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Improvement of the Communication Accuracy on Hybrid Communication System using Ultrasonic Waves and Electric Field
超音波と電界を用いたハイブリッド通信における通信精度の改善

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1. Introduction

In these days, electrical mobile gadgets have been sophisticated. They have been evolved to the small computer with wireless communication. The size of them will be expected to miniaturize in wearable size like a wrist watch or a ring. We have defined the equipment as wearable device (WD). Then we have proposed communication system for WD. The system is using the human body as the transmission path, and modulated electric field (EF) and ultrasonic waves (UW) are transmitted hybridly through the body[1)]. To adopt the two kinds of energy feature, this system can realize high usability and secure communication.

In previous studies, we confirmed the possibility of the hyblid communication system using prototypes. In this time, we have worked on the modification of UW communication in this system. One is applying the phase shift keying (PSK) modulation, in order to improve the error rate. Another is expanding the communication area using several acoustic matching materials which are easy to obtain. As a result of several experiments, the communication accuracy has been improved.

2. System Configuration

Figure 1 shows the system configuration of hybrid communication. This system communicates interactive information using a single path with half-duplex communication through the human body. The path is consisting of a pair of piezoelectric ceramic oscillators. One oscillator is mounted in the WD, and the other is in the other WD or the stationary terminal type data reader-writer (R/W). The piezo oscillator can output the EF and the UW, respectively or simultaneously, depending on the input signal waveform. The UW communication is implemented in alignment path using sinusoidal signal with the resonance frequency. The EF communication is using non-resonance signal and transmission path is arbitrary points in a human or among humans. The hybrid communication is utilized the combined signal. It is performed that the user touches the R/W or shake hands with other person, since the EF and the UW can run through the human body.

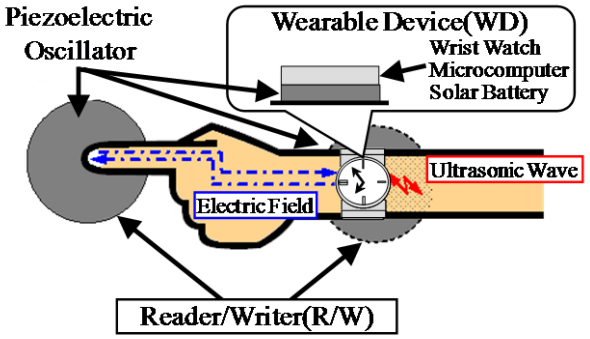

Fig.1 System Configuration of Hybrid Communication.

This system can prevent information leakage from the WD because both energies, particularly in UW, can't propagate in the air, and this system must need the conscious action of "touch". Additionally, EF can communicate between several persons with the speed of about 200 kbps. These characteristics realize high usability and secure system.

3. UW Communication with PSK

In the previous system, the amplitude shift keying (ASK) modulation was adopted because of easy to utilize. However, the ASK is disadvantaged at the noise tolerability and the sound reverberation effect. The error rate was 10-15%, it's impractical. Considering the deficits, we have introduced the phase shift keying (PSK) modulation. The PSK is communicated with sequential waveforms. Therefore, the sound reverberation does not tend to occur and the transmitted signals are strengthened against the noise. In this time, the binary phase shift keying (BPSK) is applied.

In the prototype, the piezoelectric oscillators are [Pb (Zr, Ti) O_3: PZT] with a resonance frequency of 1 MHz, a diameter of 20 mm, and a thickness of 2 mm. The experimental system is controlled totally by the software "LabVIEW" (National Instruments). This software is easy to control to the experimental equipment through the general port on PC. In this time, the demodulation is based on the synchronous detection. The received signal is multiplied the carrier and through low pass filter (LPF) and the comparator. Finally, the signal turn into digital wave shape and it is indicated the monitor.

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Using the experimental system, the PSK communication is implemented. Transmission path is between the ball and tub of a forefinger, that length is about 1 cm. Transmitting Several 8 bit numerical data, the communication is succeeded and the digital waveform can be demodulated. **Figure 2** shows the example of the transmitted waveform (numerical data $(170)10=(10101010)_2$) and **Fig. 3** shows received and demodulating waveforms. Additionally, the hybrid communication using the EF signal mixed to the UW is carried out and also succeeded. However, the present experimental system has some tasks. The system can show the result only digital waveform, not the data. This point should be improved. After the improvement, the comparison of the error rate between the ASK and the PSK, and the quantitative evaluation will be implemented.

4. UW Communication Area Extension

In order to improve the accuracy and the usability of the UW communication, extending the communication area is much needed. The method of the area extension is shown in **Fig. 4**. In this time, the piezo oscillator is allocated at an angle against the human body. The oscillators must be set parallel because they have sharp directivity. Having an angle, there is a space between the oscillators and the body. The space is required to fill with the acoustic matching material. At first, we worked to select the matching material. Through the experiment, the piezo oscillators are using same PZTs that utilized the former PSK experiment.

The materials should be easy to obtain and manufacture. We select the materials as follows: (a) sono jelly for the medical ultrasonic equipment, (b) natural rubber, which has the acoustic impedance of a human body, (c) hot bond, which is ethylene system plastic and (d) silicon bond, which is organogel system plastic. The experiment of material verification is as follows. First, the material, the thickness is 5 mm, is sandwiched by the PZTs and the output characteristics is measured. Second, similar measurement with a forefinger is carried out. In this experiment, input signal is sinusoidal wave, 1MHz of frequency and 10 Vp-p of voltage.

Table 1 shows the measurement results. As a result, the sono jelly is obtained small output less than other material. In the experiment of using a finger, the silicon bond is obtained maximum output. Additionally, silicon bond has a feature of the tough tissue, the EF shutoff and cheap price. It can be utilized instead of the EF absorption sheet. Consequently, the silicon bond is applied as a matching material for this system.

Using silicon bond as the matching material, the

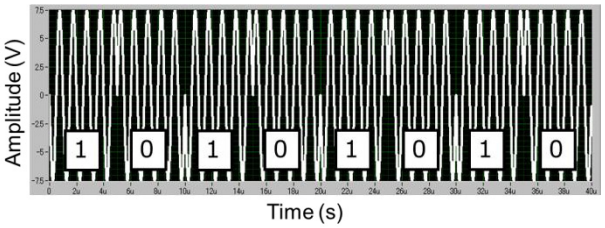
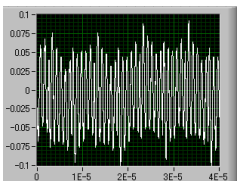
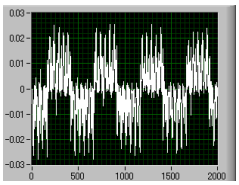


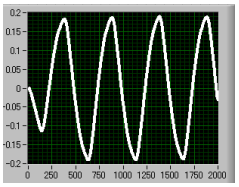
Fig. 2 Transmitted Waveform on the Experiment.



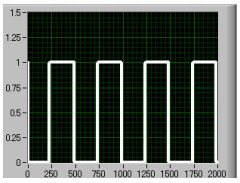
(a) Received Signal



(b) Multiplied Signal



(c) After LPF



(d) Digital Waveform

Fig. 3 Received Waveform on the Experiment.

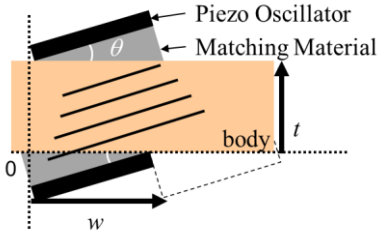


Fig. 4 Area Extension on UW communication.

Table 1 Output Characteristics about Matching Materials

Material		(a)	(b)	(c)	(d)
Output	only material	0.22	3.28	0.92	4.52
(Vp-p)	with a finger		0.44	0.24	0.60

communication can perform until 20 degree and the area is expanded 3 times larger. As a result, this method can be verified.

5. Conclusion

In this paper, we modify the hybrid communication system, particularly ultrasonic waves. In order to improve the accuracy, the modulation method is changed to PSK. In addition, the matching material is selected and the area is expanded by tilting the piezo oscillator.

Next step, we are planning to compare the ASK and PSK with quantitative evaluation.

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References

1. S. Suzuki, et al. : USE2010 (2010) 1Pb-28