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Analysis on the time delay characteristics of acoustic wave according to the receiver depth in shallow water

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1. Introduction

Recently, Underwater acoustic sensor networks are interested beacause it is available to civillian demand such as ocean environmental monitoring, resource observation and military demand such as detection, unmanned undersea vehicle, information gathering of ocean.

Underwater acoustic wave have longer path length difference compare with microwave in terrestrial communication because velocity of underwater acoustic wave is much slower than that of microwave. This physical phenomenon will be caused Intersymbol Interference (ISI) and so aggravated performance of communications. Therefore, analysis on the time delay characteristics take precedence in order to realize underwater acoustic sensor networks.

In this paper, the time delay characteristics is calculated and analyzed according to the depth in shallow water.

2. Time delay characteristic

Propagation path of acoustic wave is composed of the direct path and a number of reflected and refracted waves, due to the influence of the underwater sound velocity and wave guiding effect by sea surface and sea bottom. Therefore, underwater acoustic communication channel is in the form of multipath channel by sum of direct, reflected and refractive waves. **Fig 1** Shows the schematic of multipath in the underwater. Time delay spread of underwater acoustic wave which has various values by geometry of surface and bottom affect performance of underwater acoustic sensor networks.

Time delay characteristic parameters are comprised of mean excess delay and rms delay spread. Mean excess delay is represented as expressed by eq. 1 shown below

$$\overline{\tau} = \frac{\sum_i a_i^2 \tau_i}{\sum_i a_i^2} = \frac{\sum_i P(\tau_i)\tau_i}{\sum_i P(\tau_i)} \qquad (1)$$

where a_i is receiving signal pressure by i-th path, $P(\tau_i)$ is receiving power by i-th path, τ_i means that the relative delay time of each path with first received signal where the receiving time of the first received signal is zero second. Rms delay spread is represented as expressed by eq. 2 shown below

$$\tau_{rms} = \sqrt{\overline{\tau^2} - (\overline{\tau})^2} \qquad (2)$$

where $\overline{\tau^2}$ is represented by eq. 3 shown below

$$\overline{\tau_2} = \frac{\sum_i a_i^2 \tau_i^2}{\sum_i a_i^2} = \frac{\sum_i p(\tau_i)\tau_i^2}{\sum_i p(\tau_i)} \qquad (3)$$

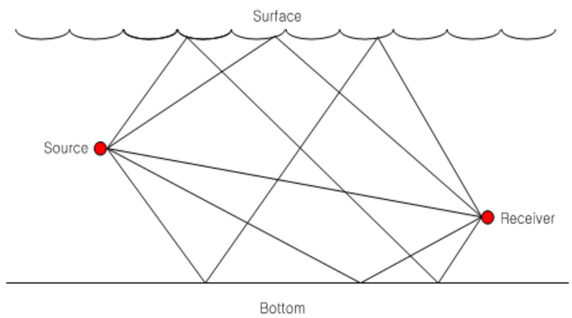

Fig. 1 Schematic of multipath in the underwater

3. Experiment and result

The experiment was performed at south sea of Korea in May, 2012. **Fig.2** shows the scenario of the experiment. Water depth of this area is about 46m and sea bottom is consists of mud. The transmitter is located at 35m water depth and the receivers are consists of array (5m, 15m, 25m, 35m). Distance between the transmitter and the receiver has a range of 100m. Transmitted signal was linear frequency modulation (LFM) which has center frequency at 15 kHz and bandwidth of signal is 4 kHz.

Table I is time delay characteristics which are derived from the experiment and are calculated by using the eq. 1 and eq. 2. Result is shown that mean excess delay and rms delay spread are increase as the receiver deepens.

Fig. 3 shows the channel impulse response according to the receiver depth. Where, D is direct wave, S is surface reflection wave and B is bottom reflection wave. The time delay characteristic is affected by both amplitude of each signal and time

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delay from the reference signal. Where, reference signal is the direct wave. Therefore, direct wave does not affect time delay characteristic because time delay of the direct signal is zero. Amplitude of bottom reflection wave is lower than that of surface wave because mud has great absorption for acoustic wave. Therefore, except for direct wave, surface reflection wave is dominant signal. Surface reflection wave gradually edged away from the direct wave according to depth of the receiver because path length of surface reflection wave is lengthening. Therefore, the deeper the receiver is deployed, the longer time delay characteristics.

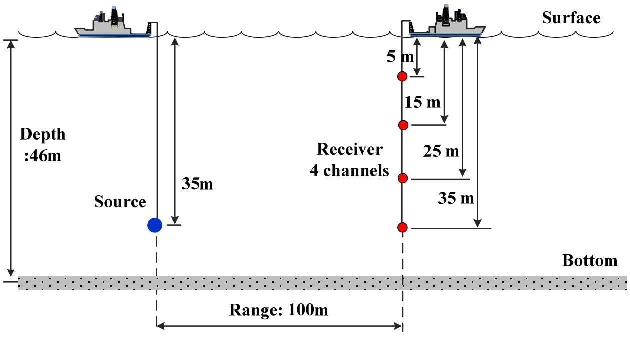

Fig. 2 Scenario of channel impulse response measurement

Table I. Mean excess delay and rms delay spread according to the receiver depth

Rx depth	mean excess delay	rms delay spread
5 m	4 ms	4.4 ms
15 m	5.6 ms	6.3 ms
25 m	6.7 ms	7.2 ms
35 m	7.3 ms	8.8 ms

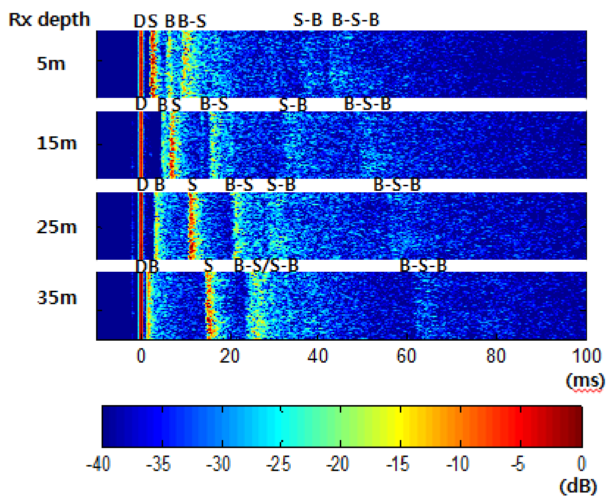

Fig. 3 Channel impulse response according to the receiver depth

4. Conclusions

In this paper, time delay characteristics is calculated and analyzed according to the depth in shallow water. It is found that multipath of the underwater acoustic wave is influenced by deployment of the source and the receiver. Therefore, in considering of the time delay characteristics, sensor nodes are deployed in order to realize underwater acoustic sensor networks.

Acknowledgment

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