Extended Abstract: A Test for Underwater Code Division Multiple Access in a Water Tank

Bo-Min Seo
Underwater Communication/Detection Research Center Daegu, Korea bmseo@ee.knu.ac.kr

Kweon Son
Agency for Defense Development Jinhae, Korea SK142298@add.re.kr

Ho-Shin Cho
College of IT Engineering, Kyungpook National University Daegu, Korea hscho@ee.knu.ac.kr

ABSTRACT
Code division multiple access (CDMA) is a promising medium access control (MAC) protocol for underwater acoustic sensor networks because of its robustness against frequency selective fading, high frequency reuse efficiency, and fewer control packets for data transmission. In this study, we design a two-channel CDMA transceiver to operate in underwater acoustic channel environments, and we evaluate the feasibility of underwater CDMA using a water tank experiment. Two users’ data are spread and orthogonally multiplexed using a Walsh code. Subsequently, a pseudorandom noise (PN) code acquisition process is added for phase error correction in the receiver.

Categories and Subject Descriptors

General Terms
Experimentation

Keywords
Underwater, CDMA, Transceiver, Water Tank

1. INTRODUCTION
Recently, there has been an increase in demand for using underwater sensor networks for various applications such as environmental monitoring, resource investigation, and disaster prevention [1]. However, because underwater acoustic channels suffer from a much longer propagation delay than terrestrial radio channels, the conventional medium access control (MAC) schemes designed for radio channels are not appropriate for underwater communications.

Many studies have been conducted on MAC protocols for underwater acoustic sensor networks. Among the methods studied, CDMA-based approaches have been the most appealing because of their advantageous characteristics such as robustness against frequency selective fading, high frequency reuse efficiency, and fewer control packets required. However, to the best of our knowledge, almost all previous studies have been conducted theoretically, without empirical evaluation.

In this study, we design a CDMA transceiver to operate in an underwater acoustic channel, and we evaluate the feasibility of underwater CDMA using a water tank experiment. The data of the two users are spread and orthogonally multiplexed using a Walsh code. Subsequently, a pseudorandom noise (PN) acquisition process is added for phase error correction in the receiver. The contribution of this paper is that performance evaluation is carried out in the real environment of a water tank, not only through simulation. We focus on verifying the possibility of applying CDMA in underwater acoustic sensor networks, and the experimental results do verify this.

2. DESIGN OF UNDERWATER CDMA TRANSCEIVER

Two orthogonal CDMA channels are built by Walsh code generation using a Hadamard matrix. The text-type data of two users are multiplexed by a direct sequence spread spectrum scheme. After spreading, a PN noise sequence is multiplied with the same chip rate as the Walsh code. The offset of the PN sequence can be found at the receiver through a PN acquisition process, which gives the starting point of data processing. In addition, by comparing the received PN with the transmitted PN sequences, we find the phase errors and correct them with a phase shift by the same amount of phase error. Finally, Walsh code despreading is carried out to separate the two users’ data.

2.1 Transmitter structure

Figure 1 shows the transmitter diagram. Data packets \( d_1(t) \) and \( d_2(t) \) are text-typed with a preamble. After attaching the
preamble, Walsh codes \( w_c(t) \) and \( w_r(t) \) spread \( d_1(t) \) and \( d_2(t) \), respectively. The reason why a Walsh code is used for multiplexing is that it can maintain orthogonality between codes in each symbol of the data packet. Pilot \( w_c \) allows the receiver to perform PN acquisition properly, and it is set to Walsh code 0 (all 0’s). After adding a pilot, PN code \( c_m(t) \) is multiplied by the sum of the multiplexed user data and the pilot. Finally, the signal modulates the carrier frequency \( f_c \) before being transmitted through an antenna.

2.2 Receiver structure

Figure 2. Structure of receiver in underwater CDMA

The block diagram of the receiver is shown in Figure 2. First, the receiver downconverts the received signal to the baseband region by multiplying it with the same carrier frequency as was used in the transmitter and then passes the signal through a low-pass filter. Then, the receiver acquires the PN code by searching for the point at which autocorrelation between the received signal and the receiver-generating PN sequence can be maximized. Through PN acquisition, the receiver is able to not only find the PN sequence offset but also determine the phase error. Thus, PN acquisition plays the most important role in determining the receiver performance. After correcting the phase error by inversely shifting the phase by the amount of error, the receiver despreads the signal with a Walsh code. Because of orthogonality, the cross-correlation between different Walsh codes becomes zero. Accordingly, the multiplexed user data are demultiplexed into two original sets of data. In the entire CDMA procedure from the transmitter to the receiver, the most important objectives are to maintain orthogonality between two different Walsh codes and to achieve successful PN acquisition.

3. WATER TANK EXPERIMENT RESULTS

Figure 3. Environment of water tank experiment

Figure 3 shows the layout of the water tank experiment. The distance from the transmitter to the receiver is approximately 8 m, and the depths of the transmitter and receiver are 3 m and 2 m, respectively. We use the ITC-1001 and B&K 8106 as the transmitter and receiver, respectively. The size of the water tank is 10 m × 15 m × 10 m. Other parameters used in the experiment are summarized in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Water tank experiment parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
</tr>
<tr>
<td>Bit rate</td>
</tr>
<tr>
<td>Spreading gain</td>
</tr>
<tr>
<td>Modulation scheme</td>
</tr>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Channel coding</td>
</tr>
<tr>
<td>Source text data</td>
</tr>
</tbody>
</table>

Table 2 summarizes the numerical results of the water tank experiment. We obtained a BER for both cases with and without channel coding. As shown in Table 2, some errors occurred in both user data 1 and 2 without channel coding. However, no error appeared after the channel coding and decoding procedure. As a result, the two test data named “wireless” and “acoustic” were perfectly decoded.

<table>
<thead>
<tr>
<th>Table 2. Numerical results of BER in water tank experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

In this study, we designed a two-channel CDMA transceiver for an underwater acoustic channel, and we evaluated its feasibility using a water tank experiment. User data was multiplexed and demultiplexed using two orthogonal Walsh codes. For the purpose of phase error correction and easy Walsh code despreading, PN acquisition was introduced. With channel coding, we obtained error-free decoded user data. In future research, we intend to consider a CDMA network with more than two nodes. In addition, a reverse CDMA link where multiple transmitters are involved will be tested. Varying CDMA parameters such as the spreading gain, PN chip rate, and bit rate is also being considered for future experiments.

5. ACKNOWLEDGMENTS

This work was supported by Defense Acquisition Program Administration and Agency for Defense Development under the contract UD1002KD.

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology (2012R1A1A4A01003029)

6. REFERENCES