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Phase Estimate using Phase Code in Underwater Spatial Variation Channel

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1. Introduction

In shallow water multipath channel, underwater acoustic (UWA) communication channel exhibits amplitude and phase fluctuations by the dynamic variation of boundary and medium[1]. Therefore, the phase coherent UWA communications experiences amplitude variation and phase shift in time domain. Also, UWA channel shows a frequency selective fading in high speed transmission and this induces an inter-symbol interference (ISI) resulting in bit error increase[2,3].

In this study, we have analyzed a phase code performance in spatial variation channel. The constant amplitude zero autocorrelation (CAZAC) signal is applied as a phase code signal for phase estimate.

2. Phase estimate using phase code

In UWA communication channel, acoustical properties, boundary and a relative position of a transmitter and receiver vary with time as shown in **Fig. 1**[4].

In the coherent detection system, the phase shift estimate requires a careful selection of the number of equalizer taps, tuning of the equalizer and phase lock loop (PLL)/delay lock loop (DLL) coefficients[5]. Also, a stable and robust operation of this time domain equalizer is difficult to obtain in time-varying multipath channel conditions.

3. Experimental Results

The experimental parameters and configuration are shown in **Table I** and **Fig. 2,** respectively. The source and the receiver are located at depth of 0.3 m and 0.2 m, respectively.

Figure 3 shows UWA communication transmission frame with phase code. **Fig. 4** shows block diagram of phase estimate using phase code. The phase estimate is obtained using the phase difference as below[5]

$$\Delta\emptyset = \Delta\emptyset_S - \Delta\emptyset_E \quad (1)$$

where, $\Delta\emptyset$ is phase difference, $\Delta\emptyset_S$ is variation phase of received S (phase detection start) phase code signal and phase code table, $\Delta\emptyset_E$ is variation phase of received E (phase detection end) phase code signal and phase code table. **Fig. 5** shows phase code table signal.

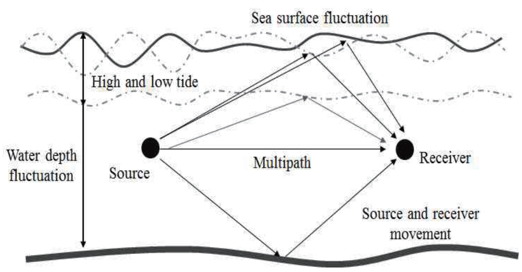

Fig. 1 Spatial variation characteristic of UWA multipath channel.

Table I. Experimental parameters.

Modulation	QPSK
Carrier frequency	30 kHz
Bit rate	200 bps
Transmission bit	9800 bit
Distance	1 m
Transmitter / receiver depth	0.2 m/ 0.2 m
Water surface state	fluctuation and mirror

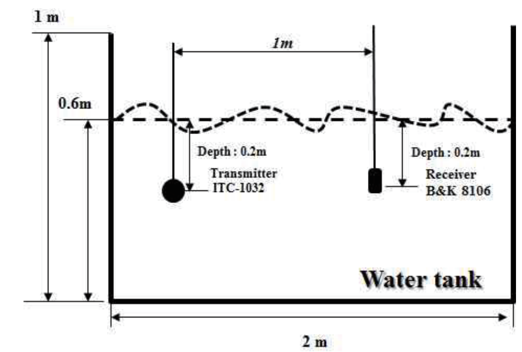

Fig. 2 Experiment configuration.

Fig. 3 UWA communication transmission frame with phase code .

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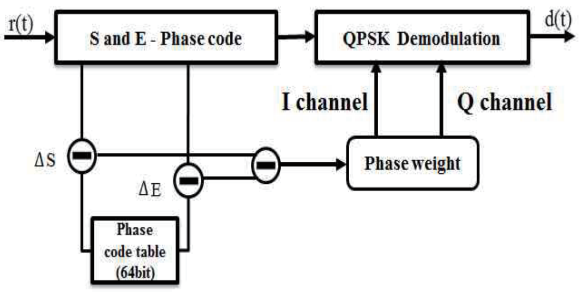

Fig. 4 Block diagram of phase estimate compensation using phase code.

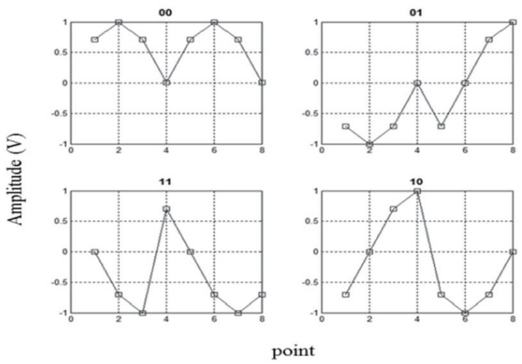

Fig. 5 Phase code table signal (CAZAC code).

Table II. BER for phase estimate compensation.

Channel phase weight	BER
I channel : 0 Q channel : 0	Error number :1268 BER : 0.13
I channel : -3 Q channel : 8	Error number :327 BER : 0.033
I channel : -1 Q channel : 8	Error number :273 BER : 0.029
I channel : -5 Q channel : 8	Error number :128 BER : 0.013

Table II shows the bit error rate (BER) results after the phase compensation in water surface fluctuation state. The BER is lower in the case of phase compensation using phase code as shown in the Table II. Fig. 6 shows corresponding constellations with (b, c, and d) and without (a) phase compensation using I and Q channel phase estimate.

6. Conclusions

In this study, we have analyzed a phase code performance in spatial variation channel. The constant amplitude zero autocorrelation (CAZAC) signal is applied as a phase code signal for phase estimate.

The proposed phase estimate is applied to QPSK system in water surface fluctuation channel and it is found that phase compensation using phase code improves the system performance.

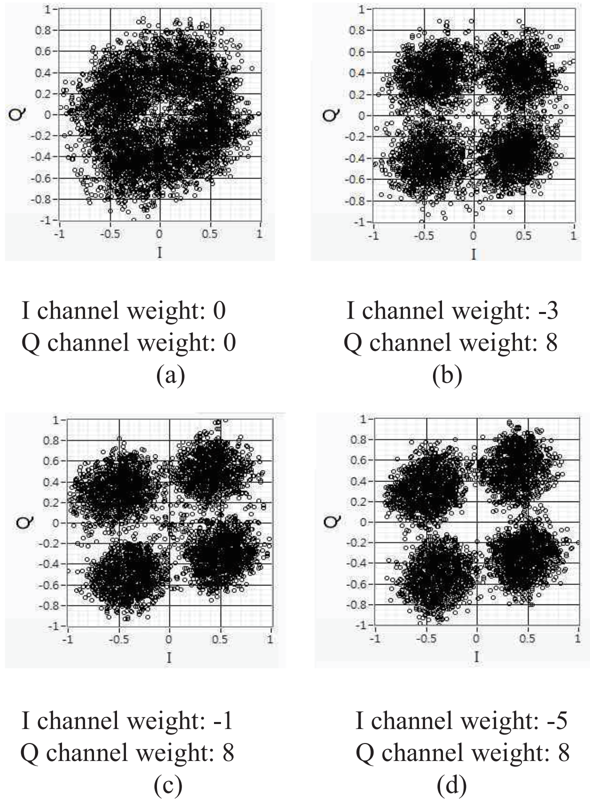

Fig. 6 Constellations of phase estimate compensation using phase code.

Acknowledgment

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