

## Comparison of the Transmission Accuracy by the Modulation Method on the Ultrasonic Waves Communication through a Human Body

生体を伝送路とした超音波通信の通信方式における通信精度の比較

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### 1. Introduction

Recently, mobile electronic gadgets have been evolving at a rapid speed. They are expected to more sophisticated and minimized like a wrist watch. In our team, those mobile communication gadgets have been defined as a wearable device (WD).

Almost all mobile devices are using electromagnetic waves to transmit information. However, the communication using electromagnetic waves have several issues, such as information leakage and usage limitation, such as in air planes. Therefore, we have proposed novel communication method using human body as the transmission line, partially alternative way for inappropriate situation using electromagnetic waves. In this communication, electric field (EF) and ultrasonic waves (UW) are applied hybridly<sup>1)</sup>. To adopt the two kinds of energy feature, this system can realize high usability and secure communication.

In this time, we aimed to reduce the error rate on the UW communication. The method is exchange the modulation way from amplitude shift keying (ASK) to phase shift keying (PSK). As a result of experimental comparison, the error rate is improved to apply the PSK quantitatively.

### 2. System Configuration

**Fig. 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

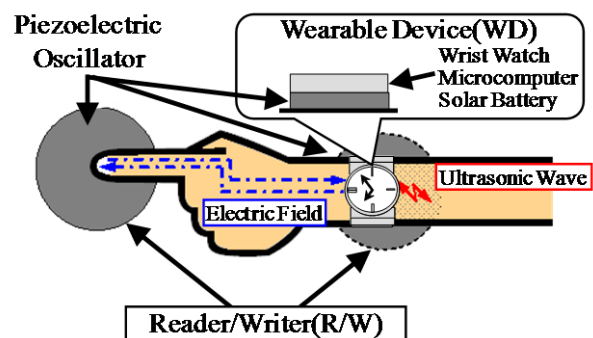


Fig. 1 System Configuration of Hybrid Communication.

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.

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. Applying PSK Modulation

In the previous system, the amplitude shift keying (ASK, **Fig. 2** (a)) modulation was adopted because of easy to utilize. However, the ASK is disadvantaged at the noise tolerability and the sound reverberation effect caused the discontinuity waves. The error rate was 10-15%<sup>2)</sup>, it's impractical. Considering the defects, we have introduced the phase shift keying (PSK, **Fig. 2** (b)) 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.

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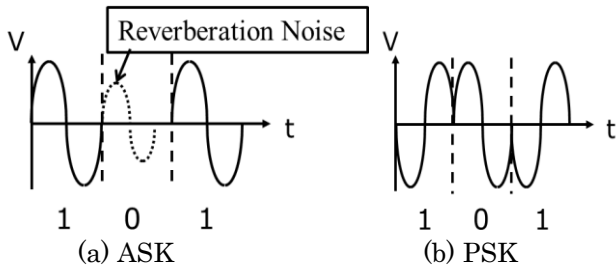


Fig. 2 Comparison of Modulation Type.

In the prototype, the piezoelectric oscillators are Pb (Zr, Ti) O<sub>3</sub> (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), because the circuit of the PSK is relative complication. This software is easy to control to the experimental system through the general port on PC, but real-time processing cannot be implemented.

In this time, the transmission data is 8 bit and the carrier wave is 1 MHz sinusoidal wave which is the resonance frequency of the PZT. For the accurate demodulation against the effect of reverberation noise, the 1bit is consisted of 5 wavelengths. The demodulation is based on the synchronous detection. The signal is multiplied the carrier and divided to plus and minus by the phase. After that, the signal is through low pass filter (LPF) and the comparator for wave shaping. Finally, the signal turn into digital wave shape and it is indicated the monitor.

#### 4. Experimental Results

Using the experimental system, the error rate of the PSK communication was measured. Transmission path is between the fingerprint side and the nail side of a forefinger (about 1 cm), top and bottom side of the wrist (3 cm), and the both sides of the upper arm (6 cm). In the experiment, the silicon bond sheet inserted between the body and PZT. The sheet is cheap and has the feature of high contact with the body and cutoff from the EF. For comparison, the transmission which the PZTs are directly connected without human body was experimented. Transmitting 8 bit data  $(170)_{10} = (10101010)_2$  was sent 100 times and the error was measured. The error rate was calculated as the average of the 5 times of the experiment.

Fig. 3 is the example of the transmitted waveform and Fig. 4 shows received and demodulating waveforms on the finger transmission. As a result, the communication is succeeded and the digital waveform can be demodulated. Table I denotes the comparison of the error rate. The ASK data in the table is referred from the paper<sup>2)</sup>. The error is improved by applying the PSK modulation. The error tends to increase depending on the transmission length. It is difficult to succeed the

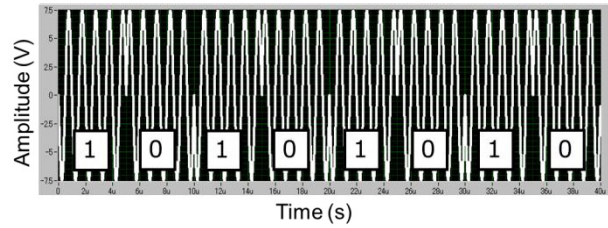


Fig. 3 Transmitted Waveform on the Experiment.

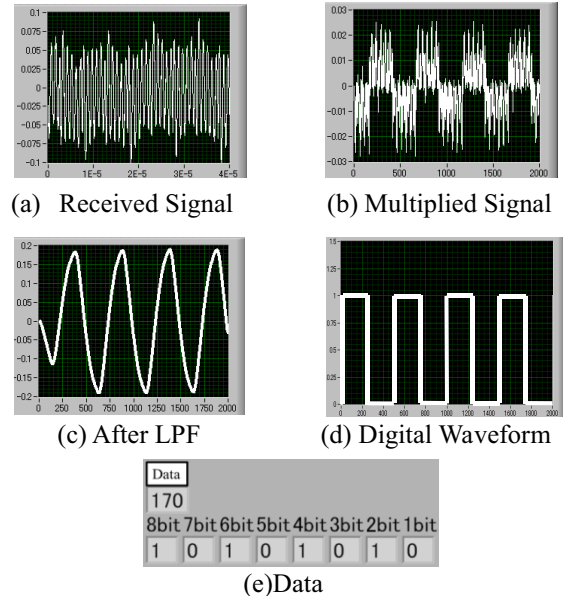


Fig. 4 Received Waveform on the Experiment.

Table I Comparison of the Error Rate.

Transmission Path	Error Rate (%)	
	ASK	PSK
without the Body	0.23	0.0
Fore-finger ( 1 cm )	10~25	0.0
Wrist ( 3 cm )		2.4
Arm ( 6 cm )		× (only once: 5.0)

transmission using the arm. The failure is caused mainly position alignment and fix of the PZTs. They are next step issue.

#### 5. Conclusion

In this time, we applied the PSK modulation to ultrasonic waves communication in the hybrid communication system. As result of quantitative comparison, the communication accuracy was improved.

Next step, we are planning to manufacture the circuit of the PSK modulation. In addition, we will consider the position alignment method of the PZTs in order to reduce the error.

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#### References

1. S. Suzuki, et al. : USE2010 (2010) 1Pb-28
2. S. Suzuki, et al. : USE2009 (2009) 1P2-3