PS-11-17
Extended Abstracts of the 2014 International Conference on Solid State Devices and Materials, Tsukuba, 2014, pp306-307

Capacitive Breathing Sensor and Evaluation of Body Movement Noise

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Abstract

Capacitive breathing sensor placing electrodes inside T-shirt is studied. For evaluating the signal and the noise, the electrodes are also fixed on the human skin. The breathing signals indicate the long-term stability although the posture is necessary to be same. Monitoring respiration during 3h sleeping is demonstrated.

1. Introduction

The respiratory rate is one of important vital signs. Its monitoring helps to figure out the progression of illness [1, 2]. Besides clinical region, monitoring respiratory rate is required in sleep studies, sport training, mountain climbing, astronauts, etc. Despite such high importance, the respiratory rate is considered as the most neglected vital sign [2]. One reason is the delay of the sensor development.

The spirometer is the common device used for monitoring respiratory rate [1]. This device has the mask or the tube tethered to the air flow sensor. The direct contact with the subject is required. This often disturbs natural breathing and is uncomfortable and not suitable for long-term measurement. Scilingo et al. showed piezoresistive fabric sensors, basically a textile band wrapping around the chest [3]. Several respiratory belt or band have been proposed, but these are inconvenient as they require accurate placement and tightness. Paradiso et al. proposed flat knitted sensor which is integrated inside of an inner garment [4]. However, as this is piezoresistive sensing, the inner garment must be always tightly fit around the chest like a respiratory belt. Cheng et al. reported an on-body capacitive sensing technique using sensorized garment to derive activity related information [5]. Capacitive changes are related to motions and shape changes of muscle, skin, and other tissues. We have proposed a capacitive sensing technique. A sensorized garment is realized by fixing electrodes inside [6]. The advantage is that the capacitive method does not require the physical contact. The garment does not have to be tightly fit with the body.

In this study, the characteristics of the capacitive sensing are studied for clearing the detail. The signal stability and the noise due to the body movements are evaluated.

2. Experimental Setup

Figure 1 shows T-shirt type sensor setup, which consists of two conductive textile electrodes, a capacitance to voltage (C/V) converter, and a power supply [7]. Two electrodes of conductive textile are placed on the abdomen and corresponding posterior back side. Flexible 24 AWG wires are used for wiring the electrodes and the capacitance meter. The sensor can suffer from the noises such as the gap chnage between the skin and the textile. For evaluating the inherent signal from the body, the electrode is fixed on the skin as shown in Fig. 2. The conductive textile (MK-KTN 260) contancts directly on the skin being covered by the elastic tape (3M, Multipore Sports Lite Elastic Tape). The body movement is allowed.

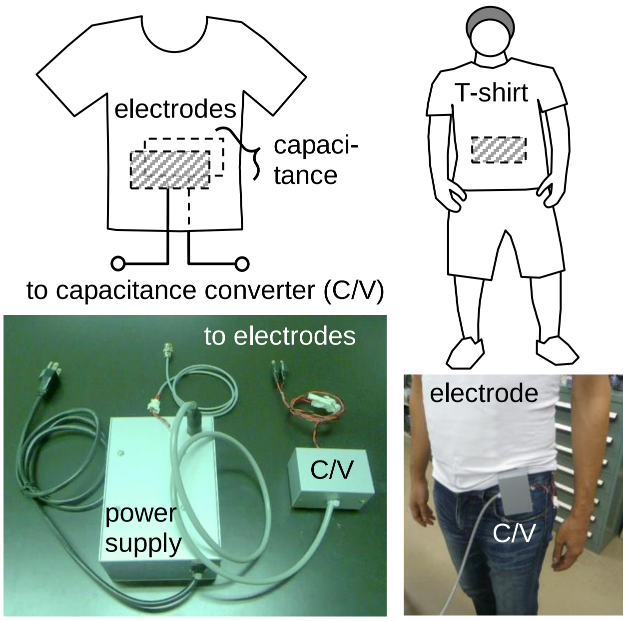

Fig. 1: T-shirt type capacitive breathing sensor. Two electrodes are fixed on the inner anterior and posterior sides.

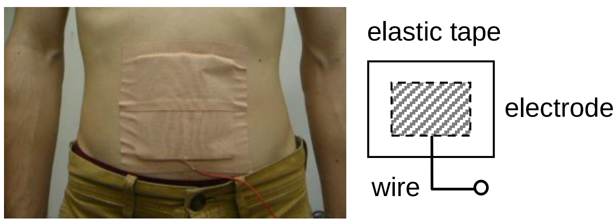

Fig. 2: Typical pasting of electrode directly on the abdomen skin. The electrode of the conductive textile is not elastic.

3. Results

Figure 3 shows two signals symultaneously obtained from C-sensor and the spirometer for 6min. At begining and ending, the subject takes the deep breathing for 3 times exhausting to his limit. The peak magnitude of the capacitive signal is larger when the breathing volume is larger. Both siganls increase at inhalation. The spirometer (RF-H, Minato Medical Science Co. Ltd.) shows the drift decreasing its voltage value. On the other hand, C-sensor shows less drift. The signal base lines at the exalation at begining and ending are almost same (about 0.4V). C-sensor signal is considered to indicate an inherent body condition. This measurement is carried out taking care about keeping the subject's posture.

Figure 4(a) shows the case when two electrodes are on the abdomen and corresponding posterior side. The subject sits. The periodic signal corresponds to breathing. Figure 4(b) shows the case when the electrodes are on the abdomen and the upper arm. The signal is obtained even when the electrodes are not placed sandwiching the body. Figure 4(c) shows the signals with the conditions of (1) quiet breathing, (2) no respiration, and (3) no respiration with moving arm. Body movement generates the confusing change of the C-sensor signal.

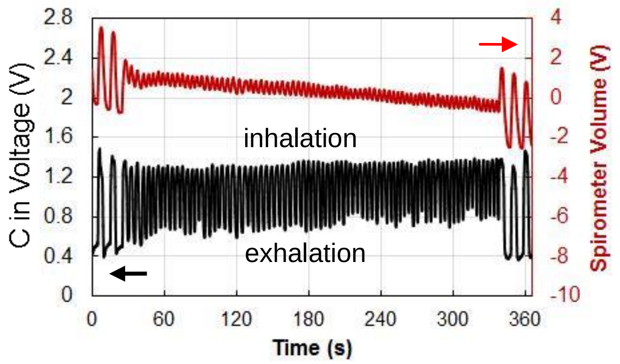

Fig. 3: C-Sensor and spirometer signals for 6min. Swallowing changes the signal form.

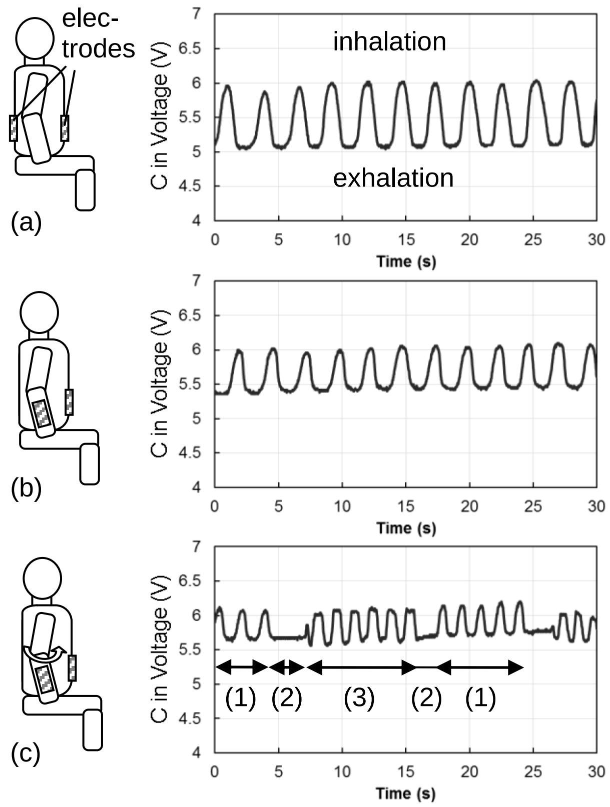

Fig. 4: C-Sensor signals fixing the electrodes (conductive textile of DW-372N) at (a) abdomen and backside at the quiet condition, abdomen and forearm (b) at the quiet condition and (c) some conditions including moving arm.

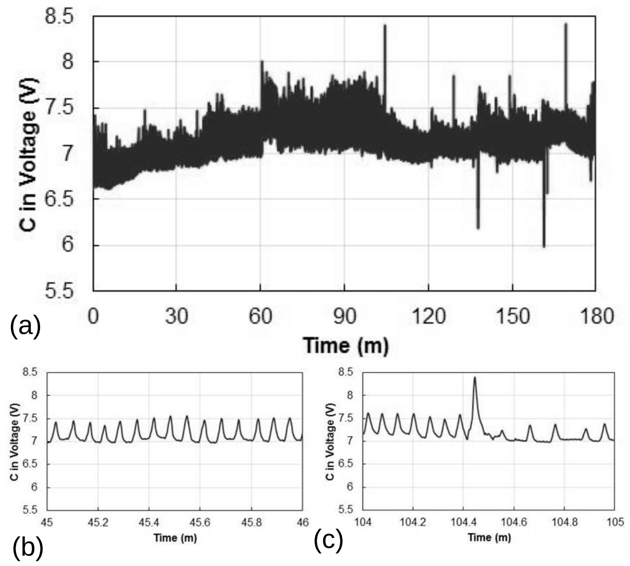

Fig. 5: (a) T-shirt type C-sensor signal during 3h sleep. Expanded signals at around (b) 45min and (c) 104min.

Figure 5(a) shows the signal during 3h sleep. T-shirt type sensor shown in Fig. 1 is used. The sensor does not spoil confortability and the sleeping is nearly usual. The signal is continuously and stably obtained. The baseline change corresponds to the body or the T-shirt movement. During the sleeping, the body movement of the adults is said to be small compared to that of the children. Figure 5(b) shows the expanded signal around 45min. Stable 15-cycle signal per 1 min is observed. Figure 5(c) shows the signal around 104min. This shows one large peak and the constant value without the periodicity, which will corresponds to the sleep apnea for a short time.

Acknowledgements

Spirometer used is supported by Prof. M. Saito, Aichi Gakuin University. This research is supported by Aichi Prefecture Chi-no-Kyoten Project No.3, MEXT grant-in-aid for challenging exploratory research (24650397), and MEXT program for forming strategic research infrastructure (S1311034), Toyoaki schlorship foundation 2013-2015. From the guidelines reported from international commission on non-ionizing radiation protection, our experimental condition is considered to be safe [7].

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