Near-Field Coupling Communication Technology For Human-Area Networking

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ABSTRACT

We propose a human-area networking technology that uses the surface of the human body as a data transmission path and uses near-field coupling transceivers. This technology aims to achieve a ‘touch and connect” form of communication and a new concept of “touch the world” by using a quasi electrostatic field signal that propagates along the surface of the human body. This paper explains the principles underlying near-field coupling communication. Special attention has been paid to common-mode noise since our communication system is strongly susceptible to this. We designed and made a common-mode choke coil and a transformer to act as common-mode noise filters to suppress common-mode noise. Moreover, we describe how we evaluated the quality of communication using a phantom model with the same electrical properties as the human body and present the experimental results for the packet error rate (PER) as a function of the signal to noise ratio (SNR) both with the common-mode choke coil or the transformer and without them. Finally, we found that our system achieved a PER of less than 10^{-2} in general office rooms using raised floors, which corresponded to the quality of communication demanded by communication services in ordinary office spaces.

Keywords: near-field coupling communication, human-area networking, common-mode noise, quasi electrostatic field, packet error rate, and signal to noise ratio.

1. Introduction

Wireless body area networks around the human body are expected to play an important role in various areas of application, such as in the remote monitoring of health, sports training, interactive gaming, sharing of personal information, secure authentication, train ticket wickets, and medical information systems [1]. Body-channel communication (BCC) technologies have recently been actively reported [2]–[6]. However, these communication technologies are only composed of transceivers (TRXs) on the human body (wearable TRXs). We propose human-area networking based on near-field coupling communication (NFCC), which consists of both wearable TRXs and those embedded in environments or in equipment that broaden the areas to which BCC can be applied [7]–[9]. We aimed at achieving the concept of “touch the network”, which is a novel idea to access networks and exchange data by simply stepping on the floor. Typical examples of this concept for ticket wickets and Internet access systems are outlined in Fig. 1. When people carry wearable TRXs in their pockets, they can access networks through embedded TRXs by simply passing through ticket wickets. User IDs are then authenticated and fares are calculated and deducted. There is also a photograph that demonstrates our concept in Fig. 2. The person in this scenario has a wearable TRX attached to his body/clothes and he is accessing his favorite Web page by simply stepping on an embedded electrode while he is sitting on a chair. As the proposed communication system using embedded TRXs is able to connect networks all over the world, this system can be applied to a wide range of applications. However, embedded TRXs are more strongly susceptible to environmental noise from earth grounding, AC power, and equipment connected to networks than wearable TRXs. The quality of reception attained by embedded TRXs is worse for this reason. We found that the quality of communication was improved by implementing common-mode noise filters in embedded TRXs. The embedded electrodes were floated above a concrete floor because there is wiring under floors in real offices. We measured the signal to noise ratio (SNR) by taking this situation into consideration and demonstrated how much the packet error rate (PER) could be ensured in general office rooms.

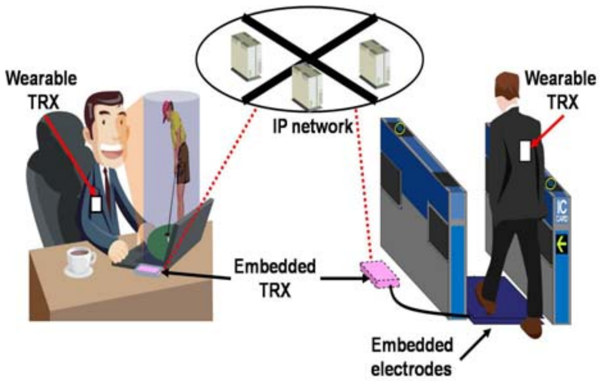


Fig. 1. Scenario for practical use.

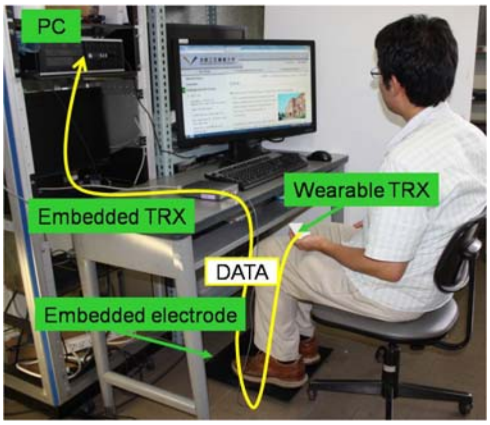


Fig. 2. Photograph of demonstration scenario.

2. COMMUNICATION MODEL

The communication model for the NFCC system is shown in Fig. 3. The NFCC consists of two types of TRXs. The first is a wearable TRX that can be carried in jacket breast pockets or trouser pockets. The second is an embedded TRX that can be embedded in walls, desktop PCs, and wickets. When modulated signals are applied to a pair of parallel electrodes implemented in a wearable TRX, a quasi electrostatic field is generated near the electrodes. An electrical field signal is induced on the human body through a mechanism for near-field coupling. The signal loop is composed of two types of paths. The first is a forward path and the second is a return path. The forward path is a route from the electrode of the wearable TRX on the body side (signal electrode) to the upper electrode through the human body's surface. The return path is also a route from the lower electrode to the electrode on the wearable TRX on the side opposite the body (ground electrode) through earth grounding.

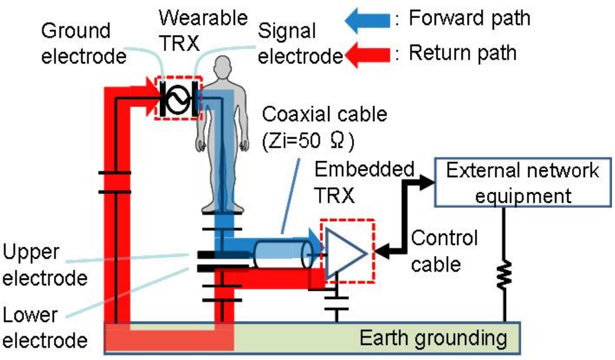


Fig. 3. Communication model for NFCC technology.

Communication where the wearable TRX transmits a signal and the embedded TRX receives it is called an up link. In contrast, communication where the embedded TRX transmits a signal and the wearable TRX receives it is called a down link.
We focused on common-mode noise as a critical factor that degraded the quality of transmission in NFCC systems. The intrusion route for noise is outlined in Fig. 4. The embedded TRX for the communication system is strongly coupled to earth grounding through an AC-power line and external network equipment. As a result, a common-mode noise loop is formed.
Next, we will describe a method of improving the quality of communication by implementing a filter to suppress common-mode noise and our evaluation of how the quality of communication varies with SNR in an ordinary office space.

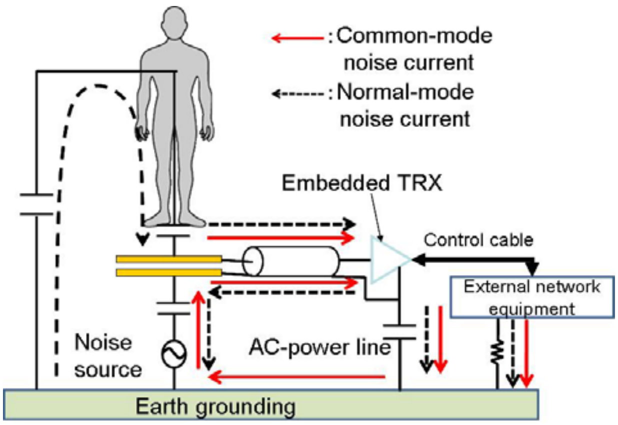
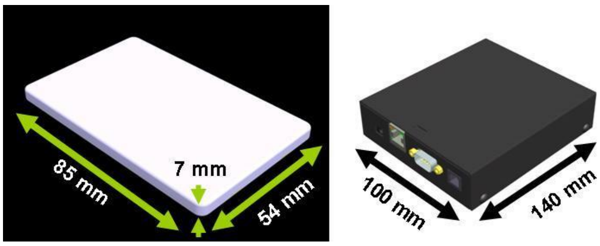


Fig. 4. Intrusion route for noise.

3. TRX CONFIGURATION

A card-type prototype wearable TRX and an embedded TRX that can be installed in environments, such as doors and floors, are shown in Fig. 5. The prototype uses a 6.75-MHz carrier frequency with binary phase shift keying (BPSK) modulation, and achieves a transmission rate of 420 kbps. The wearable TRX has a pair of parallel electrodes. It can operate for approximately one year on a single CR3032 button-type lithium-ion battery. The embedded TRX has an SMA connector acting as the signal input or output port and an RS232C serial port acting as the interface with external devices. It is driven by AC-power. In the example of rail ticket wickets that was described earlier, the card-type TRX can be carried in trouser pockets, transmitting ID information, and achieving communication with the embedded TRX built into the floor.



Wearable TRX		Embedded TRX	
Supply voltage	3.0 V	Supply voltage	6.0 V
Bitrate	420 kbps	Bitrate	420 kbps
Carrier Frequency	6.75 MHz	Carrier Frequency	6.75 MHz
		Interface	RS232C

Fig. 5. Configuration and basic specifications for TRX.

4. EXPERIMENTS

Evaluation of system

We measured the SNR for the up link as a function of the distance between the floor and the embedded electrodes, as shown in Fig. 6. As the distance between the floor acting as earth grounding and the embedded electrodes increases, the capacitance (C_L) between the floor and the lower electrode decreases. The received signal level decreases as the lower electrode is away from the floor. Raised floors in general office rooms are used to install wired communication networks or AC-power lines. We measured the SNR to ensure that our NFCC could be used on raised floors. To find what effect distance had on the SNR, we changed the distance with spacers made of foamed polystyrene. The embedded electrodes were connected to a spectrum analyzer and a person 1.76-m tall who wore shoes stood on the embedded electrodes. He wore the wearable TRX on his body. We measured the received signal power and the noise power. The distance between the person and the embedded electrodes was maintained.

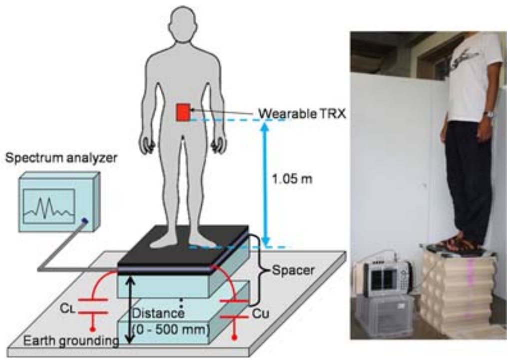


Fig. 6. System for measuring SNR.

Fig. 7 is a schematic of the experimental system. We used a phantom with the same electrical properties as the human body to ensure the experiments could be reproduced. The phantom was a rectangular solid filled with a gel material that absorbed water. Since there were spaces between the wearable TRX and human body in practical use, we placed an attenuator on the top surface of the phantom so that we could adjust the signal power. The wearable TRX was placed on the attenuator. The embedded TRX was connected to the embedded electrodes (350-mm-sq.) and the noise generator was connected to the noise electrodes (350-mm-sq.), both with a coaxial cable. We inserted the common-mode choke coil or the transformer between the embedded TRX and the embedded electrodes depending on the experiment. The embedded TRX was connected to a desktop PC with an RS232C cable. The noise electrodes were placed under the embedded electrodes. A rubber sheet, which was 5 x 350 x 350 mm, was inserted between the phantom and the embedded electrodes and between the embedded electrodes and the noise electrodes. The noise generator and the embedded TRX were driven by AC power. We held an attenuator with a thickness of 200 mm in the experiments, and we measured the quality of communication for the up link as a function of the SNR using a white noise generator.

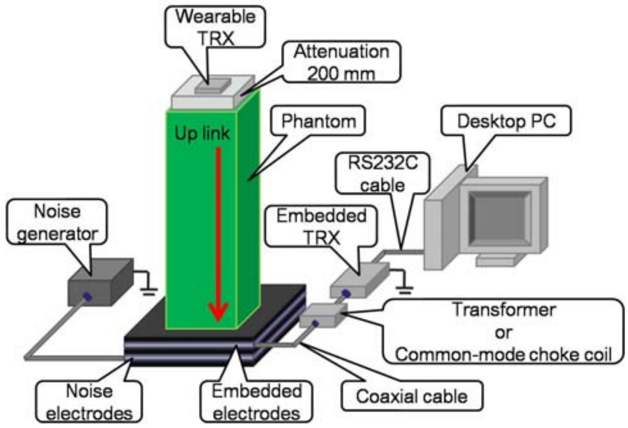


Fig. 7. System for measuring PER.

Results

The received signal and the noise power for the up link and the capacitance (C_L) as a function of a distance between the floor and the embedded electrodes are plotted in Fig. 8. The noise power increased by 3 dB when a person stood on the embedded electrodes. Although the SNR changed according to the distance, it remained at more than 23.9 dB. When the distance approached 0 m, the signal power increased, the noise power decreased, and the SNR was maximum. This is because the return path was enhanced due to increase in the value of C_L. The floating capacitance (C_U) between the upper electrode and the floor was comparable to C_L when the embedded electrodes approached the floor. Consequently, the balance between the impedance for the signal line and that for the ground signal line with respect to the earth grounding was better. As a result, the normal mode noise current was suppressed.

We designed and fabricated a common-mode choke coil and a transformer to suppress common-mode noise. The characteristics of these filters to suppress normal and common-mode noise are plotted in Fig. 9. Because the common-mode choke coil had high impedance for common-mode current, common-mode noise current was suppressed. As the transformer isolated the circuit for the embedded TRX from the embedded electrodes, common-mode noise current was suppressed.

The PER characteristics as a function of the SNR for the up link are plotted in Fig. 10. The total length of a packet was 22 bytes. Each packet consists of address, data, command, etc. We can see the SNR was improved by 2.5 dB at a PER of 10^{-2} when the transformer was used between the embedded TRX and the embedded electrodes. The SNR also improved by 5.0 dB at a PER of 10^{-2} when the common-mode choke coil was used. These results demonstrated that our system achieved a PER of less than 10^{-2}, which corresponds to the quality of communication demanded by communication services in office rooms with an SNR of more than 23.9 dB.

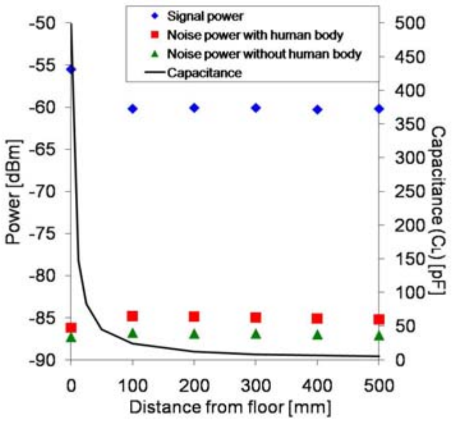


Fig. 8. Received signal, noise power, and capacitance characteristics.

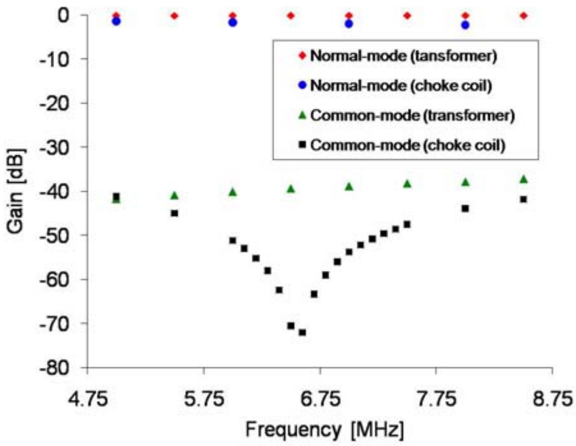


Fig. 9. Characteristics of filters to suppress normal and common-mode noise.

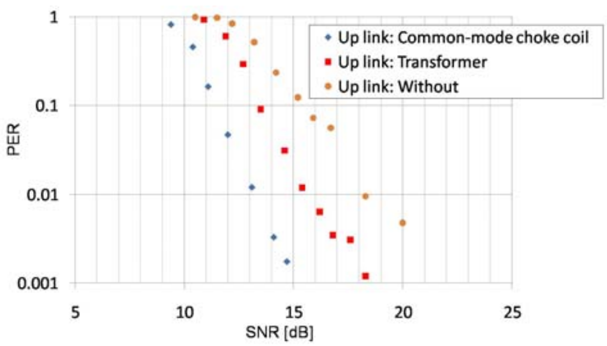


Fig. 10. PER characteristics as a function of SNR for up link.

5. CONCLUSION

We proposed a human-area networking technology using near-field coupling transceivers. We focused on the fact that embedded TRXs were strongly susceptible to common-mode noise in this work and made a common-mode choke coil and a transformer that acted as common-mode noise filters. We measured the PER of the up link as a function of the SNR both with the common-mode choke coil or the transformer and without them. Moreover, we measured the SNR as a function of the distance between the floor as earth grounding and embedded electrodes. As a result, our system could achieve a PER of less than 10^{-2} for the up link in general office rooms using a raised floor.

6. ACKNOWLEDGEMENT

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7. REFERENCES

[1] M. Chen, S. Gonzalez, A. Vasilakos, H. Cao, and Victor C. M. Leung, “Body Area Networks: A Survey,” Mobile Networks and Applications, Vol. 16, No. 2, pp. 171-193, Spring 2011.

[2] T. G. Zimmerman, “Personal Area Networks: Near-field intrabody communication,” IBM Syst. J. , Vol. 35, no. 3-4, pp. 609-617, 1996.

[3] N. Cho, J. Yoo, S. J. Song, J. Lee, S. Jeon, and H. J. Yoo, “The Human Body Characteristics as a Signal Transmission Medium for Intrabody Communication,” IEEE Trans. Microwave Theory and Techniques, Vol. 55, pp. 1080-1086, May 2007.

[4] S. J. Song, N. Cho, S. Kim, J. Yoo, S. Choi, and H. J. Yoo,“A 0.9V 2.6mW Body-Coupled Scalable PHY Transceiver for Body Sensor Applications,” IEEE ISSCC, pp. 366--367, Feb., 2008.

[5] A. Fazzi, S. Ouzonov, and J. v. d. Homberg,“A 2.75mW Wideband Correlation -Based Transceiver for Body-Coupled Communication,” IEEE ISSCC, pp. 204--205, Feb 2009.

[6] J. Bae, K. Song, H. Lee, H. Cho, L. Yan, H. J. Yoo, “A 0.24nJ/b Wireless Body-Area-Network Transceiver with Scalable Double -FSK Modulation,” IEEE ISSCC, pp. 34-35, Feb 2011.

[7] M. Shinagawa, M. Fukumoto, K. Ochiai, and H. Kyuragi, “A near-field-sensing transceiver for intra-body communication based on the electrio-optic effect,” IEEE Trans. Instrum. Meas., vol. 53, no. 6, pp.1533-1538, 2004.

[8] Y. Kado, “Human-Area Network Technology as a Universal Interface,” Symposium on VLSI Circuit Digest of Technical Papers, pp. 102-105, 2009.

[9] Y. Kado and M. Shinagawa, “AC Electric Field Communication for Human-Area Networking,” IEICE TRANS. ELECTRON, Vol. E93-C, pp. 234-243, MAR., 2011