침대에 부착된 용량성 전극 배열을 이용한 수면 중의 심전도 측정

임용규[1], 김고근[1], 박광석[2], 정도언[3]

[1]서울대학교 공과대학 의공학협동과정
[2]서울대학교 의과대학 의공학교실
[3]서울대학교 의과대학 신경정신학교실

ECG Measurement Method during Sleep with Array of Capacitive Electrodes Attached to Bed

Y. G. Lim[1], K. K. Kim[1], K. S. Park[2], and D. U. Jeong[3]
[1]Medical & Biological Engineering Major, Interdisciplinary Program, Seoul National University
[2]Department of Biomedical Engineering, Colledge of Medicine, Seoul National University
[3]Dept. of Neuropsychiatry and Div. of Sleep Studies, Colledge of Medicine, Seoul National University
imfine39@bmsil.snu.ac.kr

Abstract

In order to measure ECG in daily life, a new ECG measurement method on bed was developed. The provided method does not require any direct conductive contact between the instrument and bare skin, so that it does not cause the uncomfortable feel of touch and the possible skin trouble which are typical shortcomings of the conventional conductive contact ECG measurement. The provided method utilized an array of high-input-impedance active electrodes fixed on the mattress and an indirect-skin-contact ground made of a large conductive textile sheet and laid on lower area of the mattress. A thin cotton bedcover covered the mattress, the electrodes, and the conductive textile and subjects lay on the mattress over the bedcover. ECG was obtained successfully. However its signal quality is lower and the motion artifact is larger than direct-contact measurement. Careful measurement setup was needed to reduce the motion artifact originated from variation in static electricity. From the ECG obtained by the provided method, R-peak could be discriminated easily and the information about the position and the posture of the subject could be obtained.

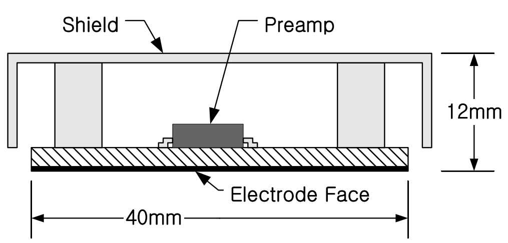
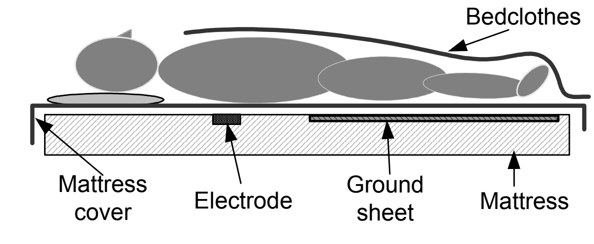


Fig. 1. Active electrode

I. INTRODUCTION

The ECG recording during sleep is carried out to assess long-term heart rate variability (HRV) [1] as an independent measurement and to diagnose various sleep disorders as a part of polysomnography. Recently, there were many trials to diagnose sleep disorders with reduced measurement from full polysomnography in order to be applied to daily monitoring in subject home [2]. And much interest in daily health monitoring is aroused also. For those purposes, a prior study was carried out to measure ECG during sleep with conductive textile fixed on the pillow and the bed cover [3]. In the prior study, the setup using the conductive textile seems inadequate for long-term everyday ECG monitoring. One of the reasons is that the feel of the conductive textile is not good. What is worse, the conductive textile placed on the pillow contacts with neck and face those are very sensitive. The other reason is that the long-term contact between skin and conductive textile may make troubles on skin. We have developed a new method without direct contact between skin and electrodes for ECG



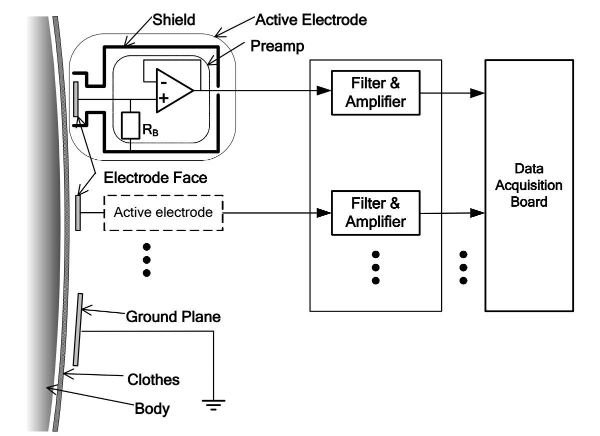


Fig. 3. Structure of the presented method

measurement on a chair [4]. The new method was applied to ECG on bed to overcome the shortcomings of the prior study. In the presented method, the electrodes are attached on the mattress and ECG is measured through clothes without direct contact.

II. METHODOLOGY

To recording electrocardiogram (ECG) through clothes, the high-input-impedance amplifier is needed because of the very high impedance of the clothes. In [4], we designed an active electrode in which a high-input-impedance amp is embedded, and obtained ECG successfully through clothes from subjects sitting on a chair and wearing normal clothes.


Fig.4. mattress with the array of electrodes and the ground sheet

We applied the indirect-contact ECG measurement method to bed during sleep. Figure 3 shows the structure of the presented ECG measurement method. Plural active electrodes are placed on the bed as Fig. 2 and Fig. 3. The ECGs as potential variations on the subject's skin are sensed by the active electrodes through clothes and mattress cover. Then, the signals from the electrodes enter their respective filter-and-amp modules. The outputs of the filter-and-amp modules are digitized by a commercial data acquisition board. Unlike the ECG measurement on a chair in [4], the difference between the signals of the electrodes is not obtained and the signals are processed respectively. A ground plane is laid on the lower part of the bed to serve the reference. Therefore the measured signal is the difference of the voltage between the skin on the electrode and the lower body.

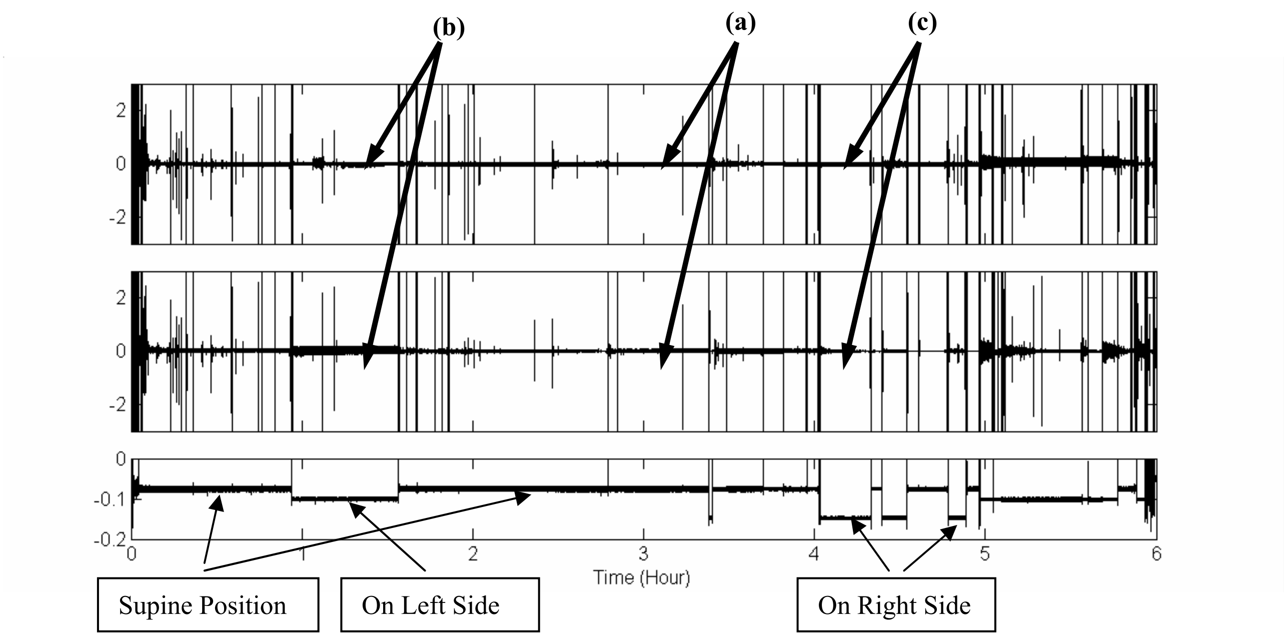


Fig. 5. ECG from two electrodes of eight electrodes for 6 hours. Upper: ECG of the 3rd electrode from the right. Middle: ECG of the 6th electrode from the right. Lower: output of position sensor. The labeled arrows indicate the times of the waveforms in Fig. 6

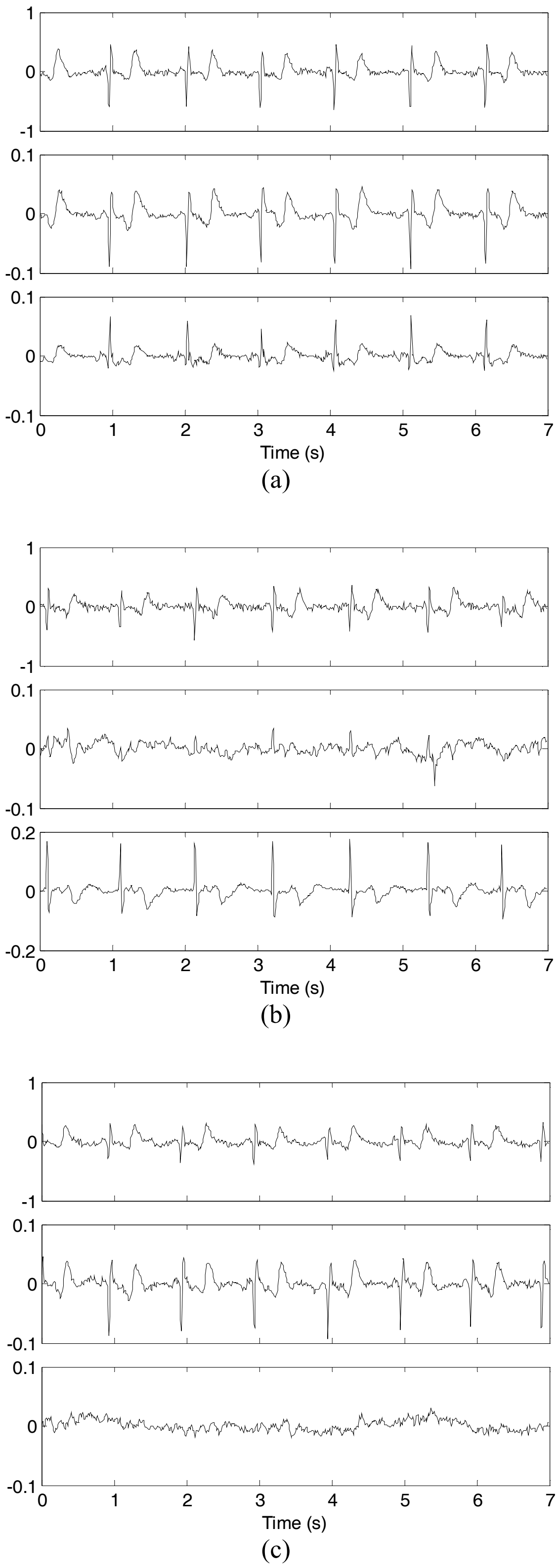


Fig. 6. ECG waveforms according to different body positions. In each pictures, the upper is from the convention Ag-AgCl electrodes attached on both upper arms, the middle is from the 3rd electrode from the right, and the lower is from the 6th electrode. The times are indicated in Fig.5

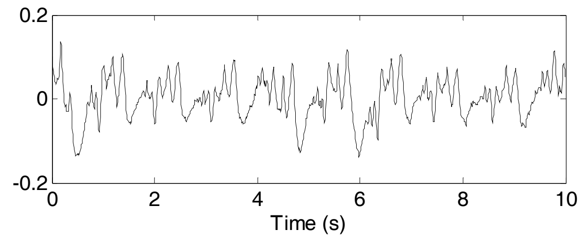


Fig. 7. An example of motion artifact of an electrode which did not contact with body

1) A. Experiment setup

The active electrodes were made similar to those designed in [4]. OPA124 was used in the preamp. Unlike [4], the resistor of 1.6 GΩ was used for bias current of op-amp input.

Eight active electrodes were fixed on a mattress in a row with center distance 58mm. The raw of the electrode was positioned at the height of the subject's 9th thoracic vertebra. The lower area of the mattress under the subject's lower body was covered with a large conductive sheet. The mattress was made of urethane sponge covered with artificial leather and its dimension was 800 x 1900 x 150 (W x L x T, mm). A thin single-layer cotton mattress cover covered the mattress. The subject lay on the mattress under bedclothes padded with cotton. The subject wore cotton pajamas.

III. Result and Discussion

To compare with normal ECG, conventional ECG measurement using Ag-AgCl electrodes was carried out simultaneously with the presented method. To reduce the influence of the normal ECG measurement on the results by decreasing the ground impedance, the normal ECG device was isolated from the power line ground by isolation amplifier. In addition to it, a position sensor was attached on the subject's chest. We made sure that the isolated normal ECG measurement and the position sensor did not make any noticeable effect on the results.

Figure 5 shows the results of two electrodes (the third and the sixth from the left) for six hours with the output of the position sensor. The Figure 5 does not show the details of the waveforms because the waveforms are condensed with respect to time axis. The peaks with large amplitude were caused by motion artifacts. We can see much more peaks in indirect-contact ECG waveform than in normal ECG waveform. The peaks without change in body position may be caused by movements of limbs.

Figure 6 shows the details of the ECG waveforms at the marked times in Fig. 5. The differences in waveform even of the same electrode show that the measured ECG waveform through an electrode can be changed by the contact condition and contact position of the body. Figure 6-(a) show the ECGs of supine position: both electrodes are well contacted with the subject's back. The signals in Fig. 6-(b) were obtained when the subject lay on his left side at the time (Fig. 5). The signal from the right electrode shows low signal amplitude and large artifacts, however the signal from the left electrode became better than that in Fig. 6-(c). Fig. 5-(c) shows the results of an opposite case to Fig. 5-(b).

Figure 7 shows a waveform from an outmost electrode (8th electrode) which did not contact with body of low-quality waveform due to bad contact with body.

The ECG measurements through clothes show large motion artifacts because of the capacitive characteristic between the body and the electrode [4]. The ECG measurement on bed without direct contact also shows large motion artifacts as shown in Fig. 5. It was observed that the movement of a static charged object near the electrode made artifacts. The magnitude of the motion artifacts induced by static electricity was proportional to the degree how large the clothes made the triboelectricity. From the experiment with various clothes, the cotton made least motion artifacts in usual clothes. So, the mattress cover, bedclothes, and pajamas made of cotton are used.

IV. CONCLUSION

It was shown that the ECG during sleep can be measured without conductive contact between skin and the electrodes by an array of high-input-impedance active electrode and capacitive grounding. The obtained ECG through the presented method showed low signal quality and large motion artifact. Furthermore, the waveforms obtained from the same electrode are different from each other according to the contact condition and contact position. Therefore, further studies on enhancing the signal quality and analyzing the waveform are needed for the diagnostic application with waveform. However, as it is now, the presented method can be applied without difficulty to assess heart rate variability by detection of R-peaks.

ACKNOWLEDGMENT

This study was supported by the Core Technology Development Program, Ministry of Science and Technology, Republic of Korea.

REFERENCES

[1] Task Force of The European Society of Cardiology, et al., "Heart rate variability; Standards of measurement, physiological interpretation, and clinical use," *European Heart Journal,* 17, 1996, pp. 354-381.

[2] W. W. Flemons, et al., "Home Diagnosis of Sleep Apnea: A Systematic Review of the Literature," *Chest*, 124, 2003, pp. 1543-1579.

[3] M. Ishijima, "Monitoring of Electrocardiograms in Bed Without Utilizing Body Surface Electrodes," *IEEE Trans. Biomedical Engineering*, Vol. 40, No. 6, June 1993, pp. 593-594.

[4] Y. G. Lim, K. K. Kim, and K. S. Park, "ECG Measurement on a Chair without Conductive Contact," *IEEE Trans. Biomedical Engineering*, to be published.