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DIFFERENTIAL BIPHASE SHIFT KEYING (DBPSK) USING AIRBORNE SOUND FOR DATA COMMUNICATION

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Abstract

We described a biphase shift keying (BPSK) using airborne sound for short-range data communication. Carrier recovery circuit which makes the reference phase becomes unnecessary, when differential PSK (DPSK) is used, and the circuitry is simplified. Acoustic wave propagates even in the opaque medium without receiving the electromagnetic interference. Acoustic transmission line can be simply composed only of a loudspeaker (SP) and a microphone (MIC). There is no necessity considering directional characteristics of the acoustic devices such as the SP and MIC, when the low frequency is used. As a result of data link experiment in 10 kHz carrier sound in the indoor space, the acoustic delay detection operated. The influence of the impulse response which originated from the inertia of the acoustic device like SP was also able to be reduced. Proposed acoustic data communication is effective for the communication to the remote manipulation robot, etc.

INTRODUCTION

Acoustic communications of underwater are often studied [1-4, 7-10]. A reason for the use of acoustic wave is that electromagnetic waves can not propagate to a long distance in underwater environment Since underwater acoustic waves can reach to longer distance than acoustic waves in air, the acoustic communication has a great advantage in underwater environment. The acoustic communication is almost only means of communications under the sea. For example, the communications to autonomous underwater vehicles or deep-sea submergence vehicles [4, 7]. In contrast, airborne sounds are not suitable for the long-range communications.

The use of airborne sounds has some advantages for such a short-range communication like beacons. Since the transceivers of the beacon station communicate with only adjacent vehicles, the locality of airborne sounds is rather an advantage than a drawback. For the communications to autonomously traveling robots in industrial plants, the use of electrical waves is not so suitable because the area of communication is hard to be limited. Acoustic or optical communications are of advantage for such a purpose. In optical communications, however, obstacles on light paths may shut the light and leads to blocking of communication. The use of airborne sound has advantages from the viewpoint of the localization and the tolerance for barriers. Since the airborne sound of about 10 kHz can be of arbitrary directional characteristics by using omnidirectional loudspeakers and horns. Because of these characteristics, the use of airborne sounds is one of most appropriate means for the purpose of beacons. Acoustic beacons like the ultrasonic beacon are widely used. However, the main purpose of the ultrasonic beacon is the localizations of vehicles and not so often used for data communications [5, 6].

In the present work, a digital communication with airborne sound is experimentally examined. The differential biphase shift keying (DBPSK) is employed for the modulation scheme. By use of DBPSK, carrier recovery circuits can be eliminated. In addition, the improvement of communication quality and the increase of data rate are expected due to the cancellation of the impulse response of the system.
In experiments, communications using a certain bit sequence are examined. By comparing experimental results with the results from numerical simulations, in which the effect of the system impulse response is not involved, the effect of system impulse response is observed. The capability of DBPSK using airborne sound for data communication is validated through the experiments.

SYSTEM FABRICATION

Computer-aided Evaluation System for Data Communication Using Airborne Sound

Figure 1 shows a schematic diagram for the DBPSK system using airborne sound. We realized the DBPSK evaluation system using a digital to analog converter (DAC) (PXI-6713 / National Instruments (NI)) and an analog to digital converter (ADC) (PXI-6133 / NI) controlled by a personal computer (PC) (PXI-8187 / NI based on PXI-1042Q / NI) without hardware electronic circuits. The PC has the Windows XP operation system, the LabVIEW 8 /NI application software, the Pemtium 4, 2.5 GHz-CPU and 1 GB-RAM. Acoustic transmission line composed only of the omnidirectional loudspeaker (SP) (9D4B / Clarion) and a condenser microphone (MIC) (CMS-64 / Bonsung Electronics) was installed in a 55 m^3-anechoic room. The transmission length L was 3.0 m.

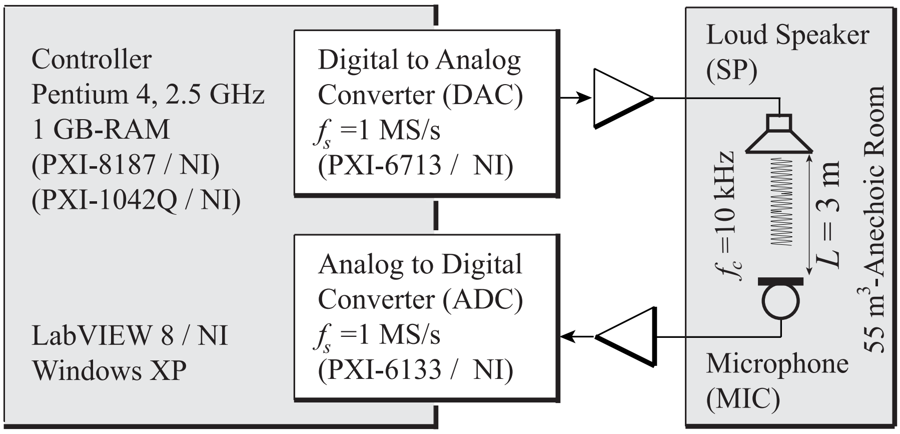

Figure 1 *– Block diagram of a performance evaluation for differential biphase shift keying (DBPSK) using an airborne sound for short range data communication. The system was simply realized by a digital to analog converter (DAC) and an analog to digital converter (ADC) controlled by a personal computer (PC). Acoustic transmission line composed by a loud speaker (SP), a microphone (MIC) and sound path was set in an anechoic room.*

DBPSK

Figure 2 shows the digital and analog implementations of the DBPSK transmitter and receiver in Figure 1. Upper diagram is reformulation of the DBPSK transmitter using the DAC. In this experiment, in order to transmit on the carrier of the burst signal, data stream is divided into several packet bits. Data-aided method requires knowledge of the data, which is provided either by a set of known symbols, in the form of a preamble (PA) at the beginning of the divided data stream (Data *n*) is effective for the symbol timing recovery. In this paper, we call the small packet of "PA+Data *n*" "frame." Each frame is input to the DBPSK modulator every repetition time. DBPSK output signal is radiated from the SP as the burst sound signal via an audio-frequency-amplifier (AF-Amp).

Lower diagram shown in Figure 2 is reformulation of the DBPSK receiver using the PC and ADC. Signal detected by the MIC is applied to the DBPSK demodulator via the AF-Amp. In the DBPSK demodulator, the delay circuit provides a one-symbol delay of the DBPSK signal. The delayed signal and the DBPSK signal are mixed together. The timing recovery is realized by the correlation between the output signal of the DBPSK demodulator and the PA. Waveforms at the points of (a) - (h) will be shown in Figures 3 and 4. Finally, detected packet data are reconstructed into the original data stream.

SIMULATION

DBPSK Transmitter

Calculated timing chart of the DBPSK transmitter and receiver is shown in **Figure 3**.

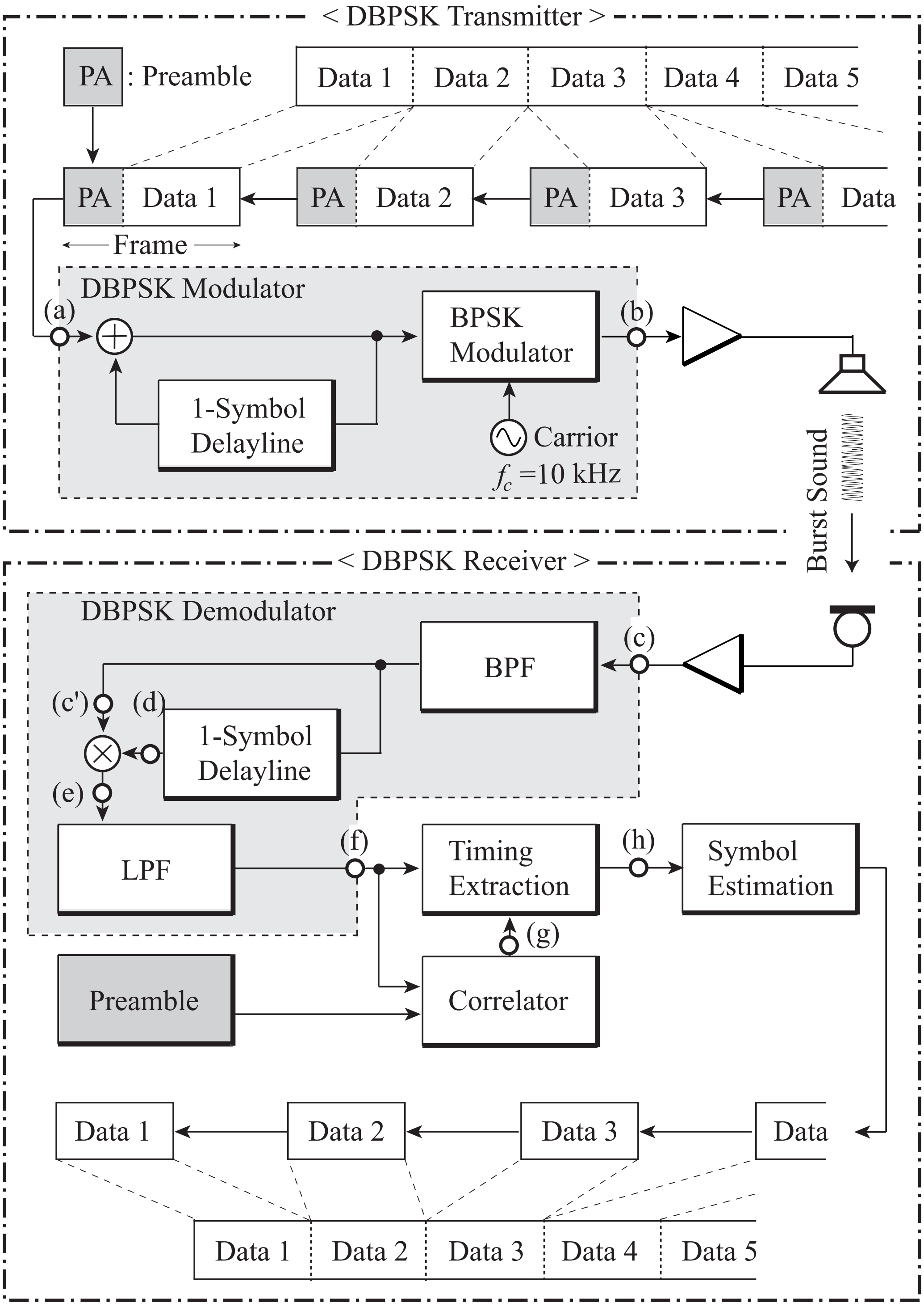

Figure 2 *– Digital and analog implementations of the DBPSK transmitter and receiver using airborne sound for short-range data communication in Figure 1. Upper and lower diagrams are reformulations of the DBPSK transmitter and receiver using the DAC and ADC, respectively. Waveforms at the points of (a) - (h) will be shown in Figures 3 and 4.*

Trace number is corresponds to the terminal number shown in Figure 2. Carrier frequency, one-symbol time and propagation length are f_c = 10 kHz, T = 0.4 ms and L = 3 m, respectively.

First **trace (a)** in Figure 3 is typical 5 bits-data frame (1, 0, 1, 1, 0) composed of 3 bits-preamble (1, 0, 1) and 2 bits-message data (1, 0). The second data frame (1, 0, 1, 0, 1) composed of (1, 0, 1) and (0, 1) is created after the time of repetition. The logical “0” and “1” are determined by comparing the symbols of two successive data bits. In BPSK, 0 and π (rad) represent a 0 and 1, respectively. The second **trace (b)** are two transmitted DBPSK burst signals of (0, π, π, 0, π, π) and (0, π, π, 0, 0, π) generated in conformity to the binary data shown in trace (a). In this paper, a sine-wave of four-wave number is distributed per one-binary data. Therefore, one-burst DBPSK signal has 24-wave numbers.

DBPSK Receiver

Trace (c) is the received DBPSK signal with time delay in the acoustic transmission line of L = 3 m. Therefore, a time of flight (*TOF*) is occurred. The *TOF* is about 8.8 ms. **Trace (d)** is the received DBPSK signal with one-symbol time delay in order to differential detection. **Trace (e)** is the multiplication of traces (c) and (d). **Trace (f)** is the binary data of the DBPSK demodulator output signal.

The receiver requires estimates of the clock timing of the original signal in order to recover the information. The preamble given at the modulator contributes to carrier and clock recovery. **Trace (g)** is the cross correlation result between trace (f) and preamble (1, 0, 1). The time in which the maximum value occurs gives the accurate time of the frame head. It follows that the clock is recovered. Finally, the preamble and data message are demodulated in the **trace (h)**.

EXPERIMENTS

Figure 4 shows the experimental timing chart of the DBPSK transmitter and receiver. **Traces (a) and (b)** in Figure 4 is same as the trace (a) and (b) in Figure 3. The conditions of the experiment are same to the calculation. Otherwise, the sampling frequency was f_s = 1 MS/s

Trace (c) is the received DBPSK burst signal of (0, π, π, 0, π, π). Influence of the impulse response which originates from the inertia of the SP and MIC was found in the waveform shown in trace (c). It is not possible problem to avoid this waveform distortion in the acoustic communication system. **Trace (c’)** is band pass filtered signal of trace (c). **Trace (d)** is the trace (c’) with one-symbol time delay. **Trace (e)** is the multiplication of traces (c’) and (d) which have same component of the waveform distortion. Although there was the waveform distortion, it was possible to carry out the delay detection. **Trace (f)** is the DBPSK demodulator output signal. **Trace (g)** is the cross correlation result between trace (f) and preamble for the timing extraction. **Trace (h)** is the demodulated original 5-bits data frame. The demodulated message had about 9.3 ms-time delay which was correspondent to sum of T = 0.4 ms and *TOF* = 8.9 ms.

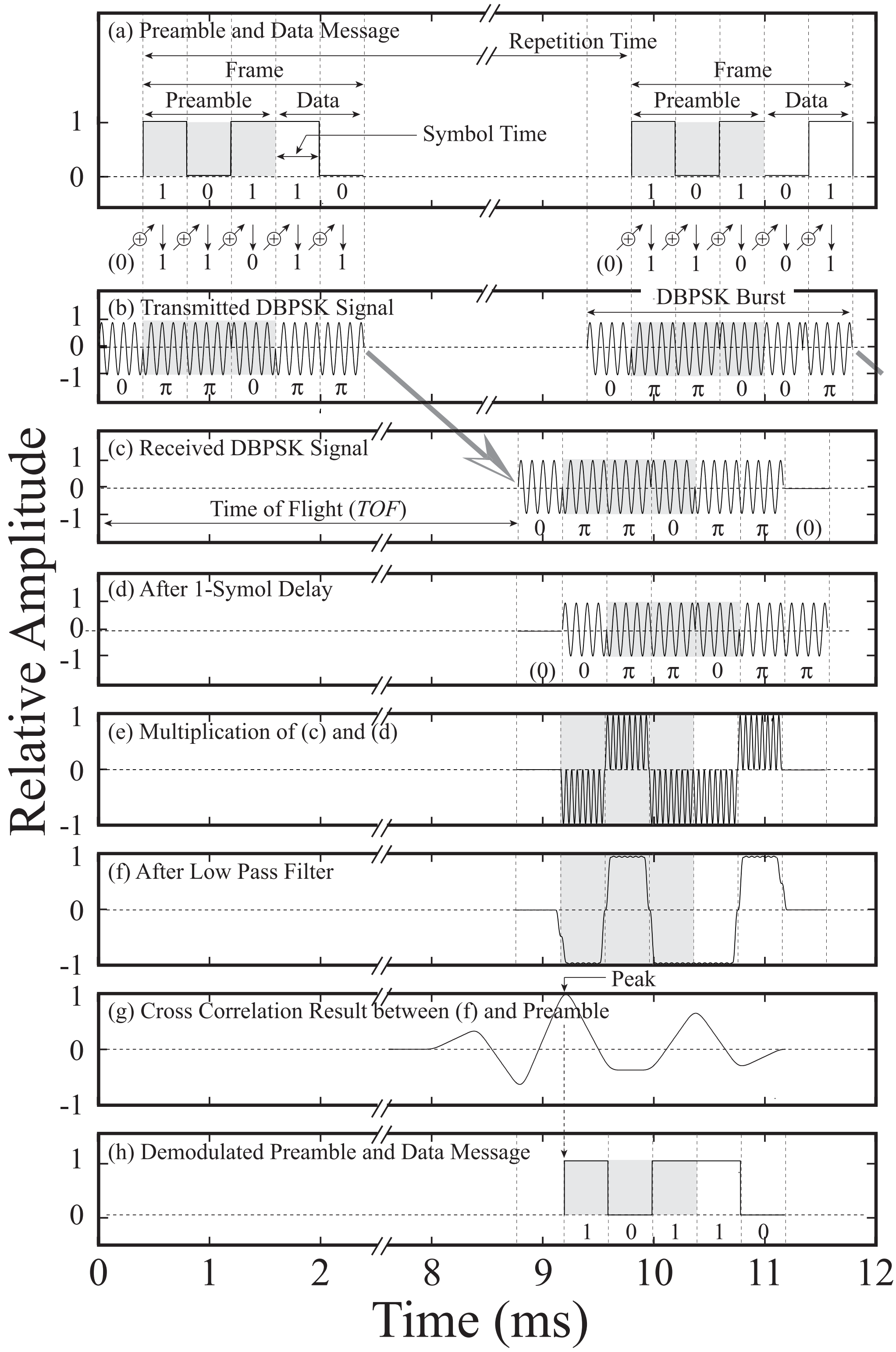

Figure 3 *– Calculated timing chart for the DBPSK transmitter and receiver. Trace number is corresponding to the terminal number shown in Figure 2.*

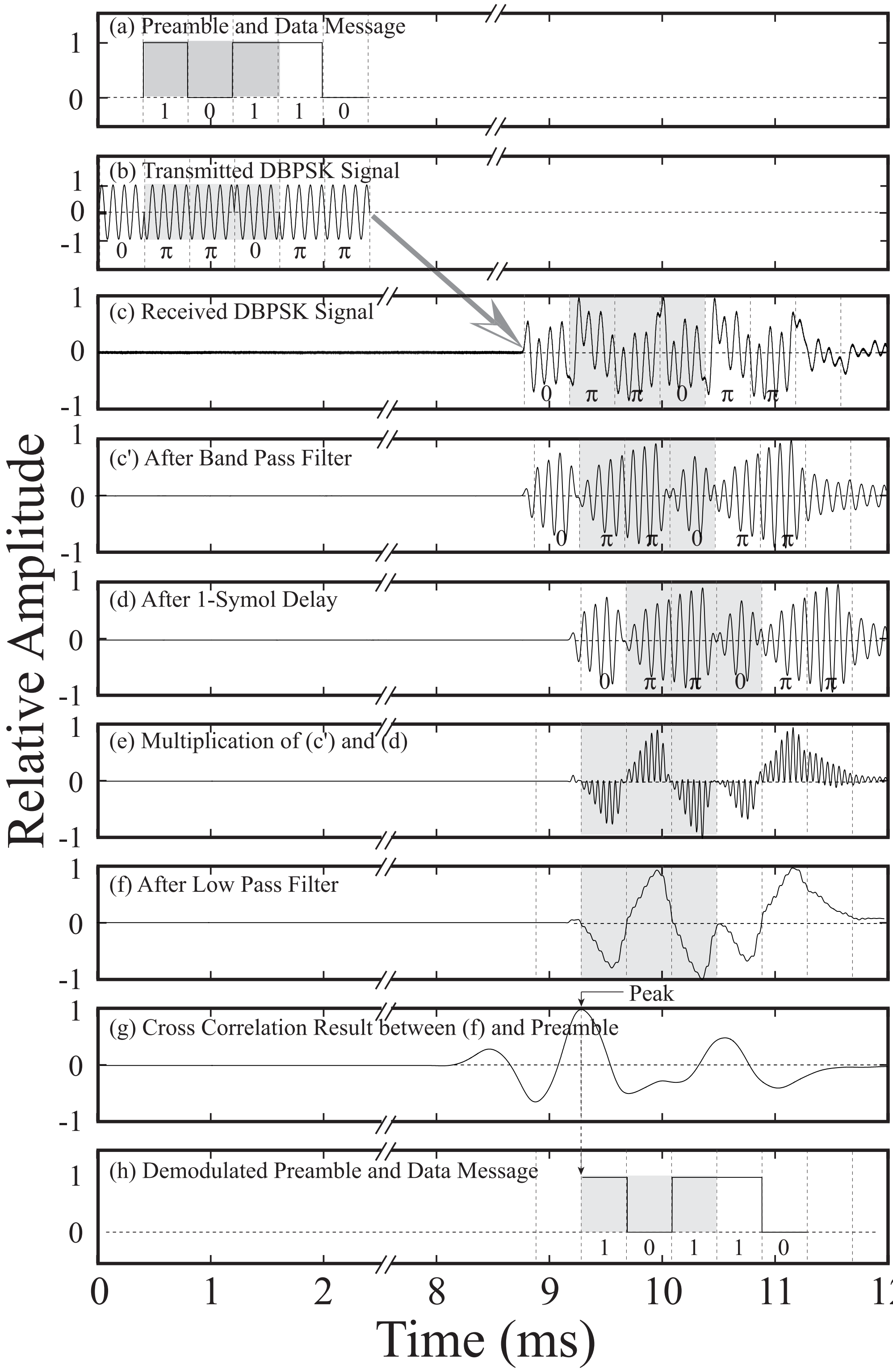

Figure 4 *– Experimental timing chart for the DBPSK transmitter and receiver. Trace number is corresponding to the terminal number shown in Figure 2.*

CONCLUSIONS

The digital communication using airborne sound was experimentally examined. The differential biphase shift keying (DBPSK) was adopted in order to improve the quality and the speed of data communication by canceling the system impulse response. A computer aided evaluation system for data communication was fabricated using a personal computer, analog to digital and digital to analog converters, a loudspeaker and a microphone. The instant data transmission rate was 2.5 kbps at a carrier frequency of 10 kHz. Since a low frequency is used, data communication is realized without precise positioning of a loudspeaker and microphone. Therefore, the use of airborne sound has the advantage that it can be used in such applications as short-range communication, limited-region communication, small-scale mobile communication and multiple access communication. In the experiment, though the received signal was quite distorted due to the system impulse response, the original data stream was nicely reconstructed from the received signal by using DBPSK.

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