Session 3

Biomedical Technology

Attempt for optical BAN on human body

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Abstract

Fundamental study was conducted to apply the optical biotelemetry technique to the body area network (BAN). With this technique, we can expect many advantages over the conventional BAN with electric signal transmission. The bandwidth was evaluated to be 2.80 GHz. The optical signal reached the longer distance in the narrower channel due to the light-guide effect in diffuser. For a prototype of a practical system, an array of LEDs was attached to the wrist area and transmitted light was detected with an avalanche photodiode. The signal transmission (100 kHz, ASK) from the wrist to the fingertips was attained in an adult hand. In the experiment, the following facts were newly found. When the transmission range in the hand exceeds 70 mm, the intensity of radiation from the hand surface became larger than that of the internal propagation through the hand tissue. The transmission range became larger with the lower duty ratio of the optical ASK signal. These results provide useful information for the realization of the optical BAN as an application of optical biotelemetry.

Keywords: *optical biotelemetry, body area network, BAN, optical BAN, data transmission, scattering, diffusion, optical communication.*

1. Introduction

In contrast to conventional communication through space, the importance of human body communi-cation, or the information transmission through the human body, has recently been recognized. A body area network (BAN) is a typical example [1-3]. Currently, most BANs use electric field or electric current. It makes trans-mission capacity limited and radiation shielding difficult. To solve these problems, we have been exploring the new possibility to use light for the data transmission medium, or an optical BAN. With the light, we can expect large transmission capacity and high security against the unexpected radiation.

We have reported some of the results of the feasibility study for the optical BAN [4-6]. The bandwidth was evaluated to be 2.80 GHz. The optical signal reached the longer distance in the narrower channel due to the light-guide effect in diffuser. Using the light, we can expect to increase the amount of information transmission. In addition, we can control the radiation shielding much easier than the BAN with electric field.

In this paper, we report the result of the recent study for the realization of this technique. We investigated the light propagation through a tissue-equivalent phantom. Also, we manufactured a prototype equipment and tested optical signal transmission through an actual human hand.

2. Analysis of optical pulse shape

To investigate the effect of optical pulse shape on data transmission, the characteristics of signal reception were analyzed in different conditions. Fig. 1 illustrates the experimental condition, and Fig. 2 shows the result. The detail of the experiment can be found elsewhere [6].

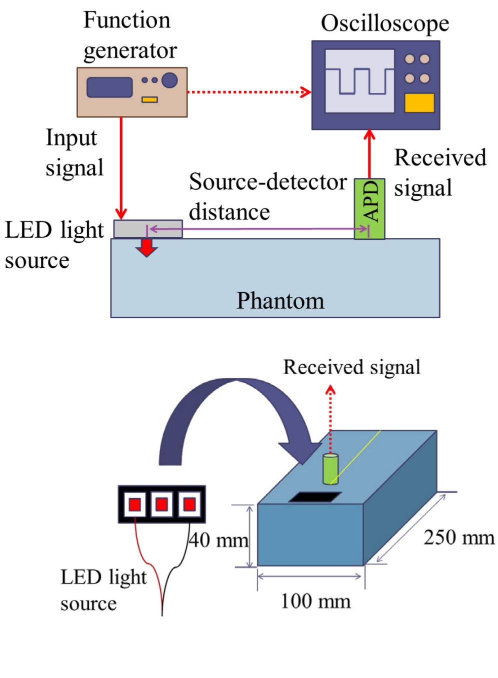

Fig. 1: Experimental setup for pulse shape analysis.

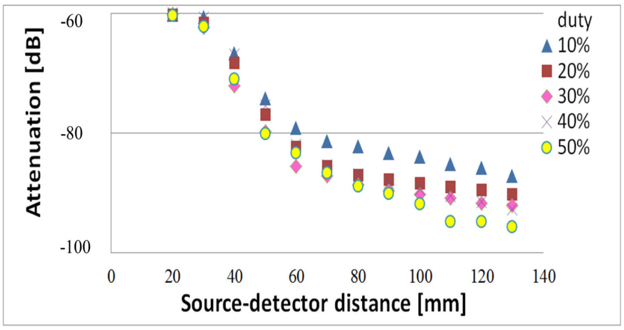

Fig. 2: Dependence of attenuation on duty ratio of optical pulse shape.

The signal was attenuated rapidly as the source-detector distance increased. The attenuation became less with the optical pulse with lower duty ratio. The reason of this result is explained as follows. When we make the duty ratio low while keeping the signal energy constant, the peak amplitude of the optical pulse becomes large. Then, the signal-to-noise ratio (SNR) becomes large against the temporary-constant noise. This result suggests that we can attain the data transmission with the higher SNR by making the duty ratio of the optical pulse as low as possible.

3. Inside propagation and surface radiation

In the optical BAN, the signal is transmitted in two different transmission channels. They are the light propagation through the body tissue, and the optical radiation from the body surface. For security of data communication, the former is preferable. For data transmission over long distance, the latter is useful.

To investigate these transmission channels, an experimental system was constructed to simulate the transmission part of the optical BAN in a practical setting. Fig. 3 shows the outline of the experimental system. Near-infrared light (850 nm wavelength) from an array of LEDs was illuminated at the wrist of an adult hand. The light was received with an avalanche photodiode (APD) while varying the source-detector distance. The light of internal propagation was measured with the APD in close contact by pressing it firmly against the hand tissue. The optical radiation was measured with the same APD at 5 mm above the hand surface. Fig. 4 shows the result of the measurement. The dominance of the transmission channel interchanged around 70 mm distance from the light source in this system. This result suggests that we should take this difference into account, and use the two channels properly according to the application requirements.

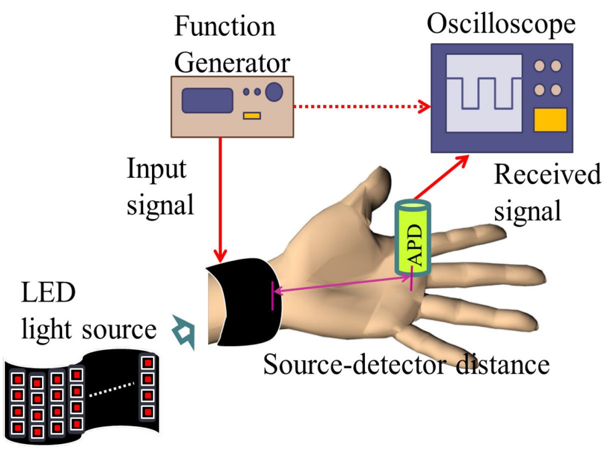

Fig. 3: Optical data transmission with human hand.

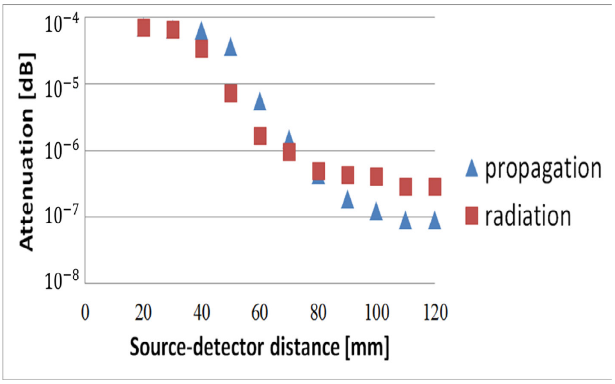

Fig. 4: Comparison between internal propagation and surface radiation.

4. Optical BAN in human hand

As a practical application of the optical BAN, we designed a wrist-watch type device to send an optical signal to fingertips. Fig. 5 shows the light detection points and the received signals. The amplitude shift keying (ASK) signal of light pulse with 100 kHz frequency and 10% duty ratio was transmitted from the wrist toward the fingertips (Fig. 5(a)). Figs. 5(b)-(d) show the received pulse shape after the low-pass filtering with the filter (IIR, 1 GHz sampling, 1 MHz cut-off frequency). This result shows that the signal transmission from the wrist to fingertips is possible with a sufficient SNR using relatively simple hardware and signal processing.

5. Conclusions

To realize the optical BAN using near-infrared light, fundamental characteristics of the optical data transmission through a human body were analyzed in experiments. Through this study, the following facts were found. The higher SNR can be attained with the lower duty ratio of the optical pulse shape in ASK signal transmission. The dominance of the data transmission is interchanged from the internal light propagation to the body-surface radiation around several centimetres from the light source. With an experimental device, the feasibility of the optical BAN from the adult wrist to fingertips was verified.

These results provide useful information to develop a practical system of the optical BAN as an application of optical biotelemetry.

This study was conducted with the approval of the Ethics Committee of Graduate School of Engineering, Hokkaido University and with the informed consent of participating subjects.

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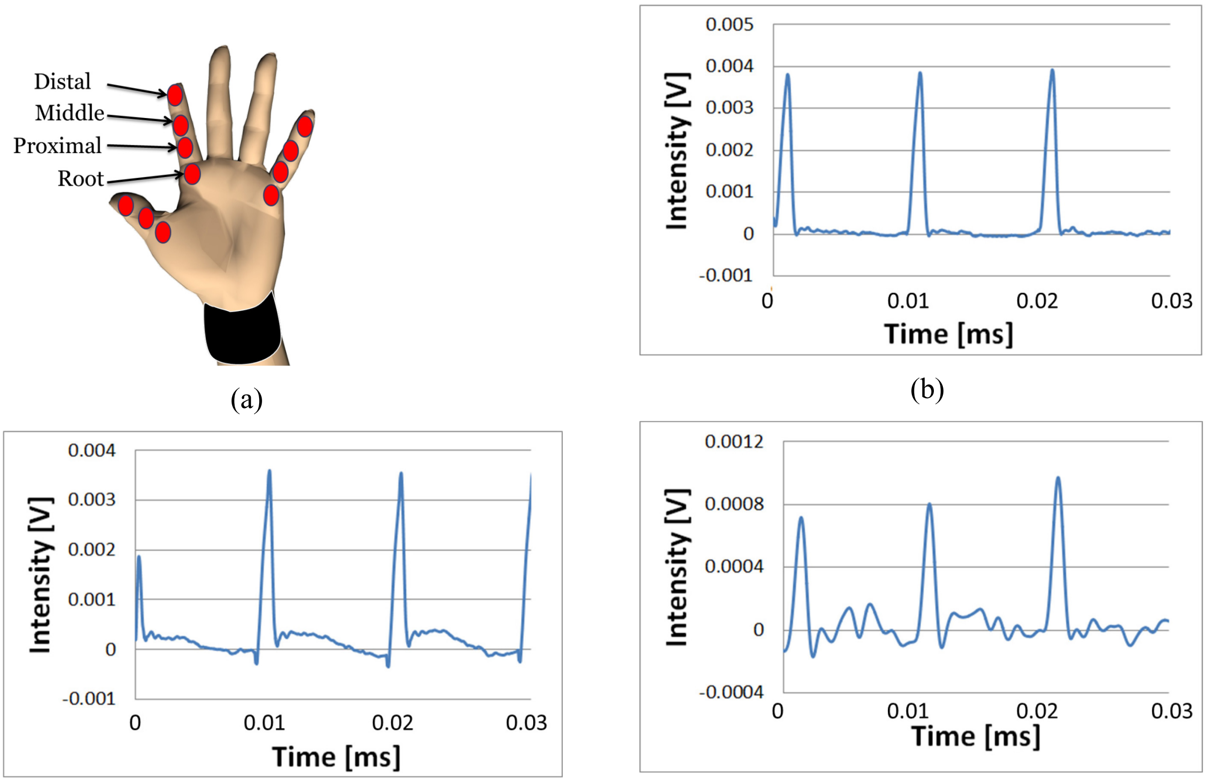

(a) (b) (c) (d)

Fig. 5: Transmitted signal from wrist to fingertips: (a) points of data reception, (b) signal shape at finger root, (c) at proximal point, (d) at distal point.