World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:8, No:8, 2014

Intrabody Communication Using Different Ground Configurations in Digital Door Lock

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Open Science Index, Biomedical and Biological Engineering Vol:8, No:8, 2014 publications.waset.org/9998979/pdf

***Abstract*—**Intrabody communication (IBC) is a new way of transferring data using human body as a medium. Minute current can travel though human body without any harm. IBC can remove electrical wires for human area network. IBC can be also a secure communication network system unlike wireless networks which can be accessed by anyone with bad intentions. One of the IBC systems is based on frequency shift keying modulation where individual data are transmitted to the external devices for the purpose of secure access such as digital door lock. It was found that the quality of IBC data transmission was heavily dependent on ground configurations of electronic circuits. Reliable IBC transmissions were not possible when both of the transmitter and receiver used batteries as circuit power source. Transmission was reliable when power supplies were used as power source for both transmitting and receiving sites because the common ground was established through the grounds of instruments such as power supply and oscilloscope. This was due to transmission dipole size and the ground effects of floor and AC power line. If one site used battery as power source and the other site used the AC power as circuit power source, transmission was possible.

***Keywords*—**Frequency shift keying, Ground, Intrabody, Communication, door lock.

I. Introduction

RECENTLY communication through human body so called intrabody communication (IBC) or human body communication has attracted a lot of attention. IBC is based on the fact that very small amplitude of current can travel through the body. It is well known that biopotentials are the quantities of ionic current in the body. One of the well-known signals is electrocardiogram (EGC). Contraction and relaxation of the heart produce the ionic current. This current can travel through the body [1], [2]. Human body is indeed a conductive medium. Another widely known example is body fat measurement where AC currents less than 1 mA of different frequencies are sent through the body and amplitude decrease and phase difference are measured [3], [4]. Fat absorption is higher than water at one frequency and vice versa at another frequency. Thus, body fat portion can be calculated.

IBC uses minute current without having extra power consumption. In IBC, body behaves as electrical wires or the atmosphere in case of wireless communication network. The advantages of IBC include its low power consumption [5] and communication capability of high data rate [6], [7]. IBC does not require additional electrical wires and complicated connectors compared to wire communication. Communication is theoretically possible through simple touch through which communication becomes easy and convenient. Compared to wireless communications such as Bluetooth or Zigbee networks, IBC is very effective in terms of security measures since data are contained inside the body whereas anyone can have access to wireless networks. Other advantages of IBC are more immune to the external interferences and the provision of intuitive and straightforward services to the customers [8], [9].

IBC can be directly applicable during daily lives. Through mere touch, information such as music, photographs or videos can be exchanged among the devices such as smartphone, MP3 and Smartpad without having electrical connections or using additional wireless networks [10], [11]. In this study, hardware configurations for transmitter and receiver devices were tested in order to determine whether reliable IBC could be available under different ground configurations. For this purpose, a digital lock based on IBC was developed and tested.

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II. Development of A Digital Door Lock Using IBC

There are two types of data transmission in IBC; pulse transmission and frequency shit keying (FSK) modulation. Pulse transmission sends pulses simple denoting 1 or 0 depending on the presence or absence of pulse. Frequency shift keying (FSK) modulates carrier frequencies depending on 1 or 0 of digital value. Two different frequencies should be assigned in FSK modulation. Hardware implementation becomes simple for pulse transmission. However, pulse transmission is more subject to noise interferences and the propagation length becomes shorter due to attenuation in the body. On the other hand, FSK modulation uses AC carrier frequencies that propagate easily through body. Even with a little more complexity involved with developing modulation and demodulation circuits, FSK was expected to be more suitable and was selected as a modulation method in this investigation.

A. FSK Modulation and Demodulation

An IBC system based on FSK modulation and demodulation is shown in Fig. 1. First, carrier frequency ranges between 0.5 Hz and 100 kHz were discarded since body internal noises in low frequency might interfere with the IBC [12]. Tens or hundreds megahertz were not chosen since high frequencies can be emitted out of body [13]. Another consideration on high frequency bands was the cost of high frequency devices. Taking these restrictions into account, 100 kHz and 120 kHz

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were finally selected as modulation frequencies. Once data received, they were demodulated and the original data were retrieved.

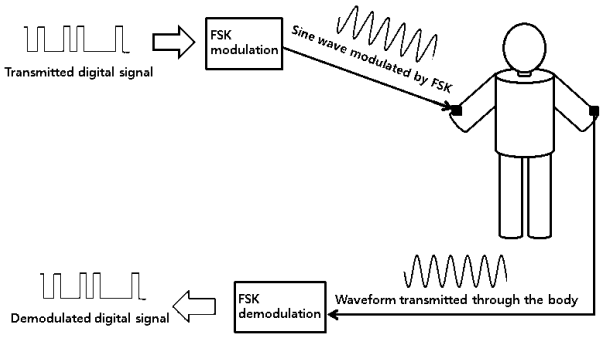


Fig. 1 Intrabody communication based on FSK modulation and demodulation

XR 2206 (EXAR Corp.) for FSK modulation and RC2211 (Raytheon Electronics Co.) for FSK demodulation were used. Signal amplitudes passing through the body should be limited within the safety limit. One of first IBC publications brought safety issues and safety is a sensitive issue. XR2206 has a maximum swing of 6 volts peak-to-peak and, therefore, +3 ~ - 3 volts was its range. The guidelines for low voltage ground fault protection in JEAG 801 of the Korea Electrical Safety Corporation limit the current to be less than 1mA that does not pose dangers for human body. Though there are variations among individuals, 5 mA stimulation can be felt in general. A sensitive person can feel even 0.5 mA. In our study, we limited the current to be less than 0.3 mA by adding a 10 kΩ chip-resistor before transmitting data to the body through an electrode.

B. Digital Door Lock

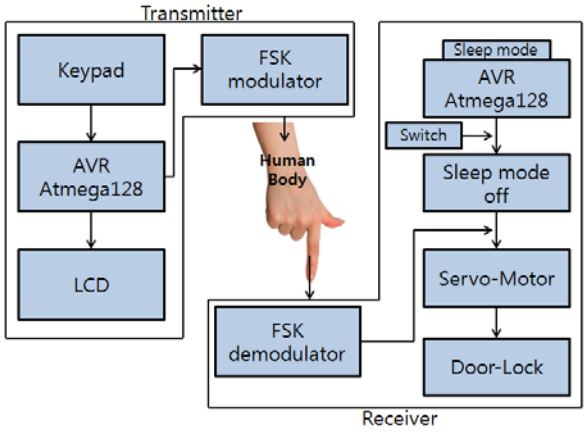


Fig. 2 System configuration of a digital door-lock system using intrabody communication

A prototype of digital door lock system was developed for our experiments and its block diagram is shown in Fig. 2. A password was typed using a keypad in the transmitter side or a stored password in the microprocessor (AVR Atmega 128) could be used as an alternative method. This microcontroller controlled FSK modulation as well as LCD display. Received passwords were check by another microprocessor, AVR Atmega 128 in the receiver side. One can verify numbers inputted by the keypad. Once the correct password is pressed, a motor was activated to open the door lock.

C. Problems Associated with Electrical Grounding

Grounding is the most critical issue for intrabody communication. IBC interconnects two separate objects and how to form electrical-grounding among three parts (transmitter, body and receiver) becomes very important. Many applications may include battery-operated devices such as smartphones and other electrical instruments. Among the parts the ground should be precise since the potential of showing voltage difference is a relative value. Otherwise, grounds may be floating.

For example, during our investigation at the initial phase, DC power supplies were used and data transmission was checked using oscilloscope probes. Data transmission was found to be successful. However, in the subsequent experiments where DC batteries were used as power source data transfer was not done properly. In these experiments data transfer was examined through a LCD monitor where data were displayed in real time, not by the oscilloscope probes. What we observed was that there all the parts shown in Fig. 2 were grounded to the common through the AC ground if DC power supplies or oscilloscopes were used. These devices used 220 volts AC sources and the device ground formulated common grounds among the IBC parts.

III. Experiments and Discussions

To verify ground problems, experiments were performed using two different power sources; DC power supplies and batteries. Another parameter for the experiment was a verification method of successful data transfer; use of oscilloscope probes or the verification through the LCD monitors. For this purpose, an additional LCD display was installed in the receiver side even though it is not shown in Fig. 2. Even only use of the oscilloscope probe, without using the DC power supplies, could arrange a different ground setting since the oscilloscope probe was internally connected to the AC ground through the instrument. In case of using a LCD monitor to very data both in the transmitter and receiver sides, no instrument ground could exist and there were only floating grounds of the batteries in this case. Data transmission was checked through data displayed on the two LCD monitors in the transmitter and receiver systems.

The results were summarized in Tables I~III. First we used 9 V as DC supply voltage. Data transmission through IBC was successful in the cases of using the oscilloscope probe in order to verify transmitted as well as received data. There was no difference whether battery or DC power supply was used as a power source either at the transmitter side or receiver side. For battery, one 9 V battery was used and its current capacity was +625mAh.

However, when the oscilloscope probe was not used and data

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transmission was verified only through the on-board LCD monitors powered by batteries, different results were obtained. In this situation, data transmission was successful accomplished only when the DC power supplies were used for both transmitter and receiver sides. Data transmission was not reliable when one of the sides was powered by the DC power supply and the other side was powered by the battery. 'Not reliable' indicates that IBC was successful sometimes and not successful for some other times. When both sides used batteries as power sources, IBC failed. These are summarized in Table I.

TABLE I
RELIABILITY OF IBC DATA TRANSMISSION WITH RESPECT TO DIFFERENT POWER SOURCES AND DATA MONITORING METHODS: 9V OR 18 V BATTERY OF 625MAH CAPACITY

	Oscilloscope monitoring	LCD monitoring
Transmitter (power supply) Receiver (power supply)	O	O
Transmitter (power supply) Receiver (battery)	O	Δ
Transmitter (battery) Receiver (power supply)	O	Δ
Transmitter (battery) Receiver (battery)	O	X

O: successful, Δ: not reliable, X: no data transfer

Our observations were as follows. When the oscilloscope probes were used, common grounds were established through the instrumentation ground of the oscilloscope and IBC was successful regardless of the types of power source.

TABLE II
RELIABILITY OF IBC DATA TRANSMISSION WITH RESPECT TO DIFFERENT POWER SOURCES AND DATA MONITORING METHODS: 9V BATTERY WITH 1200MAH CAPACITY

	Oscilloscope monitoring	LCD monitoring
Transmitter (power supply) Receiver (power supply)	O	O
Transmitter (power supply) Receiver (battery)	O	Δ
Transmitter (battery) Receiver (power supply)	O	Δ
Transmitter (battery) Receiver (battery)	O	X

O: successful, Δ: not reliable, X: no data transfer

When no oscilloscope probes were used, IBC worked only when DC power supplies were used for both transmitting and receiving sides. In this circumstance, common ground formed through the instrumentation grounds of DC power supplies. One of either side was supplied by battery power source. Then IBC data transmissions were not reliable since one side had a floating ground. In the case of using batteries for both sides, it was speculated that the grounds were floating and no IBC was working.

Next, the voltage of power supply was increased to 18 V instead of 9 V and performed the same test. This was because of operating voltages of FSK modulation and demodulation ICs. XR2206 FSK modulation has an operating range of 10 ~ 26 V. It was suspected that 9V might not be a sufficient voltage. Therefore, 18 V was arranged by connecting two 9 V batteries in series. However, the results were the same as those of 9 V (Table I).

Our next experiment was to use a higher current capacity of battery from 625mAh to 1200mAh in order to increase current stability. In case of the battery as power source, insufficient current capacity could affect the signal-to-noise ratio. For experiments summarized in Table I, the battery maximum current was up to 625 mAh. In this case, 6 AA-size 1.5V batteries (9 V) were used as power supply where instantaneous current up to 2~3 A might be handled with 1200 mAh. However, the results were the same as shown in Table II.

The next experiment used 18 V as power supply voltage that might be sufficiently high to handle FSK demodulation ICs. 18 V was arranged by connecting 12 1.5V-AA-batteries in series. The results were more successful. In this case, IBC was not reliable only when both power supplies for the transmitting and receiving sides were batteries.

TABLE III
RELIABILITY OF IBC DATA TRANSMISSION WITH RESPECT TO DIFFERENT POWER SOURCES AND DATA MONITORING METHODS: 18V BATTERY WITH 1250MAH CAPACITY

	Oscilloscope monitoring	LCD monitoring
Transmitter (power supply) Receiver (power supply)	O	O
Transmitter (power supply) Receiver (battery)	O	O
Transmitter (battery) Receiver (power supply)	O	O
Transmitter (battery) Receiver (battery)	O	Δ

O: successful, Δ: not reliable, X: no data transfer

From our series of experiments, it was found that sufficient power supply voltage and the current capacity of battery were important for reliable IBC channeling. However, successful IBC networks were not guaranteed when both transmitting and receiving sides were supplied by batteries. It is expected that IBC channels were not reliably established due to the problem of floating grounds.

An IBC digital door lock system described in Fig. 2 was implemented using battery as a power source in the transmitter side and a DC power supply supplied power to the receiver side at the door site. Therefore, a reliable IBC channel was guaranteed. More detailed operations are depicted in a flowchart of Fig. 3. Normally, the door lock was in a sleep mode so that power consumption should be minimal. When a switch in the transmitter side was pushed, an on-board microprocessor was activated. When a finger in the transmitter side was touched on the door lock, a pre-assigned password transmitted through the finger. When the correct password was acknowledged, then the door lock was released.

Password can be inputted in a few different manners. First, the on-board microprocessor has a stored password in advance and mere finger touch provides the password through IBC. Second, the password is typed through the keyboard on the

transmitter side, then, this password is sent to the receiver side through IBC.

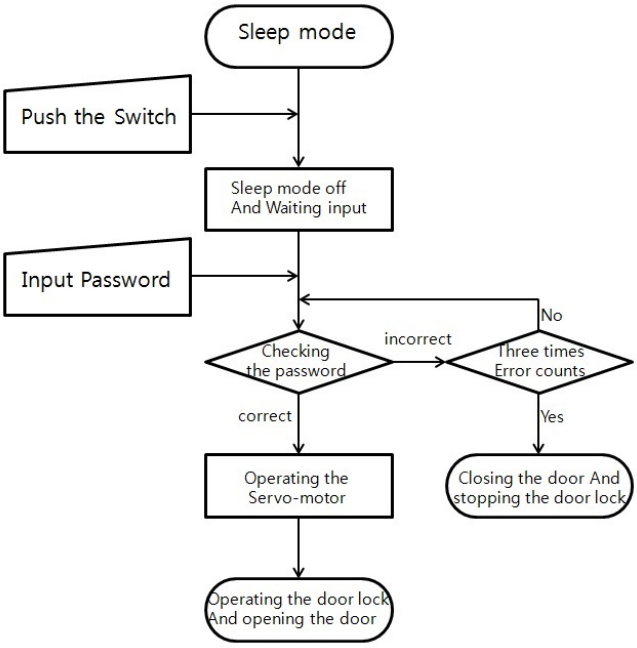


Fig. 3 A flowchart of system operation for a digital door lock system using the IBC channel described in Fig. 2

IV. Conclusions

In IBC networks, the ground problem is utmost important. During IBC experiments, using the oscilloscope and AC or DC power supply can produce false results because the ground channel can be established through instrument grounds. In order to check whether IBC networks were functioning correctly, LCD monitors were installed to both the transmitting and receiving sides. In this manner, no instrument ground either by the oscilloscope or power supply could be established. When both transmitting and receiving sides had to use batteries as power source, no reliable IBC channel could be established during our experiments. For the development of IBC digital door lock, therefore, the receiver side installed to the door had to use DC power supplies and the system worked properly under this condition.

Acknowledgment

This study was supported by Seoul National University of Science and Technology

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