Measurement 51 (2014) 206–213

Contents lists available at ScienceDirect

Measurement

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

Noise analysis for intra-body communication based on parasitic capacitance measurement

Mitsuru Shinagawa [a,*], Jun Katsuyama [a], Kazuki Matsumoto [a], Shinya Hasegawa [a], Ryo Sugiyama [a], Yuichi Kado [b]

[a] Faculty of Science and Engineering, Hosei University, 3-7-2, Kajino-cho, Koganei-shi, Tokyo 184-8584, Japan
[b] Kyoto Institute of Technology, Matsugasaki, Sakyo-ku, Kyoto 606-8585, Japan

ARTICLE INFO

Article history:
Received 23 November 2013
Received in revised form 6 February 2014
Accepted 11 February 2014
Available online 21 February 2014

Keywords:
Intra-body communication
Parasitic capacitance
Impedance balance
Common-mode noise
Human interface
Ubiquitous computing

ABSTRACT

This paper describes noise transmission analysis for near-field intra-body communication systems based on parasitic capacitance measurement around the human body. Intra-body communication systems use the human body as the signal transmission medium. In communication systems of this type, the transmission line's impedance balance between the signal line and the ground line is extremely degraded by human body contact. Such systems are affected by large common-mode noise from various kinds of electronic equipment in living spaces, such as lighting devices, air conditioners, liquid crystal televisions, and refrigerators. Impedance balance deteriorates as a result of adding parasitic impedance to the transmission lines. Changes in the impedance balance are estimated by measuring parasitic capacitance in the human body, transmission lines, electrodes, and floor ground. It was verified that impedance balance between the signal line and the ground line is related to the noise power of a near-field intra-body communication system. It was found that connecting a compensative electrode or a compact capacitor to a ground node is an effective way to improve impedance balance and reduce common-mode noise.

1. Introduction

The concept of intra-body communication [1–5] has been investigated for developing useful ubiquitous computing services [6]. The concept uses the human body as the signal transmission medium, whereby communication data is transmitted and received using an induced electric near-field around the human body. Connection to a network can be achieved through natural actions such as touching a poster or stepping on a floor mat, providing intuitive interfaces between humans and computers. For example, the simple act of touching a doorknob can enable a secure entrance system to authenticate identification data and unlock the door [7]. A walk-through gate and navigation system using intra-body communication has been developed for railroad ticketing applications [8]. Electromagnetic field analyses of intra-body communication devices [9–11] have been reported confirming that they provide safety to their users and electromagnetic compatibility with electronic equipment. Signal channel analyses [12–16] have been reported to demonstrate improved communication performance. Low-power transceiver chips [17,18] have been developed and high performance electrodes [19,20] have been studied for medical applications. Communication between a device implanted in the human body and a monitoring computer, in which the body is used as a conductive medium, has been investigated [21]. High speed intra-body communication using an electro-optic modulator has been studied for transmitting video data [22,23].

* Corresponding author. Tel.: +81 42 387 6243.
E-mail address: m.shina@hosei.ac.jp (M. Shinagawa).

http://dx.doi.org/10.1016/j.measurement.2014.02.020
0263-2241/

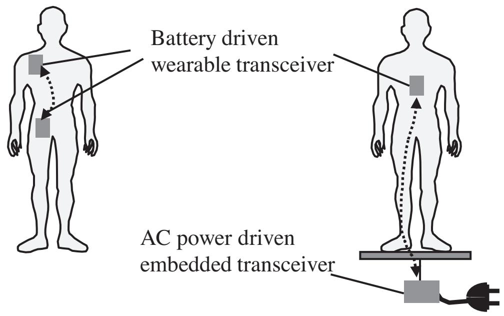

Fig. 1. Wearable and embedded transceivers.

Two types of transceivers (Fig. 1) are used in the field of intra-body communication. One is a wearable type that persons have with them during their everyday life; the other is an embedded type mounted in an ordinary object in a living space, such as a floor, a door, or a chair. Since many services can be provided by systems with communication established between the two types, the performance of such systems should be studied in detail. For both medical applications and public services, several problems related to usability for people with disabilities and elderly persons can be solved by using the human body as a communication interface [24]. Human body information data including heart rate, blood pressure, and temperature stored in a wearable computer are transmitted to a server computer through natural actions such as touching a medical appliance or sitting down on a chair (Fig. 2).

However, noise is a serious problem for intra-body communication systems. The system performance is strongly dependent on environmental noise from various kinds of electronic equipment in living spaces, such as lighting devices, air conditioners, liquid crystal televisions, and refrigerators. The wearable transceiver is battery-driven and its communication performance is not dependent on environmental noise. However, the embedded transceiver is usually AC power-driven and large environmental noise is transmitted into it through the power line. It has been established that this problem cannot often be solved merely by changing the location of the embedded transceiver. Moreover, even a person's touching the embedded electrode will increase the noise power and degrade communication performance. It is thought that common-mode noise is the source of the noise phenomena occurring in intra-body communication systems [25].

In communication systems of this type, the signal line is the human body and the ground line is the parasitic capacitance between the body and the earth ground. The transmission channel's impedance balance between the signal line and the ground line becomes extremely degraded under these circumstances. In such systems, large common-mode noise from various pieces of electronic equipment strongly affects performance and makes stable communication impossible.

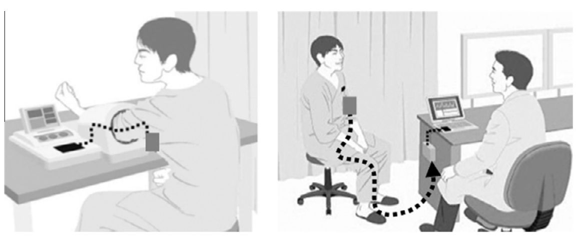

Fig. 2. Sensor data transferred to a doctor's PC by sitting on a chair.

We have previously proposed a channel model for intra-body communication that includes a common-mode noise source. In this model, the floor ground and the power source ground were made distinct from the earth ground so that the model would accurately reproduce the conditions of an actual communication system [16]. Our idea was that measuring parasitic capacitance would be an effective method to examine changes in the transmission line's impedance balance. Finding that the detected noise power is related to changes in the parasitic capacitance, we connected a compensative electrode or a compact capacitor to a ground one and found that this was an effective way to improve impedance balance.

2. Impedance balance in transmission line

Fig. 3 shows a basic model of common-mode and differential-mode noise on a transmission line in a communication system. When studying the data signal transmission in the system, not only the signal line and circuit ground line but also the earth ground (E-GND) should be investigated. The data signal amplitude V_{DATA} is input to the signal receiver circuit via the transmission line (=a signal line and circuit ground line).

Here, Z_1 is the signal line impedance, Z_2 is the circuit ground line impedance, Z_{10} is the parasitic impedance between the signal line and the earth ground, and Z_{20} is the parasitic impedance between the circuit ground line and E-GND.

Generally, two kinds of noise go through the transmission lines: differential-mode noise V_{DN} and common-mode noise V_{CN}. The differential-mode noise has the same characteristics as those of the data signal V_{DATA}; for that reason it is also called normal-mode noise. As transmission distance becomes long, the differential-mode noise damps. Since the common-mode noise fluctuates the ground node, the noise is hard to damp independent of the transmission distance. It has been reported that the DC-to-DC converters used in electric equipment generate the common-mode

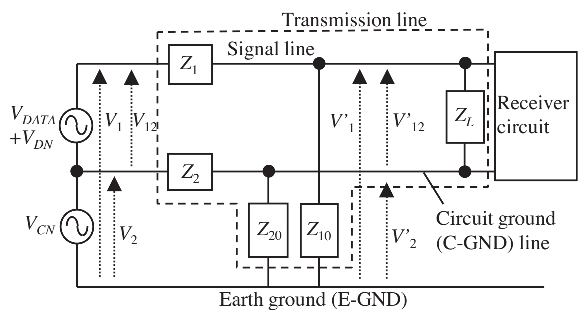

Fig. 3. Basic model of common-mode and differential-mode noise on transmission line in communication system.