Dependence of Transmission Characteristics of Intra-Body Communication System on the Body Posture and Surrounding Environment

Shouta Igou[1], *Masao Taki*[1], *Akinori Furuya*[2], *Nobutaro Shibata*[2], *Mitsuru Shinagawa*[2], and *Mitsuo Hattori*[3]

[1] Dept. of Electrical and Electronic Engineering, Tokyo Metropolitan Univ., Tokyo, Japan, Igou@com.eei.metro-u.ac.jp

[2] NTT Microsystem Integration Laboratories, Nippon Telegraph and Telephone Corporation 3-1, Morinosato Wakamiya, Atsugi-shi, Kanagawa Pref., 243-0198 Japan.

[3] NTT Advanced Technology Corporation

Abstract

The transmission characteristics of an intra-body communication system using electric near-field was investigated with the interest in the dependency on posture of human body and surrounding environment. Numerical approach was employed for the investigation. The received voltage depended on the posture of the human body but the variation was not quite critical as far as the conditions assumed in this study. Presence of a metal door in front of the body showed enhancement of transmission from wearable device to the floor-buried device.

1 Introduction

The intra-body communication system using electric near-field was originally proposed by Zimmerman in 1995[1]. This technology has been developed for practical applications in recent years. Various applications of this technology are expected such as communications between wearable devices, access control, personal identification systems [2] and medical equipments [3].

Human body constitutes a part of the transmission channel by mediating the electric signals between communication devices in this kind of systems. Hence the transmission characteristics should change depending on various conditions such as the locations of the devices on the body, posture, and objects in the environment. It is necessary to characterize and quantify the variation of transmission of the signals due to the changes in those conditions to realize reliable communications with a hand-touch or a holding over the electrodes.

In this study we investigate electric field distributions around the body and the communication devices for different conditions of the posture of the body, and objects near the body. Received voltages at the electrodes of the receiver are calculated numerically to quantify the transmission characteristics of the system for different conditions. The results are expected to be useful in the development of efficient communication systems.

2 Method

2.1 Models and Numerical method

Figure 1 shows the illustration of the intra-body communication system. The wearable communication device (A) is placed at 10 mm distance from the surface of the breast of the human body. The floor-buried communication device (B) is placed at 10 mm distance beneath the surface of the feet bottom. The wearable device (C) is placed at 10 mm distance from the surface of the hip.

The wearable devices (A), (C) are modeled by a pair of parallel plates of 50×50 mm^2 made of perfect electric conductor (PEC). The floor-buried device (B) is modeled by parallel plates of 400×400 mm^2 made of PEC. The gap distances between the parallel plates (A), (B), (C) are 10 mm for each. The device (A) is the transmitter and the device (B) or (C) is the receiver.

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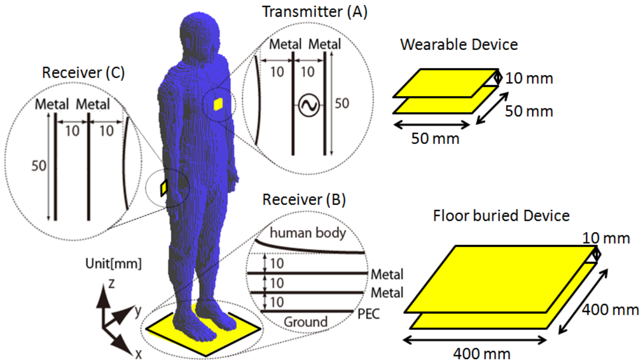

Figure 1: Intra-body communication system

Table 1: Calculation conditions

Cell size	5 mm
Cell size (near devices)	2.5 mm
Time step	9.628×10^{-12} s
Boundary Condition	UPML (22 layers)
Frequency	5 MHz (sinusoidal waves)
Applied	1 V

The finite-difference time-domain (FDTD) method is employed for the numerical calculations. The human model is a realistic numerical human model derived from a software mannequin named gqueteh (OGIS-RI Co.,Ltd.). The human model is homogeneous adult male and the electric constants are assumed those of muscle (relative permittivity 308, electric conductivity 0.59 S/m at 5 MHz[5]). A PEC sheet is placed on the lower boundary of the calculation region as the ground. Other boundaries are assumed to be absorbing boundary conditions of uniaxial perfectly matched layer (UPML). The calculations are performed with a software SEMCADX (Schmid and Partner Engineering AG).

The applied voltage between electrodes of the transmitter (A) was 1 V with a 50 Ω source impedance. The carrier frequency was assumed 5 MHz. The electrodes of the receivers (B) and (C) were assumed open ended. The transmission characteristics were evaluated with the voltages between the receiver electrodes of the device (B) or (C). Calculation conditions are summarized in Table 1.

2.2 Posture of the human model and surrounding environment

Seven different postures were assumed to investigate the effect of the postures. Those are; (a) standing, (b) raising an arm up with the other down, (c) raising both arms up, (d) sitting, (e) stepping on the floor-buried device with one foot while the other outside, (f) extruding an arm forward with the other down, (g) extruding both arms forward.

Two different surrounding environments were also assumed; (h) standing in front of a door made of PEC floating 10 mm above the ground with a contact by a hand, (i) the same situation except for the door connected to the ground.

3 Result

Figure 2 shows the calculated results of received voltages between the electrodes of the receiver (B) or (C) for different postures of the human body. The received voltages were influenced by the postures of the human body but the changes were not quite significant for those conditions, where the locations of the devices were fixed to the body regardless of the different postures. The variations of the received voltages were smaller for the receiver located on the hip, or the wearable receiver (C), than the floor-buried receiver (B). It should be noted that the received voltages were enhanced due to the presence of the door in front of the human body, especially when the door was connected to the ground.

Figure 3 shows the electric field distributions on the coronal sections for the postures (a), (b), and (c). Figure 4 shows the electric field distributions on the transverse sections for postures (a), (f), and (g). Figure 5 shows the electric field distributions on the sagittal sections of the human model standing in front of a door connected to the ground (h) or not (i).

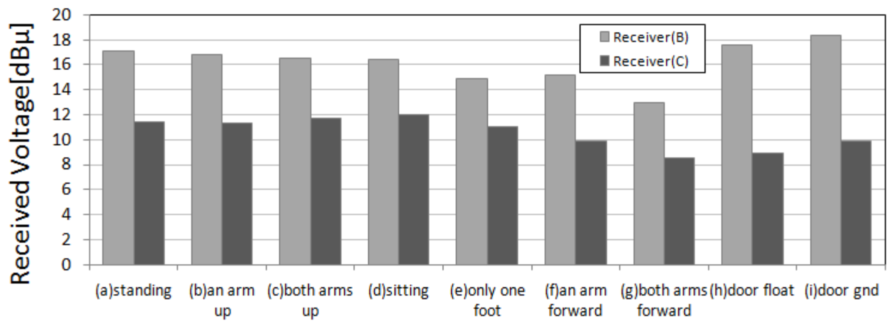

Figure 2: Received voltage for the different postures (a)-(g) and for the surrounding environments (h) and (i).

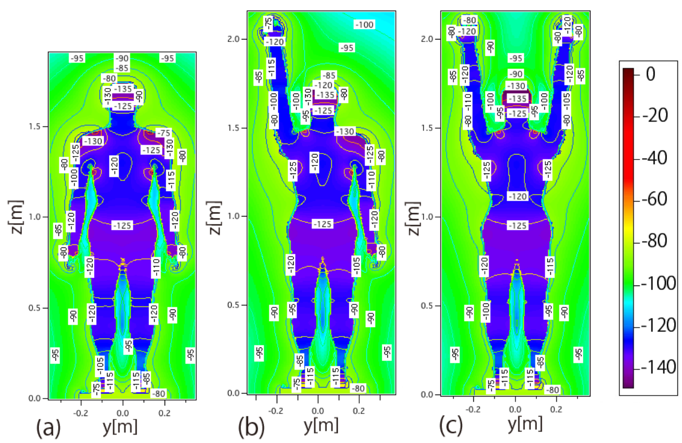

Figure 3: The electric field [dB] (0dB, 100 V/m) distributions on the coronal sections for the postures (a), (b), and (c).

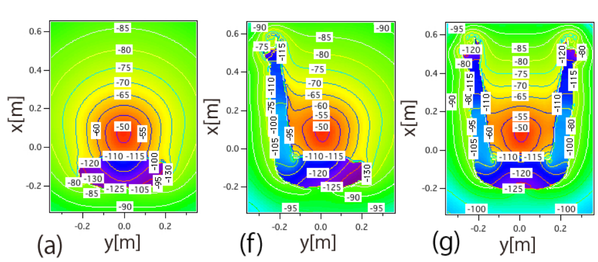

Figure 4: The electric field [dB] (0dB, 100 V/m) distributions on the transverse sections for postures (a), (f), and (g).

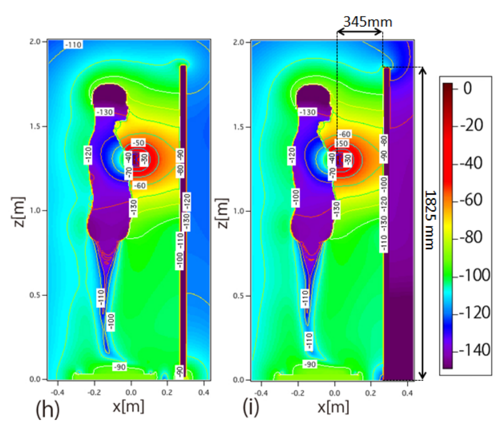

Figure 5: The electric field[dB](0 dB, 100 V/m) distributions on the sagittal sections for (h) and (i).

4 Conclusion

The transmission characteristics of an intra-body communication system using electric near-field were investigated by numerical calculations. The variation of the voltage detected by the receiver was not very significant regardless of the postures when the locations of the communication devices were fixed. The effect of surrounding environment was investigated for the cases where a door existed in front of the human body. The existence of the door enhanced the received voltage by floor-buried receiver especially when the door was connected to the ground.

Further investigations are necessary to delineate the more detailed dependency of the characteristics on the posture and surrounding environment. It is also necessary to evaluate the human exposure as well as the emission of electric and magnetic fields for various postures and surrounding environments.

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