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Performance Test of Direct Sequence Spread-Spectrum Signal for Range Estimation in Deep Sea

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1. Introduction

To estimate of the distance between a transmitter(i.e, Autonomous Underwater Vehicle) and a receiver(i.e, Base) in the underwater like as **Fig. 1**, it is important for underwater applications; monitoring of the position or navigation, etc. For the precise estimation of the range, it is needed to extract the synchronous signal from the received signal. So we considered the direct sequence spread-spectrum (DSSS) system[1)] in the deep sea. In this paper, we present the simulation results of range estimations from the peak detection with cross-correlation[2)] using binary phase shift key (BPSK) modulation.[1)]

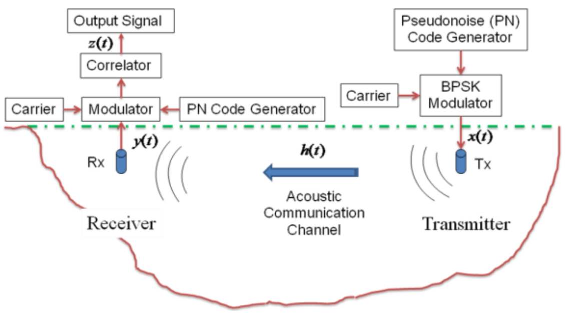

Fig. 1 Concepts of the Underwater Acoustic Communication Channel with DSSS system.

2. Simulation Model, Their Impulse Responses with Image Method and Simulation Results

Figure 2 shows a simulation model. There are four transmitter points and a receive point. In this model, we assumed the situation of deep sea; (a) and (c) are respectively assumed the vertical channel and the horizontal channel. For the implementation of underwater acoustic communication channel, the image method is used and its results are presented(**Table. 1**). The scheme of the image method[3)] is shown as **Fig. 3**. It is expected just two impluse pulses with a direct signal and a surface reflected signal. From Table I, we note that transmitter (d) is the worst case in underwater communication channel. Because delay points between 1st signal and 2nd signal is very small,

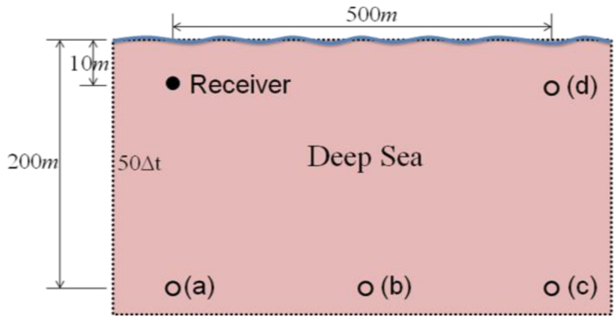

Fig. 2 A Simulation Model.

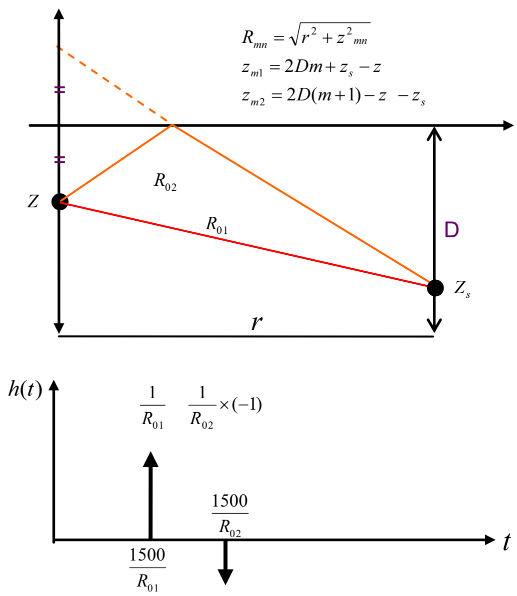

Fig. 3 Scheme of the Image Method.

Table I. Channel Implementation Results

Transmitter	1st signal arrival time (ms)	2nd signal arrival time (ms)	time delay between two signals (ms)	delay points in f_s
(a)	126.67	140.00	13.33	2667
(b)	209.34	217.66	8.33	1665
(c)	356.59	361.54	4.95	990
(d)	333.33	333.60	0.27	53

the strong intersymbol interference (ISI) is expected. The distance between transmitter and receiver is more closer than (d), more stronger ISI is expected. So we investigated the error rate of peak detection with transmitter (d) and more worst case. For the communication simulation, we assumed that the

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sampling frequency f_s is 200kHz, the carrier frequency is 20kHz, a symbol length of PN code is 50points, PN code length is 11*50bits.

At first, we just tested the BPSK modulator and demodulator without delay and environment noise as shown **Fig. 4**. XCorr1 and XCorr2 are respectively the results of peak detection. XCorr1's procedure is exactly same with diagram in Fig. 1. XCorr2 is result of between the demoluator with low-frequency pass filter and the PN code. 0 means no delay.

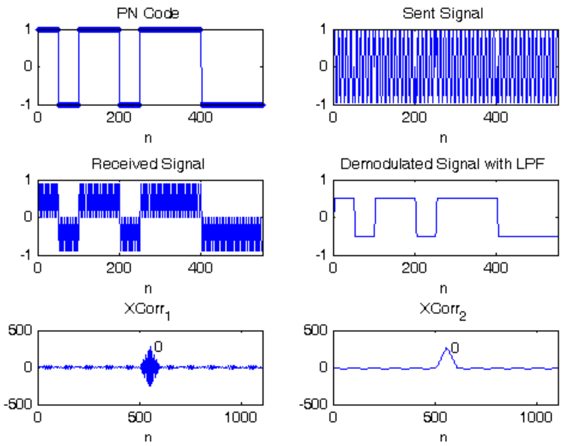

Fig. 4 Result of a DSSS Signal without Delay & Noise

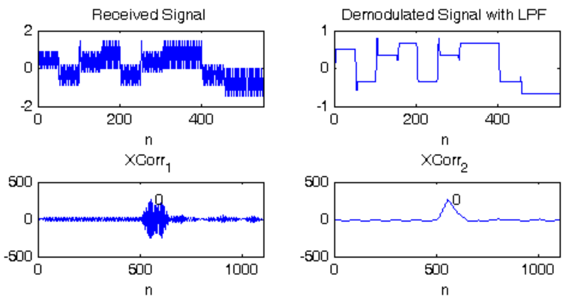

Fig. 5 Result of a DSSS Signal with Delay without Noise

Next, we demonstrated DSSS signal with delay points 53 without noise. In **Fig. 5**, the output of LPF is not clear than LPF's output in Fig. 4. But, from XCorr1 and XCorr2's results, there is no influence by the 2nd signal.

Finally, we considered the environment noises in the same condition with Fig. 5. The SNR(power of signal/power of noiese) is chosen 1.0. The result is shown as **Fig. 6**. From XCorr1 and XCorr2's results, there was some influence by the 2nd signal. The peak detection was delayed one or two points. The error rates of XCorr1 and XCorr2 were respectively 0.47% and 4.68% in 1000 try. XCorr1 showed better performance than XCorr2.

From these simulations, we could conclude that delay points 53 between 1st signal and 2nd signal is large than a symbol length of PN code 50, so there is less influence to peak detection. So we demonstrated with delay points 26 to expect ISI's influence. The result is shown as **Fig. 7**. The error rates of XCorr1 and XCorr2 were respectively 10.5% and 100.0% in 1000 try. It looks like that XCorr1 showed better performance than XCorr2. While XCorr2's results was concenturated one and two point delays in the amount of error points, Xcorr1's results was concenturated 10 and 21 points delays. In the estimation of range, XCorr2 showed better performance than XCorr1. Unfortunately, the worst situation can be obtained our simulation situation, so the a symbol length of PN code should be considered shorter than two signals' time delay.

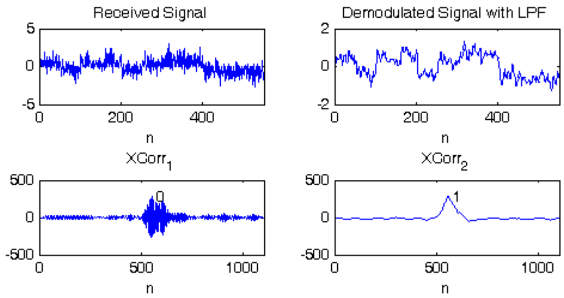

Fig. 6 Result of a DSSS Signal with Delay and Noise.

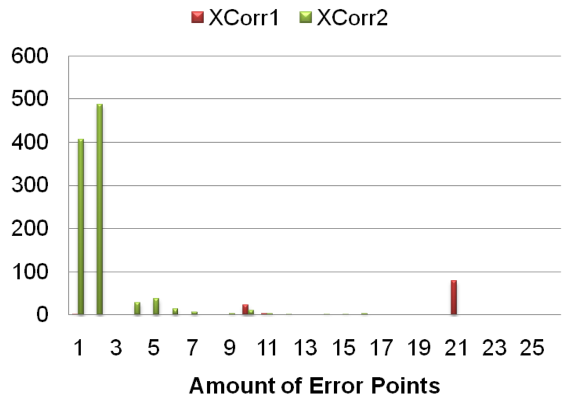

Fig. 7 Error Distribution of a DSSS Signal.

Acknowledgment

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