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Reconsidering of the Communication Method for a Wearable Device using Ultrasonic Waves
ウェアラブルデバイスにおける超音波通信の再検討

Shin-nosuke Suzuki[1‡], Manabu Ishihara[1], Yukio Kobayashi[1], Nagaya Okada[2] and Kazuto Kobayashi[2] ([1]Dept. of Elec. and Comp., Oyama N. C. T; [2]Honda Electronics co., ltd.)
鈴木真ノ介[1‡]，石原学[1]，小林幸夫[1]，岡田長也[2]，小林和人[2]（[1]小山高専 電気情報; [2](株)本多電子）

1. Introduction

In our daily life, the cellular phones are spreading at quite a pace. They have evolved from only mobile phone to a small computer, becase they are installed with many functions, such as music player, digital camera, IC card and so on. According to them, we can use computers at any time and any place and an ubiquitous society has been constructed. In the near future, a large amount of electric devices will have computing and wireless communication functions and they will miniaturized to a wearable size, such as wrist watches. The authors define them as wearable devices. We have studied digital information transmission using modulated ultrasonic waves[1), 2)] and applied it to the communication of the wearable device. In our previous study, the transmission speed of about 250 kbps is obtained in the prototype, which is using one-chip microcomputer.

However, it is found out according to subsequent studies that the transmitter device outputs not only ultrasonic waves but also electric field and the communication is implemented using both energy medium under specific conditions. In this time, we investigated the condition of the communication using only ultrasonic waves. As a result, we find out the condition by several experiments and reconsider the system development in next step.

2. System Configuration

Figure 1 shows the communication system for wearable device. The 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 wearable device (WD), and the other is in the other WD or the stationary terminal type reader-writer (R/W). The communication is performed that the user touches the R/W or shake hands with other person. The system can prevent leakage of information from the WD because ultrasonic has a large attenuation at high frequency

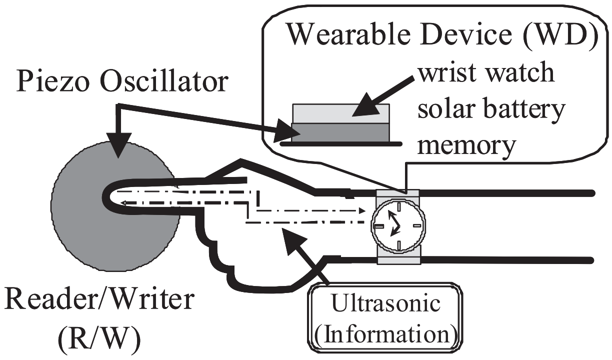


Fig. 1 Communication System for Wearable Device.

in air. Using this system, private information is absolutely safe. The WD can store data and several functions, similarly to an IC card. The function can enhance the usability and remove the burden of taking the card out from the pocket or the bag. In addition, the system is effective for people with visual impairments or who use wheelchairs. They wear the WD, and the communication is enable simply by joining hands with the third person who touches the R/W.

As explained above, the prototypes have possibilities that the information is transmitted by using electric field in addition to ultrasonic.

3. The condition of Ultrasonic Communication

In the past studies, we submit that the prototype communicate with modulated ultrasonic waves corresponding to the input voltage waves. However, the piezoelectric oscillators also output the electric field. When the oscillators received the field, the voltage is output. If the output signal is the voltage transformed from ultrasonic waves, the input and output signals have a time difference according to the sound velocity. The time difference is larger than the signal by the electric fields. Using several input waveforms and transmission paths, the condition of ultrasonic communication is investigated by measuring the time difference. The piezoelectric ceramic oscillators in this experiment are the same type of the prototypes. The configuration is [Pb (Zr, Ti) O3: PZT] with a resonance frequency of 1 MHz, a diameter of 20

E-mail: shin-s@oyama-ct.ac.jp

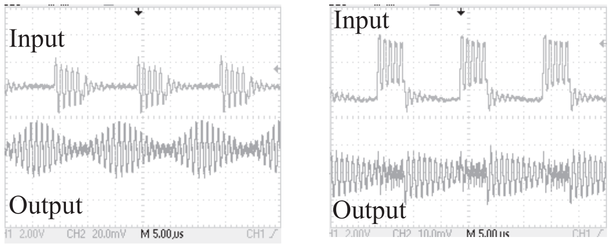
mm, and a thickness of 2 mm. The input voltage waveforms are a sinusoidal wave and a rectangular wave, which is for 1 bit in the prototype. Both frequencies are 1 MHz. The transmission paths are two types. One is between the ball and tub of a forefinger, there are in alignment with transmitter and receiver. Another is between a forefinger and a wrist, not in alignment.

First, between the ball and tub of a forefinger, when a sinusoidal wave is input, the output signal has reverberation in addition to the time difference at receiver side. Therefore, the transmission waves are ultrasonic. (Fig. 2(a)) When a rectangular wave is input, the output has two components, no time lag component and time lag component. As a result, the output is the mixture of the electric field and the ultrasonic. (Fig. 2(b)) Second, between a forefinger and a wrist, the output signal is almost no time lag component. As a result, the communication of this path is performed by electric field mainly. Furthermore, when the non resonance frequency wave is input, the output is almost all electric field components, regardless of the waveforms and transmission paths. Consequently, the ultrasonic communication in this prototype is preferred at in alignment path using sinusoidal input.

4. The Information Transmission Experiment

Information transmission experiment under the ultrasonic communication condition was carried out. The transmission of this system is dependent on the amplitude shift keying(ASK) moduration. The digital signals “1” and “0” is corresponding to sinusoidal waves ON and OFF. “1” was applied 5 of wave numbers, because single wave could not cause the appropreate output amplitude. Similarly, “0” was applied no-input of 5 wave lengths.

Transmission is attempted between the PZTs, they are set on the ball and tub of a forefinger. The PZT is attached the electromagnetic wave absorption sheet (λ GEL, Taica Corp.). Transmission signal is produced by a function generator and the signal is input to the PZT. It is transformed into modulated ultrasonic wave and transmited to the receiver side PZT through the finger. The received signal is thorough the amplifier and comparator, and removed high frequency component. In order to demodulate accurately, the signal is amplified and filtered again. After the process, it is digitalized by comparator. The digital signal is put into micro computer. In this experiment, AVR (Atmel Corp.) is adopted as the micro computer. The LCD connected with the AVR indicates the “1” and “0” corresponding to the transmitted signal.



(a)Sinusoidal Wave. (b)Rectangular Wave.

Fig. 2.Input and Output Waveform between Ball and tub of a forefinger.

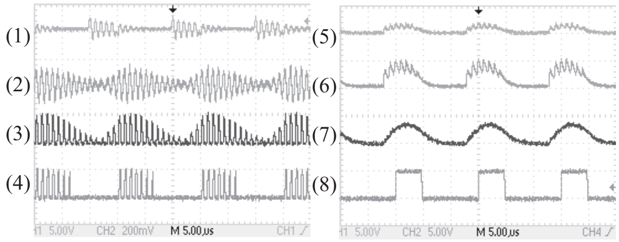


Fig. 3. Information Transmission Experiment. (200kbps, “10101010”, (1)Input (2)Output (3)Amplifier (4)Comparator (5) LPF (6) Amplifier (7) LPF (8) Comparator)

Figure 3 shows the waveforms on the experiment. The transmission speed is about 200kbps. However, on the combination of “1” and “0”, it is need more no-input time for the accurate demodulation, because of sound reverbration. Though it cause the decrease of the speed, the speed maintais by exchanging the PZT to higher resonance frequency type.

5. Conclusions

In this paper, we claryfied the condition of ultrasonic communication in the prototype of the wearable device. Under the condition, the system has a possibility of the communication by the speed of 200 kbps.

Next step, we try to the communication on the not in alignment transmission path. In addition, we plan to utlize both of the ultrasonic wave and electric field in positive way and consider the advanced system applied the hybrid communication.

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