Intrabody Communication using Galvanic Coupling

Akshay Yadav Sheetal Bhujade
Department of Electronics & Telecommunication, Mumbai University
Saraswati College of Engineering, Kharghar, Navi Mumbai
India

ABSTRACT
This paper proposes a concept of Intrabody Communication as a new wireless technology to exchange messages through human body. The concept of Personal Area Network (PAN) is also presented. In this work, we are using new electromagnetic model instead of radio wave communication for data transfer. This model is based on multi-layered ellipsoidal geometry which can be applied to any part of the body. The advantages of these technologies over other conventional technologies are also discussed. Further the real-world applications of this technology are proposed.

Keywords
Intrabody Communication (IBC), Personal Area Network, Galvanically Coupled IBC, Electrode, Electromagnetic Model.

1. INTRODUCTION
Intrabody Communication (IBC) is a new technology for communication between electronic devices. Human body is used a communication medium to transfer information based on the electrical conductive properties of human body tissues. Devices transmit & receive message signals through the conductive electrodes attached to the skin. Since the transmission takes place through human body, there are very low chances of any kind of noise or interference. IBC is an antenna less technology which results in low power consumption & minimum issues with the use of spectrum. This technology is based on near field coupling, therefore the transmitted signal remains confined to the body and has no interference whatsoever. As compared to other conventional technologies, the power consumption is also low since antenna enlargement is not required.

The characteristics of IBC include high transmission quality, high data rate, high security, easy network access and no communication bandwidth problem. Intra-body transmission methodology can be categorized in three types: the simple circuit, electrostatic coupling, and waveguide which are further discussed in the report.

The concept of intra-body communication was first proposed in 1996 by IBM. This communication mechanism has undergone many research ever since. The reported technologies had two limitations: the operating range through the body was limited to a few tens of centimetres and the top communication speed was only 40 bit/s. These limitations were overcome by NTT (Nippon Telegraph and Telephone Corporation) located in Tokyo, Japan by using photonic electric field sensors. They finally came up with a IBC technology that was sustainable. Electrostatic coupling type of transmission was used.

2. LITERATURE REVIEW
Several studies were performed to investigate transmission and reception of data through the human body using IBC. Some attempts were made to characterize IBC and to model the human body communication channel. The main differences between these investigations were due to different coupling schemes, signal strengths, frequency ranges, data rates, transceiver coupler sizes and structures, body channel modelling approaches and signal modulation methods.

The most important electric field paths in a system are that it developed an electrical model of the IBC system. In that model, the body was modelled as a perfect conductor and the electric coupling among the electrodes of the transceiver, body and environments modelled as capacitors [1] [2].

Quantitative measurements had been performed to determine the system performance under various circumstances. These include variation in hand distances to the RX electrode and electrode locations on different positions on the body as a belt, on the wrist and in the shoes. Touch electrode sizes and shapes with different conductive materials and different subjects are also examined [3].

Calculation models of the TX and RX attached to the arm using finite-difference time-domain (FDTD). Next, they had compared the calculated received signal to the measured ones employing a tissue-equivalent phantom. In their measurement system, the signal was generated by a battery-powered TX and sent to the human body by two horizontally placed electrodes. The signal was received by two electrodes at RX side and measured by a mobile receiver [4], [5].

The interference between IBC devices of two persons had been examined experimentally. Two scenarios had investigated; in the first, the TX and RX are on one person's body and in the second the TX is on one person's body and RX on another person's body. In their setup, the TX is fixed on the fingertips and the RX is located on two different positions on the body, 15 cm and 150 cm from the TX. Electrodes are structured horizontally and a single electrode size was employed. The interference signal propagates from one body to the other body [6].

Different transceiver designs, a distributed RC-model of the human body and characterization of the human body as a new communication method was presented. To achieve low power consumption and a high data rate, a wide band transceiver with a direct coupled interface (DCI) was implemented for IBC. In their measurement system set up, a battery-fed crystal based TX is employed and only a single electrode is used to transmit the data to the body. At the RX side, a single electrode was connected to a digital oscilloscope and its ground was floated to isolate it from the signal ground of the TX. The transceiver with a fixed data rate and without any modulation was not suitable for a shared body channel. Hence, it modified to a scalable PHY transceiver [7-9].

The model was a four-terminal circuit model with 10 impedances representing the coupling electrode impedances, the input and output impedances, as well as the longitudinal l transmit impedance and a butterfly cross impedance. The measurement performed by positioning the electrodes on a large number of different positions on the human body. These positions were classified into four groups: along the arm, on the thorax, along the leg and on the entire body. The influence of different electrode types and various sizes of TX and RX electrodes on signal attenuation investigated. Moreover, the level of signal attenuation for subjects with different tissue properties such as skin, fat, bone and muscles assessed by finite element simulation. It was concluded from these results that high variation of the transmission attenuation at different location on the body occurs. The thorax showed excellent transmission characteristics, while the extremities and joints resulted in additional attenuation. Consequently, transmission over larger distance will result in lower RX signal levels. The size of the RX electrode shasa neglectable impact, while the attenuation decreases with an increased [10].

The main advantage of this technology, using one medium (human body) for full duplex transmission. The socking related problem is not possible because the system works on low power [11].

In electrostatic coupling signal is transmitted through human body & return path is formed between the transmitter electrodes & receiver electrodes by electrostatic coupling through the external environment. Due to that, signal is affected by the noisy environment. Grounding is necessary in electrostatic coupling, which increases the circuit complexity. In galvanic coupling, viz. focus of this study the signal is applied differentially between the transmitter electrodes & received differentially by the two receiver electrodes. Signal in this coupling approach confined within the body as it is transmitted from pair of transmitter electrodes to the pair of receiver electrodes & therefore it is not affected by the noisy environment. In galvanic coupling grounding is not required that is why this circuit is less complex [12].

A circuit ground of a wearable device is connected to an earth ground with an instrument driven by AC power. The wearable device overestimates a voltage signal around the human body, preventing precise measurements from being performed. This problem is solved when an electro-optic (EO) technique is used between the wearable device and the instrument to enable precise measurements [13].

3. PROBLEM DEFINITION

Portable electronic devices like MP3 players, mobile phones & watches have received an increased demand over the last years. These devices interact with each other or with other devices like e.g. desktop computers. To avoid a clutter of wires, it will be required to set up a wireless radio frequency (RF) communication link between two or more devices, for instance using Bluetooth, ZigBee or Wi-Fi. This typically can be a very lengthy and inconvenient procedure, as it often requires manual user invention.

There is an increasing need to efficiently connect the electronic equipment surrounding a person's body into what we refer as a wireless body-area network (WBAN). A possible application of these BANs can be a head set wirelessly connected to both a media player and a mobile phone. Protection of the personal devices is another reason to form a WBAN. The fact that people wear more expensive mobile electronic devices increases the need for a BAN, where portable devices check the presence of each other in order to instantaneously detect the theft of one of them.

Therefore, due to the sketched problems of the RF-based technologies, a novel transmission technique had proposed in the 90s, which seems a promising approach for WBAN. In this solution, which will refer to as Intra-Body communications (IBC), the human body is used as the propagation medium for the data signals. The devices can be placed on or very close to, the human body and communicate with each other via the body.

4. BASIC CONCEPTS

4.1 Intra-Body Communications Technology

In the IBC technology, the human body acts as a communication medium. The basic principle of IBC is that an electric field is induced onto the human body in order to propagate a signal between devices that are in direct contact with the human body. There are two different approaches to induce an electric signal on the body i.e. capacitive coupling and galvanic coupling. For both approaches, the IBC consists of a transmitter (TX) and a receiver (RX), together connected to a coupler. Each coupler consists of two electrodes. In galvanic coupling, the electrodes have to be placed on the skin directly. For capacitive coupling, a direct human skin contact is not required; however, the devices must be in close proximity. These electrodes can be structured horizontally or vertically where the spacing between them is filled by a dielectric material. The vertical structure is only used for the capacitive body coupling approach**.** Illustration of an Intra-Body Communications (IBC) network with 5 devices depicted in Fig. 1

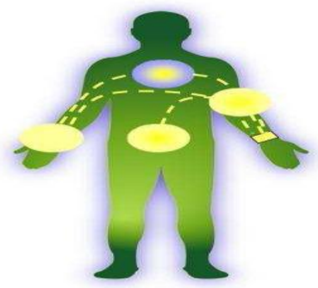

Fig.1 Illustration of an Intra-Body Communications (IBC) network with 5 devices

The two types of electrode structures are depicted in Fig. 2.

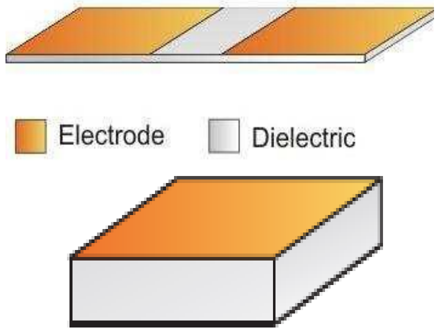

Fig. 2 Coupler structure for capacitive/galvanic body coupling

a) Horizontal Structure
b) Vertical Structure
The horizontal coupling can be applied for both approaches.

4.2 Galvanic body coupling or Waveguide body coupling

Figure 3 illustrates the galvanic coupling approach. At the TX, an electrical signal is applied differentially between two electrodes that are directly attached to the human body. At the RX, there are also two electrodes attached to the body. The induced current results in a differential signal between these two electrodes and is detected by them. This technique uses the dielectric properties of human tissue; hence, the carrier of information is the flow of ions within the human body. In this solution, the human body acts as a special kind of transmission line.

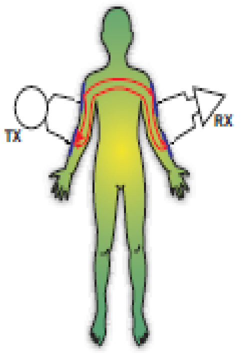

Fig.3 Galvanic body coupling for data transmission between TX and RX

In this approach, the human body is treated as a waveguide. Hence, galvanic coupling is also called as waveguide coupling. This technique grounding is not required. The high-frequency electromagnetic waves are generated at the input terminal which propagates through the human body and are received by a different terminal. External wires are not required and transmission quality is not affected by surrounding environment. In galvanic coupling, a pair of transmitter electrodes imposes differential signals into the body and the body is used as waveguide to transfer the signal. On the other end, the signal is detected at the receiver electrode pair. Waveguide IBC has low data rate in the kbps range because the body effectively shorts the transmitter electrodes. Waveguide technique can be categorized on the basis of the location of the electrodes which are to be places either on the body surface or implanted in the body [9]. Illustration of waveguide coupling depicted in Fig. 4

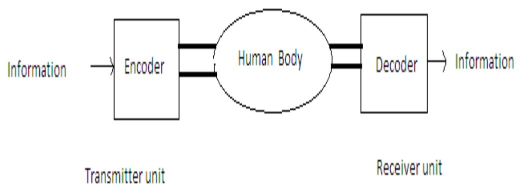

Fig 4 Waveguide technique

Types of Waveguide Methods:

Implant to surface communication:

In implant to surface communication, waveguide coupling is used to transmit signals from a device implanted in the body to electrodes on the skin. To improve the quality of signal reception, this technique allows for easy placement and repositioning of the skin electrodes. But signals have to travel through the skin, viz. less conductive than many of the tissues inside the body, high signal attenuation takes place in implant to implant communication [10]. Illustration of Implant to Surface communication depicted in Fig. 5

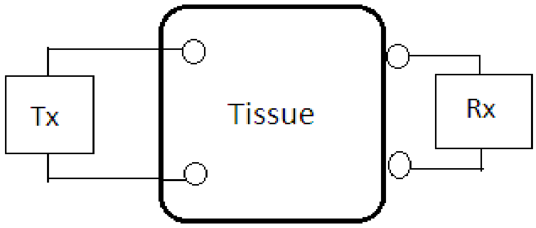

Fig.5 Implant to Surface

Surface to surface communication:

In surface to surface communication, devices are placed on the skin. Surface to surface communication allows for quick and easy placement of electrodes, lesser constraints on the size and power demands of the transmitting devices, and prevents surgical implantation. But in this technique, the sensors are positioned on the skin and not implanted in the body. Hence many times they are far from the signal sources that are being measured and can result in weak physiological measurements compared with implanted sensors. Surface to surface signals can be combined with signals from implanted devices to create a network of sensors across and body which will give further better output [10]. Illustration of Surface to Surface communication depicted in Fig. 6

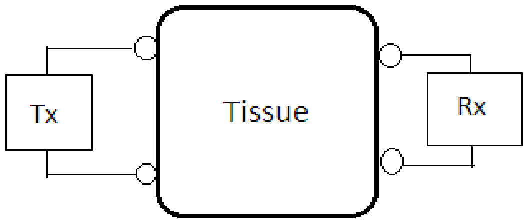

Fig.6 Surface to Surface

Implant to implant communication:

In implant to implant communication, both the transmitter and the receiver are implanted within the body. Hence signals are transmitted from the implanted device to receiver electrode. The implanted receiver can be connected to equipment outside the body using a short wire or with wireless RF or with implant to surface communication, again forming the network of IBC. The implanted receiver electrodes cannot be as easily repositioned as the skin-mounted receiver electrodes. In this approach, less power is required to transmit to the implanted receiver electrodes than to electrodes on the skin [10]. Illustration of Implant to Surface communication depicted in Fig. 7

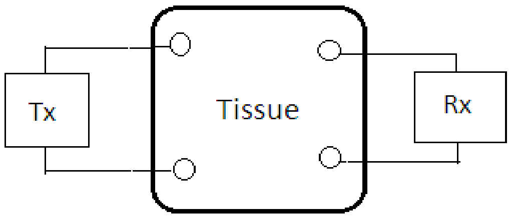

Fig. 7 Implant to Implant

4.3 Electrostatic body coupling or capacitive body coupling

In electrostatic coupling, different pair of electrodes are used at both transmitting and receiving ends. At the transmitter side, a signal is applied between the electrodes and since the electrodes have different capacitive coupling to the body, an electric field is induced in the body which passes through the body. At the receiver side, the two electrodes are situated at different distances from the body, so it is possible to detect a differential signal between them as a function of the varying electric potential of the body. In this technique, the human body acts as a conductor that forms a medium between the transmitter & receiver that are capacitively coupled to it. The surrounding environment is used as a reference to force or detect a variation of the electric potential of the human body [11].

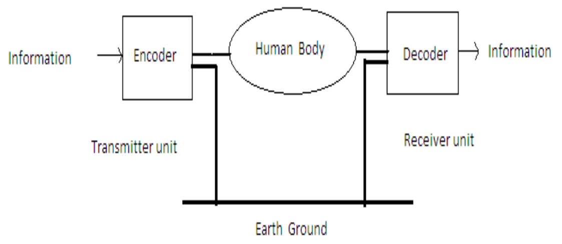

Fig 8 Electrostatic coupling technique

Illustration of Electrostatic coupling technique depicted in Fig. 9

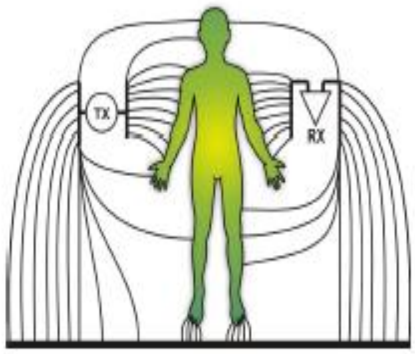

Fig. 9 Capacitive body coupling for data transmission between TX and RX

4.4 Comparison of Coupling Approaches

Both approaches have their advantages& disadvantages from a technical and application point of view. The vital difference between the two solutions is that the communication behavior in the capacitive coupling approach is highly dependent on the environment around the body, while in the galvanic coupling approach it is greatly influenced by the physical parameters of the body. From the application point of view, a significant difference between these two approaches is that the electrostatic approach does not require a direct contact between the coupler and the human body while for the galvanic coupling this is preferred, if not necessary. In other words, the galvanic coupling requires the devices to be fixed to the person with the electrodes in direct contact to the skin, while the capacitive devices can be just in its proximity of the human body and more loosely coupled. For that reason, we consider the electrostatic approach to be the most relevant [12].

The basic difference between the two types is that, in capacitive coupling technique, grounding is necessary. Zimmerman used this type of transmission in the study of Personal Area Network. Capacitive coupling is independent of an external wire, but quality of transmission depends on the surrounding environment. Capacitive coupling ensures that the signal is transmitted between the TX and the RX assuming that a suitable capacitance coupling is available to provide grounding between the I/p and o/p terminals. The signal is transmitted between the body channel transceivers by making a current loop, which comprises of the transmitter electrode, the body channel, the receiver electrode, and the capacitive return path through the external ground. In this model, the human body is considered to be a perfect conductor, and the electric coupling among the electrodes of the transceiver, body, and environment are modelled as capacitors. Before transmitting the signals through body, they are encoded and on receiving they are decoded. Illustration of Electrostatic coupling technique depicted in Fig. 8

5. PROPOSED METHODOLOGY

Construction: Mode selection switch.

Temperature sensor: thermostat 10K.

Microcontroller: AT MEGA 16 with 14 pin micro-controller consisting of 4 ports which is built in ADC. To start the microcontroller power supply, clock, reset is given to the microcontroller. The 1st output is the LCD display 16/ 2 alpha numerical display while the 2nd output is the transmitting pins i.e. electrodes which transmit data media through human body which includes only skin not any part of the body as skin contains moisture which will conduct electricity. The data will then be received with the second device through touch plates which is a voltage minor amplifier LM358 controller. Output will have extra component relay driver or transistor DC549. Relay is the electromagnetically switch relay.

Working

It is seen that electric fields exist between bodies at different potentials. Following this principle, consider that an electrode that's transmitting a signal is placed close to the human body. Due to difference in potentials, the same oscillating potential is imposed on the body, causing electric fields to be generated around the body, and ultimately on the receiving electrodes. This transfer of signal takes place due to the low impedance path provided by the body from the transmitter to the receiver. Thus, the transmitting electrode capacitively couples to the receiver electrode, through the human body; the earth ground serves as a return path for the circuit. Such capacitive coupling produces pico-currents at the receiver electrode, proportional to the transmitted signal, resulting in data transfer. Along with the transmission technology, we also have a 3-axis accelerometer hosted on the bracelet which keeps track of your daily activities. This provides for an overarching array of applications which were never before possible through a wearable. It also hosts a LED based screen for visual feedback. We are currently considering the option of having hepatic feedback on the device.

6. APPLICATIONS

Visiting card: if two people are greeting each other than by using this device data from one person is transfer to another person for e.g. Profile, messages, etc. Illustrated in Fig.11 [13].

Medical application: if doctor touch the patient then the information of a patient is transmitted to the doctor. Illustrated in Fig.12

ATM Machine: instead of card our touch will display our profile which will secure us from getting rob by any person. Illustrated in Fig.13

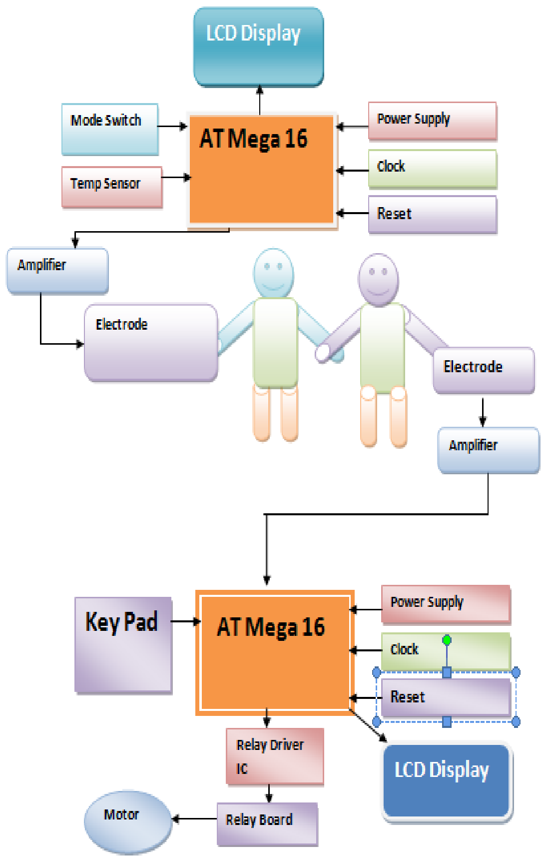

Fig 10. Block diagram of body area network

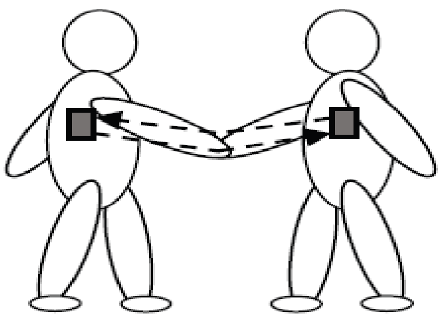

Fig 11 Example of Visiting Card

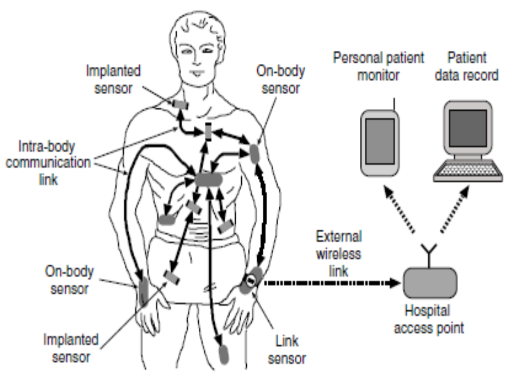

Fig 12 Example of Medical Application

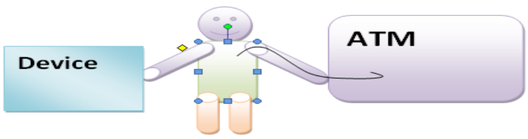

Fig 13 Example of ATM Machine

7. FUTURE SCOPE

Here in this report an external hardware is being developed to transmit the data from one device to another mobile device but in future we can develop the device with this inbuilt facility. Also some option for data transmission and security can be provided. The devices will not transmit the data without user's prior permission. To transmit the data between two devices also data rate can be increased and also buffered size can be increased. This may also expand to transmit the audio, video or image file.

One of the key concerns for IBC is the behavior of such communication when Human Body is in motion. As body movement severely impacts the received signal strength .Also, research needs to be done on data transfer rate variation due to body movement. This is critical since most of the practical implementation of this technology will involve body movement. The success of many new technologies has been driven by standardization. Standardization drives adoptability and helps by making devices interoperable. It also drives down cost of owning the technology or devices.

8. CONCLUSION

Galvanic coupling is a promising approach for intra-body communication. The versatile platform presented here offers sophisticated possibilities for signal application and data transmission using a differential pair of electrodes that are galvanic ally coupled to the human body.

To develop a wearable transmitter that was not affected by earth ground through A power by using an electro-optic technique. The wearable device was electrically isolated from an instrument. The wearable transmitter had a band width from 10kHz to20MHz and a40-d B signal-to-noise ratio at the transmitter output voltage of0.36V.A20-dB over estimation was obtained when the transmitter was affected by earth ground through AC power.

Different electrodes were compared with the proposed measurement system. Pregelled Swarmed electrodes feature lower coupling resistances compared to solid–gel electrodes. Nevertheless, solid–gel electrodes with lower capacitive values are superior to pregelled electrodes.

With application-specific electrodes, the technology is enhanced. The proposed system will be miniaturized with the goal of realizing data transmission based on galvanic coupling in biomedical system for monitoring vital functions.

9. REFERENCES

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