Ubiquitous Health Monitoring at Home – Sensing of Human Biosignals on Flooring, on Tatami Mat, in the Bathtub, and in the Lavatory

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***Abstract*—In the graying society, it is important to monitor health-related biosignal with sensors in the living environment for the sake of emergency response and long-term health management. In order to use biosignal data monitoring systems daily at home, noninvasive monitoring and system maintenance are crucial. We propose a method of estimating the sleep stages of sleeping subjects through noninvasive measurement of heartbeat and respiration using a pneumatic method and an air mattress. However, the method incurs maintenance for periodically refilling the air of the mattress. In this paper, another pneumatic method, which uses an air tube made of the silicon rubber instead of the air mattress, is proposed. The change in S/N ratio in heartbeat and respiration signals, under greater background noise, are compared for the following: in a room with wooden flooring; in a room with tatami mats; in a bathtub; and in a lavatory. The results show that both the heartbeat and respiration can be measured with the S/N ratio of around 30 dB, and the signal of each heartbeat can also be confirmed provided the maximum background noise in the room with wooden flooring, in the room with tatami mats, in the bathtub, and in the lavatory are 0.1 m/s^2, 0.9 m/s^2, 100 ml/s, and 0.1 m/s^2, respectively.**

***Index Terms*—Health monitoring, heartbeat, respiration, S/N ratio, unconstrained biosensing.**

I. Introduction

In THE graying society, it is important to enable senior citizens to maintain and improve their health and lead active lives. Adequate monitoring of biosignals in various situations in the home, such as in the living room, dining room, tatami mat room, bedroom, bathroom, and lavatory, is helpful for daily control of health status. Especially in a bedroom, bathroom, or lavatory where privacy is important, insufficient care could lead to a delay in an emergency. Therefore, monitoring biosignals and automatically judging people's safety using computer systems are useful not only for maintaining health but also responding in an emergency. Bio-signal sensing systems for domestic use need to be developed assuming that they will be used daily at home. This requires an unconstrained, noninvasive environment for users so that they will not be aware of being monitored. The system must also be easy to maintain, without requiring frequent setting or cleaning. To meet these requirements, a number of research activities have been carried out focusing on the monitoring of biosignals at home. These include researches on: the measurement of heartbeat, respiration, and blood stream using electrodes and a photoplethysmography sensor placed inside a bathtub[1]–[3]; the measurement of weight, excretion amount, excretion speed, and heart rate in a lavatory [4]; the measurements of heartbeat and respiration using a cardiac sound sensor on a bed [5]; the monitoring of respiration using a CCD camera [6]; and, by combining the above, the measurement of heartbeat, respiration, snoring, weight, and blood pressure, in a bedroom, bathtub, and lavatory[7], [8]. Among them, we previously proposed a method to estimate sleep stages through unconstrained and noninvasive measurement of heart rate, respiration, snoring, and body movements with the air mattress type pneumatic method[9]–[14]. This pneumatic method, however, required periodic air refills since the air inside the mattress leaks during long-term use, so maintenance is an issue.

In this paper, another pneumatic method, which uses an air tube made of the silicon rubber (here after we call it a silicon tube) instead of an air mattress, is proposed. A system to measure heartbeat and respiration signals in a room with flooring, in a tatami mat room, in a bathtub, and in a lavatory, is devised, and their S/N ratios to the background noise in each of these conditions are surveyed.

II. Air Tube Type Pneumatic Method

In this paper, a pneumatic method using a silicon tube is proposed to overcome the problem of decreasing sensitivity due to the air leakage from the air mattress. Silicon tubes, compared with tubes made from other materials such as polyvinyl-chloride, are less elastic and suffer less plastic strain even under long-term pressure by weight from above, thus the sensitivity does not degrade. In addition, the method with a silicon tube, compared with the air mattress type pneumatic method, can be more generally used, since the tube length and installation method can be flexibly tailored to each environment. Fig. 1 shows a schematic diagram of the pneumatic method using a silicon tube. A groove with the depth of roughly the radius of the silicon tube is dug into a board. The silicon tube, after having one of its ends closed, is laid on the groove. When a cover board is placed on top, the silicon tube is compressed halfway. A

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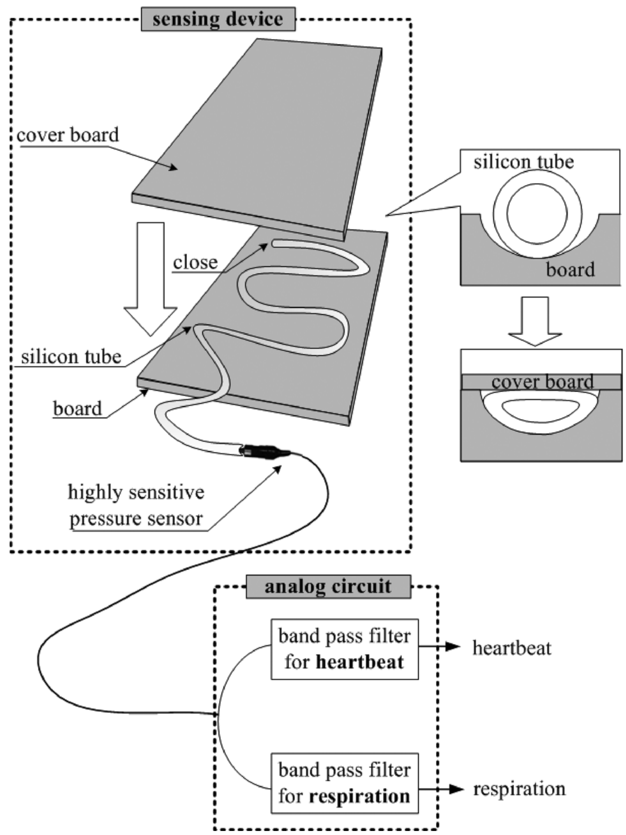


Fig. 1. Schematic diagram of silicon tube type pneumatic method.

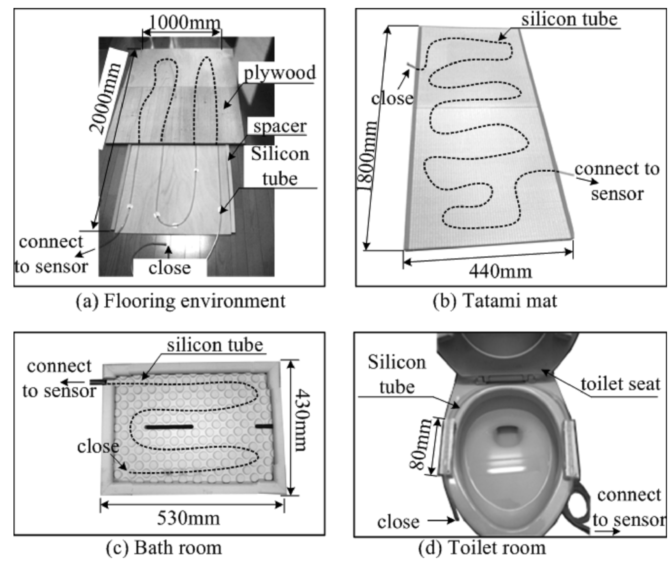


Fig. 2. Sensing devices for each environment.

highly sensitive pressure sensor is connected to the open end of the silicon tube. When a person is on the cover board, the heartbeat and movement of the lung thorax system and diaphragm accompanying respiration are conveyed to the silicon tube as vibrations. The air pressure changes inside the silicon tube caused by the vibrations are measured with the highly sensitive pressure sensor. The measured pressure signals contain heartbeat, respiration, and other biosignals, and the signals are separated based on their frequencies using an analog bandpass filter.

III. Level of Background Noise, and S/N Ratios of Heartbeat and Respiration Signals

A. Sensing Devices for Flooring, Tatami Mat, Bathtub, and Toilet

This paper focuses on the measurements of human heartbeat and respiration in a room with flooring, a tatami mat room, a bathtub, and a toilet. Fig. 2 shows the sensing devices for each of these environments based on the mechanism shown in Fig. 1.

The sensing device for the room with flooring, as shown in Fig. 2(a), uses a silicon tube (Tokawa Sangyo Company, Ltd.: SS4 $\times$ 4, external diameter: 7 mm, internal diameter: 4 mm) and wooden spacer boards placed on a flooring board (2000 mm$\times$ 1000 mm$\times$ 30 mm). Since the height of the spacer is less than the diameter of the silicon tube, the tube is slightly compressed when another flooring board of the same size is placed on top. The sensing device for a tatami mat room, as shown in Fig. 2(b), uses a silicon tube embedded inside a tatami mat. The mattress used for the measurement contains three tatami layers inside, and the surface of the second layer is grooved as shown in Fig. 1 to receive the silicon tube. Then the first layer is placed on top and the mattress is sewed up. For the measurements in Fig. 2(a) and (b), the tube is placed such that the subject's body always remains over the tube, even his/her posture on the sensing device changes due to rolling over or other reasons. The sensing device for a bathtub, as shown in Fig. 2(c), uses a bath mat, which is divided into upper and lower layers. The lower layer is grooved to receive a silicon tube, and the upper layer is replaced on top. The edges of the bath mat are covered with waterproof rubber material to prevent water intrusion. The sensing device for a toilet, as shown in Fig. 2(d), uses two pieces of Styrofoam in which grooves are carved and silicon tubes are placed. These pieces are placed on either side of the toilet, and the cover as shown in Fig. 1 is substituted by the lowered toilet seat.

B. Experiment Method and Subjects

The sensing devices shown in Fig. 2 are arranged to measure the heartbeat and respiration signals. During the measurements, background noise equivalent to noise from the daily environment is applied, and the changes in S/N ratios of heartbeat and respiration signals to the changes in amplitude of the noise are measured.

The measurement conditions for the flooring, carried out on the sensing device shown in Fig. 2(a), require the subject to adopt three postures; dorsal position, sitting down, and dorsal position on a setup bed. The measurement conditions for the tatami mat, carried out on the sensing device shown in Fig. 2(b), require the subject to adopt two postures; dorsal position, and sitting down. The measurement conditions for the bathtub require the sensing device shown in Fig. 2(c) to be placed either on the upright surface of the tub (facing the back of the subject), or on the bottom surface of the tub (under the buttocks of the subject). The measurements are carried out with hot water filled to the height of 40 cm from the bottom of the tub. The measurements for the lavatory are carried out using a toilet mounted with the sensing device shown in Fig. 2(d), with the subject sitting on the lowered toilet seat.

Under each of the above conditions, the silicon tube is connected to a highly sensitive pressure sensor (Primo Company, Ltd.: S11-M2), as shown in Fig. 1, and heartbeat and respiration signals are separated by a bandpass filter. As the signals measured with a pneumatic method contain harmonic components of the heartbeat, the heartbeat components of 5–15 Hz, where the $\mathrm{S/N}$ ratio is relatively high among the harmonic components, is extracted using the bandpass filter. The extracted components then undergo full-wave rectification and envelope processing, and are output as the heartbeat signal. The respiration component is output after going through the bandpass filter of 0.1–0.5 Hz. Both the separated signals are input to a PC after A/D conversion at the sampling interval of 0.01 sec. A pulse oximeter is attached to an earlobe of the subject to obtain reference data for the heartbeat, and a strain gauge is attached to the abdomen and the diaphragm movements accompanying respiration are measured to obtain reference data for the respiration.

To reproduce daily-environment noise on the flooring, on the tatami mat, and in the lavatory, cyclical vibrations are generated by stepping on the ground at the distance of 2 m from each sensing device. The vibrations are conveyed to the device at four amplitudes, Levels 1–4, the smallest of which is the stepping from normal walking and the largest of which is as strong as footfalls from running. The amplitude of the vibration is measured using an acceleration sensor (Hitachi Metals, Ltd., RF-H48C-O) mounted to the sensing device, and the root-mean-square (RMS) of the output signals is determined to be the amplitude of the noise. To reproduce daily-environment noise in the bathtub, faucet water is poured into the bathtub. The speed of water inflow is controlled to 0, 50, 100, 150, and 200 ml/s.

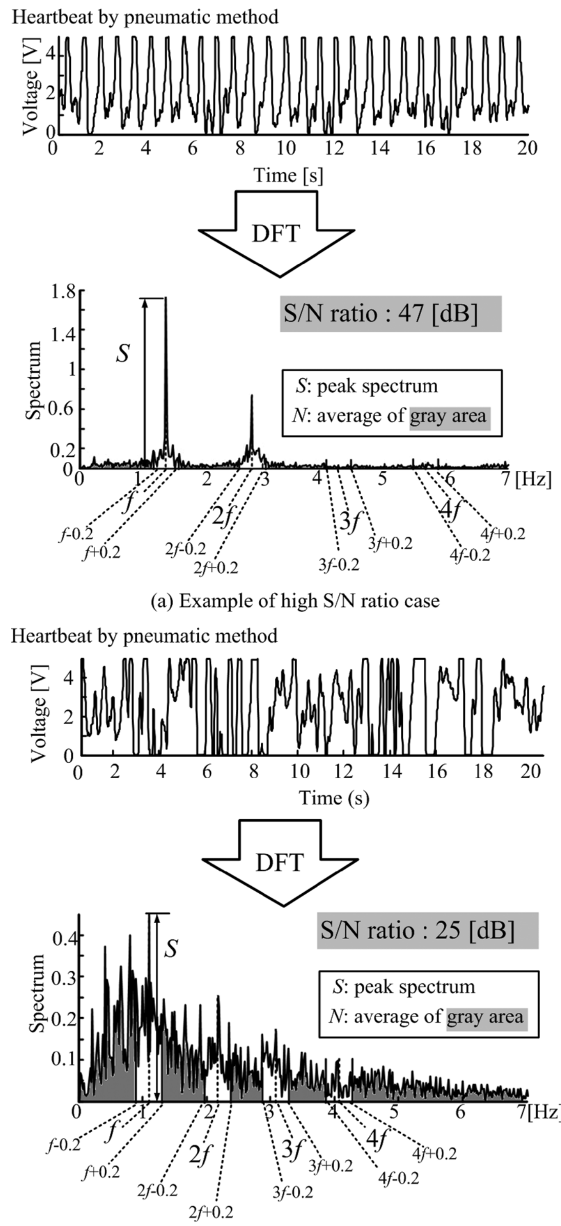
The subjects who participated in the experiments were three healthy males (average age 23 ± 0.2 years old, height 1.73 ± 0.03 m, and weight 72 ± 5.4 kg), and actual experiments were carried out after informed consent was obtained.

C. *Definition of* $\mathrm{S/N}$ *Ratio*

The reliability of the heartbeat and respiration signals is evaluated through their $\mathrm{S/N}$ ratios. In this paper, the signal "S" and the noise "N" are determined based on the frequency properties of the DFT-processed heartbeat and respiration signals measured for 20 s, as shown in Fig. 3, and the $\mathrm{S/N}$ ratios are shown in dB. The DFT is operated using MATLAB, a programming language created by MathWorks. Twenty seconds of data of heartbeat signal (measured with the pulse oximeter) and of respiration signal (measured with the strain gauge) are processed through DFT, and their frequencies with the peak spectrum are defined as "f." The heartbeat signals and respiration signals measured with the pneumatic method are then processed with DFT, and their values at "f" are defined as "S." The mean value of the frequency bands, except for ±0.2 Hz of the base frequency f, and its harmonic components $2f$, $3f$, and $4f$, is defined as noise "N," and the $\mathrm{S/N}$ ratio is defined as follows:

$$\mathrm{S/N\ ratio} = 20\log_{10}\left(\frac{\mathrm{S}}{\mathrm{N}}\right)\ [\mathrm{dB}].$$

As shown in Fig. 3(a), in case each beat of the heartbeat or the respiration can be confirmed with the pneumatic method as the noise is small, the value of S at f becomes large. Other frequency components, on the other hand, become small and N takes a small value. The $\mathrm{S/N}$ ratio thus becomes large. As shown in Fig. 3(b), in case the amount of noise is large the value of S at f becomes small and N takes a large value. The corresponding $\mathrm{S/N}$ ratio also becomes small, and the small $\mathrm{S/N}$ ratio enables the mean heart rate and the mean respiration rate during the 20 s to be read from the DFT peak frequencies. Each beat of the heartbeat and respiration signals, on the other hand, cannot be identified. Table I shows the information read from the heartbeat and respiration signals, and their corresponding ranges of $\mathrm{S/N}$ ratio for the case of air mattress bed sensing method [10]. For both the heartbeat and respiration signals, when the $\mathrm{S/N}$ ratio is 30 dB or more, each beat can be confirmed from the measured wave shapes. With the $\mathrm{S/N}$ ratio between 20 and 30 dB, accurate reading of each beat becomes difficult. However, by



(a) Example of high S/N ratio case

(b) Example of low S/N ratio case

Fig. 3. Definition of $\mathrm{S/N}$ ratio.

TABLE I
RELATION BETWEEN S/N RATIO AND INFORMATION OF HEARTBEAT, RESPIRATION SIGNALS MEASURED BY PNEUMATIC METHOD

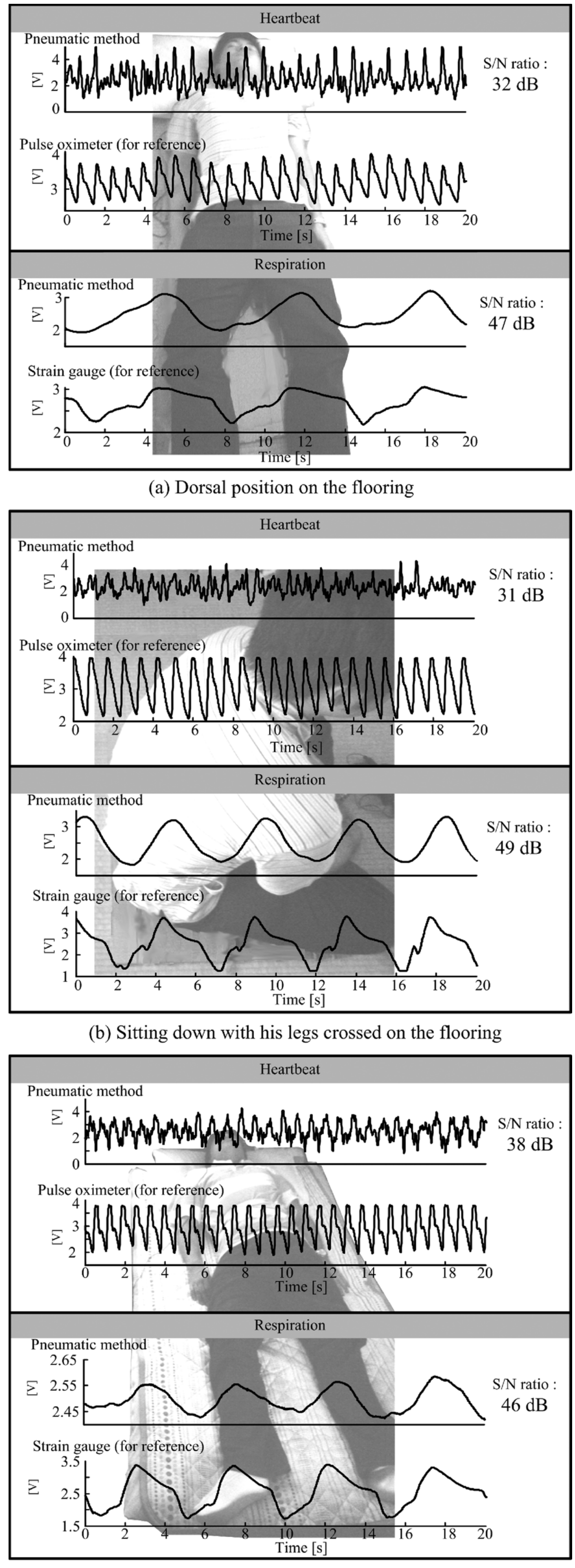
S/N ratio	Bio-information	
	Heartbeat	Respiration
Over 30 dB	R-R interval	Respiration interval
20dB-30dB	Heart rate	Respiration rate
0dB-20dB	None	None

partially reading the cycles, the mean heart rate for the 20 s can be obtained from the peak frequencies of the spectrum obtained from the DFT processing. When the $\mathrm{S/N}$ ratio becomes 20 dB or less, the noise component increases and it becomes difficult to identify the mean heart rate for the 20 s even with the spectrum peak frequencies through the DFT processing. These $\mathrm{S/N}$ ratios are calculated ten times for each subject under each of the stepping-vibration or water-inflow conditions used as background noise. The mean values and standard deviations of the ratios are then obtained.

IV. RESULTS

A. Flooring Environment

Fig. 4 shows the heartbeat and respiration signals measured for three postures, dorsal position, sitting down, and dorsal position on a setup bed, using the sensing device shown in Fig. 2(a), as well as the wave shapes of the signals measured by the pulse oximeter and by the strain gauge. The $\mathrm{S/N}$ ratio of the heartbeat signals obtained through the pneumatic method shown in Fig. 4(a) was 32 dB. The signal accompanied a noise component between 2 and 5 s, and the R-R interval was rather difficult to read, but the R-R interval was obtained for the rest of the period. The $\mathrm{S/N}$ ratio of the heartbeat signals obtained through the pneumatic method shown in Fig. 4(b) was 31 dB. Although the data partially corresponds with the reference data, the overall noise component is too large to read the R-R interval accurately. The peak frequencies after the DFT, however, correspond with the reference data, and the mean heart rate for the 20 s can be read. The $\mathrm{S/N}$ ratio of the heartbeat signals obtained through the pneumatic method shown in Fig. 4(c) was 38 dB, and the same R-R interval as the reference heartbeat signals can be confirmed. The respiration wave shapes, on the other hand, in Fig. 4(a)–(c) were 47, 49, and 46 dB, respectively, relatively higher than those of the heartbeat signals, thus synchronizing with the reference respiration signal. Fig. 5 shows the changes in the mean $\mathrm{S/N}$ ratios of heartbeat and respiration signals against the RMS of vibration noise. The overall $\mathrm{S/N}$ ratio of respiration signals is higher than that of heartbeat signals, and with the RMS of vibration noise under 0.3 $\mathrm{m/s^2}$, 0.5 $\mathrm{m/s^2}$, and 0.1 $\mathrm{m/s^2}$ for Fig. 5(a)–(c), respectively, the $\mathrm{S/N}$ ratios of both the heartbeat and respiration signals become 30 dB or more.

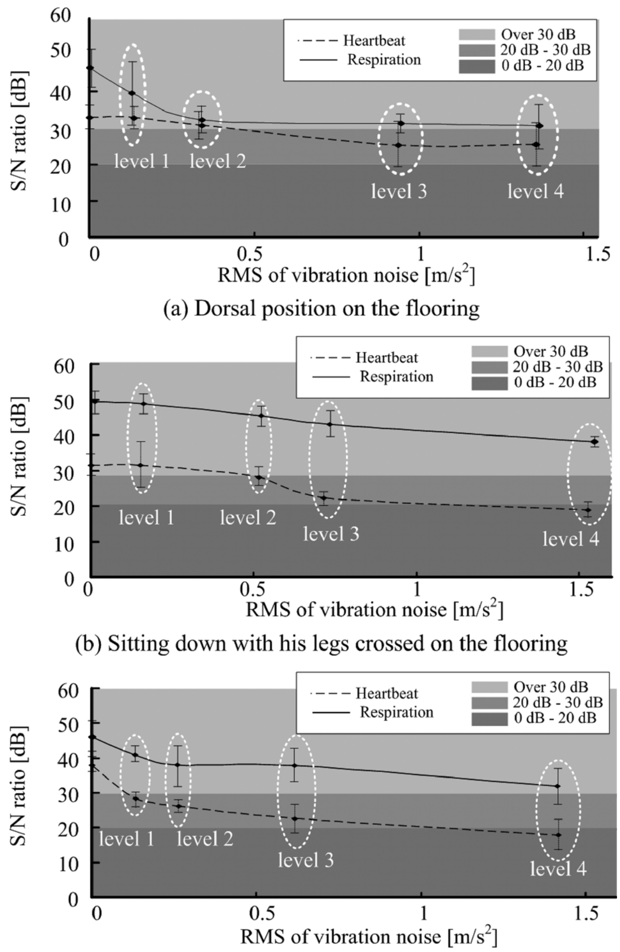


(a) Dorsal position on the flooring
(b) Sitting down with his legs crossed on the flooring
(c) Dorsal position on bed set upped on the flooring

Fig. 4. Heartbeat and respiration measured by sensing device for flooring.

B. Tatami Mat

Fig. 6 shows the heartbeat and respiration signals measured for two postures, dorsal position and sitting down, using the sensing device shown in Fig. 2(b), as well as the wave shapes of the signals measured by the pulse oximeter and by the strain gauge. With the dorsal position shown in Fig. 6(a), the $\mathrm{S/N}$ ratios of both the heartbeat and respiration signals are relatively high, with values of 41 dB and 45 dB respectively, and each beat of the signals can be read. With the sitting position as shown

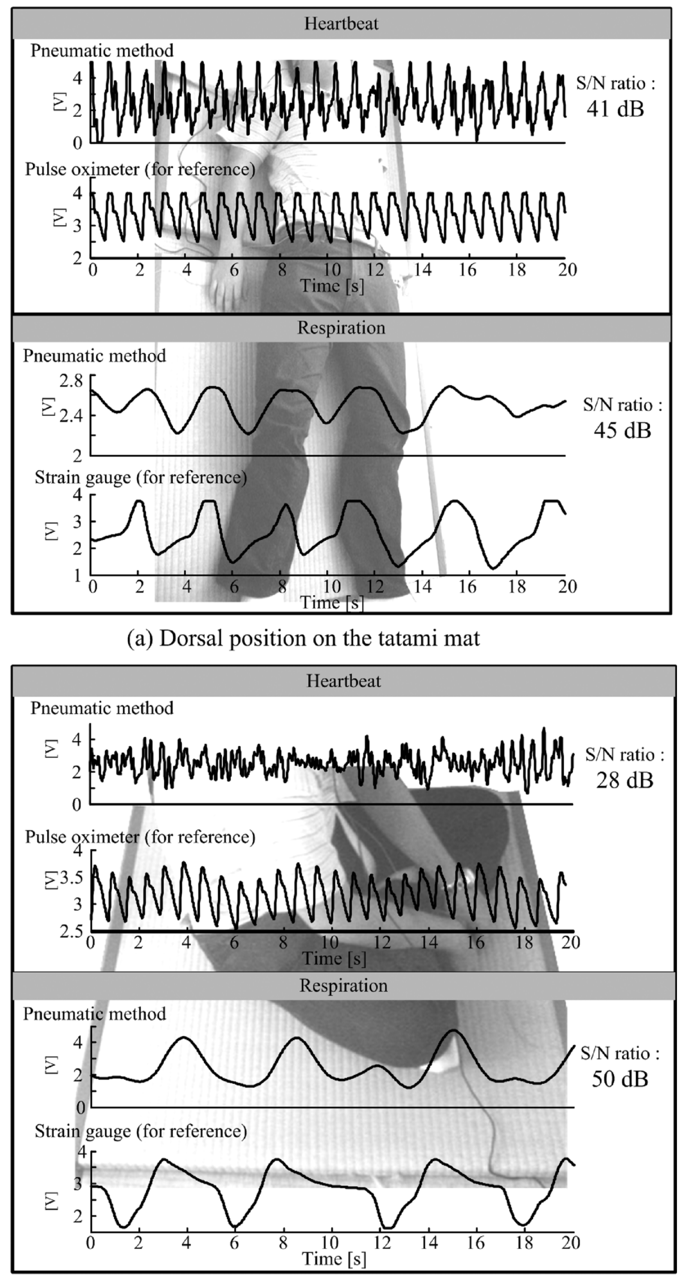


(a) Dorsal position on the flooring

(b) Sitting down with his legs crossed on the flooring

(c) Dorsal position on bed set upped on the flooring

Fig. 5. Relation with $\mathrm{S/N}$ ratio and background noise on the flooring.



(a) Dorsal position on the tatami mat

(b) Sitting down with his legs crossed on the tatami mat

Fig. 6. Heartbeat and respiration measured by sensing device for tatami mat.

in Fig. 6(b), the $\mathrm{S/N}$ ratio of respiration signals is rather high at 50 dB, but that of the heartbeat signals is low at 28 dB. This makes it difficult to read the R-R interval, but the mean heart rate can be read. As shown in Figs. 4(b) and 6(c), the $\mathrm{S/N}$ ratios of the respiration signals in the sitting position are rather high, but the $\mathrm{S/N}$ ratios of the heartbeat signals became lower than those measured in the dorsal position. Fig. 7 shows the changes in the mean $\mathrm{S/N}$ ratio of heartbeat and respiration signals to the RMS of vibration noise. With the dorsal position shown in Fig. 7(a), the $\mathrm{S/N}$ ratio of the heartbeat signals is higher than those shown in Fig. 5(a) and (b), and the $\mathrm{S/N}$ ratio becomes 30 dB or more when the RMS is 0.9 $\mathrm{m/s^2}$ or less. The overall $\mathrm{S/N}$ ratio of the heartbeat signals in the sitting position, however, as shown in Fig. 7(b), becomes rather low, and the ratio is less than 30 dB even without any noise. The $\mathrm{S/N}$ ratio of the respiration signals is high both in Fig. 7(a) and (b), with the value of 35 dB or more when the RMS of vibration noise is 0.15 or less in Fig. 7(b) and when the RMS is 0.25 or less in Fig. 7(b).

C. Bathtub

Fig. 8 shows the heartbeat and respiration signals measured for two conditions, with the device set facing the back of the subject and with the device set under the buttocks of the subject, using the sensing device shown in Fig. 2(c), as well as the wave shapes of the signals measured by the pulse oximeter and by the strain gauge. With regard to the heartbeat signals, the $\mathrm{S/N}$ ratios for both these conditions, with the device set either on the back [Fig. 8(a)] or below the subject [Fig. 8(b)], were close to each other; 35 and 36 dB, respectively. The amplitudes of the wave shapes were larger for the measurements with the device below the subject than on the back, due to the weight acting on the device. The $\mathrm{S/N}$ ratios for the respiration signals were 46 dB for both, rather higher than those measured for the flooring and tatami mat. Fig. 9 shows the changes in the mean $\mathrm{S/N}$ ratios of heartbeat and respiration signals to the speed of water inflow into the bathtub. The $\mathrm{S/N}$ ratios of both the heartbeat and respiration signals were 39 dB or more when the water inflow speed was 100 ml/s, for both the measurements with the device set on the back [Fig. 9(a)] or below [Fig. 9(b)] the subject. With regard to the measurement with the device on the back

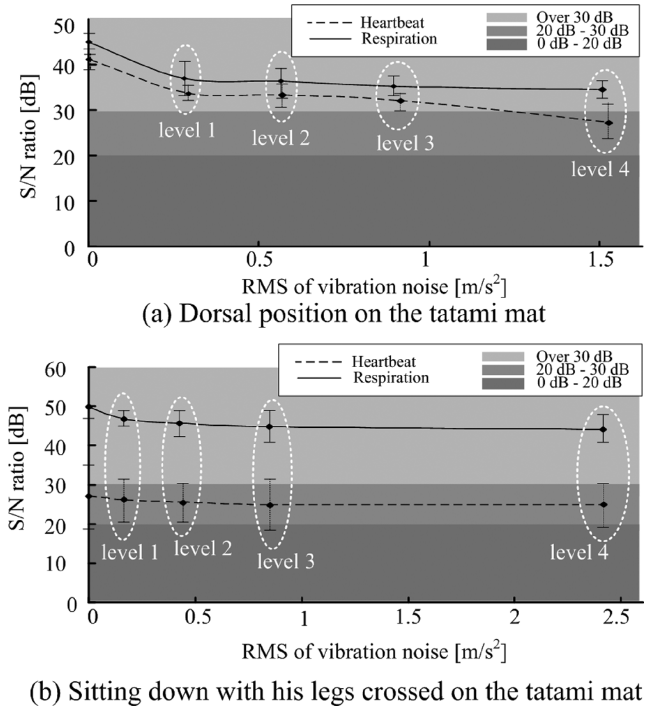


Fig. 7. Relation with SN ratio and background noise on the tatami mat.

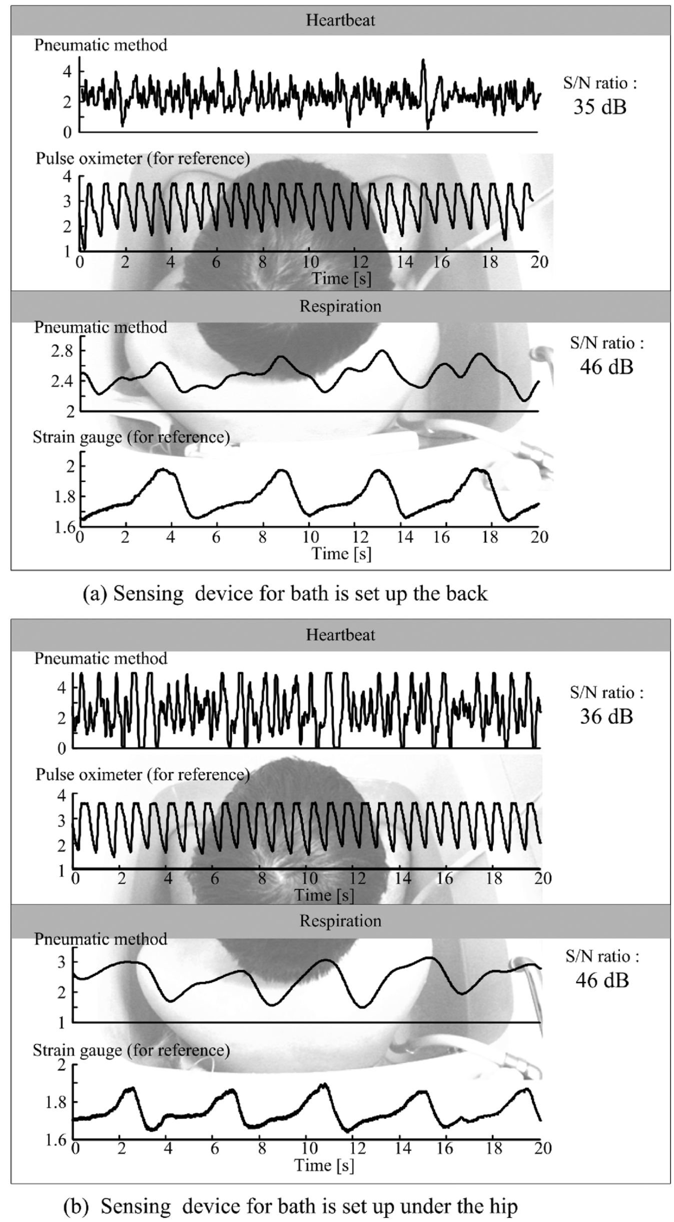


Fig. 8. Heartbeat and respiration measured by sensing device for bath.

of the subject [Fig. 9(a)], the $\mathrm{S/N}$ ratio of respiration signals decreased as the water inflow speed increased. The measurement with the device under the subject [Fig. 9(b)], on the other hand, resulted in the fixed mean $\mathrm{S/N}$ ratio of 45 dB for water inflow speeds of 100 ml/s or less. These results were considered to be caused by the fact that the device under the subject was less susceptible to the inflow of water than the device behind, since it is placed deeper under the water surface.

D. Toilet

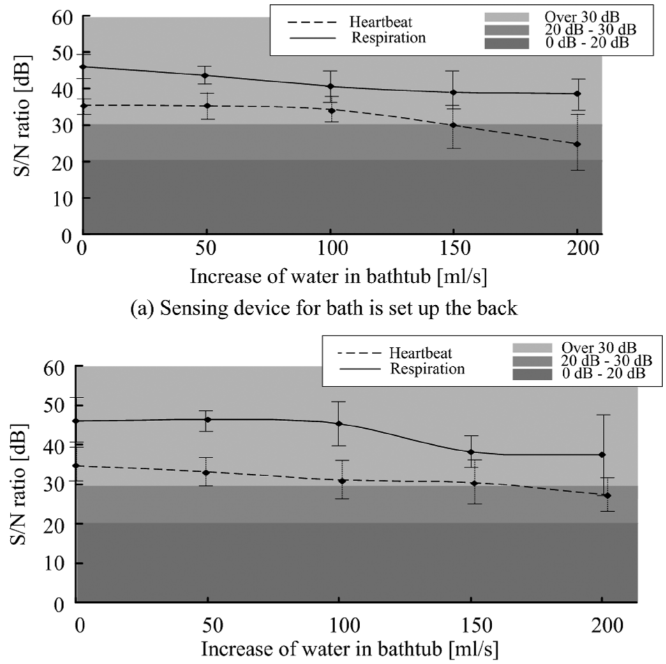
Fig. 10 shows the heartbeat and respiration signals measured using the sensing device shown in Fig. 2(d), as well as the wave shapes of the signals measured by the pulse oximeter and by the strain gauge. The $\mathrm{S/N}$ ratio of heartbeat signals shown in Fig. 10 is high at 40 dB, and the R-R intervals that correspond to the reference data can be confirmed although the signals partially contain small amplitudes. The $\mathrm{S/N}$ ratio of the respiration signals is also high at 48 dB, and each beat of the respiration can be confirmed. Fig. 11 shows the changes in the $\mathrm{S/N}$ ratios of heartbeat and respiration signals to the RMS of vibration noise. The $\mathrm{S/N}$ ratios of both the heartbeat and respiration signals become 30 dB or more when the RMS of vibration noise is $0.1\mathrm{m/s}^2$ or less. The $\mathrm{S/N}$ ratio of respiration signals has more tolerance to vibration than heartbeat signals: its value remains at around 50 dB, and the value only slightly decreases even with the RMS near 0.2 $\mathrm{m/s}^2$.

V. Discussion

Silicon tubes were used for the sensing devices for the method proposed in this paper. Tubes made of polyvinyl-chloride and some other materials, which have higher elasticity than a silicon tube, are considered to be susceptible to plastic strain under long-term use, and the sensitivity of the tubes degrades. A tube made from silicon or other material with less elasticity, therefore, is considered more appropriate for long-term monitoring.

With regard to the length and layout of the silicon tube, a comparison among the sensing devices with tubes of different length, layout, and degree of concentration, as in Fig. 2(a) and (b), did not show large differences in the $\mathrm{S/N}$ ratios, as shown in Figs. 5 and 7. It is therefore considered that the length, layout, and degree of concentration of the silicon tube do not largely affect the sensitivity.

With regard to the thickness of the silicon tube, the sensitivity is not largely affected provided the depth of the groove is adjusted to half the diameter of the tube and the space to convey the air pressure is maintained as shown Fig. 1. With regard to the sensing device for the flooring environment, as shown in Fig. 2(a), the type and the layout of the spacers are thought to have no effect on the tube's sensitivity, as long as the spacers



(a) Sensing device for bath is set up the back

(b) Sensing device for bath is set up under the hip

Fig. 9. Relation with SN ratio and background noise in the bathtub.

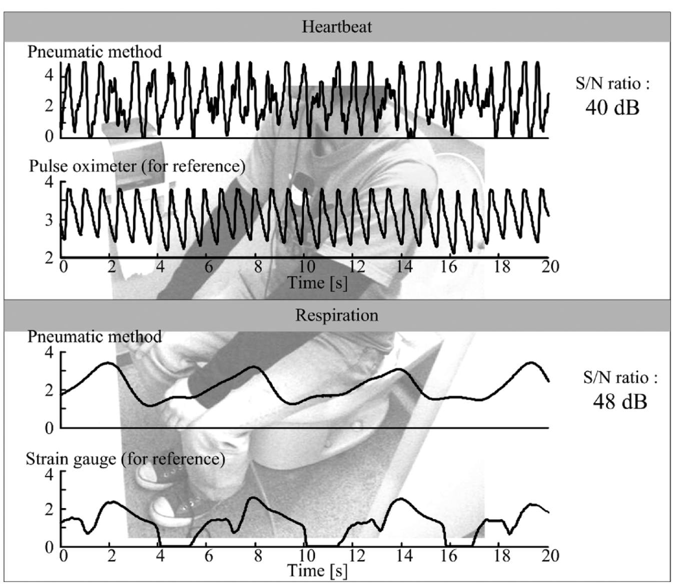


Fig. 10. Heartbeat and respiration measured by sensing device for toilet.

are made from materials hard enough to sustain a plywood board and their heights are around half the diameter of the silicon tube.

With regard to the experiments using the sensing devices shown in Fig. 2(a) and (b), the $\mathrm{S/N}$ ratio is thought to decrease when two or more subjects are on the sensing device or when a dog, cat, or other pet is on the device with the subject, because the heartbeat and respiration components of more than one subject overlap in the measurement.

For the measurements on the flooring, on the tatami mat, and in the lavatory, vibration from cyclical stepping on the ground was used as background noise. As a result, the period of vibration can occasionally be close to the basic period of heartbeat.

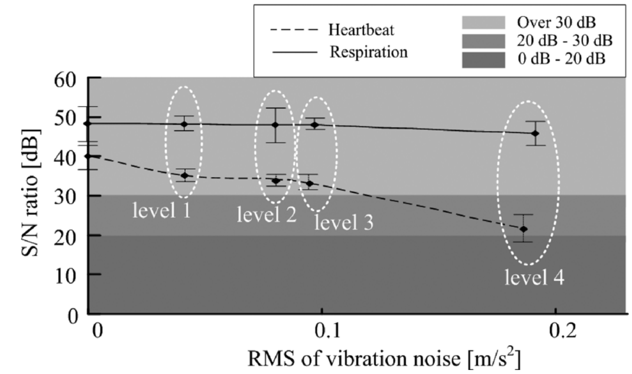


Fig. 11. Relation with $\mathrm{S/N}$ ratio and background noise on the toilet.

The heartbeat component, therefore, was extracted by the band-pass filter for the harmonic components between 5 and 15 Hz, and the degradation of sensitivity caused by the vibration close to the basic cycle of heartbeat, was alleviated. If the amplitude of the vibration becomes too large, the components between 5 and 15 Hz within the vibration also become large. The $\mathrm{S/N}$ ratio of the heartbeat signals therefore decreases as shown in Figs. 5, 7, and 11.

The reasons why the respiration signals measured through this system showed higher $\mathrm{S/N}$ ratios than the heartbeat signals are considered to be: 1) the mechanical impedance and characteristic frequency of the sensing devices were close to the frequency of the respiration signals and 2) the respiration signals were extracted using a bandpass filter with the bandwidth of 0.1 to 0.5 Hz, which is lower than the vibration frequencies of cyclical stepping on the ground.

With regard to Fig. 7(b), the RMS of the largest vibration noise at Level 4 was 2.5 $\mathrm{m/s^2}$, about 1 $\mathrm{m/s^2}$ larger than the values in Figs. 5(a)–(c) and 7(a). The difference was caused by large fluctuations of the vibration noise from stepping on the ground. The sensing device for measuring the data in Fig. 11 was distant from the ground, as shown in Fig. 2(d), and the vibration noise from stepping on the ground had already decreased when the device detected the noise. Therefore, the overall RMS of vibration noise was smaller in Fig. 11 than those in Figs. 5 and 7.

Regarding background noise, few reports have performed a quantitative evaluation such as the $\mathrm{S/N}$ ratio defined in this paper; most papers are qualitative such as "robust to environmental noises"[9], [10]. We confirmed robustness against background noise by applying large artificial vibration noises which seldom happen in daily life.

Finally, we describe here the feasibility of the system using a silicon rubber tube in terms of long-term durability, maintenance and cost. Regarding long-term durability and maintenance, we carried out experiments for one and a half years using the air mattress and experiments for six months using the silicone rubber tube for monitoring sleep. Both of them worked well for the period without any malfunction, but the air mattress required the air to be refilled once a week, whereas the silicone rubber tube did not require refilling. The system using a silicon rubber tube was reliable and completely maintenance free. Although it is difficult to estimate the cost of the system, the cost of the air mattress or silicon rubber tube is generally less than that of a pressure sensor or signal processing unit, accounting for less than 1 or 2 percent of the total system cost. Further, to manufacture air mattresses for different purposes, we need to develop different metal molds, which are expensive. In contrast, even if silicon rubber material is expensive, we can use commercially available silicon rubber tube with simple devices. The consumer price of the silicon tube used in our experiment was 2.3 $/m and a 2-m silicon tube is long enough for a floor area of 2000×1000 mm, which would cost just $4.6. In contrast, even when ordering ten polyvinyl chloride air mattresses each measuring 450×900 mm, the cost of one air mattress is about $200, including the cost of the metal mold. Thus the initial fixed cost when using silicon rubber might be less than when using an air mattress. Furthermore, the running cost when using silicon tube is lower because no maintenance or maintenance fee is required.

VI. Conclusion

In this paper, a pneumatic method using an air tube made of the silicon rubber was proposed as a sensing device to measure human heartbeat and respiration at home. In this method, sensing devices for flooring, tatami mat, bathtub, and toilet were made to measure the heartbeat and respiration under each environment. As background noise in the room with flooring, in the tatami mat room, and in the lavatory, vibration noise from stepping on the ground of about 0.1 $\mathrm{m/s^2}$ to 1.5 $\mathrm{m/s^2}$ was generated for measuring the heartbeat and respiration signals and for comparing their $\mathrm{S/N}$ ratios. As background noise in the bathtub, water inflow of 50 ml/s, 100 ml/s, 150 ml/s, and 200 ml/s was applied for measuring the heartbeat and respiration signals and for comparing their $\mathrm{S/N}$ ratios. When the $\mathrm{S/N}$ ratio was more than 30 dB, each beat of the heartbeat and the respiration signals was read from the measured wave shapes. When the $\mathrm{S/N}$ ratio was less than 30 dB, on the other hand, the mean cycle was read through the DFT procedure, but each beat of the signals was hard to obtain. With regard to the measurements on the flooring and in the lavatory, the $\mathrm{S/N}$ ratios could be measured at around 30 dB and each beat of both the heartbeat and the respiration signals could also be confirmed from the wave shape, if the vibration noise was 0.1 $\mathrm{m/s^2}$ (equivalent to walking with normal steps) or less. With regard to the measurements on the tatami mat and in the bathtub, the same results were obtained: if the vibration noise was 0.9 $\mathrm{m/s^2}$ (equivalent to walking with somewhat heavier steps) or less for the tatami mat, and if the speed of the water inflow was 100 ml/s or less for the bathtub.

Further verification with long-term collection of data from more subjects, however, is required in future research.

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