Journal of Electrostatics 71 (2013) 524–528

Contents lists available at SciVerse ScienceDirect

Journal of Electrostatics

journal homepage: www.elsevier.com/locate/elstat

Spectrum analysis of induction voltage from walking human body

Tamae Mizuno [1], Kazunori Takashima, Akira Mizuno*

Department of Environmental and Life Sciences, Toyohashi University of Technology, 1-1 Hibarigaoka, Tenpaku-cho, Toyohashi 441-8580, Japan

ARTICLE INFO

Article history:
Received 1 September 2012
Received in revised form
16 November 2012
Accepted 9 December 2012
Available online 21 December 2012

Keywords:
Personal identification
Human body potential
Induction voltage
Walking

ABSTRACT

Human body is charged during walking. Continuous monitoring of the body potential has been made using an induction electrode set on ceiling of a room. The body voltage estimated from the induced voltage was a few hundred volts and dependent on material of shoes, as expected. The induced voltage varied periodically while walking and the waveform was different depending on examinees or manner of walking, even the same footwear was used. In this study, spectrum analysis was made on the acquired voltage, and frequency component was compared. The voltage spectrum of 4 different persons, and 3 different walking patterns of one person were obtained, and their correlation was compared. The results indicate that the spectrum was different depending on the examinees. Among the tested 4 examinees, personal identification was possible using the correlation of the induced voltage while walking. This novel contactless body potential monitoring method can be applied to many new fields such as medical practice and food factory.

1. Introduction

It is well known that human body is electrostatically charged while walking. From the point of view of electrostatic hazards prevention, human body potential should be controlled. Therefore, monitoring of the potential is necessary in various fields such as semiconductor device factory, handling of inflammable gas or liquid, use of ESD-sensitive electronic devices and so on. Body potential sometimes exceeds 10 kV, and these high voltages should enhance attraction and attachment of suspended particles in air, including bacteria and viruses. Therefore it is important to keep the human potential below a certain level in the fields of medical practice, food industry and so on.

Human body potential is normally measured by using a direct method, in which human body is connected to a plate electrode and potential of the electrode is measured by a surface potential meter [1,2]. Practically, more simple method should be developed for high speed and high throughput monitoring. In this paper, a novel body potential monitoring method employing continuous measurement of induction voltage is presented. This method has the advantages that no contact to the body is required and that highly charged objects can be measured without failure of the measurement device, which is normally ESD-sensitive too.

Our contactless body potential measuring method can be used as a sensor to detect people because human body is normally charged. When someone walks, periodical fluctuation of the body potential is observed, because capacitance between human body and floor changes periodically [3]. The body potential is sensitive to the motion of feet, especially the gap between a foot and ground, since the body voltage $V = Q/C$ (Q: the amount of charge on the body, C: capacitance between the body and the ground). By utilizing this phenomenon, personal identification by monitoring body potential could be possible if the periodical potential change is highly dependent on people. For this, our potential monitoring method should be examined to see if it can be used to acquire feasible data while walking and how it differs depending on people.

In this study, time-change of the induction voltage during the passage in front of the sensor was measured by our contactless measurement system. Frequency spectrum analysis was made on the data to extract examinee-dependent characteristics.

2. Experimental apparatus

The human body potential was measured using induced voltage to a metal electrode set apart from the body [4]. Schematic illustration of the measurement system is shown in Fig. 1. A metal mesh of 120 cm × 90 cm was supported by insulators on ceiling of a laboratory. An electrometer (Keithley 6514) having input impedance high enough was used to measure the induced voltage of the metal mesh. Signal of a monitor output of the electrometer passed through a low pass filter (time constant: 0.1 s) to attenuate

* Corresponding author. Fax: +81 532 44 6904.
E-mail address: mizuno@ens.tut.ac.jp (A. Mizuno).
[1] On leave from Kyokuryo-High School, Dekimachi 3-6-2, Higashiku, Nagoya 461-8654, Japan.

0304-3886/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.elstat.2012.12.012

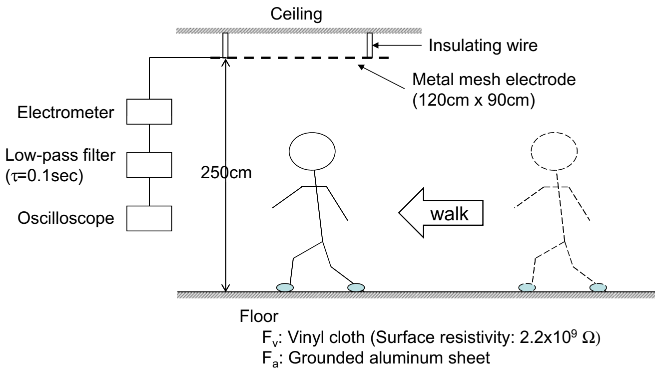

Fig. 1. Measurement of induction voltage of human body during walking.

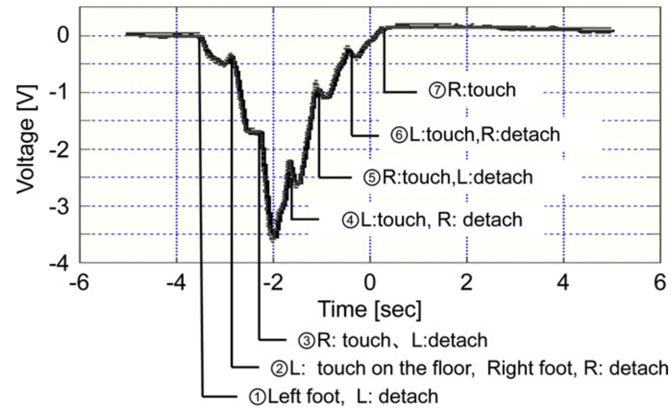

Fig. 3. Induction voltage of human body walking under the metal mesh electrode (F_v: vinyl cloth floor, slipper with rubber sole).

electro-magnetic noise from commercial power line and recorded by an oscilloscope. The floor of the laboratory was covered with vinyl cloth for floor finishing (Denoted as F_v). Surface resistivity of the floor was about 2.2 G-ohm or comparison, grounded aluminum foil was used to cover the floor (Denoted as F_a). 8 different footwear including sneakers, sandals, slippers, and Japanese traditional footwear made of wood (Geta) was used. And walking in barefoot was also examined.

3. Experimental results

3.1. Calibration of the measured induced voltage

Under the mesh electrode, a human stood motionless and 10 or 20 V dc voltage was applied to the human body periodically. The induction voltage appeared due to this dc voltage application, as shown in Fig. 2. This ratio is determined by the capacitances between the electrode and ground, and the human body and the electrode. In this experimental condition, the human voltage was about 250 times of the measured induced voltage at the mesh electrode.

3.2. The induction voltage

Fig. 3 shows an example of the time course of the induction voltage due to charged human body during walking. The floor F_v, and the rubber slippers (sole is made of rubber) were used. When the examinee approached toward the metal mesh electrode, the induction voltage appeared. 1 When Left foot (L) detached the floor, the induction voltage increased. 2 L touched on the floor, the voltage decreased slightly, then Right foot detached the floor and the voltage increased (between 2 and 3). The maximum voltage appeared when the human body was just under the center of the electrode, and one foot (L) detached from the floor (between 3 and 4). Peak voltage was −3.6 V, which corresponded to about −900 V of the human body potential.

Fig. 4 shows example of the induced voltage with different footwears. Fig. 4(1) is the same as Fig. 3 for comparison with other conditions. F_v and F_a denotes that the test was made on the vinyl cloth floor and on a grounded aluminum sheet, respectively. In (1)–F_a, the maximum voltage observed is −3.0 V. The results indicate that, even floor was conductive and grounded, human body can be charged with the rubber slippers on. Fig. 4(2) shows the induction voltage with barefoot. Both F_v and F_a shows lower voltage of less than 0.1 V. Fig. 4(3) shows the induction voltage when the shoes made of wood (Geta) was used. The voltage was nearly same as that of barefoot and lower than that of rubber sandal.

Fig. 5 shows difference of the pattern. These data were obtained when two different persons walked in their own manner. Although the same floor and the same slipper with rubber sole were used, results (1) and (2) were different. This could be due to the difference in walking manner. These results show that induction voltage varied depending on both the amount of charge on the examinee and the examinee's manner of walking. The former affects the intensity of the signal and the latter time course. In order to separate the effect of materials of shoes, floor, humidity and so on, personal identification should be examined on the basis of analysis in frequency domain.

3.3. Spectrum analysis of the voltage

Fourier transform was made on the measured waveform of the induction voltages to extract person-dependent characteristics. Induction voltage of 4 examinees (A, B, C and D) was measured.

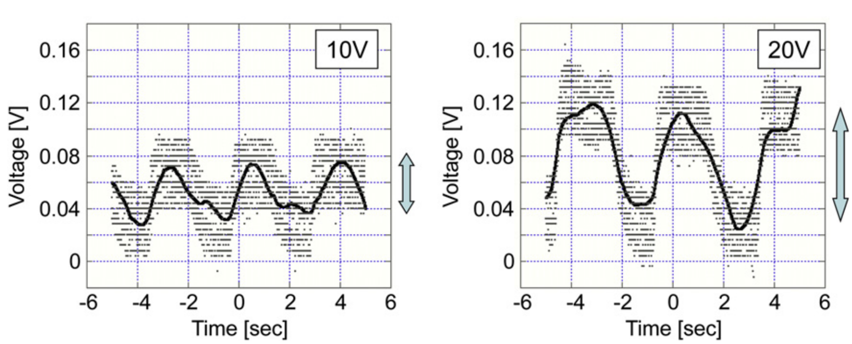

Fig. 2. Calibration of the measuring system.