Novel Pair Electrode with Coils Sensing Magnetic Energy on Human Body Surface for Intrabody Communication

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1. Introduction

The spread of small mobile terminals, such as cell phones, is spurring interest in Wireless Body Area Network (WBAN), including intrabody communication [1] utilizing electromagnetic field on human body surface. In order to generate or detect the change in the EM field on human body surface, intrabody communication usually utilizes a pair electrode, instead of antenna. The pair electrode consists of a signal electrode and a ground (GND) electrode. When the signal electrode is in contact with human body surface or is close to human body surface, capacitive coupling occurs between the signal electrode and human body surface. Through the capacitive coupling, the electrode can transmit or receive electromagnetic wave on human body surface. The capacitive coupling decreases in proportion to the distance between the signal electrode and human body surface. As a result, the power received by the receiver degrades.

In most research on intrabody communication, the signal electrode is in contact with human body surface [2]-[5]. There are few reports [6] on improvement of the received power. In Reference [6], an electric-field sensor implemented with a transverse EO sensor is used to improve the received power. However, the EO sensor is so costly that other countermeasure is demanded to improve the received power.

In this paper, we propose a new method in which bar antennas employed with pair electrode acting as variable capacitance is implemented in order to improve the received power when the signal electrode is not in contact with human body surface.

2. Basic Principle

If a bar antenna designed to operate in intrabody communication frequency is utilized, the bar antenna generates or receives magnetic energy regardless of distance from human body surface. This bar antenna is unsuitable for intrabody communication, because communication is performed when the signal electrode is in contact with human body surface or is close to human body surface in intrabody communication. Figure 1 shows the equivalent circuit schematic of the proposed pair electrode consisting of a coil acting as a bar antenna and a variable capacitor. The conventional pair electrode is used as the variable capacitor because the pair electrode changes its capacitance depending on the distance from human body surface. The inductance of the coil is designed so that the resonance frequency is equal to the intrabody communication frequency when the signal electrode is close to human body surface. Using this pair electrode, communication is performed when the communication devices are close to a human body.

3. Calculation and experimental results

In this proposition, as described above, magnetic energy is received by the coil in parallel with an electrode. However, it is not how the magnetic field is distributed around a human body. In this chapter, the magnetic field distribution calculated by full-wave simulation software: CST Microwave Studio, is shown. Then the experimental results for the electrode are shown.

3.1 Calculation results for magnetic field distribution around a human body

Figure 2 (a) shows the model used to calculate the magnetic field around a human body. The 180-centimeter-tall human model is seated on a chair whose seat is a transmitting pair electrode. The human body consists of homogeneous medium whose electric conductivity and relative permittivity are 0.6183 S/m and 170.73, respectively. The transmitting pair electrode, as shown in Figure 2(b), consists of two 30-centimeter-square conductor plates. The two conductor plates are set parallel to each other at a distance of 2 cm. The transmit frequency is 10.7 MHz. The excitation voltage between the two conductor plates is 1 v/m.

The parallel and vertical components of calculated magnetic field with respect to the human body surface are shown in Figure 3 (a) and (b), respectively. The parallel component of magnetic field with respect to the human body surface is stronger than the vertical component around the human body as shown in Figure 3 (a) and (b). These results show that the electrode can receive magnetic energy and that placing the coil parallel with respect to the human body surface is effective for receiving magnetic energy.

3.2 Experimental results for the proposed pair electrode

Figure 4 (a) shows the experimental pair electrode. The pair electrode consists of four coils formed by ferrite bar wound with enamel wire and the conventional pair electrode acting as a variable capacitor. The conventional electrode consists of two 3-centimeter-square conductor plates that are set parallel to each other at a distance of 5 mm. Four coils are connected in series in order to obtain inductance for resonating at 10.7 MHz. In light of calculation results, the four coils are placed parallel with respect to the two conductor plates. Figure 4 (b) shows the conventional pair electrode that receives the electric energy. The two pair electrodes shown in Figure 4 (a) and (b) have the same constitution.

Figure 5 shows the VSWR frequency characteristic of the experimental pair electrode. In Figure 5, the solid line shows the result when the signal electrode of the proposed pair electrode is placed parallel to human body surface at a distance 5 mm, and the dashed line shows the result when the signal electrode of the proposed pair electrode is placed more than 5 cm from human body surface. From these results, the proposed pair electrode resonates at 10.7 MHz when it is close to a human body. Low VSWR at high frequency when the proposed pair electrode is close to a human body is attributable to dielectric loss of a human body.

Figure 6 shows the received power of the proposed pair electrode and the conventional pair electrode shown in Figure 4 (a) and (b), respectively. The transmitting power is 0 dBm. The posture of human body and the position and constitution of the transmitting electrode are the same as those shown in Figure 2. The proposed pair electrode and the conventional pair electrode are located on the clothes over the left breast or the abdomen. From Figure 6, the received power of the proposed pair electrode receiving magnetic energy is higher than that of the conventional pair electrode receiving electric energy regardless of location. These results show that the proposed pair electrode is efficient for improving the received power when the signal electrode is not in contact with human body surface.

4. Conclusion

This paper proposed an pair electrode that consists of a coil and an pair electrode acting as a variable capacitor. It is found that the resonant frequency of the proposed pair electrode changes when the signal electrode is close to a human body and that the pair electrode improves the received power. These results indicate that the proposed pair electrode will be suitable for intrabody communication.

References

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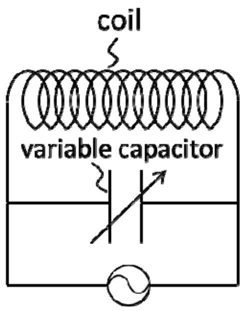
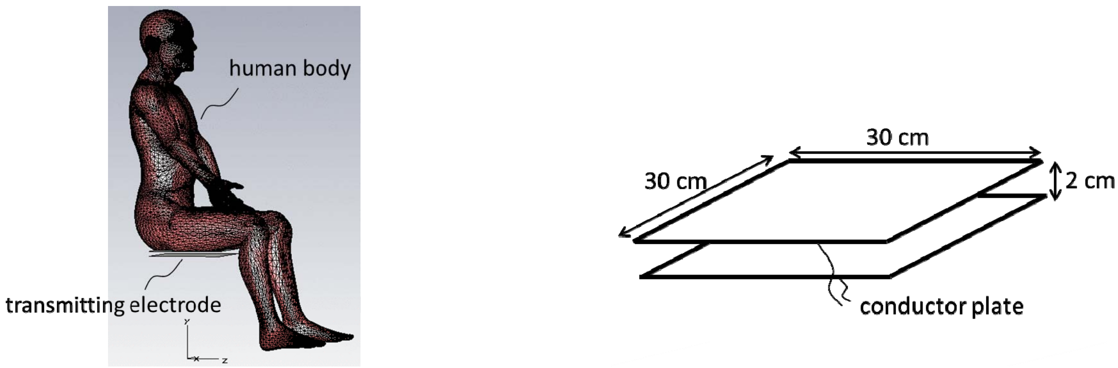
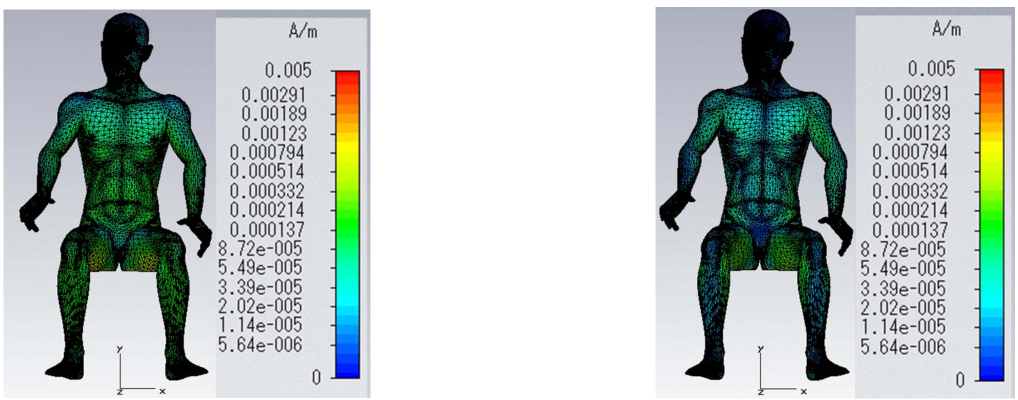


Figure 1: Equivalent circuit schematic of the proposed pair electrode.



(a) Calculation model (b) Schematic view of the transmitting pair electrode

Figure 2: The model used to calculate the magnetic field around human body and the transmitting pair electrode.



(a) Parallel component (b) Vertical component

Figure 3: Parallel and vertical components of calculated magnetic field with respect to the human body surface.

(a) Proposed pair electrode (b) Conventional pair electrode

Figure 4: Experimental proposed pair electrode and conventional pair electrode.

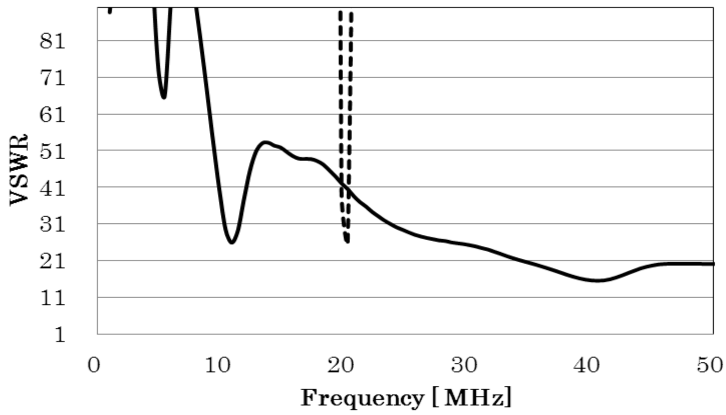


Figure 5: The VSWR frequency characteristic of the experimental proposed pair electrode. The solid line is the result when the signal electrode of the proposed pair electrode is placed parallel to human body surface at a distance 5 mm, and the dashed line is the result when the signal electrode of the proposed pair electrode is placed more than 5 cm from human body surface.

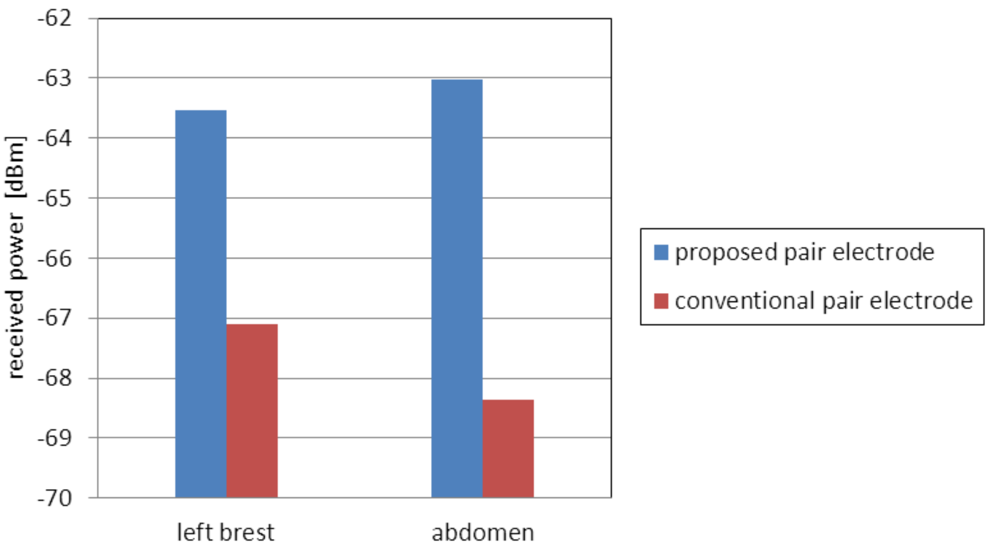


Figure 6: The received power of the proposed pair electrode and the conventional pair electrode.