2007 6th International Conference on Information, Communications & Signal Processing,
10-13 Dec. 2007 Page(s):1 - 5

Future Applications of Body Area Communications

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Abstract— **Ubiquitous communication seems to be in practical use these days. However we are still looking for a new promising communication infrastructure for personal area network. In this paper, we show some of the body area communication characteristics and applications for the future personal area application. We have investigated both of the Intra-Body communication and Inter-Body communication in terms of propagation and application respectively. Various kinds of wearable devices have been developed for many purposes. Some of the medical applications require very small size of the transmission device in order to have enough portability and long life time. Body area communication seems to give us the answer such requirement.**

Keywords—Intra-Body Communication, Inter-Body Communication, Body Area Network, Healthcare

I INTRODUCTION

Human body communication (or Intra-body communication) is a new way for electronic devices to communicate with each other. Zimmerman [1] introduced the Intra-body communication (IBC) system in 1995. He proposed a wireless communication system that allowed electronic devices on and near the human body to exchange digital information through near field electrostatic coupling. Information was transmitted by modulating electric fields and electro-statically coupling electric currents into the body. The body conducted the tiny current to body mounted receivers. The environment provided a return path for the transmitted signal. In Zimmerman's work, he took low frequency carrier (330 kHz) for 2400 bps transmission. Kurt Partridge [2] had designed and constructed intra-body communication system, modeled after Zimmerman's original design, and extended it to measured signal strength. He used quantitative measurements of data error rates and signal strength while varying distance, electrode location on the body, plate size and shape, and several other factors. In his work, plate size and shape have only minor effects, but that the distance to plate and the coupling mechanism significantly affect signal strength. The transceiver size was 8cm x 13cm, and he achieved 56 kbps data rate. Katsuyuki Fujii [3] used higher frequencies from 10MHz to 100MHz and studied transmission characteristics of IBC. Both of signal and ground electrodes were attached to skin and he mainly studied location and positioning of electrodes. In the IBC, transceivers send and receive signals using dry electrodes: conductive surfaces of several square centimeters in close contact with the skin. Different electrical coupling methods have shown the potential of data communication through the human body. Methods for intra body transmission can he divided into the two types, shown in Figure 1; electrostatic coupling and electromagnetic wave.

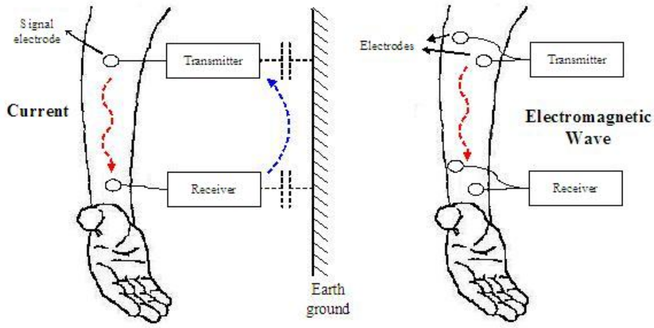

Fig.1 Typical IBC Transmission Methods

In the first method, electrostatic coupling, devices need to be grounded. This type of transmission was used in the study of PAN by Zimmerman[l]. Transmission quality is dependent on the surrounding environment. The earth ground needs to be electrically isolated from the body to prevent shorting of the communication circuit. In the second method, electromagnetic wave, the human body is treated as a waveguide, with the high frequency electromagnetic waves generated at a terminal propagating through the body, and being received by another terminal. Marc Wegmueller [4] has proposed electromagnetic wave or galvanic coupling. A transmission was done through galvanic coupled links between 2 differential electrode pairs. The human body is characterized as a transmission medium for electrical current by means of measurements and is investigated as communication channel for biomedical parameter monitoring by using different modulation schemes at low frequency (10 kHz to 1 MHz). BPSK transmission, a data rate up to 255 kbps was achieved with a carrier frequency of 600 kHz. FSK modulation poses higher requirements to the analog part. In Hachisuka's [5] work, propagation through the body can be seen to be superior to propagation through air, with I/O gain reaching a maximum of -26 dB at around 10 MHz. He proposed that, 10 MHz is the most suitable carrier wave frequency for transmitting data with minimal energy consumption. In addition, he used seven different common commercial metals (Ag-AgC1, aluminum, copper, bronze, brass, stainless steel, and nickel silver) as wearable electrodes without conductive paste to measure the contact impedance between contacts at the wrist and upper arm, a separation of 280 mm. The dimension of each electrode was 30 mm by 30 mm. Impedance of the electrodes is largely independent of the electrode metal. This indicates that stable communication through the intra body can he achieved using different kinds of electrodes, even when electrically conductive paste is not used to reduce contact impedance.

We[6, 7, 8] have shown that the optimal configuration is composed by transmission and receiver electrodes without ground electrodes and a diameter of 2cm because of the lowest attenuation performed. From a point of view of time delay, the configuration of transmission and receiver electrodes without ground electrodes does not provide the best performance. However, we mentioned that, this electrode configuration as the most suitable one. We have studied the transmission characteristics of the human body as a conductor of radio signals with higher frequency carriers (up to 2.5GHz) in order to find an optimal frequency range for broadband intra-body communications with high data rates. We carried out experiments on the delay time profile and the attenuation of the received signal. From the experiment results, suitable frequency range for the intra-body communications is proposed as up to 600MHz.

II INTRA-BODY SIGNAL PROPAGATION

Fig. 2 illustrates the measurement models employed in the experiments of this and next sections: arm to arm model, foot to head model and foot to arm model. In the arm-arm model, the TX position was always fixed on one hand and the RX was located along both arms (distances from 20cm, i.e. hand to wrist of the same arm, up to 160cm, i.e. hand of one arm to wrist of the other arm, were considered). The foot-head model was defined based on the idea of guidance application for blind people explained previously. The test person's foot stood on the TX and several RX measurement positions were settled (distances of 90cm and 155cm that corresponded to a distance between the foot and, the waist and the ear respectively). In the foot-arm model, the TX was located in the foot and the RX in the wrist (the distance between TX and RX was approximately 180cm, the maximum considered in this paper). This measurement model was defined based on the idea of the payment application for handicapped people. Figs. 3 and 4 illustrate the frequency domain responses obtained for both arm-arm and foot-head measurement models respectively. The horizontal axis represents the frequency in MHz (from 1MHz to 2.5GHz) and the vertical axis the power of the received signal in dBm. We measured the received signal power considering the test person in both sitting and standing test condition. Both graphs show that the attenuation of the received signal increases when the frequency also increases. Moreover, the decay of the received signal power is faster when the distance between TX and RX is longer. We also observe from both figures that sitting and standing test conditions yield similar results for all the distances and, therefore, we can affirm that there is not a better position forthis kind of communication. On the other hand, we believe that a suitable frequency range for IBC could be up to 600MHz,based on the zone with the lowest attenuation results from both figures.

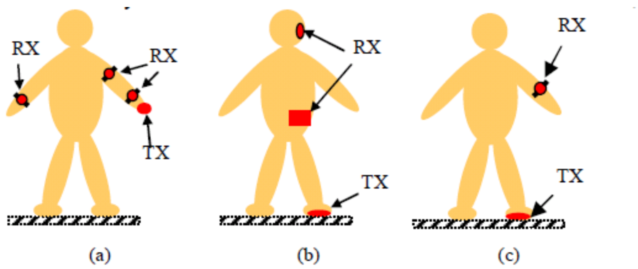

Figure 2. Measurement models: (a) arm-arm model, (b) foot-head model, (c) foot-arm model.

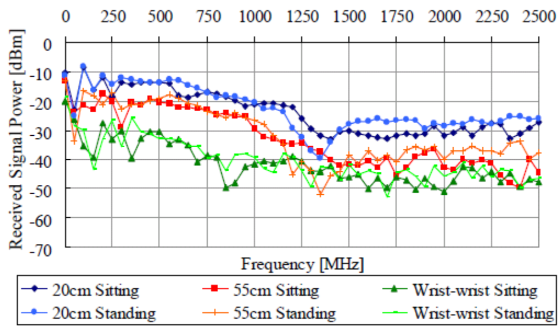

Figure 3. Average received signal power of arm-arm model.

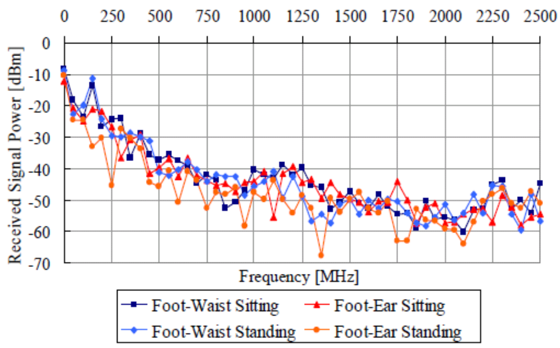

Figure 4. Average received signal power of foot-head model.

III EXAMPLES of INTRA-BODY COMMUNICATION

The number of potential applications using IBC is enormous. For example, IBC could allow touch business card exchange by shaking hands and open a door of a car by attaching an IBC terminal to an arm, and can open a key. Moreover, we have envisioned applications for handicapped people For example, Fig. 5 shows that IBC could be used by blind people as a guidance system when walking in the streets, shopping centers and train stations. Whenever the blind person's shoes step the IBC enabled ground sensors, communication could be carried out between the IBC enabled foot sensor installed in the shoe and the IBC enabled sidewalk. Then, the data received in the foot sensor could be forwarded through the body to an IBC enabled earphone, so that he/she could hear the information by voice.

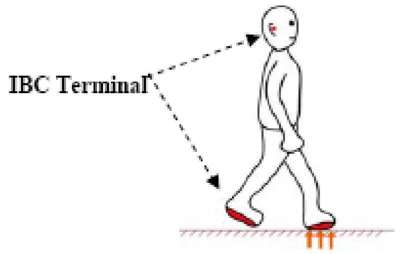

Figure 5 Blind Person Assistance System

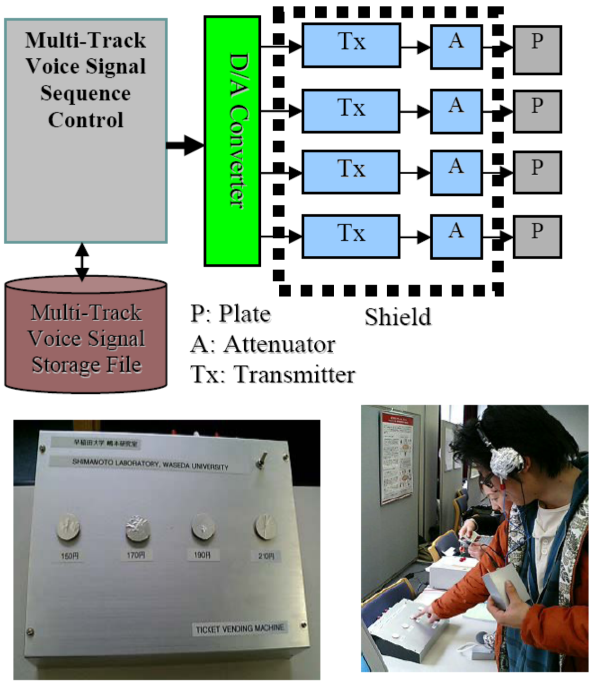

Figure 6 Touching Voice System

E-payment could be another application suitable for blind people whereupon e.g. instead of purchasing a train ticket in the vending machines, the blind person's credit card information stored in an IBC enabled device could be transmitted to an IBC enabled detector located in the ground of the ticket gate so the blind person could go through the gate[5]. We have already implemented an application that we call touching voice system by using IBC. In this application (Figure 6), users have attached an IBC enabled headphone. When they touch a plate with their fingers, voice information is transmitted from the plate through the body to the ear phone , so the users can listen such information. We believe that this kind of application could be suitable for blind people and elderly in places such stations when purchasing train tickets.

We have proposed FIS(Finger Identification System) in order to detect the finger being used when a person is using touch panel devices. By using FIS, the system can change responses according to the finger being used. [9]

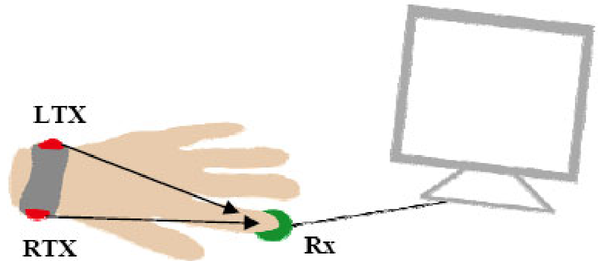

Figure 7 2TX Model

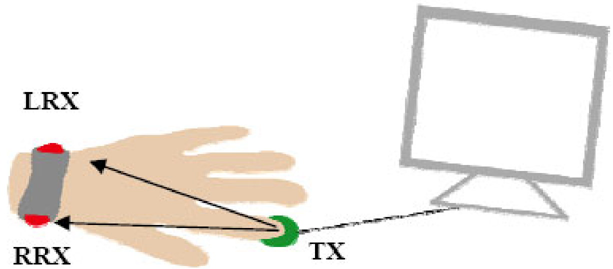

Figure 8 2RX Model

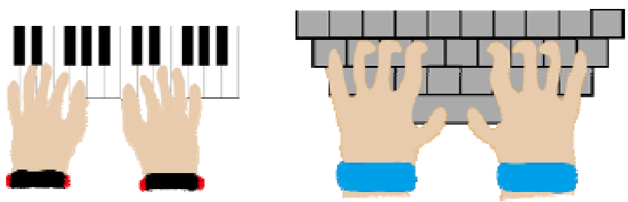

Figure 9 Keyboard Typing Prctice

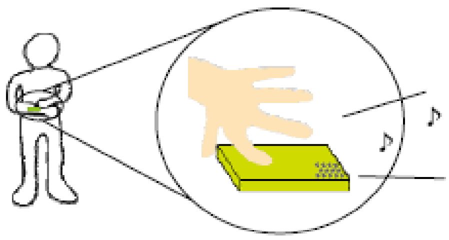

Figure 10 Speech Assistance for Dumb People

We have configured two FIS models: a two transmitters (TX) model and a two receivers (RX) model that are shown in Figs.7 and 8 and respectively. In the former model, the 2 separate TXs have the capability to transmit at the same time. There is also one RX which is touching the fingers. Firstly, FIS needs to calibrate information related to each finger for this process is carried out as follows:

I. FIS system establishes setup information by using IBC to determine the time range of the transmitted signal from each finger to arrive to the RX.

II. The setup information is recorded in the IBC terminal.

III. Next, when the finger is touching the sensor device, setup information is sent with the detected information to the sensor device

IV. Then the sensor device will compare the setup information and the detected information and the detected information and then determine which finger has been used.

In the 2RX model, IBC terminal is the receiver side with Left RX and Right RX. The 2 separate RXs have the capability to receive signals at the same time. There is also one TX which is touching the fingers. The setup and identification process for this model is equivalent to the 2TXs model.

FIS is used to distinguish each finger and can be used in many application just as any other input method. In music lesson, this system can be used to determine whether the piano keys are being played by the right finger (Figure 9). Also by distinguishing different fingers in both hands, ten different numbers can be input depending on the finger being used. (i.e. each finger representing one number from 0 to 9). The combination of several fingers would enable to represent numbers bigger than 9, i.e. , for example, if left and right little fingers represent 1 and 2 respectively, pressing both fingers at the same time could represent 12. At the same time, each finger and combination of fingers could represent a letter that when touching a panel that is connected to a speaker, this letter could be converted into sound (Figure 10).This application could be used to assist elderly or handicapped people. Moreover, each finger could store not only numbers or letters but also information such as personal, identification and password numbers. We think that combining FIS and biometrics encryption technology, the transmission of information could be performed safely.

IV INTER-BODY COMMNUCATION

In this chapter, we study short-range wireless communication method between human bodies, the Inter Body Communications. The near-field electrostatic coupling method is used for the inter body communications. We carried out experiments to investigate transmission characteristics of the inter body communications. We show an introduction, measurement procedures, results and discussions.

This kind of human-to-human communication can be applied for many interesting applications, such as people exchange business cards, transfer multimedia data, human ad-hoc networks, and an assistance system for handicap people, etc. Main advantage is low power, because power consumption is vital in small mobile devices for battery life and regulation standards. Also low power should be safer for a human. Furthermore, it makes possible not only human-to-human communications, but also communication between human body and an access point. One of the examples could be an assistance system for handicaped people in service area. In addition, some of possible advantages are easy to use, touch selective, no shadowing etc. In case of conventional personal area network communications, a human body itself becomes a shadowing obstacle for communication devices. However, in the near-field radio, the human body itself is used as an antenna not an obstacle. As well, it can be applied for touch selective applications. When a person touches a device, communication could start between a human and an access point.

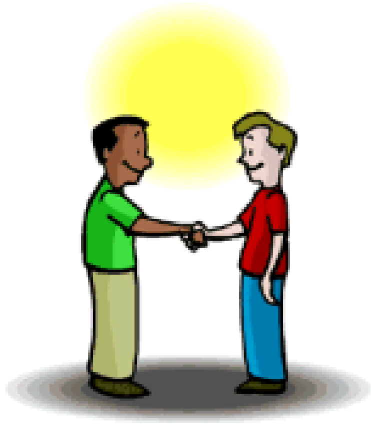

Figure 11 Inter-Body Communication via Hands

Radio signals, generated in the signal generator, input in first person's body through the TX, received in the RX on the other person and finally evaluated in the wireless communication analyzer. The transceivers are both placed on the wrists respectably and configured as same as in the previous measurements. In this measurement, four people, two men and two women, are experimented. We measured signal transmission between a man and a woman, between men and between women. At each frequency point, measurements are done 5 times and an average of received data is kept as final result. A transmission distance is defined as the distance between people. Intra-body communications have many interesting potential applications towards a ubiquitous world. Recent studies succeeded sending 10 Mbps in the intra-body communications and they send multimedia data between personal devices. Intra-body communication method could be applied in communications between personal mobile devices on or near the body, such as PDA, mobile phone, media player, earphone, etc. Moreover, IBC could be used in touch selective communications, such data transfer in printer, camera, personal computer, etc. We also present a study on direct communications between human bodies through their hands as well. (Figure 11) We have studied characteristics of Direct-Touch Inter-Body-Communication by some experiments. Figure 12 shows the measured results of communication employing handshake. The blue line shows the received signal power of the inter body communication, where the people do not touch each other. A signal transmits only through air. The yellow line shows the results for shaking by left empty hands. And the red line shows the results for shaking by right hands, which is connected to the transceivers.

From the results depicted in Figure 12, we observed that, the received signal power attenuation is different in the two cases. When the people touch by right hands, which is connected to the transceivers, the received signal power is higher than communication's through air. This happened, because the transceivers get closer to each other in the case of touching by the right hands. However, when the people touch by left empty hands, the signal attenuation is same as in the transmission through air. In the case of touching by left hands, signal transmission through the hands is almost invisible. It shows that, it is impossible to transmit a signal through hands between people.

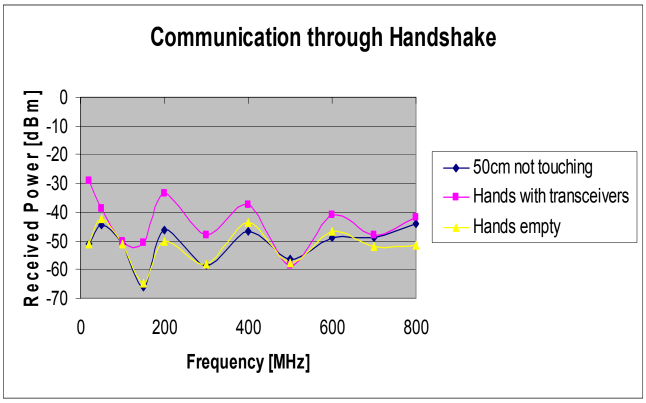

Figure 12 Results of Inter-Body-Communications

V FUTURE APPLICATIONS of IBCs

We think that there are many application areas adopted for the intra body communication. Security is one of the promising areas for this. For example, the key system which has unlocked status only when 2 persons are shaking hands. That means we need to have at leaset 2 persons to unlock the key.

During the last few years, there has been a significant increase in the number and variety of wearable health monitoring devices, ranging from simple pulse monitors, activity monitors, sophisticated and expensive implantable sensors. Wearable IBC systems for continuous health monitoring can be a key technology in helping the transition to more proactive and affordable healthcare. They allow an individual to closely monitor changes in her or his vital signs and provide feedback to help maintain an optimal health status. In addition, IBC systems could be used for health monitoring of patients in ambulatory settings. For example, they can be used as a part of a diagnostic procedure, optimal maintenance of a chronic condition, a supervised recovery from an acute event or surgical procedure, to monitor adherence to treatment guidelines, or to monitor effects of drug therapy.Personal wireless communication systems generally comply with the safety limits for electromagnetic fields. IBC uses much less than the recommended value for occupational exposure (0.08 W/kg). Considering an average weight of human of 65kg, the maximum transmit signal power could be 37dBm. Therefore, IBC devices can be considered safe. Compared to other short-range wireless communication technologies, IBC gives advantage in low power consumptions. From previous researches, there is difficulty to find optimum frequency range for IBC. Most of studies suggested that, low frequency range is preferable, because if carrier frequency increases, radio signal radiation from transmitter increases. Otherwise, signal does not couple to the human body or just radiate to air. However, broadband applications cannot work on lower frequency range, so the IBC should work at higher frequency band.

VI CONCLUSION

We have shown some of the characteristics of IBCs (Inter Body Communication and Intra Body Communication) in this paper. We have shown that wireless communication between human bodies is feasible by using the near field radio. In addition, we studied feasibility of signal transmissions between people through their hands. Some of the promising applications are shown in this paper.

ACKNOWLEDGMENT

The work was supported by Waseda university Special grant.

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