Noise Measurement via Human Body for Intra-body Communication

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ABSTRACT

Intra-body communication has a serious problem with the noise via the human body. In this system, the noise via the human body is transmitted along the same path as a signal because of capacitance coupling among nodes. These are transmitted in a coordinate phase as common-mode, but the distinction between the signal and noise is difficult. We present an analysis of the noise from an approach to clarify the method of measurement. A measurement of the noise was done by assuming the noise source via the human body and an electric light. To determine the noise to maintain the influence in a signal electrode, we connected an additional electrode to a ground electrode. The noise level was almost unchanged. Thus, the noise was influenced more by the signal electrode than by the ground electrode in this measurement system.

Categories and Subject Descriptors

J.2 [**Computer Applications**]: PHYSICAL SCIENCES AND ENGINEERING– *Electronics, Engineering, Physics.*

General Terms

Measurement, Experimentation

Keywords

Intra-body communication, Noise transmission model, Common-mode noise, Capacitance coupling, Internet of Things, and Wearable and embedded transceivers.

1. INTRODUCTION

Intra-body communication [1] has been developed as a communication system to make our lives better. This is one of the key-communication systems for the looming period of the Internet of Things (IoT), in which all nearby things can access the Internet [2].

The concepts of this system are that the human body is used as a transmission path and that communication area is limited within the human body. The method of accessing the network can be achieved through natural human actions such as sitting on a chair or touching a door handle. Therefore, it is an intuitive and user-friendly interface [3]. The transmission path of intra-body communication is composed of capacitance coupling among nodes [4-9]. This system can be communicated through the human body even if you touch the transceiver through dielectrics such as clothes or shoes. The transceiver does not need to be touched directly. However, a problem with intra-body communication occurs with the transmission paths of the signal and noise. This system has two kinds of transmission paths of noise. One is noise via the human body from the electromagnetic environment [9-12]. The other is noise via the ground from the system's ground [5,6,9]. The transmission paths of the signal and the noise in this system are shown in Fig. 1.

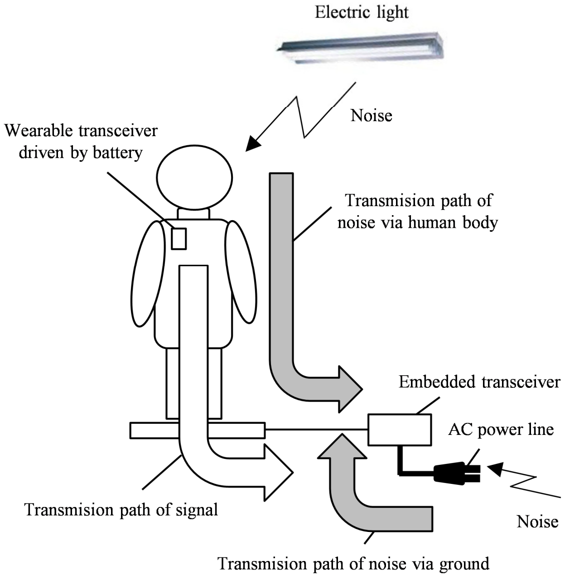

Fig. 1 Transmission paths of signal and noise via human body and via ground for intra-body communication

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The focus in this system is that the signal and noise are transmitted in a coordinate phase as common-mode by capacitance coupling among nodes. When using wearable and embedded transceivers, a distinction between the signal and noise is difficult.

This system has been attracting attention for various kinds of applications [13,14], such as people who have a transceiver like an IC card transmit identification in touching a door handle, locking a door, and going through a ticket gate. Mainly, wearable and embedded transceivers are used in this system. A typical communication configuration for intra-body communication is shown in Fig. 2.

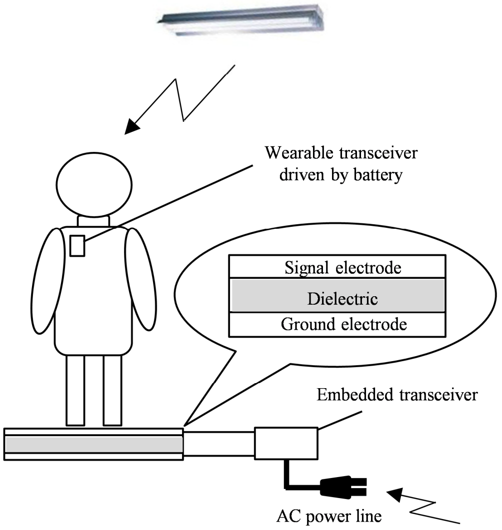

Fig. 2 Typical communication configuration for intra-body communication

Wearable transceivers have been attracting attention because people can use these transceivers every day. Watches, glasses, or bracelets can include them, for example. Wearable transceivers enable us to take care of certain activities without conscious effort. Embedded transceivers embedded in the surrounding environment such as door handles, walls, or floor mats are used for intra-body communication. Various kinds of applications between wearable and embedded transceivers have been reported for this system. [13,14].

A different driving method is used between wearable and embedded transceivers. The former is driven by a battery. It means that it is ungrounded and at a potentially floating state. The latter is driven by an AC power line. Embedded transceivers are just influenced from the ground because they are grounded. In previous work, the noise through the AC power line via the ground was the focus [5,6,9]. However, noise via the human body is a serious problem for intra-body communication [9,10]. Various kinds of noise sources are present in electric and electronic equipment, such as light fixtures, air conditioners, personal computers, televisions, and microwave ovens [5].

In this paper, we present our analysis of noise via the human body to clarify the method of measurement. As an antenna, electrodes composed of dielectrics sandwiched by signal and ground electrodes were used to consider the best transmission efficiency [5-7,9].

2. NOISE VIA HUMAN BODY

The problem of noise via the human body for intra-body communication is described herein. The main noise is electromagnetic noise emitted by a light fixture or peripheral electronic equipment [5]. In this paper, we regard an electric light installed in the ceiling as a noise source for intra-body communication. Therefore, we need to determine the noise spectrum of electric light and intra-body communication. An experiment using an electric light was conducted with a coaxial cable as an antenna that was brought close to the electric light. An experiment was also conducted using intra-body communication wherein a person stood on electrodes and was brought close to the electric light. The noise spectrums of the electric light and intra-body communication are shown in Fig. 3 when the electric light was on and off.

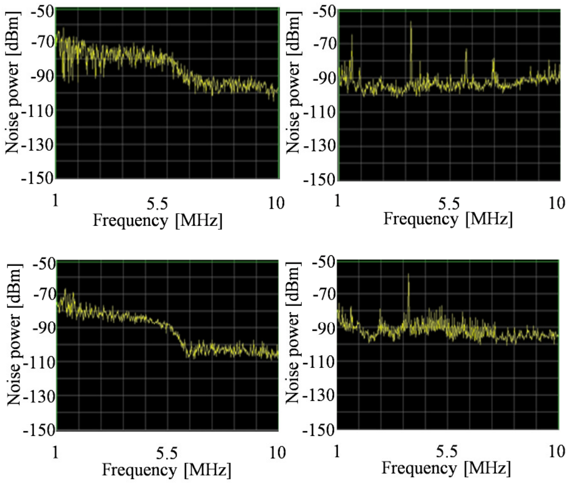

Fig. 3 Comparison of noise spectrum of electric light (a) "on" and (b) "off" and intra-body communication when electric light is (c) "on" and (d) "off"

(a) On **(b) Off**

(c) On **(d) Off**

The noise spectrum of electric light is shown (a) and (b) for on and off, respectively. The noise spectrum of intra-body communication is shown in (c) and (d) when the electric light is on (c) and off (d). A comparison of the noise spectrums (a), (b), (c), and (d) revealed them to be highly similar depending on the status of the electric light. Therefore, we regard the electric light as the noise source in intra-body communication.

Assuming a scene using wearable and embedded transceivers in Fig. 4, noise via the human body is transmitted along the same path as a signal because of capacitance coupling among nodes. Also, it is transmitted in a coordinate phase as common-mode. Therefore, a distinction between the signal and noise is difficult. Noise via the ground for the method of measurement and improvement has been reported in previous work [5,6,9]. We focus on the method of measuring noise via the human body.

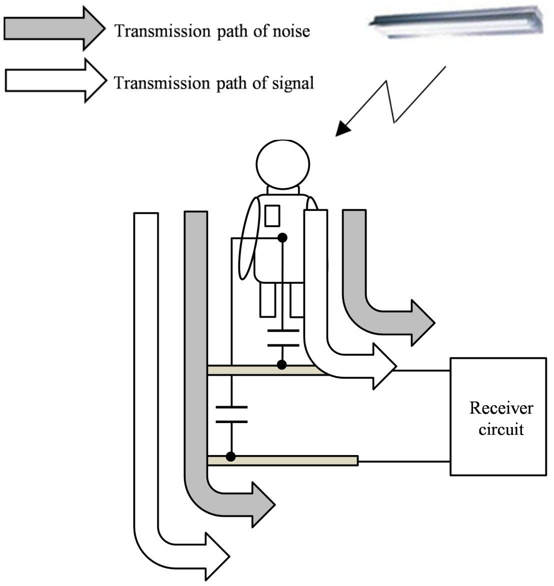

Fig. 4 Noise and signal transmitted as common-mode by capacitance coupling among nodes

3. NOISE MEASUREMENT SYSTEM

The basic model of noise in the transmission path has been reported [5,9]. Basically, two types of noise occur: differential-mode and common-mode noise.

A figure of a noise transmission model for intra-body communication [5,6,9] is shown in Fig. 5. The floor ground and power source ground are distinct from the earth ground because the electrical properties that each ground has is unknown. The distances d_{BS}, d_{SG}, and d_{GF} are defined by sandwiching foamed styrol as insulation plates. Impedance elements between each type of ground (Z_{CP}, Z_{PE}, Z_{FP}) are defined. The noise V_{CNF} via the floor ground was the focus in previous work [5,6,9]. In this paper, we focus on the noise V_{CNB} via the human body.

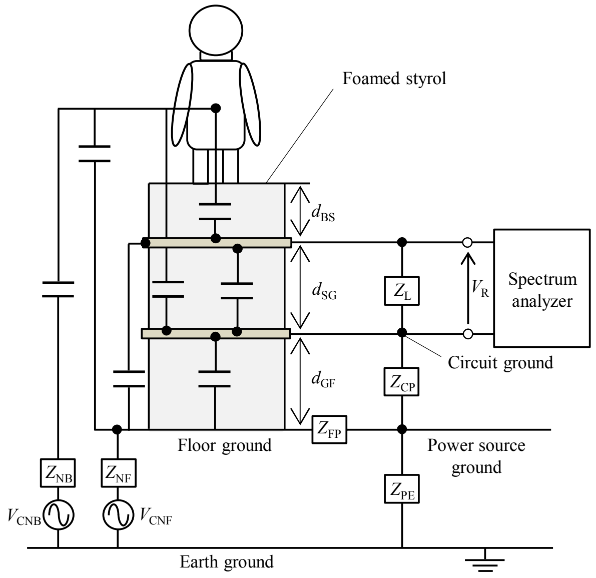

Fig. 5 Noise transmission model for intra-body communication

To measure the noise via the human body, we need to bring the human body close to the electric light and assume the noise source in a laboratory environment. Therefore, d_{GF} is changed by changing the thickness of the foamed styrol. Also, the measurement system must not be influenced by the ground. Therefore, the spectrum analyzer (Agilent N9340B) was driven by a battery. Electrodes composed of dielectrics sandwiched by signal and ground electrodes were used as the antenna to take impedance matching on the transmission path. If the distance between the signal and ground electrode is short, the characteristics of the noise may not be considered. Therefore, d_{SG} was fixed at 0.3 m to keep the influence in the signal electrode. A photograph of the experimental setup for the noise measurement is shown in Fig. 6.

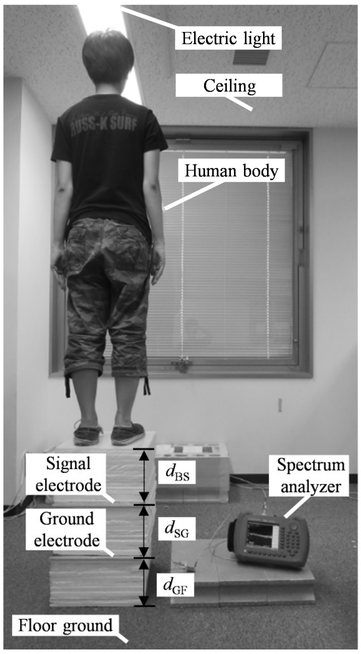

Fig. 6 Photograph of experimental setup for noise measurement

4. EXPERIMENTAL RESULTS

The height of the room in the laboratory environment and the person who participated were 2.6 m and 1.8 m, respectively. To measure the characteristics of intra-body communication, the measurement system needed to be regarded as high impedance. A non-inverting amplifier was connected just before the spectrum analyzer. To consider the characteristics of the noise via the human body, we paid attention to a certain frequency band where the noise level was notably different in Fig. 3: from 1.9 MHz to 2.8 MHz. d_{BS}, d_{SG}, and d_{GF} were fixed at 0.01 m, 0.3 m, and 0.01 m, respectively. d_{GF} was only changed by changing the thickness of the foamed styrol to bring the human body close to the electric light. When the electric light was on, the noise power was measured using the aforementioned setting shown in Fig. 7.

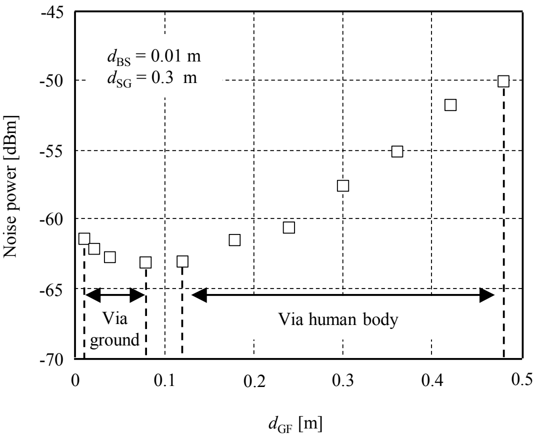

Fig. 7 d_{GF} dependence on noise power for intra-body communication

We divided d_{GF} into via ground and via human body. When via ground was considered (d_{GF} = 0.01 m - 0.08 m), this system was influenced more by the noise via the ground than by the noise via the human body. The noise level was gradually decreased by taking the impedance matching of the transmission path. And, when the electric light was off, the characteristics of the noise were also highly similar. When via human body was considered (d_{GF} = 0.12 m - 0.48 m), this system was influenced by the noise via the human body. This is because the human body was close to the electric light, and this system was influenced more by the noise via the human body than by the noise via the ground. We found that the kinds of noise influenced in intra-body communication were divided. Subsequently, to determine that the noise via the human body was influenced more by the signal electrode than by the ground electrode, we connected an additional electrode to the ground electrode. The measurement system of the additional electrode and the change in the noise level are shown in Fig. 8 and in Table 1.

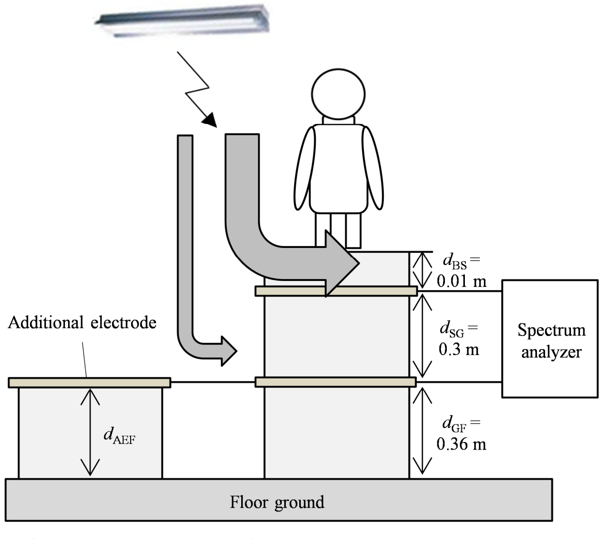

Fig. 8 Estimation system of noise level by additional electrode

Table 1 Change in noise level by additional electrode

d_{AEF} [m]	Without	0.01	0.02	0.04	0.08	0.12
Relative noise level [dB]	0	3.1	3.0	2.5	1.9	1.8

It has been reported that the noise transmitted as common-mode by connecting the additional electrode to the ground electrode decreased [5]. However, the noise level was almost unchanged even if d_{AEF} was changed. Therefore, the noise was not transmitted as common-mode. And this means that the noise was influenced more by the signal electrode than by the ground electrode in this measurement system.

5. CONCLUSION

The problem of the noise via the human body in intra-body communication was analyzed. The distinction between the signal and noise is difficult as these are transmitted as common-mode by capacitance coupling among nodes. We analyzed the noise from the approach of clarifying the method of measurement. In assuming the noise source via the human body with electric light, this finding indicates the measurement of the noise. We found the kinds of noise are different depending on the distance between the human body and the noise source. We connected an additional electrode to a ground electrode. The noise was found to be highly influenced by a signal electrode.

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