OFDM 기반 실질적인 수중 음향 채널 모델링 기법

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A Realistic Channel Model for OFDM Based Underwater Acoustic Communications

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요 약 (Abstract)

In this paper, we present a realistic channel modeling technique for underwater acoustic communications. Underwater wireless sensor networks are prone to multipath and random fading due to the volatile nature of the medium. We use a lognormal distribution to model the fading effects in the underwater channel. Finally, we provide simulation results of the proposed channel model when used for point-to-point communication in the underwater networks and compare the results with the ideal flat channel model.

Ⅰ. 서 론 (Introduction)

Sound propagation characteristics in the sea are very important to understand and model the underwater acoustic channel to develop applications for military, research, monitoring, survey, disaster prevention, and navigation etc. The most challenging task in the design of underwater acoustic channel is to model the real environment that affects the transmission of acoustic signals. Acoustic waves propagate in the sea through different paths such as direct path, surface reflection, and bottom bounce (sound waves reflected from the sea floor) [1]. Multipath propagation of the acoustic wave depends on the location of transmitter and receiver. The propagation characteristics of sound waves are different in shallow and deep water due to the changes in refraction, reflection, multipath, path loss, ambient noise, and Doppler spread [2]. Apart from the characteristics mentioned above, random fading also plays a very important role in the underwater signal propagation. Accurate modeling of the fading effects can lead to a realistic channel model that will significantly increase the performance of the designed communication system. In our earlier works [2], [3], we have considered flat sea surface and bottom conditions. In this paper, we also include a realistic fading scenario to our channel model. Since the underwater sensors are prone to failure, corrosion, and discharge due to limited battery power, the peer-to-peer communication cannot assure good performance of the underwater network. Apart from this, the assumption of flat channel condition is not realistic. Although most of the models such as [4], assume a flat channel condition to model the underwater channel, there are some rocks, coral reef, pebbles, cracks, and slopes that cause fading effects in the underwater acoustic signal propagation. We model these fading effects as lognormal random distribution [5]. Further, we provide simulation results of LDPC-coded OFDM communication system over the designed channel model and compare our results with the flat channel model.

Ⅱ. 본론 (System Description)

i. Channel Modeling

We model the simulation channel with an aim to design realistic channel conditions. Our model assumes a water depth of 50 m, maximum sea surface wind of 15 m/s, and a distance of 1000 m separating the node and buoy, as shown in Fig. 1. We set the location of the node and buoy at 7 m and 45 m from the sea bottom, respectively.

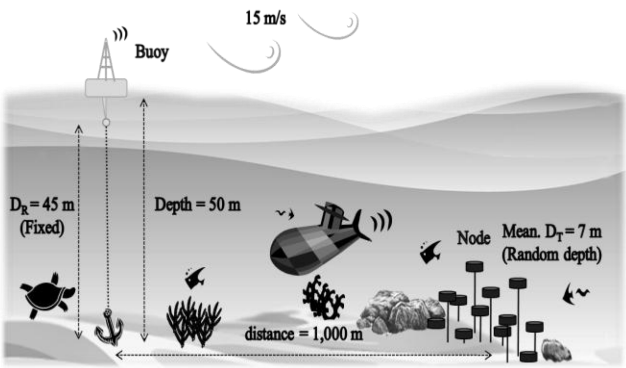

Fig. 1. Realistic Channel Model (Lognormal Fading)

We use the lognormal random distribution [5] with mean 1 and variance 2, to model the fading effects in the above-mentioned underwater channel. Fig. 2 shows the lognormal distribution with varying channel gain coefficients. The received signal can be denoted as follows,

$$y(t) = g_i\, h(t) * x(t) + n(t),\;\; n(t) \sim N(\mu, \sigma^2)$$

where, $y(t)$ is the received signal, g_i is the channel gain, $h(t)$ is the channel impulse response, $x(t)$ is the transmitted signal, and $n(t)$ is the AWGN noise with mean μ and variance of σ^2 .

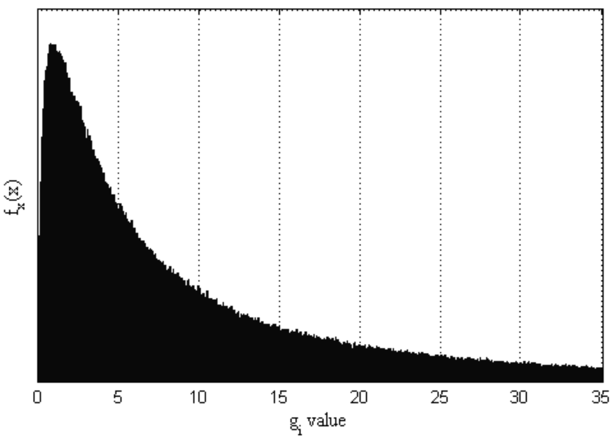

Fig. 2. Lognormal Distribution (μ = 1, σ^2 = 2)

We assume a fixed channel gain within an OFDM symbol transmission time to reduce the complexity. So, the value of g_i is kept fixed for the duration of one OFDM symbol.

ii. Simulation Results

Fig. 4 shows the performance of the un-coded OFDM and LDPC-coded OFDM communication systems when lognormal random fading is used to model the fading channel.

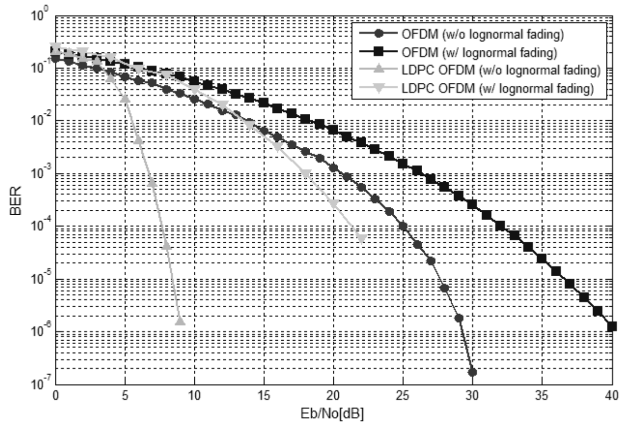

Fig. 4. Performance over Lognormal Fading Channel

As we can see, the non-lognormal or flat channel simulation shows a better BER performance for both un-coded and LDPC-coded OFDM communication systems. This is because the non-lognormal fading or flat fading model does not model the underwater acoustic signal fading phenomena exactly as it assumes flat conditions on the sea surface and bottom. In the case of un-coded OFDM system, the lognormal faded channel shows the same BER (10^{-3}) at about 6 dB higher SNR. While, in the case of LDPC-coded OFDM system, the lognormal faded channel shows the same BER (10^{-3}) at about 10 dB higher SNR. This shows that fading plays a very significant role in the underwater acoustic channel and lognormal fading provides a realistic model to study the behavior and performance of the designed communication system.

The lognormal distributed channel simulation shows a performance improvement of about 7 dB in the BER of LDPC-coded OFDM system over the un-coded version, which shows the significance of coding in the underwater acoustic communication systems. This model can also be used for modeling and simulation of the underwater multiple-sensor networks.

Ⅲ. 결론 (Conclusion)

Underwater acoustic communication systems are becoming increasingly important for military as well as civil use applications. The design and simulation of the underwater acoustic channel is a challenging task due to the nature of the medium. In this paper, we have presented a realistic underwater acoustic channel model by considering the factors that affect the sound signal propagation in real environment. We have shown that lognormal distribution can be used to accurately model the underwater fading environment and performed simulations to compare the results with flat fading channel model. Our results show that the lognormal faded channel shows degraded but realistic performance in the underwater acoustic communication using the un-coded and LDPC-coded OFDM based communications systems.

Future works may include the study of different distribution models for modeling the fading characteristics of the underwater acoustic channel. This model can also be used in the design of underwater multiple-sensor networks.

ACKNOWLEDGMENT

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