Personal Area Network for Biomedical Monitoring Systems Using Human Body as a Transmission Medium

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Abstract

Personal Area Network for Intra-body communication using human body as the transmission medium enables wireless communication without transmitting radio waves through the air. With the vision of transmitting data through the human body, several trials have been made to model the human body as communication channel through which cable-free transmission is achieved. Making use of human body as a transmission medium signal transmission offers new data communication scheme in biomedical monitoring systems. Such a new wireless data communication technology will offer substantially increased freedom for long-term risk patients. On body sensors in the form of intelligent band-aids monitor the human vital functions. Enabled by the intra-body communication capability of every on-body sensors, the recorded data will be transferred wireless through the body within the Body Area Network sensor nodes. Eventually, one single node will act as a central monitoring node and is connected by a traditional wireless link, e.g. blue tooth, to the remote hospital monitoring infrastructure. There , the data will be displayed or stored in the patient's record. Electronic data transfer over and through the human body has been proposed by research and industry as a promising technology for ultra low power wireless Body Area Networks .

Keywords: *Personal Area Network, Intra-body communication, Biomedical monitoring systems.*

1. Introduction

Intra-body communication is a novel approach in which the human body is used as a signal transmission medium. It has attracted much attention in the study of personal area networks (PANs) [1]. In this approach, signals pass through the human body, and hence electromagnetic noise and interference have little influence on transmissions, while the signals are largely contained by the skin. These characteristics of intra body communication are superior to those of other radio-based network technologies, such as Bluetooth.

Three different methods can be employed for intra-body transmission and they are: the simple circuit, electrostatic coupling, and waveguide as shown in Fig. 1. In the simple circuit method, the human body is treated as a conductor and this principle is already used by devices such as body fat meters. This is one of the simplest method but it requires the use of a wire external to the body. In the second method, electrostatic coupling the devices need to be grounded.

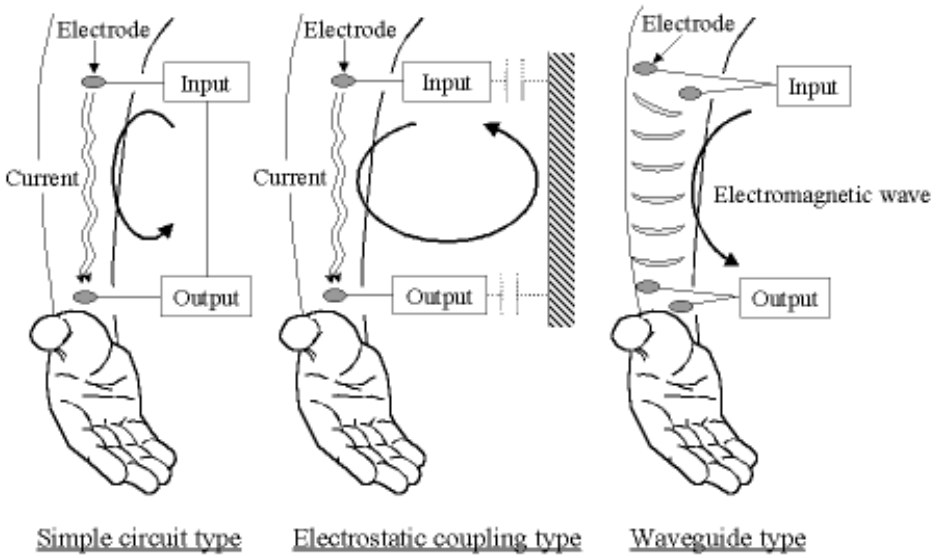

Fig. 1. Three methods of data transmission through the human body

Electrostatic coupling is not dependent on an external wire, but the transmission quality is dependent on the surrounding environment. In the last method, the human body is treated as a waveguide, in which the high-frequency electromagnetic waves are generated at a terminal and propagated through the body, and is received by another terminal [2]. In this method, external wires are not necessary and also the transmission quality is not affected by the surroundings. In waveguide intra-body communication methods, external cables are not required , with signals transmitted by high-frequency carrier waves. To determine the transmission characteristics of the human body several basic experiments are conducted. A human arm phantom is developed to obtain better reproducible results over repeated experiments and these results are applied for the development of small analog and digital data transmission devices.

2. Personal Area Network

Wireless Personal Area Network is a new technology used for the permanent monitoring and supervising of the health status of patients. This technology is mainly applied for the patients suffering from diseases such as diabetes and asthma. Another prominent area of application for long-term logging of patient data is cardiology, where twenty four hours-ECGs are required for continuous monitoring and as early indicators for impending heart attacks.

The basic elements of Personal Area Network (PAN) consists of a set of mobile, compact intercommunicating sensor units which enable transfer of vital parameters between the patient's location and the clinic or the doctor's site. These compact sensor units may be either wearable or implanted into the human body, which monitor the vital body parameters and movements. These data flow passes a chain of PAN modules from each sensor to a main body station, which consolidates the data streams of all sensor modules attached to it. These devices, communicating through wireless technologies, transmits the data from the human body to a home base station, from where they can be forwarded via telephone line or internet towards the doctor's site, real-time.

Considering the system and device-level security, high level of security measures are followed for this new PAN transmission protocol. Appropriate encryption mechanisms are also integrated in this PAN communication system. Also, it must be guaranteed that individual patient data are only derived from each patient´s dedicated PAN system and must not be mixed with any data from other patients or PAN systems at the same location. Further, the data generated from PAN should have secured and limited access. PAN is not only appropriate for communication in hospital and at home but has lot of other applications in wide areas such as monitoring of new-borns and wireless hearing aids and many others.

Applications of Personal Area Network is expected to appear primarily in the healthcare domain, especially for the continuous monitoring and logging vital parameters of patients suffering from chronic diseases such as diabetes, asthma and heart attacks.A wireless PAN network can alert the hospital, even before a patient has a heart attack, through the measured changes in his vital signs. Considering a diabetic patient the insulin level can be maintained automatically by injecting insulin through a pump when the level goes down. This enables the patient to be healthy in a doctor-free environment. This new technology can be extended to business people to exchange business cards, just with a handshake, with the help of PAN sensors.

3. Signal Transmission Characteristics

To determine the basic transmission characteristics of the human body as a waveguide, signal input to output (I/O) gain must be investigated.

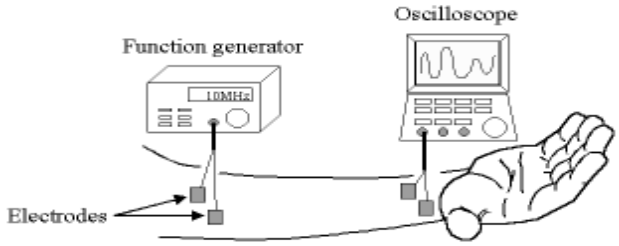

Fig. 2. Experimental setup for the measurement of intra-body propagation gain

As shown in Fig. 2, the setup for the measurement of intra-body propagation gain consists of two pairs of Ag-AgCl electrodes which must be attached to the wrist and the upper arm of the human body using electrically conductive paste. Input signals are sine waves of frequencies between 1 and 40 MHz (1 V peak-to-peak) that are produced by a function generator [3].These input signals are applied to the upper arm electrodes and the output signals can be observed and measured using an oscilloscope. From Fig. 3, it is also seen that propagation through the human body is superior to propagation through air at frequencies of up to 30 MHz, with input to output gain reaching a maximum of -26 dB at around 10 MHz. Thus after various level of observations it is seen that 10 MHz is the most suitable carrier wave frequency for transmitting data with minimal energy consumption.

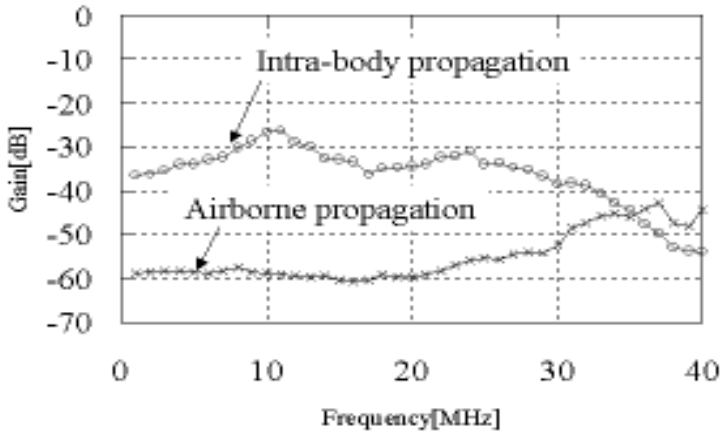

Fig 3. Gain comparison between intra-body propagation and airborne propagation

The effect of height above the ground with respect to transmission characters are also observed and transmission characteristics are found to be independent of the distance between the ground and the body.

3.1. . Impedance Fluctuations

In the experimental setup conductive paste must be applied to the Ag-AgCl electrodes, but repeatedly spreading paste onto the electrodes is inconvenient. Also, this conductive paste may cause inflammation of the skin over the human body. So better electrodes are required which do not require electrically conductive paste to make good electrical contact with the skin. For this purpose six additional common commercial metals (aluminum, copper, bronze, brass, stainless steel, and nickel silver) can be used as wearable electrodes which make good electrical contact with the skin without conductive paste. These can be used to measure the contact impedance between contacts at the wrist and upper arm, with a separation of 280 mm. Contact impedance can be measured using the simple circuit model, because the inputs and outputs are same as that of the waveguide model.
It is seen that the impedance of electrodes are largely independent of the electrode metal and hence stable communication through the human body can be achieved using these different kinds of electrodes, even when electrically conductive paste is not used to reduce contact impedance.

3.2. Human Phantom

A human arm phantom is designed and used to reduce uncertainty in experiments with the human body. By considering the human arm as a column, human phantom was created which consists of an elongated insulator containing conductive liquid. The thickness of the PVC skin of the phantom is 98 μm, which is similar to that of human skin. Signal transmission characteristics of the phantom can be predicted in a similar way that is used for the human body. The gain of the phantom is almost same as that of the human body for frequencies of up to 10 MHz. Above 10 MHz, there exist certain differences between the two mediums but the shapes of the gain curves are similar. By using the phantom, repeated experiments can be conducted without using the human body.

4. Intra-body Communication Devices

Small, lightweight, energy-saving, wearable intra-body FM transmitters and receivers are readily available. A carrier frequency of 10.7 MHz is selected because 10.7 MHz is in the middle of the frequencies used in FM radios, and thus 10.7 MHz ICs are readily available. The selection is also influenced by the gain characteristics of the human body[4][5]. Using these devices, the influence of outside noise on intra-body communications can be measured. The effects of the external noise sources are considerably small. Intra–body communication hence appears to be tolerant to external noise sources.Using these devices heartbeat informations can also be carefully transmitted through the human body, even in the presence of excessive external noise. Again data can be transmitted with less energy consumption using intra –body communication devices.

5. Conclusion

Personal Area Network is a promising approach for intra-body communication over a wide range of frequencies. Clinical trials showed the feasibility of the new technology to transmit data through the human body in a secured manner. In the future, the proposed measurement system will be miniaturized in terms of the electronic circuitry size, so that it becomes much reliable. Intra-body communication can be used in a distributed on-body sensor network for biomedical monitoring of vital functions allowing wireless data transfer from ECG, pulse oximetry, or temperature sensors to a central monitoring unit. In a future study, the capabilities of this technology for implant communication will be investigated separately.

6. References

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