# 2Pa6-1

# Results comparison of spatial diversity techniques in horizontally and vertically arranged multiple array sensors in underwater acoustic communication

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## 1. Introduction

In underwater acoustic communication, the transmitted acoustic signals are severely influenced by multiple reflected signals from boundaries. Very large reflection signals from boundaries cause inter-symbol interference so that the performance of the underwater acoustic communication is degraded. Many techniques have been applied to compensate this problem. In this study, we applied the space diversity technique and evaluated its result on the QPSK modulation and demodulation system in a water tank. Experiments were carried out using various bit rates and array sensors of the receiver. Receiver arrays were arranged by horizeontally and vertically, respectively. And their results were compared each other.

## 2. QPSK system and the experimental conditions

Figure 1 shows the experimental configurati -on in a water tank on (a) and the receiver sensors' structures on (b). The size of the water tank is 2m×1.5m×1m in length, width and height respectively. An ITC-1001 is used for the transmitter and five H1a sensors are constructed in the form of crosses for receives. The distance from each sensor is 0.16m from center in width and height, respectively. The carrier and sampling frequency 16 kHz is intended to be used close to the 18 kHz transducer's center frequency. The sampling frequency was set at 128 kHz so that the carrier frequency was 8 points in one cycle. The specific experimental parameters are given in Table I.

Table I. Experimental parameters in water tank.

| | |
|---|---|
| Mod/Demod. System | QPSK |
| Carrier frequency (kHz) | 16 kHz |
| Sampling frequency (kHz) | 128 kHz |
| Bit rates (bps) | 100, 200, 400 |
| Data Transmission Type | Packet |
| Tx and Rx range (m) | 1.2m |
| Tx and Rx depth (m) | 0.3m |
| Water Depth (m) | 0.7m |
| Data (bits) Image | 9,800 bits |

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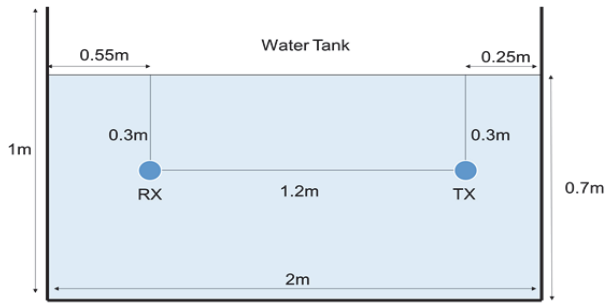
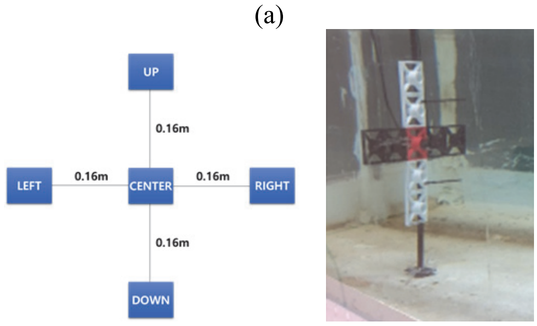



(a)




(b)

Fig. 1 The experimental configuration in water tank on (a) and the receiver sensors' structures on (b).

## 3. Experimental results and discussion

At first, a linear frequency modulated (LFM) signal with a length of 128 ms is transmitted to measure the channel impulse response in the frequency range of 13 kHz to 23 kHz. From this result, a reverberation time of the water tank is given by about 31 msec. As result, the transmission time of each frame is set to be 1s. The interval between LFM and DATA was set to 50 msec considering the reverberation time. Next, each received LFM's amplitude response was divided by the transmitted LFM's amplitude responses calculated, and shown in Fig. 2. The dotted lines show each bandwidth according to 100, 200 and 400 bps. From each result, several deep fading near to the carrier frequency were founded in channel CENTER and RIGHT. It can be expected that the communication quality can be degraded.

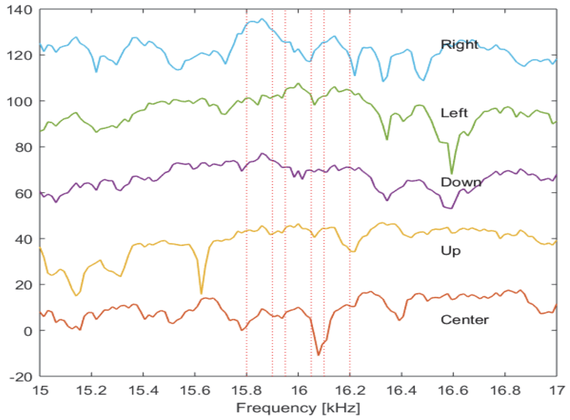



Fig. 2 Channels' frequency responses.

The width of the carrier frequency of the first valley determines the coherence bandwidth. On the other hand, it couldn't find the deep fading in the channel DOWN's spectrum. From this, the standard deviation was calculated to estimate whether there is deep fading from each frequency characteristic or if there is a lot of fading in the passband characteristics of the channel. The standard deviations for each bandwidth are shown in Table 2. It can be also seen that the channels with number of fading and the values of the standard deviation are proportional to each other. From this, it can be seen that the standard deviation value can be used as a way to estimate the fading characteristics.

Table II. Channel's standard deviations in passband according to bps.

| bps / channel | 100 | 200 | 400 |
|---|---|---|---|
| LEFT | **4.320** | **1.882** | **0.801** |
| RIGHT | 0.929 | 0.705 | 0.451 |
| CENTER | 0.945 | 0.453 | 0.222 |
| UP | **2.810** | **1.263** | **0.557** |
| DOWN | **4.404** | **1.101** | **0.519** |
| Average | 2.681 | 1.081 | 0.510 |

Table III. Channel's bit error rate according to bps.

| bps / channel | 100 | 200 | 400 |
|---|---|---|---|
| LEFT | **0.000** | **0.000** | **0.013** |
| RIGHT | 0.000 | 0.246 | 0.196 |
| CENTER | 1.E-04 | 0.167 | 0.102 |
| UP | **0.000** | **0.000** | **0.000** |
| DOWN | **0.000** | **0.000** | **0.000** |

The result of the selection technique is applied to an additional technique as channel combination. There are 6 types of 2 channel combination (C-L, C-R, L-R, C-U, C-D, and U-D). The result is shown Fig. 3 and the number above each figure shows the BER. The number of combined channels also affected to some extent, but it was found that the combination with channels that did not have errors alone had a greater effect.

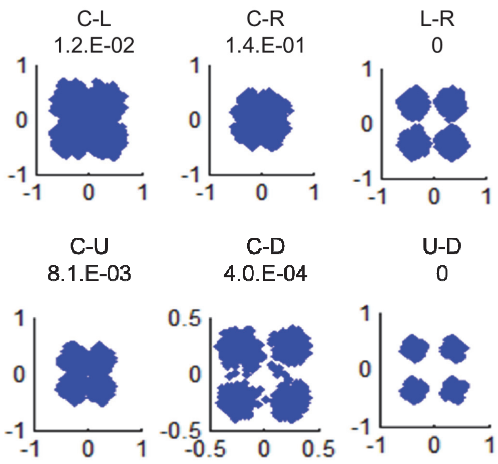



Fig. 3. Comparison of channel combinations.

## 4. Conclusions and further study

In this paper, we investigated the effect of space diversity on the underwater acoustic communication. For the choosing of the proper channel, we calculated the standard deviation in their transfer functions on each channel. As results, those standard deviations are related to the bit error rate on each channel. When the standard deviation value of the transfer function was smallit was found that the fading was low and the frequency characteristics were flat. This result is expected to be useful with less errors in multipath environment such as in the shallow water or the water tank.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