Development of Impulse Radio HBC Transceiver for Vital Signal Monitoring of Drivers

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ABSTRACT

Human body communication (HBC) technology provides a promising physical layer for wireless body area networks in healthcare, medical and entertainment applications. In this study, we developed an impulse radio (IR) type HBC transceiver for monitoring vital signals of drivers in a car. The basic structure of the transceiver was described and its communication performance were evaluated experimentally. The results show a sufficient feasibility to realize a HBC transmission at a data rate as high as 1.2 Mbps from the human chest to a fingertip.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design-Wireless Communication

General Terms

Experimentation

Keywords

Human body communication, impulse radio transceiver, bit error rate, vital signal

1. INTRODUCTION

Human body communication (HBC) uses human body itself as a communication route to transmit data [1]. It usually operates at frequencies from dozens of kHz to dozens of MHz, because at these frequencies the propagation loss along the human body is smaller than that through the air. HBC provides a new possibility for on-body communication. Its low propagation loss may yield a superior communication performance compared to other frequency bands, and low radiation toward outside of the human body also brings to a high security. Due to these superior features IEEE 802.15.6 standard has defined it as one of physical layers for wireless body area networks in healthcare, medical and entertainment applications [2].

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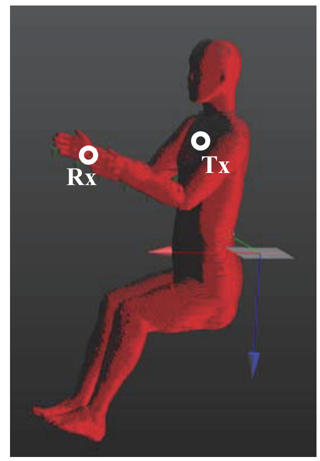

Figure 1: A scenario of signal transmission from the chest to a fingertip by HBC technology.

A promising application is to monitor driver's health condition as a means of automatic drive of cars [3]. In this scenario, some vital sensors are placed on the driver's body to collect healthcare data such as electrocardiogram (ECG), blood pressure and pulse rate. The vital sensors may be embedded in the driver's seat, seat belt, or steering wheel to make the driver unconsciously wear these sensors. This is attributed to the fact that these parts of the car are always contacting the driver's body when driving. Such a system makes it easy to collect the driver's healthcare data and send them to a control unit with the HBC technique. The control unit can then analyze the driver's health condition and generate warning signs or make automatic control of car, if necessary, for safety driving.

However, HBC realization usually employs narrow-band modulation schemes such as frequency shift keying (FSK) or on-off keying (OOK) which yield a low data rate [4][5]. The authors previously proposed an impulse radio (IR) type transceiver structure for HBC realization [6]. Instead of a sinusoid signal, digital data are modulated with wide-band pulse signals. The pulse signals range between 10 and 60 MHz with a central frequency of 30 MHz, which yields a fractional bandwidth as high as 1.4. Such a wide-band transmission can

Table 1: Path loss between the chest and fingertip at 30 MHz

Receiver position	Left hand	Right hand
Path loss	72 dB	78 dB

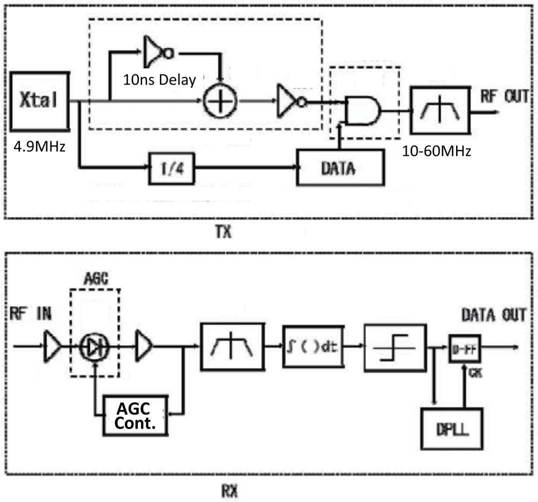

Figure 2: Block diagram of the prototype HBC transceiver.

provide some advantages such as high data rate and anti-interference feature. Its low power density also contributes to less electromagnetic energy absorption in human body. Although the IR technique itself is not new, its application to HBC should be a new attempt.

In this paper, we describe the detailed structure and performance of our developed IR transceiver for transmitting an ECG signal from the chest to a fingertip by the HBC technology. Section 2 describes a fundamental investigation on the path loss at the HBC band by numerical simulation in order to determine the required specification of the IR transceiver. Section 3 describes the structure and realization of the IR transceiver, and Section 4 gives its basic communication performance such as bit error rate. Section 5 concludes this study.

2. PATH LOSS

To clarify the path loss characteristic for on-body signal transmission, a numerical simulation was first conducted as shown in Fig. 1. The numerical simulation employed the finite difference time domain (FDTD) method together with a human body model, which was a homogeneous one with dielectric properties equivalent to muscle [7]. The simulated scenario assumed a HBC band signal transmission from the left chest to a fingertip. A transmitter electrode was arranged on the chest surface, and the receiver electrode was fixed at the fingertip. The path loss was then obtained from the ratio of the received voltage at the receiver electrode to the excitation voltage at the transmitter electrode by the FDTD simulation.

Table 1 shows the calculated path loss from the left chest to a fingertip of left hand or right hand at 30 MHz. It was found that the path loss is around 70 - 80 dB. It means that the IR transceiver must meet this path loss requirement for assuring a reliable communication for the ECG signal transmission.

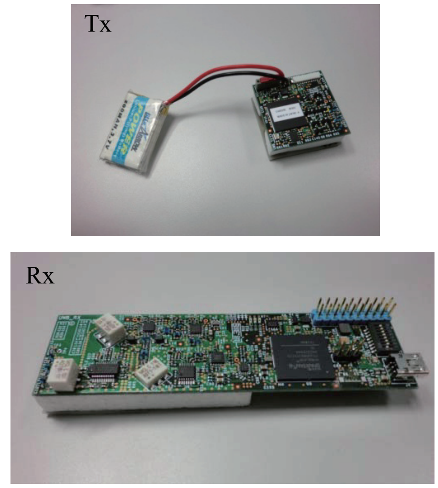

Figure 3: Circuit realization of the prototype transceiver.

3. TRANSCEIVER STRUCTURE

Fig. 2 shows the block diagram of the prototype HBC transceiver. The transmitter employed the IR scheme in which the information data were modulated by pulses. First, the information with a date rate of 1.2 Mbps was modulated with eight pulses for bit "1" and nothing for bit "0", which is actually an OOK scheme. The pulses were produced by a 4.9-MHz oscillator and a XOR gate, as a result the pulses had a width of 10 ns. The OOK modulated pulses were then spectrum-formed by a band-pass filter to have their main spectrum components within 10 and 60 MHz. Fig. 3 shows the circuit realization of the prototype transceiver. It was packaged on a 3 cm x 3 cm printed circuit board (PCB). The signal electrode was mounted on the top of the PCB, and the PCB's ground plane acted as the ground electrode. Fig. 4 shows a detailed time chart of the IR modulation, but one bit were expressed by two pulses for making it legible. The receiver employed the envelope detection scheme. The received signal was filtered and amplified, and is then adjusted to an adequate level by an automatic gain controller (AGC). The envelope detection was realized by a diode and a low-pass filter. The detected signal is then judged as "1" or "0" by a comparator after the envelope detector. Fig. 5 shows the time chart of the demodulation. The receiver was packaged in a two-layer PCB with discrete components. The basic specifications of the IR transceiver are summarized in Table 2.

4. TRANSCEIVER PERFORMANCE

Fig. 6 shows the spectrum of the modulated signal. As can be seen, the maximum signal level was around -4.1 dBm at 30 MHz and most of the signal powers were within 10 and 60 MHz. Such a signal level actually meets the law for weak

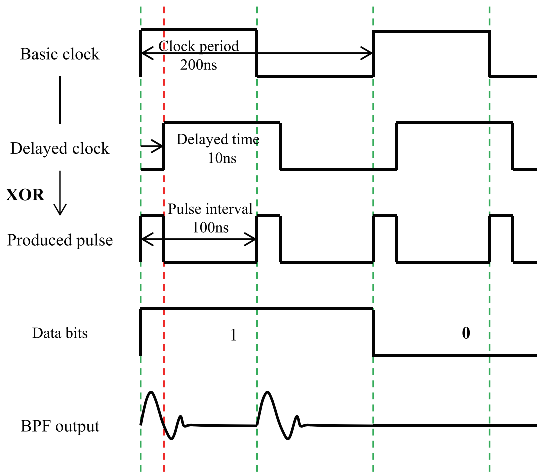

Figure 4: Time chart of modulation.

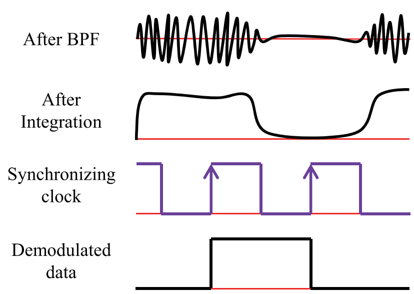

Figure 5: Time chart of demodulation.

Table 2: IR transceiver specifications

Frequency band	10 - 60 MHz
Modulation	OOK
Data Rate	1.2 Mbps
Maximum output	-4.1dBm
Demodulation	Energy detection

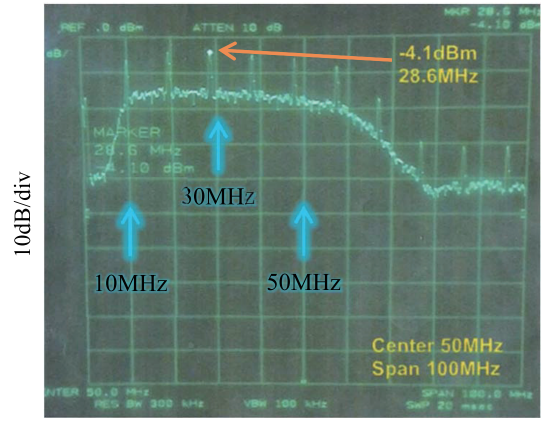

Figure 6: Spectrum of modulated signal.

Table 3: Measured BER

Subject	BER
1	$0.7x10^{-3}$
2	$0.5x10^{-3}$
3	$2.4x10^{-3}$
Average	$1.2x10^{-3}$

radio stations in Japan.

To evaluate the communication performance of the transceiver, the bit error rate (BER) was first measured as a function of attenuation or path loss. We connected the transmitter and the receiver with a programmable attenuator by coaxial cables. Fig. 7 shows the measured BER as a function of attenuation. As can be seen, when the AGC works, the BER can be in the order of 10^{-4} up to 75 dB attenuation. Moreover, if we carefully adjust the amplifications in the two-stage amplifiers to have an optimal gain, the BER can be obtained in the order of 10^{-4} between 72 and 82 dB attenuation, which corresponds with the path loss between the chest and the fingertip.

Fig. 8 shows an example of ECG signal to be transmitted. The ECG signal was AD-converted to a 10-bit digital signal at a sampling frequency of 500 Hz, and was then transmitted by the IR transceiver. Fig. 9 shows the measurement view. The transmitter electrode consisting of two metal pieces was directly contacted to the left chest, and the receiver was connected to a personal computer via a USB cable for recording the received data and counting the BER. The same measurements were conducted for three persons, and the obtained BERs were tabulated in Table 3. It can be seen that the average BER is $1.2x10^{-3}$. Such a BER level is acceptable in the physical layer design, because it can provide an error-free communication after applying an error correction technology. So the IR transceiver exhibits a sufficient feasibility to realize a HBC transmission at a data rate as high as 1.2 Mbps for monitoring and transmitting the vital data of drivers in a car.

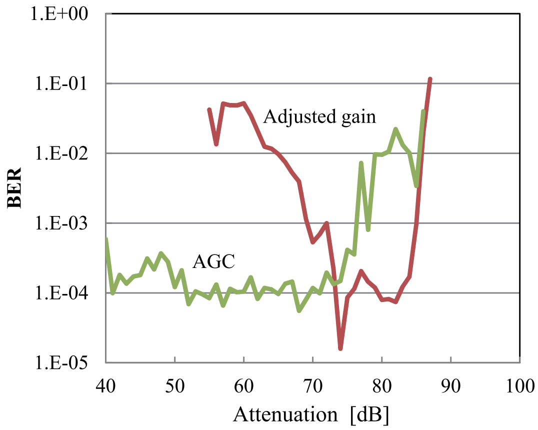

Figure 7: Measured BER as a function of attenuation.

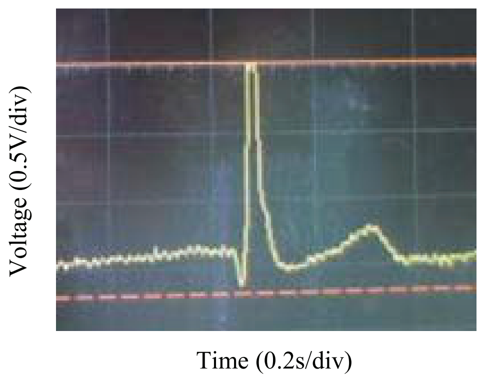

Figure 8: Example of ECG signal.

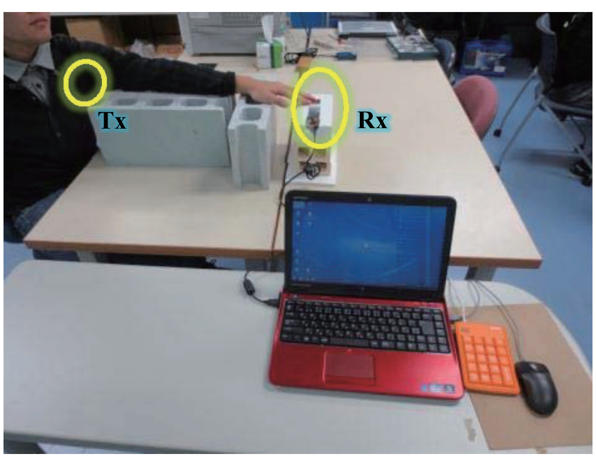

Figure 9: Measurement view of BER for the transmission from the chest to fingertip.

5. CONCLUSIONS

In view of the low path loss on the human body and low radiation toward outside of the human body, the HBC has attracted much attention for wireless body area networks in healthcare, medical and entertainment applications. In this study, we have developed a IR type HBC transceiver for monitoring the driver's health conditions in a car. Its communication performance has been evaluated experimentally and found to have a sufficient feasibility for an on-body transmission from the chest to a fingertip at a data rate as high as 1.2 Mbps. The future subject is to develop an effective algorithm for the vital data collecting and transmission at the same time.

6. ACKNOWLEDGMENTS

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