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Wearable Capacitive Breathing Sensor

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1. Introduction

There are many trials for measuring body signals for the health-monitoring (for example, iPhone application) [1]. Technology is to enable doctors to see the patients' signal using the remote-sensing system [2]. The breathing is one of the important signals for the health-monitoring and the indispensable physiologic functions for keeping the biological activity. The breathing is characteristic because it is also controlled consciously. Monitoring the breathing during the exercising is important, since this shows the actual lung function. Conventionally, the measurements are carried out using the sensors with the masks and the thermal sensitive resisters. These sensors are necessary to be fixed on the body being connected with cables or pipes. Since the subjects are stressed, the breathing tends to be far from the natural one. The sensor is expected not to disturb the subject's exercising allowing the natural breathing.

The equipments for decreasing the stress of subjects are reported. For measuring biopotential signals (electrocardiogram, electroencephalogram, electromyogram), some electrodes are prepared inside the cloth using the conductive textiles. Makikawa's group measures the electrocardiogram by detecting the minute voltage using the capacitively coupled electrodes. The voltage-follower or the differential circuits are used [3]. The capacitive method is useful without the mechanical contact for reducing the stress against the subjects. Cheng et al. reports an on-body capacitive sensing to derive activity related information [4]. Using conductive textile electrodes, the changes inside the human body are measured. Such changes are related to motions and shape changes of muscle, skin, and other tissues.

In this study, the capacitive sensing is applied for measuring the breathing. The electrodes used are the conductive textile realizing the wearable sensor.

2. Principle and Preliminary Experiment

Figure 1 shows the possible principle of the capacitance change caused by the breathing. The material of the body is mainly water, whose permittivity is about 80 and the conductive electrolytic solution. Compared to this, the air which flows into or out of the lung has the value of about 1 and non-conductive material. When the subject breathes, the regions of body material and air will change inside. When the electrodes are fixed facing each other across the body, the capacitance value should reflect the change inside the body. Since the lung volume of the male adult is 2000-3000cc, the significant change is expected.

Figure 2 shows the setup for measuring the capacitance

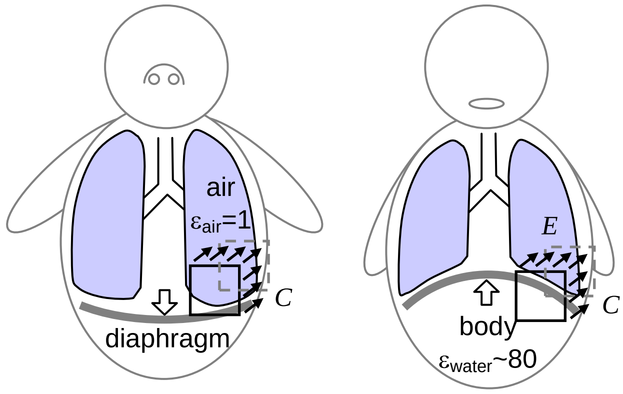

Fig. 1: Possible principle for measuring the breathing showing the change inside the body.

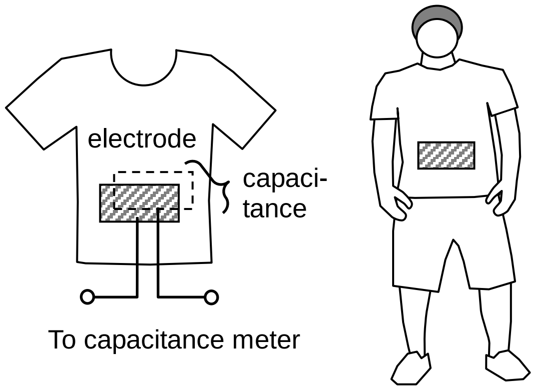

Fig. 2: Setup of breathing sensor using the electrode pair fixed inside T-shirt.

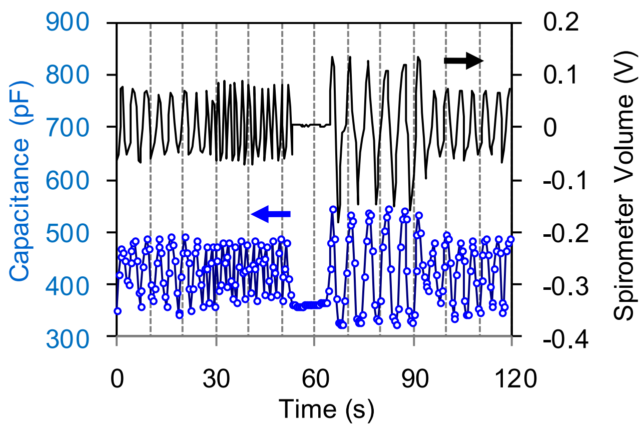

Fig. 3: Signals from capacitance sensor and spirometer volume for three subjects. Since the capacitance data is obtained from the movie image of the equipment display, the sampling rate is 2 Hz.

being constructed by the electrode pair placed at the front abdomen and the backside. Here, the electrodes are conductive textile (area: 160x160mm^2) fixed inside T-shirt. Its surface is covered by the tape for the water protection. In this preliminary experiment, the electrodes are connected to the capacitance meter (Yokogawa Hewlett Packard, HP4718A). The measurement voltage is 1V, and the frequency is 1MHz. Subjects shits on the chair. During 120s, breathing patterns are tried consciously (quiet breathing for 0-25s, panting for 25-50s, apnea for 50-60s, deep breathing for 60-90s, and quiet breathing for 90-120s). For comparison, subjects set the mask being connected to the standard spirometer (Minato Medical Science Co. Ltd., RF-H).

Figure 3 shows typical data obtained from the capacitance meter and the voltage signal proportional to the air volume. The cyclic signal pitch and the signal magnitude correspond well with those of the spirometer volume signal.

3. Wearable Sensor Setup

The small circuit can be designed for sensing the capacitance. Figure 4(a) shows the hand-made circuit. The circuit consists of two boxes connected with a cable. Larger box (170x120x75mm^3) is the power supply. Smaller box (90x60x50mm^3) is C/V converter. The measurement voltage is 6V, and the frequency is 350-400 kHz. This converter is connected to the electrodes on the shirt. Figure 4(b) shows the shirt with the electrode underneath. The electrode can slide on the skin without the fixation keeping the comfortable condition. The C/V converter box can be fixed on the belt of the trousers. The exercise is easy. The cable is 7mm in diameter and has 4 lines for the power supply and the signal connection to the larger box.

4. Results

Figure 5 shows measured capacitance signals obtained from the circuits. Two independent circuits are included in the same box for measuring the capacitances. One signal measures at the abdomen which will correspond the abdominal breathing. Another signal measures at the chest which will correspond the costal breathing. The electrode sizes are both 50x50mm^2. Both signals show the breathing cycle clearly. The increasing or decreasing of the signal is opposite between two signals. The reason is not clear at present but this indicates the sensor measures the change inside the body. The detailed shape difference between them will relate to the difference between the abdominal and costal breathing.

5. Conclusions

The breathing signal is measured using the capacitance constructed by the electrodes facing each other across the body. The electrodes are fixed inside the cloth. Not only the number of breathing but also the depth information can be measured. The measurement is non-invasive and the subject condition is almost natural without the mental or physical stress.

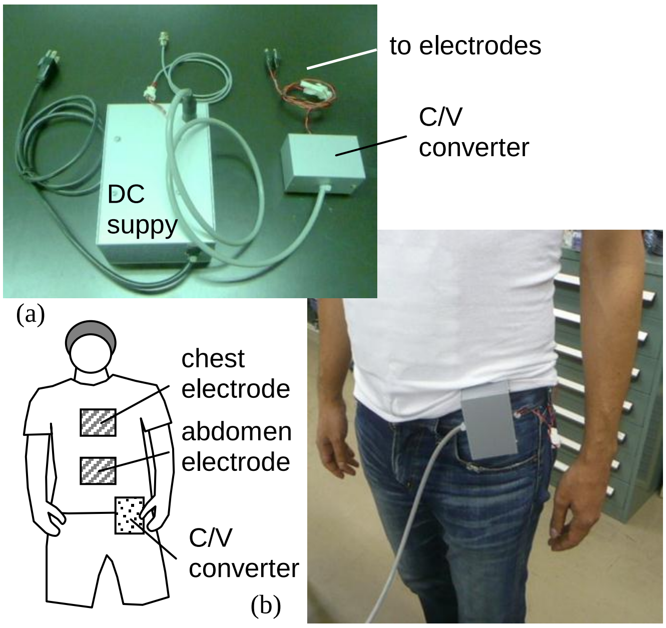

Fig. 4: Wearable sensor system using hand-made C/V circuit and the electrode fixed on the shirt.

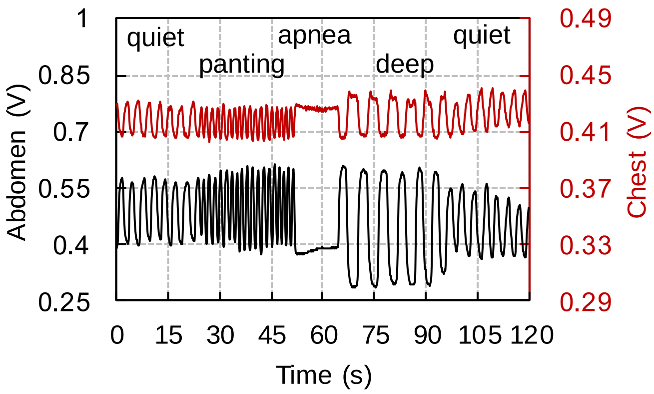

Fig. 5: Obtained two sensor signals from the capacitances at the abdomen and the chest. The frequency is different each other. The sampling rate is 10Hz.

Acknowledgements

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References

[1] G.-Z. Yang, *Body Sensor Networks*, Springer.
[2] J. M. Smith, *IEEE Spectrum*, (Oct. 2011) pp.51-56.
[3] For example, Jpn. Patent #2008-213588, #2009-043312.
[4] J. Cheng, O. Amft, P. Lukowicz, *Proc. 8th Int. Conf. on Pervasive Computing* (2010) pp.319-336.
[5] *Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300GHz)*, Int. Commission on Non-Ionizing Radiation Protection, Apr. 1998.