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Acoustic Communication in Air Using DBPSK with Influence by Impulse Response

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1. Introduction

Underwater acoustic communication has been studied[1-4,7-10]. Since acoustic waves propagate longer distance than electromagnetic waves in underwater, the acoustic communication has a great advantage in such environments. In contract, because airborne sound can't propagate a long distance, the communication that uses the airborne sound doesn't have the so many examples. However, it is thought that it is effective to short-range communications like beacons[11]. Acoustic beacons are used widely at present. However, the prevailing purpose of using acoustic wave is the localizations of vehicles, and not used for the data communication so much[5, 6].

In this study, a differential biphase shift keying (DBPSK) digital communication that used airborne sound is experimentally examined. In addition, the impulse response of a loudspeaker (SP) and microphone (MIC) affects the quality of acoustic communications. Therefore the influence of the impulse response is evaluated. The effects of background noise are also considered.

2. System Fabrication

Figure 1 shows a schematic of the DBPSK system using airborne sound. The DBPSK system consists of a SP, a MIC and a sound propagation path. The SP and MIC are connected to a personal computer (PC) via an analog to digital converter (ADC) and a digital to analog converter (DAC).

Figure 2 shows the digital and analog block diagrams for the DBPSK transmitter and the receiver. The left side diagram is the DBPSK transmitter realized by the DAC with controller software. Binary data are input to the DBPSK modulator on every repetition time. The input binary data are modulated into square-wave with the clock whose frequency is $1/n$ of the carrier frequency, and differential encoded. The DBPSK output signal is radiated from the SP as the burst sound signal via an audio-frequency-amplifier (AF-Amp). The left side diagram shown in Fig. 2 is the DBPSK receiver by the ADC and software. The signal detected by the MIC is applied to the DBPSK demodulator via the AF-Amp. In the DBPSK demodulator, the delayline delays the DBPSK signal by one-symbol. The delayed signal and the DBPSK signal are multiplied each other. The signals delay-detected and passed through the LPF are converted into binary data by the symbol estimation circuit. The data finally estimated are expected to identical to original data.

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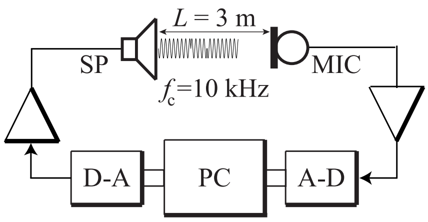

Fig. 1 Block diagram of a performance evaluation for differential biphase shift keying (DBPSK) using an airborne sound for short range data communication.

3. Experiments and Results

The experimental setup is shown in Fig.1. The SP (9D-4B / Clarion) and the MIC (CMS-64 / Bonsung Electronics) were placed face-to-face in a 55 m^3-anechoic room at the distance of 3 m. The SP and MIC were controlled through the ADC(PXI-6133 / NI) and DAC (PXI-6713 / NI) by the PC (PXI-8187 / NI with PXI-1042Q / NI). Each of the transmitted data is (0, π, π, π, 0, 0, 0).

The carrier frequency was 10 kHz. First of all, the impulse response of the system was measured. In order to determine the one-symbol time T required to reduce the influence by the impulse response, the quality of the communication is

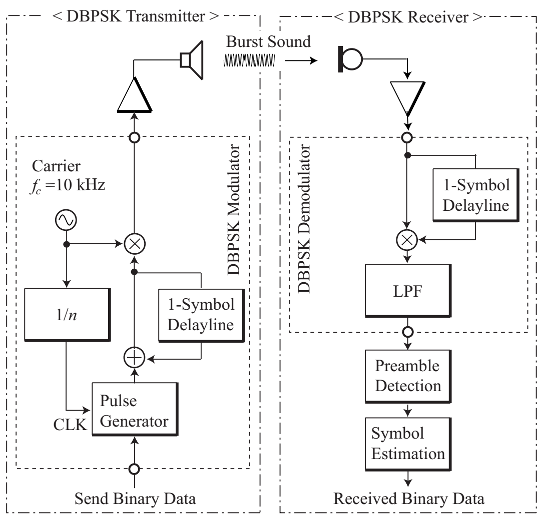

Fig. 2 Digital and analog block diagrams for DBPSK transmitter and receiver.

experimentally examined under the conditions of T = 0.3, 0.4, 0.5, 0.8 (ms) and constant SNR. In addition, the communication quality is also examined under the conditions of various SNR and constant T. **Figure 3** is the waveform of the impulse response of the system. It is supposed from Fig. 3 that the demodulated signal is affected for 0.3-0.5 (ms) when the transmitted data become π. Therefore, the one-symbol time T to reduce the influence of the impulse response of the system is regarded as 0.5 ms and over.

Figure 4 is the result of transmission experiment under the condition of f_c = 10 kHz, SNR = 29 dB and T = 0.3, 0.4, 0.5, 0.8 (ms). When T is short, the width of the pulse of the demodulated signal become short because of the great influence of the impulse response. The threshold of the judgment of polarity is set as Fig. 4. When T = 0.3 ms, the pulse width of demodulated signal is only about 40% of T. However, the influence of the impulse response is reduced and the ratio of the pulse width of the demodulated signal is increased as T gets longer. When T = 0.8 ms, the pulse width of demodulated signal is about 80% of T. It is thought that the waveform can be recovered without trouble if the pulse width of the demodulated signal is 50% or more of T by setting the appropriate threshold values in the polarity decision.

Figure 5 is the result of transmission experiment under the condition of f_c = 10 kHz, T = 0.3 ms and various SNR. When SNR worsen, the polarity decision becomes difficult because the amplitude of the demodulated signal becomes smaller than the primary value. Now, we consider about the threshold values. In order that the waveforms obtained by the delay-detection against the background noise are not misjudged to be significant data, the threshold should be set with some margin. However, the problem occurs that the demodulated signal may not exceed the threshold if it is set to be too high especially under the lower SNR environment as understood from Fig. 5.

4. Conclusions

DBPSK digital communication that used airborne sound is experimentally examined. The influence of the impulse response was estimated by the waveform of the impulse response of the system. The one-symbol time T required to reduce the influence was experimentally determined. In addition, the effects of background noise are also evaluated, and it is found that the noise mainly effects to the level of the demodulated signal.

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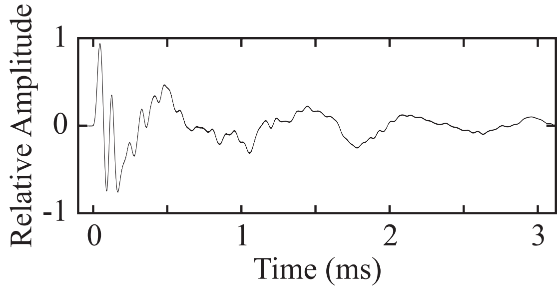

Fig. 3 The impulse response of the system.

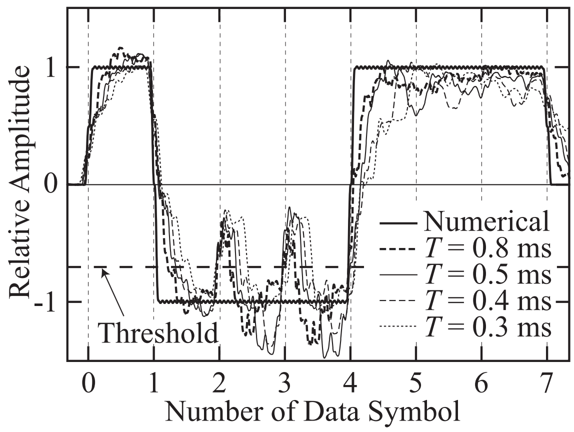

Fig. 4 Demodulated signals under the condition of f_c = 10 kHz, SNR = 29 dB and T = 0.3, 0.4, 0.5, 0.8 ms.

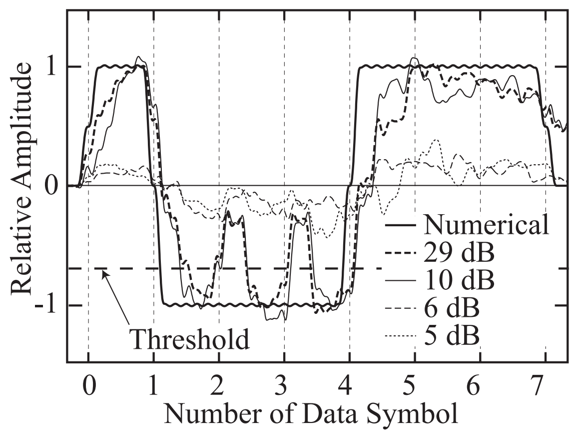

Fig. 5 Demodulated signals under the condition of f_c = 10 kHz, T = 0.3 ms and SNR = 29, 10, 6, 5 dB.