

Design of Seat Mounted ECG Sensor System for Vehicle Application

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ABSTRACT

The causes of deaths in traffic accidents are predominantly human factors such as careless or “heedlessness” driving; recently, accidents that are believed to be due to deteriorated physical conditions, such as heart attacks, have been reported. Non-contact electrocardiography (ECG) monitor for continuous ECG detection while driving is needed to reduce a number of fatal accident by human error like this. Recently there are a lot of papers to detect cardiac electricity using capacitance coupling between human body and electrode. This sensor system must be adopted appropriate high input impedance circuit and noise reduction technique as a function of source impedance value especially for a seat mounted sensor.

We investigated the impedances of the intermediary materials such as a seat cover and clothing for installing vehicle use by dielectrics measurement system can measure extra-high impedance (100TΩ), and designed an effective circuit configuration for common noise resistance, considering the effect of the sitting posture according to their results. The sensor system employed the DRL (Driven Right Leg) circuit is composed of two sensor head mounted into the seat cover and an electrode mounted on a steering wheel for reducing well common mode noise in cardiac electricity frequency.

We have succeeded in attaining stable detection of cardiac electrical impulses during two driving conditions, stable driving at the average speed of 70km/h and driving with frequent changes at the speed of 0-30km/h, operations of the accelerator, brake, steering wheel, and direction indicator.

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INTRODUCTION

Recently, the development of automobile-related infrastructures and the widespread use of automobile safety devices are reducing serious accidents, particularly those involving fatalities. The number has still kept at high level, however, and it is reported that the major causes of these accidents were human factors with drivers who drove carelessly or without full attention [1]. In addition, accidents for which poor physical health, such as heart attacks, were suspected to be causes have been reported recently [2]. It is feared that, in addition to careless driving, accidents due to poor physical health might occur more frequently as the aging population increases.

To address this problem by providing a more sophisticated driving aid, we are making efforts to build a system that is capable of estimating the state of attention and the physical condition of the driver on the basis of information on his or her body and on signals from the vehicle, with the aim of the provision of appropriate information and managing the control of operations.

As means of estimating the condition of a driver and vehicle, the use of biological signals, such as brain waves, heart rate, skin conductance, respiration, and blinking frequency, are used, alongside specific vehicle signals, such as vehicle speed and steering angles, have been studied. In our study, we have identified cardiac electrical impulses that allow us to estimate the state of attention and the physical state and serves as a useful index of autonomic nervous activities. Ordinary methods of placing electrodes directly on the human body or grasping the heart electrodes with both hands to detect cardiac electricity cannot be utilized because they obviously pose a hindrance to driving. With these drawbacks in mind, we attempted to develop a sensor built into the seat with the aim of creating a system allowing one to measure cardiac electricity continuously and without making the subject conscious of being measured. (Figure 1) The measurement of cardiac electricity by means of this sensor may be characterized by the presence of intermediaries, such as the seat and clothing between the driver (heart) and the sensor, which forms a high insulation resistance, the variation in the characteristics of the resistance as a result of the

difference in the physique between drivers and in the seating posture. These factors amplify the effect of noise superimposed on the cardiac signals. It is anticipated that noise due to static electricity charged over the entire body of the driver and airborne noise will fluctuate greatly as the driver performs accelerator pedal operations and so forth during driving. This common mode noise superimposed over the entire human body varies in its effect depending on the characteristics between the driver and the sensor, with the effect being superimposed on cardiac electricity signals. This is random noise, and their frequency zones coincide with the cardiac electricity frequency zones, making it difficult to separate the frequencies one from another.

With these problems in the background to this study, we first determined the impedances between the human-body-to-sensor intermediary materials in the working environment, such as the seat and clothing, building a circuit scheme less susceptible to noise due to static electricity charged over the human body (common mode noise) with the hope of realizing a workable sensor system. Lastly, with a sensor system equipped with these inventions installed in an experimental vehicle, we assessed the performance of cardiac electricity detection during an actual run.

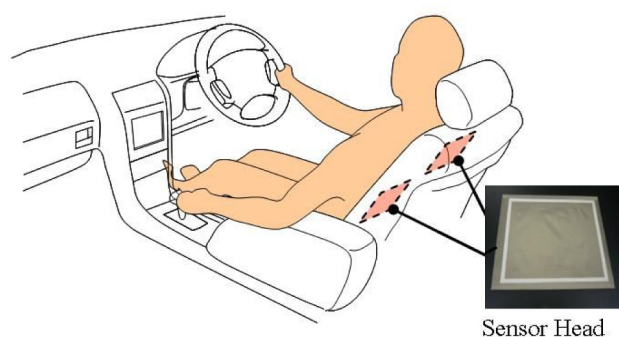


Figure 1. Image of the sensor in place.

MEASUREMENT OF THE SEAT AND CLOTHING

Methods

With the sensor built into the seat and located directly below the seat surface, the intermediary materials between the human body and the sensor are the seat surface and the driver's clothing; for this reason, the impedance was measured using a leather sheet, T-shirt, shirt, and a jacket this time. With T-shirt and shirt made of cotton or polyester, the measurement was conducted on a 100%-cotton and a 100%-polyester T-shirt and a 100%-cotton and a 100%-polyester shirt.

A dielectrics measurement system with an impedance measuring range up to 100 TΩ was used. Samples of leather, T-shirts, shirts and a jacket were each put between the upper and the lower copper electrode sample holder with a diameter of 40 mm (Figure 2), and sweep measurement was conducted

on the samples with a measured potential amplitude of 1 V and a measured frequency range between 1 mHz and 1 MHz. Guard electrodes were installed around the lower electrode on the sample holder to prevent leakage currents from occurring. With the distance between the upper and the lower electrode adjustable using a micrometer, the sample thickness can be controlled also. This allows the impedance to be measured accurately using this measuring system.

With measurements conducted in a low humidity environment of a room temperature of 25°C and a relative humidity (RH) of 38%, humidity affects the impedance characteristic greatly. For this reason, the sample holders were placed in a thermo-hygrostat so that measurements could be conducted at 50% RH and at 70% RH (both under a temperature of 25°C).

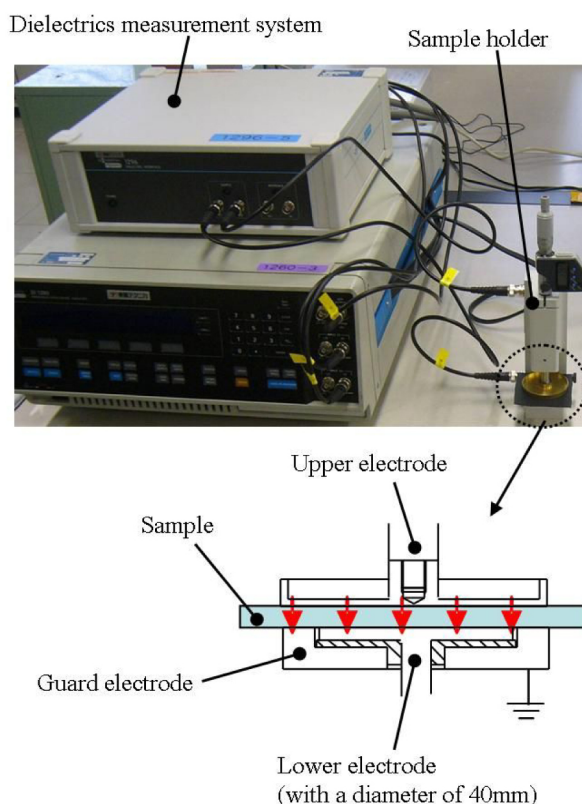


Figure 2. measurement system

Results

We obtained an equivalent circuit by plotting the $|Z|$ values and the θ values between 1 mHz and 1 MHz obtained through the measurement on a Nyquist diagram (x axis: real part, y axis: imaginary part). Figure 3 shows a typical Nyquist plot at 38% RH for a leather and a T-shirt (cotton) sample. Since the plot defines a semi-circle beginning with the origin as shown in Figure 3, the equivalent circuit was a parallel CR circuit, and we calculated the C and R values on the basis of the plot. From the fact that a semi-circle was drawn on all other samples, we confirmed that parallel CR circuits represent the equivalent ones. Table 1 shows the C and R

values in the equivalent circuits for all measured samples. In all samples, the R components exceed $G\Omega$, which is a very large value, and in particular, it was in order of $T\Omega$ for the polyester material.

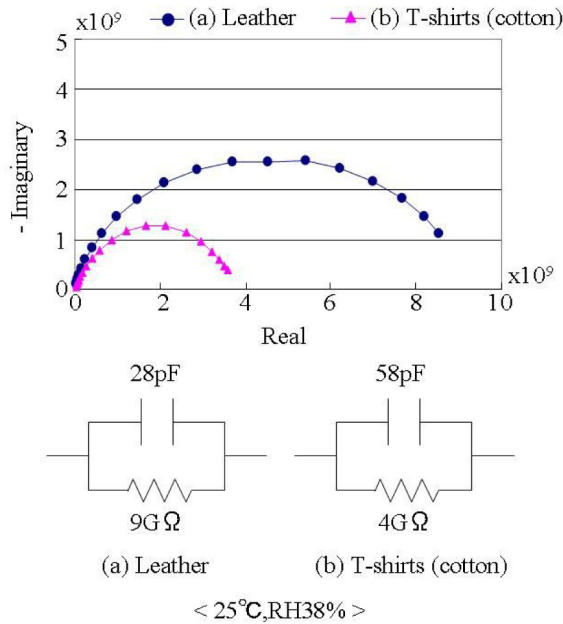


Figure 3. Example of Nyquist Plot and Equivalent circuit (25°C,RH38%)

Table 1. C and R values of Equivalent circuit (25°C,RH38%)

< 25°C,RH38% ; electrode size ϕ 40mm >

sample	thickness (mm)	C (pF)	R (GΩ)
Leather	1.3	28	9
T-Shirt (Cotton)	0.47	58	4
T-Shirt (Poly)	0.57	33	1,200
Shirt (Cotton)	0.24	97	41
Shirt (Poly)	0.31	66	6,000
Jacket (Wool,Poly)	0.79	26	600

Next, a description of the effect of humidity on the thermo-hygrostat is given. Figure 4 shows the Nyquist plots and equivalent circuits at 38% RH and at 70% RH for a leather material. Figure 5 shows the same for a T-shirt (cotton). It was confirmed that, although the equivalent circuit is represented by a parallel CR circuit for each sample at a high humidity also, the capacitive semi-circle becomes smaller with the C and R values changed. The R-component decreased from 9 GΩ to 3 GΩ in the leather material, while it significantly decreased from 4 GΩ to 800 kΩ in the T-shirt (cotton). This is considered to be due to the extremely high hygroscopicity of the T-shirt (cotton) compared with that of the leather material. Figure 6 shows the results of measurement of impedance of individual samples (15 Hz) at different values of relative humidity. It was confirmed, as

shown in Figure 6, that the impedance lowers as the humidity rises, although the rate of change varies depending on the material. It was also confirmed, as described above, that the polyester material exhibits higher impedance than the cotton material in the T-shirt and the shirt.

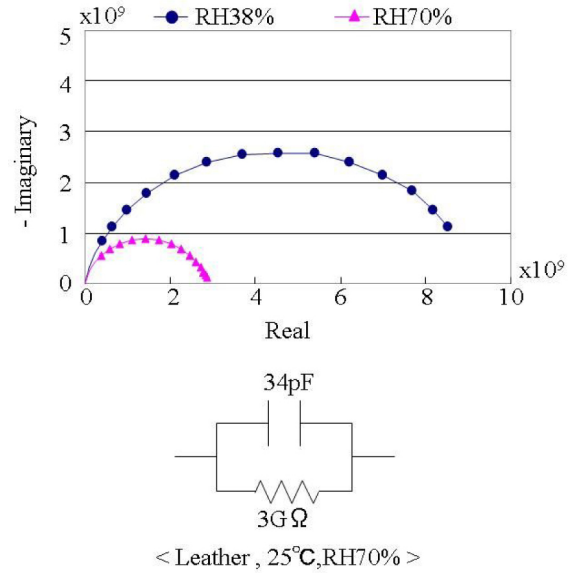


Figure 4. Nyquist Plot and Equivalent circuit of Leather (25°C,RH70%)

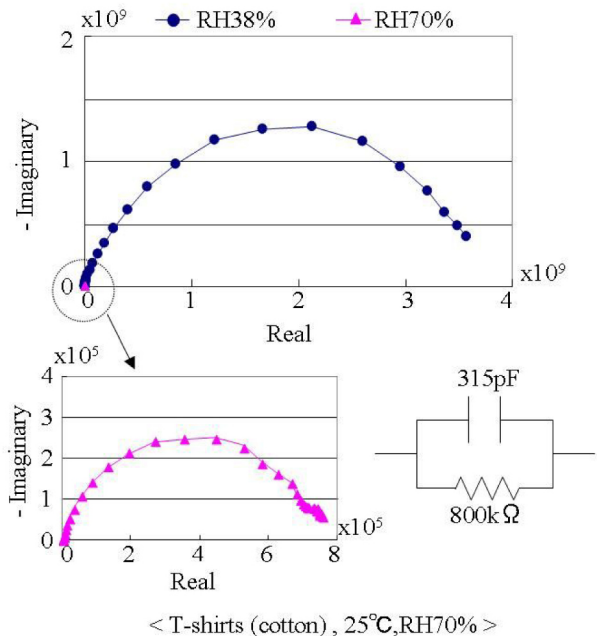


Figure 5. Nyquist Plot and Equivalent circuit of T-shirt (cotton) (25°C,RH70%)