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Detection of Sleeping and Rising States in Care Environment Using Sound at upper vocal register of 18-20 kHz Installation in Sensor Network

18-20kHz 可聴音高域を用いた介護環境での就寝と起床状態の検知

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1. Introduction

We have developed new sensor technologies which can be used in care environment. They can detect movements of the elderly in old people's home and sick persons in hospitals. They can also be installed in sensor network, which requires extreme low-power consumption for sensor devices. In the previous paper, 40-kHz Tx and Rx transducers transmitted and received ultra-sound CWs (continuous waves). But due to short wavelength of 8.5 mm at 40 kHz, sensitivity seemed to be so high that other processing technique might be necessary. In order to solve this problem we focus on detection of the elderly's sleeping and rising states by using 18-20-kHz sound waves at upper vocal register. These sound waves are already used to transmit merchandise information and entertainment / event guide in shopping malls in Japan. These technologies will also be introduced in airports, stations, etc. in near future. Conventional audio speakers and mikes in smart phones are used to transmit and receive information. We attempted to combine these sound-wave techniques at 18-20 kHz with our precise distance-measurement and movement-detection method.

It has also been pointed out this vocal register will become one of the new communication bands. Moreover, speakers and mikes which transmit and receive sound waves are small enough to be mounted in sensor nodes of sensor network. Continuous sound waves at discrete frequencies which correspond to those of the Inverse Fast Fourier Transform (IFFT) procedure are transmitted (Fig. 1 and Fig. 2(a) and (b)). Based on the relative amplitudes and phases between the received and transmitted CWs, the impulse response can be calculated in the center node, which can provide accurate distance information between nodes via many reflecting objects. If we subtract the impulse response at present time from that at preceding time, we can obtain the change of distances to objects at two different times (Fig. 3). By this procedure, we can exclude effects of inactive objects and detect only moving objects.

Sensor network such as ZigBee and Z-Wave including these devices will be applied not only to care environment but also home/office monitoring, prevention of crime and watch in hospitals. We also developed sound automatic-measurement systems which included functions of sensor node and center node of sensor network. Experimental results measured with the system and comparison between results using 19-kHz sound waves and 40-kHz ultra-sound waves are also presented.

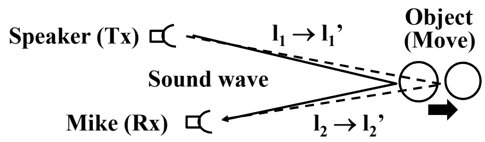
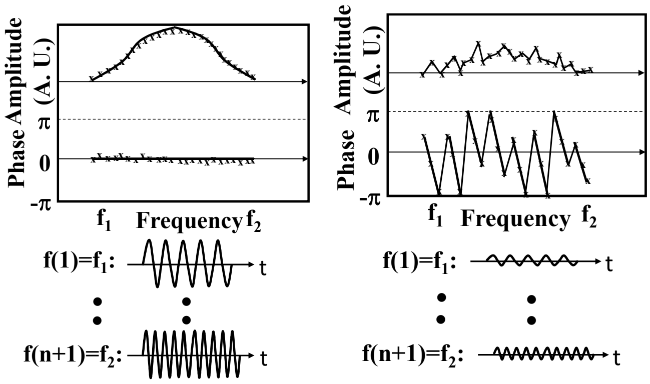


Fig. 1 Transmission and reception of sound waves at upper vocal register via reflecting object.



(a)Transmitted signals (b) Received signals
Fig. 2 Sound CW signals corresponding to IFFT frequencies.

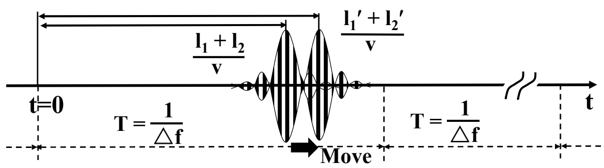


Fig. 3 Impulse responses calculated by IFFT and subtraction between two impulse responses for Fig. 1's model.

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2. Monitoring room model and automatic measurement system

The elderly or sick person are lying on a bed in a room with many reflecting objects as shown in Fig. 4. Our aim is detecting sleeping and rising states. The sensor node (1) transmits sound CWs and the sensor node (2) receives them. Relative amplitudes and phases of the received CWs to the transmitted CWs are sent to a center node via ZigBee. In the center node, impulse responses are calculated. To confirm our detection method experimentally, we developed automatic -measurement system (Fig. 5), which has not only almost same functions as Fig. 4's sensor node but also part of the center node. In the system Lock-in amplifier produces transmitting signals according to control commands from PC. The received signals are transferred to Lock-in amplifier again and the relative amplitudes and phases are derived. In PC impulse responses are calculated using IFFT and two impulse responses at different times are mutually subtracted, which provides movement information of sleeping or rising states.

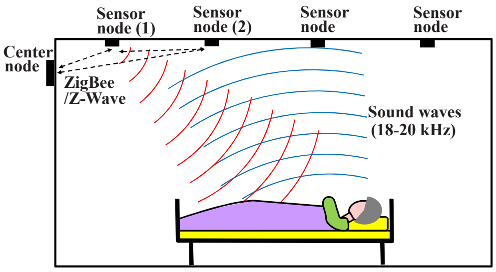


Fig. 4 Room model installed with sensor network.

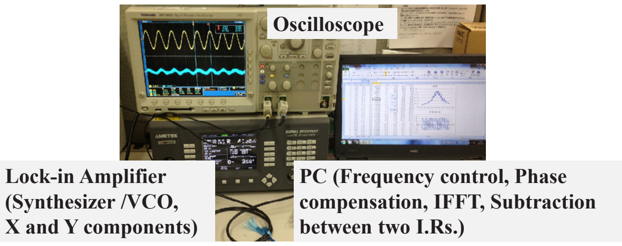


Fig. 5 Developed automatic-measurement system at 18-19 kHz (Subtracted data are stored in PC).

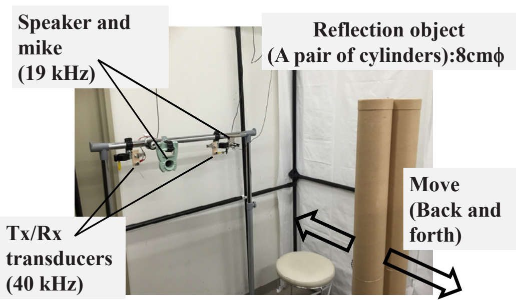
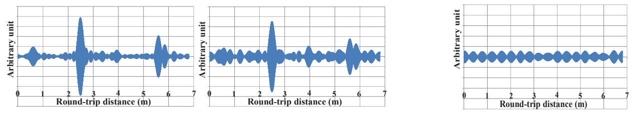


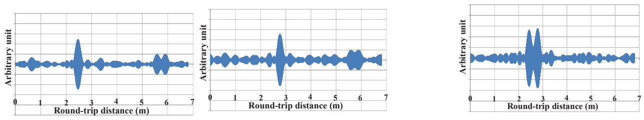
Fig. 6 Experimental setup. A pair of cylinders with 8 cmϕ can move. Speaker and mike around 19 kHz are fixed at about 1.5-m height. Tx and Rx transducers at 40 kHz are also fixed for comparison.

3. Experimental results

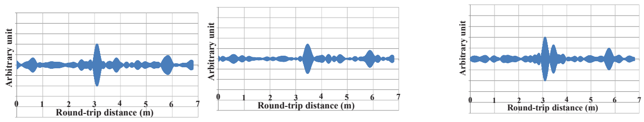
An experimental setup is shown in Fig. 6. To achieve almost same room condition, the setup is surrounded by 2.5×3.5-m square curtains. The required time to obtain impulse response under one condition is about 15 seconds. So we repeated measurements in a 1-minute cycle by changing distances. First we measured 1-minute before-and-after impulse responses. Two impulse responses at 18-20 kHz are shown in Fig. 7(a). Subtracted results between them are shown in Fig. 7(b), which indicates that there are no moving objects. Impulse responses with 2.5 → 2.8 m and 2.8 → 3.1 m are shown in Fig. 8 and 9, respectively. Reflection object and movements are clearly recognized. As a comparison results at 40 kHz are shown in Fig. 10. Sensitivity and decay characteristics are different one another, which are not clearly illustrated in experimental data.



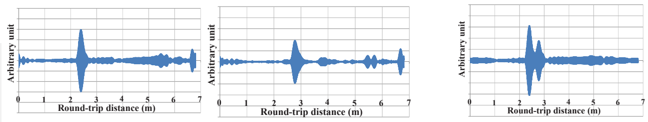
(a) Left:I.R.; Right:1-minute after (b) Subtraction
Fig. 7 Impulse responses of 2.5 m without move.



(a) Left: 2.5 m.; Right: 2.8 m (b) Subtraction
Fig. 8 Impulse responses moving from 2.5 to 2.8 m.



(a) Left: 3.1 m.; Right: 3.4 m (b) Subtraction
Fig. 9 Impulse responses moving from 3.1 to 3.4 m.



(a) Left: 2.4 m.; Right: 2.8 m (b) Subtraction
Fig. 10 Impulse responses at 40 kHz as comparison.

4. Conclusion

We proposed new ultrasonic movement detection based on impulse responses, which can be installed in sensor network. Experimental results at 18-20 kHz were illustrated. We will continue to investigate merit and demerit of his band.

References

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2. Y. Kaneta, T. Sato and M. Hikita, in IEEE Ultrason. Symp. Proc., 2015.