Contactless Electric-field Intra-body Communication with Zone Localization

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Abstract

Zone localization with an electrode for contactless electric-field intra-body communication is investigated. We propose a selective receiving circuit that receives voltage signals only when the voltage signals detected at two lateral-side electrodes have different polarity. The proposed circuit allowed the zone to be localized.

Keywords : Intra-body communication Contactless Zone localization Polarity

1. Introduction

Communication around humans, such as UWB[1], Zigbee[2], and intra-body communication[3-7], is expected have applications in security systems and sensor networks. In the application of the intra-body communication to security, a user who has a mobile device for authentication is specified and authenticated by contacting an electrode, connecting to device installed in a floor or door. From the point of view of system design, the security system lets the user's action of stepping and touching synchronize with the start of communication. If the user's action of entering a security entrance can be synchronized with the start of communication without stepping and touching, the following benefits will be obtained:

- Convenience in that a natural action becomes the action for the authentication, compared with using the contactless IC card.
- The ability to deal also with users who dislike touching.
- The ability to install electrodes without constructing a floor in an existing building.

In this case, the communication should start when the user enters the security entrance. For example, an electrode is installed at its lateral side of the security entrance. Therefore, it is necessary that the communication zone be localized in order to specify the user. This paper presents principal of signal propagation, the concept of zone-localization and zone-localization preliminary experiment for an electrode installed at the lateral side.

2. Principal of Signal Propagation

A conventional intra-body communication installs an electrode of the installed device at a position that a human usually contact. For instance, the electrode is installed on a floor as shown in Fig. 1(a). In contrast to this, the electrode used in the contactless intra-body communication can be installed even at the position that the human doesn't usually contact. In this work, the electrode is installed at a lateral-side as shown in Fig. 1(b). The mobile device used in both cases is the same. The principal of signal propagation in using a lateral-side electrode is explained in this section.

The situation considered here is the authentication of a walking user where a lateral-side electrode is installed on the wall at the security entrance lane. In this situation, the lateral-side electrode is installed on the insulator wall, and the user (human body) stands on Earth ground, which is voltage standard of the system. The mobile device has a battery-powered transceiver circuit in an insulated case that is set between parallel-plate electrodes (Fig. 2). When the mobile device transmits signals to an installed device connected with the lateral-side electrode, the mobile device is simplified to be an AC signal source V_s.

In the capacitive-coupled circuit model shown in Fig. 2, capacitances C_{bl} and C_{gl} are added from the circuit model introduced in Refs.3 and 7. C_{bl} is capacitance between the human body and the lateral-side electrode, and C_{gl} is capacitance between the lateral-side electrode and mobile device's electrode far from the human body. These stray capacitances are formed even when the human body or mobile device's electrode doesn't contact the lateral-side electrode. Z_{rcv} is impedance between the lateral-side electrode and Earth ground, which includes the input impedance of the installed device.

The propagation of AC voltage from the mobile device to lateral-side electrode is considered as follows. AC signal voltage generated by signal source V_s is applied to the human body via C_t from the mobile device's electrode close to the human. Then, signal voltage is applied to the lateral-side electrode via C_{bl}, the same as in the case of the contact electrode.

In addition, signal voltage with the inverse polarity is applied to the mobile device's electrode far from the human body because the electrode is floating from Earth ground. The signal voltage with the inverse polarity can be applied to the lateral-side electrode because the lateral-side electrode is connected to the electrode far from the human body via C_{gl}.

Therefore, although signal voltages with a different polarity are propagated to the lateral-side electrode via C_{bl} and C_{gl}, it can be predicted that signal voltage will be received at the lateral-side electrode when the amplitude of the signal voltages is not equal. Moreover, although the values of C_{bl} and C_{gl} vary as the human body moves in front of the electrode, the variety of those to his movement is not the same and signal voltage will be received at the electrode.

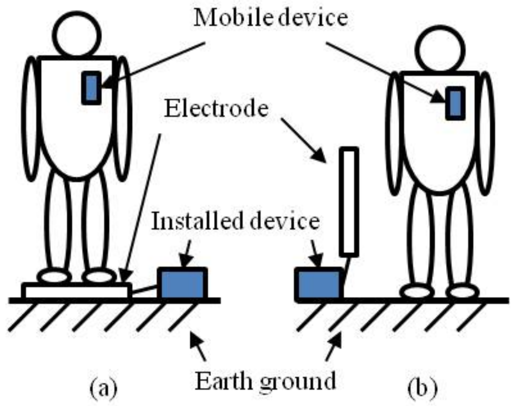

Fig.1 Schematic of an electrode (a) for contact and (b) for contactless.

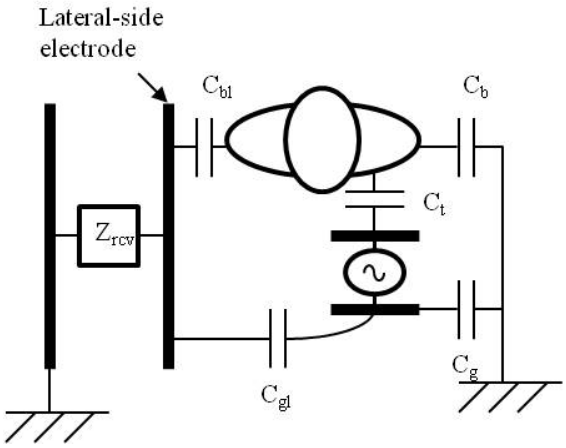

Fig. 2 Circuit model (top view)

3. Concept of Zone Localization

To achieve zone localization, we focus attention on the feature that the polarity of the voltage received in a forward position of the user is different from that of the voltage received in a side or backward position. When the human maintains the mobile device in front of him, the signal voltage via C_{gl} at the lateral-side electrode should be larger when the electrode is in a forward position of the human. When the electrode is in a side and backward position of the human, the signal voltage via C_{bl} at the lateral-side electrode is larger. By taking into account this feature, we propose zone-localized method where signal voltage is received only when the polarity of the signal voltages received at two lateral-side electrodes aligned along travelling direction is different.

Fig. 3 shows a block diagram of a selective receiving circuit that realizes the proposed method. Signals detected at each lateral-side electrode are amplified at Amp & BPF, and then their amplitude is equalized by automatically gain control (AGC) in order not to exceed the input range of the mixer. Each signal is multiplied in the mixer, and harmonics are eliminated by a LPF. When signals received at each lateral-side electrode have homo-polarity, the level output of the mixer becomes high (H) level as shown in Fig. 4(a). When they have hetero-polarity, it becomes low (L) level as shown in Fig. 4(b). By designing the comparator circuit so that the switch (SW) shuts when the level is L, the proposed method is realized. Because the aim of this work is to measure received voltage at the lateral-side electrode, the difference between voltages received at the lateral-side electrodes is taken by a differential amplifier and output to a spectrum analyzer. Therefore, observation of signal output from the selective receiving circuit shows that voltages received respectively at two lateral-side electrodes have a different polarity.

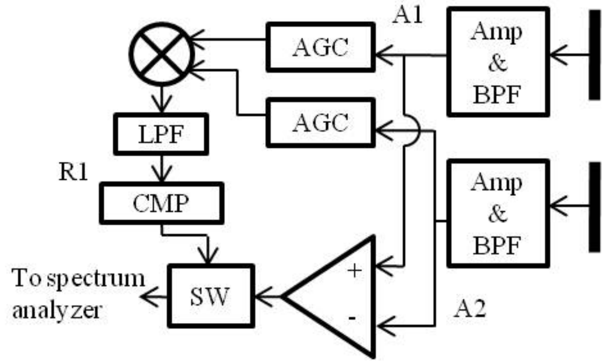

Fig.3 Block diagram of selective receiving circuit.

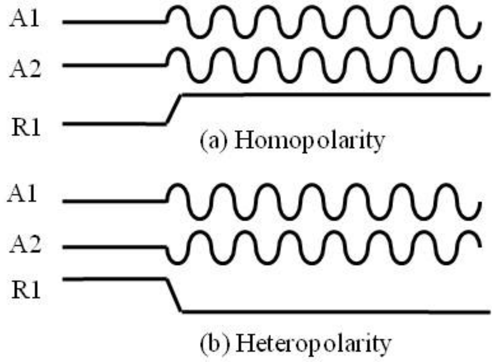

Fig.4 Waveform diagram

4. Experiment

Received voltage was measured for a single lateral-side electrode and for two lateral-side electrodes with the selective receiving circuit. The measurement set-up is shown in Fig. 5. The received voltage to the position of the human body was measured, where a mobile signal source imitating a mobile device was in the breast pocket of a shirt. The mobile signal source consists of a battery-powered signal source with frequency of 5 MHz and parallel-plate electrodes. The electrode size is 8.8 x 5.3 cm, and the distance between the parallel electrodes is 1 cm. As a role of Earth ground, which was the voltage standard of system, a Cu sheet was set on the floor and the ground of the measurement equipment was connected to it.

A lateral-side electrode (size of 20 x 30 cm) was set at a position where the top of the electrode was at 85-cm from the floor. The ground electrode was set in the backside of the lateral-side electrode with a 1-cm-distance between them so that undesired signals from equipment would not be received. In the case of two lateral-side electrodes, the lateral-side electrode 1 and 2 were aligned along travelling direction as shown in Fig. 5. The lateral-side electrode 1 was near the entrance. A distance between two electrodes was 20cm. The origin of the human position was set in the middle of the lateral-side electrode 1 and 30-cm from it. The received voltage was measured as the human body stood on the point at 20-cm intervals. The indicated values in the spectrum analyzer were converted to be received voltage between the two electrodes by the gain of Amp and a differential amplifier. In case of the single lateral-side electrode, the lateral-side electrode 1 and an amplifier with the same input impedance as the selective receiving circuit were used.

Measurement results are shown in Fig. 6. In the measurement with the single lateral-side electrode, we confirmed that signal voltages were received at the lateral-side electrode. In this case, there are two local maximums in the received voltage to the human position. When we imagine that the lateral-side electrode moved from the front to back of the human, the reason would be that the received voltage became small at the position of changing polarity, because the voltages received in a forward position and side and backward position had different polarity.

For the two lateral-side electrodes with the selective receiving circuit, received voltages were drastically decreased at positions that were outside of the origin by 40 cm or more. This is because voltages received at the two electrodes didn’t have different polarity and the SW opened. Received voltages around the lateral-side electrode 1 were almost the same as those for the single lateral-side electrode. This means that voltages of a different polarity respectively at two electrodes were received at these positions. The selective receiving circuit with two lateral-side electrodes localized the zone more clearly than single electrode.

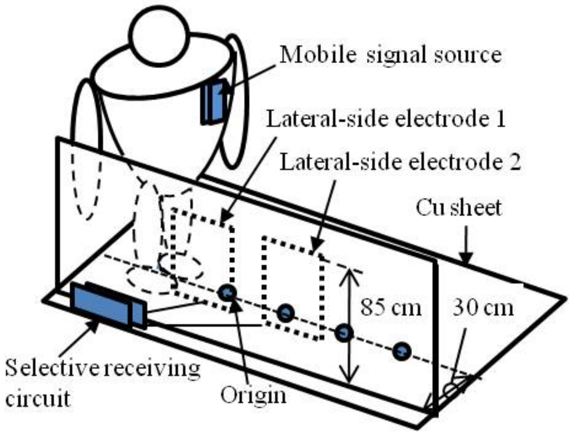

Fig. 5 Schematic of measurement.

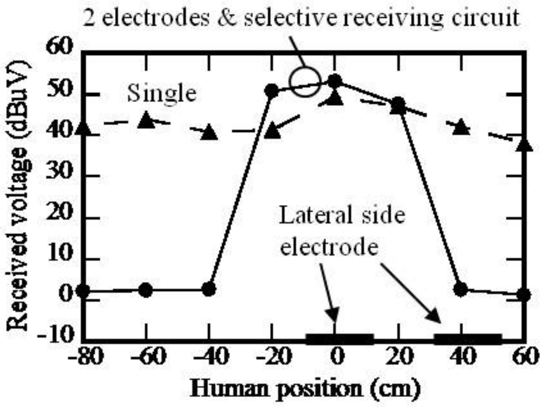

Fig. 6 Measurement results.

5. Conclusion

This paper performed preliminary study of signal propagation and zone localization for an electrode installed at the lateral side of a security entrance, with the aim of achieving communication only when the user enters the entrance. We focused attention on the feature that the polarity of the voltage received in a forward position of the user is different from that of the voltage received in a side or backward position. And we proposed a selective receiving circuit that receives voltage signals only when the polarity of voltage signals received at two lateral-side electrodes aligned along the travelling direction is different. In the measurement of voltage signals using the selective receiving circuit, voltage signals were observed at the position around the lateral-side electrode near the entrance. This indicates the localization of the zone, and implies that the polarity of the signal voltage received forward of the human is different from that of the signal voltage received to the side of and behind him when he has the mobile device in front of him. This work is expected to expand applicable field of the intra-body communication.

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