Performance Verification of LDPC coded OFDM System in Underwater Acoustic Channels

Hyeong-Won Jeon, Su-Je Lee, Heung-No Lee*
School of Information and Communications, GIST
{hyeongwon, sujerago, heungno}@gist.ac.kr*

Abstract

The underwater acoustic channel (UAC) is complex and thus it is regarded as a difficult task to obtain robust performance. In this paper, we aim to design an orthogonal frequency division multiplexing (OFDM) system combined with low density parity check (LDPC). For realistic evaluation of the performance of the proposed scheme, a detailed channel model has been developed and used in simulation. We have shown that the robustness of the designed LDPC coded OFDM system under a realistic channel scenario.

Keywords: Underwater acoustic channel, LDPC codes, OFDM system. LDPC coded OFDM system

1. Introduction

It is well known that the underwater acoustic channel (UAC) is complex and it is difficult to maintain robust communications performance over such a channel. There are numerous reflections causing severe inter-symbol interference (ISI) and frequency-selective fading. In addition, sea surface wind causes the delay dispersive channels to be time-varying [1].

It is known, in some underwater acoustic communications and perhaps more widely in wireless communications literature, that the use of OFDM system [2] combined with a powerful error correction code, such as the LDPC codes [3] and the turbo codes can provide a robust performance over such a channel [4]. There are only a limited number of papers, however, which have verified the performance over realistic underwater channel scenarios. Thus, to date, a realistic performance evaluation of the coded OFDM system over the UAC remains in great demand.

In this paper, we aim to (*i*) model a realistic simulation channel against which a proposed system can be verified, (*ii*) design a good LDPC coded OFDM system which works well under the realistic channel and (iii) show the robust performance of our designed system under the realistic channel setting. We note that there are a limited number of papers with a similar set of objectives in the literature, which have motivated this work.

The rest of this paper is organized as follows. We described realistic simulation channel modeling in Section 2, and presented the system parameter design in Section 3. Simulation results were reported in Section 4. Conclusions were contained in Section 5.

2. Simulation channel modeling

The UAC modeling is difficult since the geometry of the channel is complex as well as due to node mobility. Accordingly, there exist difficulties in applying important factors into a model. In this paper, we have modeled a simulation channel with the ideal assumption of *flat* sea surface and ocean bottom, invariable node and buoy position, and a 15 m/s maximum sea surface wind speed based on the reflection characteristics [5]. We assume 50 m water depth. The node and buoy are fixed at 7 m and 45 m from the bottom, with 1,000 m separated in distance.

Figure 1 and 2 show the multipath and the impulse response of the simulation channel. There are infinitely many such multipath came from reflection on the sea surface and the bottom but we only considered those paths within 30 dB energy gap against the direct path. The maximum delay spread and coherence bandwidth can be estimated from Figure 2 as about 20 ms and 50 Hz.

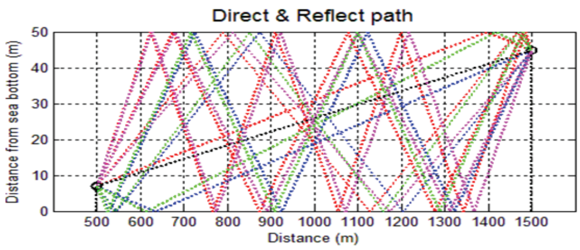

Figure 1. The multipath of modeled UAC

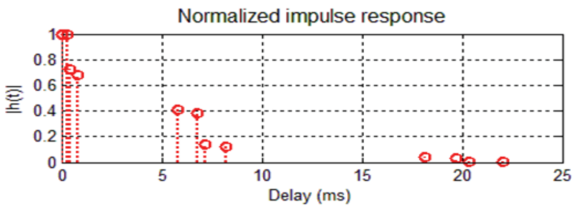

Figure 2. The impulse response of modeled UAC

3. OFDM system design

Table 1 represents the suggested LDPC coded OFDM system parameters. To deal with frequency selective fading and time selective fading, we set the carrier frequency as 10 kHz with considering Doppler spread. Under such setting, maximum delay spread and coherent time of the channel are about 6.778 Hz and 148 ms, respectively. To satisfy the condition which overcomes the time selective fading ($T_S \ll T_C$) [6], we set the transmission bandwidth and the number of sub-carriers as 10 kHz and 256. In addition, we set the CP period as 20 ms to mitigate the ISI problem.

4. Simulation results

Figure 3 shows performance of proposed LDPC coded OFDM system. We use the regular LDPC code with the block length 256 and a parity check with four 1s in each column and eight 1s in each row. Over the threshold SNR of 15 dB, the proposed system performance improves sharply and overcomes the deep fading effects. It is noted that the proposed system achieve about 6 dB SNR benefit at the 10^{-3} BER point.

5. Conclusions

The proposed LDPC coded OFDM system, it has been shown, is able to overcome not only frequency selective fading, since the sub-carrier bandwidth is selected smaller than the coherent bandwidth of channel, but also the ISI due to the use of a sufficiently long CP period. Further, it overcomes time selective fading since OFDM symbol duration is chosen shorter than the coherent time of the channel. We use a (256, 4, 8) LDPC code and the iterative message passing decoder. The proposed system is shown to achieve 6 dB SNR benefit at the 10^{-3} BER point against the uncoded OFDM system.

Acknowledgment

This research was supported by the National Research Foundation of Korea under (K20902001632-10E0100-06010) and under (N0. 2010-0017944)

Table 1: The OFDM system parameters

Parameter	Value
Carrier frequency	10 kHz
Transmission bandwidth	10 kHz
Maximum Doppler Spread : $B\tau_{max}$	6.778 Hz
Coherent Time : $T_C = 1/ B\tau_{max}$	148 ms
Maximum Delay Spread : τmax	20 ms
Coherent Bandwidth : B_C=1/τmax	50 Hz
Number of sub-carriers : N_{FFT}	256
Sub-carrier bandwidth : $\Delta f = BW/N_{FFT}$	39.0625Hz
Valid symbol duration : $T_D = 1/\Delta f$	25.6 ms
CP period : $T_{CP} \geq$ τmax	20 ms
OFDM symbol duration : $T_S = T_D + T_{CP}$	45.6 ms

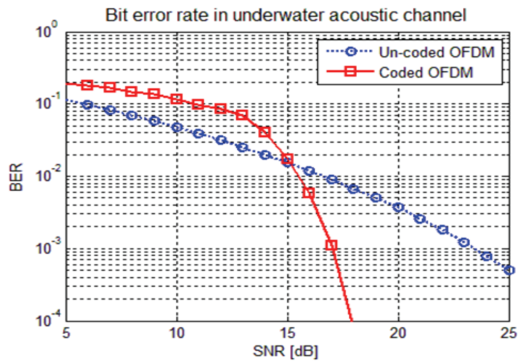

Figure 3. BER performance (with 10 iterations)

References

[1] M. Stojanovic and J. Preisig, “Underwater acoustic communication channels: Propagation models and statistical characterization,” *IEEE Communications Magazine*, vol. 47, no. 1, pp. 84-89, Jan. 2009.

[2] L. Litwin and M. Pugel, “The Principles of OFDM,” *RF Signal Processing*, pp. 30-48, Jan. 2001.

[3] R. G. Gallager, “Low density parity check codes,” *IRE Trans. Inform. Theory*, vol. IT-8, pp. 21-28, Jan. 1962.

[4] J. Huang, S. Zhou, and P. Willett, “Nonbinary LDPC coding for multicarrier underwater acoustic communication,” *IEEE JSAC Special Issue on Underwater Wireless Communications and Networks*, vol. 26, no. 9, pp. 1684–1696, Dec. 2008.

[5] P. Qarabaqi and M. Stojanovic, “Statistical modeling of a shallow water acoustic communication channel,” in *Proc. Underwater Acoustic Measurements Conference*, Nafplion, Greece, Jun. 2009.

[6] A. Goalic, J. Trubuil, and N. Beuzelin, “Channel coding for underwater acoustic communication system,” in *Proc. of OCEANS*, Boston, MA, Sept. 18-21, 2006.