution as shown in Fig. 3(a). If the coherent components of multi-paths interfere constructively then the received signal phase corresponds to that of Fig. 2(c) and 2(d). The waveform and statistics of envelope or $r_i(t)$ becomes to Rice distribution as shown in Fig. 3(b).

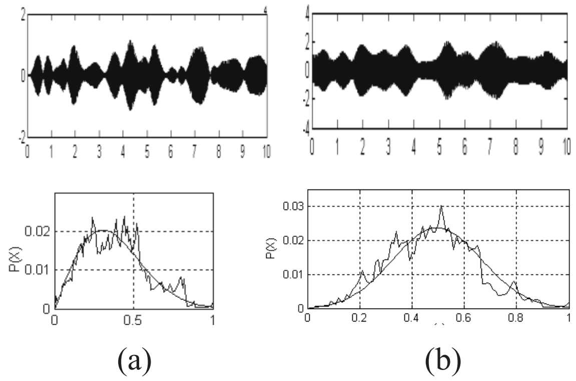

Fig. 3. Received signal waveform in shallow water; (a) destructive interference of coherent components and magnitude destribution, (b) constructive interference of coherent components and magnitude destribution.

5. Conclusions

The acoustic channel parameters in shallow water are characterized by the physical and boundary conditions between a source and a receiver. The signal at receiver is analyzed on the phasors of a coherent and incoherent componts by considering the physical and boundary conditions. The results in our previous publication are reanalyzed to give more insight for an digital underwater acoustic communication design. The relation between the acoustic channel parameters and signal-to-noise ratio or bit-error-rate in a digital underwater acoustic communication is ongoing and will be presented in this conference.

Acknowledgment

This research was supported by the 'ISABU Creative Research Program (PE99361)' of the Korea Institute of Ocean Science & Technology (KIOST).

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