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Master's Degree Thesis

A Study of Ground Effect Based on the Analysis of Optimum Distance and Frequency for Power Transmission System through the Human Body

Graduate School of Chosun University

Department of IT Fusion Technology

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Acronyms

HBC	Human Body Communication
WPT	Wireless Power Transmission
IMD	Implantable Medical Devices
EMF	Electromagnetic Field
ICNIRP	International Commission on Non-Ionizing Radiation Protection
PAN	Personal Area Network
BCC	Body-Coupled Communication
PDA	Personal Digital Assistants
RFID	Radio Frequency Identification
CPU	Central Processing Unit
AC	Alternating Current
DC	Direct Current
CMOS	Complementary Metal-Oxide-Semiconductor
PDMA	Physical Division Multiple Access
I/O	Input/Output
IBC	Intra-body Communication
PTS	Power Transmission System
SAR	Specific Absorption Rate
PTSTHB	Power Transmission System through the Human Body

요약

인체를 통한 전력전송체계를 위해 접지 효과를 기본으로 한 최적의 거리 및 주파수 분석에 대한 연구

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현재 휴대전화, PDA, 휴대용 게임기 및 다른 작은 휴대용 기기들과 같은 다양한 형태의 휴대용 단말기들에 의해 많은 정보들이 다루어진다. 그래서 휴대용 단말기들 간의 통신을 위한 일반적인 방법으로 인체내 통신의 중요성이 증가하고 있다. 동시에 휴대용 단말기들간의 전원도 고려되어야 한다. 이 연구에서는 인체를 통한 최대 1mW 정도의 실제 전력 전송에 대한 연구를 수행하였다.

이 논문에서는 국제 위원회(ICNIRP)의 규정에 기본으로한 인체를 통한 전력전송에 대한 최적의 거리와 주파수에 대한 조사와 분석을 하였다. 이 분석은 인체를 통해 전력을 전송하는 효율적인 변조방식을 설계하는데 사용된다. 최적의 거리 및 주파수를 결정하기 위해 기본적인 제한(예, 전류밀도)나 기준 수준(예, 전류)와 같은 기본적인 제한에 대해 정의하였다. 기본적인 제한과 기준 수준은 전기, 자기, 전자기장의 측정되는 물리적 량에 의한 특별 조건하에서의 전자기장(EMF)방출에 의해 제한 될 것이다. 첫 번째로 인체를 통한 전력 전송의 성능 (예, 가능한 전력)에 대한 실험은 무선 전력 전송에 비교하여 고효율이 나타날 때까지 전송거리를 줄이는 내용 이였다.

MATLAB을 이용한 시뮬레이션과 규제(예, ICNIRP)로부터 인체를 통한 전력전송의

최적 주파수범위는 100kHz부터 50MH 의 사이에 있음을 확인 하였으며, 최적주파수는 이 범위를 벗어나지 않는다. 또한 거리(d_{body})와 접지크기(예, 송신부과 수신부) 사이에 대한 좋은 결과를 얻었다. 수신부와 송신부의 거리는 짧을수록 높은 성능을 나타났다. 추가로 접지크기가 클수록 성능을 향상시킨다.

I. Introduction

A. Human Body Communication

Recently human body communication (HBC) has been developed as a new communication technique. HBC, which uses the human body as transmission medium for electrical signal, is a special type of communication methodology and treats human tissue as a "cable" for electrical signal transmission. The merits of this technique are the elimination of the need connection cable, the reduction of possible electromagnetic radiation, and a reduced probability of interference by external noise. These features have attracted much interest in the concept of a *body area network* (BAN), and HBC, which is also known as *intrabody communication* (IBC), works through and relies on the human body.

This concept was first introduced by Zimmerman in 1995 [1] and was known as the *personal area network* (PAN). Zimmerman discovered that capacitive coupling of the human body to its environment and certain parts of the near field could be exploited to make the human body act as medium for data transmission. Figure 1.1 shows a model of electric near-field produced by a PAN transmitter in body proximity. The PAN transceiver is composed of transmitter and receiver unit, each of which has two electrode plates. The electric field *Ea*, induced by a signal electrode of the PAN transmitter, passes through the body and flows toward ground. The goal is for the receiver unit to detect the electric field *Es*. The field *Es* is extremely small because a significant part of the electric field *Ea* is canceled by the electric field *Eb* that established toward the ground electrode of the transmitter. In addition, a major part of the electric field

Ec escapes through the feet, which are in direct contact with the ground. The return transmission path is established by the second plate of each unit via ground. According to Zimmerman [2], near field communication can operate at very low frequency and low transmission power. The prototype of the PAN transmitter operates at 330 kHz, 30 V, with a transmission power consumption of 1.5 mW for charging the electrode capacitance. The PAN technology was proposed for integration into a custom *complementary metal-oxide-semiconductor* (CMOS) chip to decrease the size and cost. Since the development of the Prototype PAN system by Zimmerman, several interesting applications have been introduced and applied in various field such as medical field e.g., heart and oxygen saturation sensor [3]; electro-optic sensors [4]; and various communication techniques [5] [6].

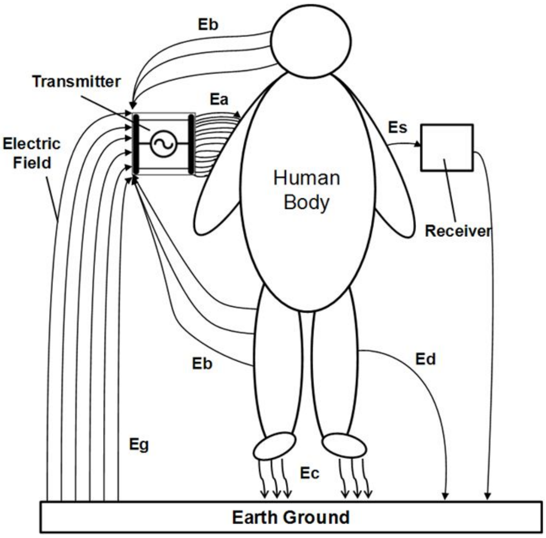


Figure 1.1. Personal area network (PAN) transceiver by Zimmerman.

PAN devices do not transmit a significant amount of power into the far-field, thereby partially circumventing channel-sharing and eavesdropping issues. The communication channel is shared by *physical division multiple* *acces* (PDMA). PAN devices do not interfere with each other if they are reasonably far apart. The communication channel is shared physically in space.

B. Power Transmission System (PTS) through the Human Body

The human body has been used as the medium for transmitting data signal for Ubiquitous-Healthcare (U-Healthcare). Many groups have studied HBC by using various approaches with focus on data transmission. However, only a few groups have investigated the need of power transmission system through human body by transmitting the reasonable power [7],[15],[16]. Currently, significant amounts of data are handled on various type of mobile terminal, such as cellular phones, personal digital assistants (PDA), pocket games and the other small portable devices. Therefore, the importance of intra-body communication is increasing as a common tool for communication among mobile terminal. At the same time, the need of power resource among mobile terminal should be considered.

Commonly, a power transmission system (PTS) through the human body has two components as shown in Figure 1.2. There is a source component (i.e., transmitter) that has four important sub-components, i.e., control logic, energy harvesting circuit, battery, modulation and interface. The function of energy harvesting circuit is to harvest ambient mechanical energy. An input vibration is applied on to a piezoelectric material [8],[9] causes mechanical strain to develop in the device, and this strain is converted to an electrical charge. Usually, these piezoelectric elements are placed under the heel of the shoes and wrist that can be easily used to drive the piezoelectric material. The second component is the receiver which has two sub-components i.e., energy receiver and load. The energy receiver rectifies the energy that received from the source component, and it is connected to the load (e.g., wireless sensor or implantable devices) to power it. Between the source component and the receiver component, the human body is used as a transmission medium that provides an interface between the various components.

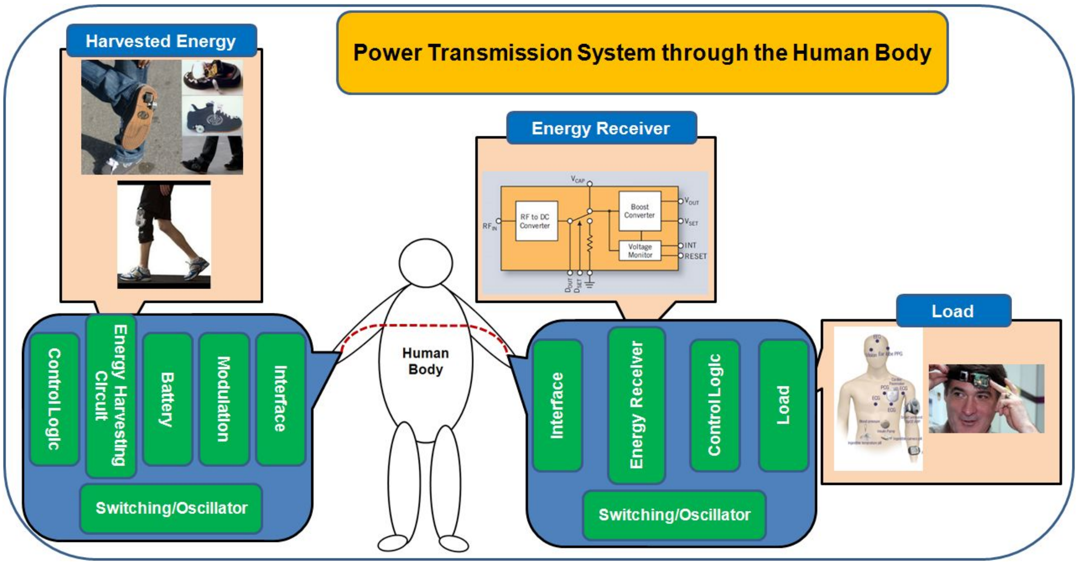


Figure 1.2. Power transmission system (PTS) through the human body.

The human body has a unique characteristic compared to the other common transmission media such as air (i.e., wireless) and wired transmission. The human body has high signal loss that increases exponentially with distance, but there is an acceptable amount of signal loss for short distance. Further, we examine the reasonable current density (basic restriction) and current (reference level) by defining the maximum exposure that is allowed for biological tissue (e.g., human body) according to frequency range established in ICNIRP's regulation [10]. This information will be useful for determining the optimum frequency for PTS through the human body. By evaluating the performance of power transmission (human body and wireless) and the regulation i.e., basic restriction and reference level, we may design the effective modulation scheme to transmit signal and power simultaneously. Various parameters, such as distance and frequency, are applied in the HBC channel model. Using HBC channel model as a reference, we calculate the impulse response and transform it from a time response to a frequency response. Futhermore, this frequency response can be used to determine the signal loss in the human body. When we measure the HBC channel model, distance (i.e., distance between a transmitter and a receiver for both air and body) and the size of ground plane have to be considered.

C. Safety Regulations

The major issue considered in HBC and PTS through the human body is the safety requirement for limiting exposure to time-varying electric, magnetic, and electromagnetic fields. These requirements are enforced by the official regulation, e.g., the EU directive [11] and the FCC [12]. These regulations are based on international guidelines by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [10] and IEEE Standard for Safety Levels [13]. Table. 1.1 summarizes threshold currents for indirect effects. In general, threshold currents, which produce perception and pain, vary little over the frequency range of 100 kHz and 1 MHz. Below 100 kHz, the primary effect of alternating current is nerve and muscle stimulation perceived as a primary sensation of nerve tingling. At increased frequencies from 100 kHz to 10 MHz, the dominant effect changes towards heating, while, above 10 MHz, the limits are defined in terms of the *specific absorption rate* (SAR). Temperature increases of less than one degree celsius are considered to be safe, i.e., no adverse heating effects occur.

Table 1.1. Rangers for threshold current for indirect effects, including children, women and men [10].

Indirect effect	Threshold Current (mA)			
	50/60 Hz	1 kHz	100 kHz	1 MHz
Touch perception	0.2-0.4	0.4-0.8	25-40	25-40
Pain on finger contact	0.9-1.8	1.6-3.3	33-35	28-50
Painful shock	8-16	12-24	112-224	n/a
Severe shock difficulty	12-23	21-41	160-230	n/a

According to guidelines, HBC is restricted by the limits of contact currents [14]. Depending on the frequency range, the allowed contact current increases up to 20mA at 100 kHz and remains constant above according to Tab. 1.2. The occupationally-exposed population consists of professionals who are exposed under known conditions. So, these people are trained to be aware of potential risks and to take appropriate precautions.

Table 1.2. Reference levels for time varying contact currents from conductive objects [10].

Exposure Characteristic	Frequency Range	Maximum Contact Current (mA)
Occupational Exposure	2.5kHz - 100kHz 100kHz - 100MHz	0.4f [kHz] 40
General Public Exposure	2.5kHz - 100kHz 100kHz - 100MHz	0.2f [kHz] 20

However, the general public comprises individual of all ages and varying health status and may include particularly suspectible groups or individuals. Since the threshold currents that elicit biological response in children and adult women are approximately one-half and two-thirds, respectively, of those for adult men, the reference levels for contact current for the general public are set to half the values for occupational exposure [31].

D. Research Final Target

The goal of this thesis is to explore and analyze the characteristic of power transmission system through the human body by using human body communication (HBC) channel model concept. For this purpose, we analyze the optimum distance and frequency on power transmission system through the human body. We design and develop an effective modulation scheme to transmit power through the human body. Finally, we measure and simulate the performance of power transmission system through the human body with different grounding conditions.

D. Thesis Organization

Chapter Ⅰ introduces the principle of human body communication (HBC), the principles of power transmission system through the human body, and safety regulation. Chapter Ⅱ presents the literature review of power transmission system through the human body, briefly discusses previous, related work. Chapter Ⅲ shows the human body communication (HBC) channel, presents the method used in the experimental process, explains how to analyze the ground effect on the power transmission system (PTS) through the human body. Chapter Ⅳ presents and discusses the experiment results that were obtained. Our conclusions are presented in Chapter Ⅴ.

II. Literature Review

Human Body Communication (HBC) has been improved and applied in several different fields. In many electronic systems, energy consumption are supplied by batteries which make difficulties to reduce the size and weight of devices. In addition, there are some disadvantages associated with replacing or recharging batteries, especially for handicapped and disable people. A self-powered system is requirement in order to realize the benefits HBC in our life. Some solutions have been investigated to building similar systems. Some researchers [1] have suggested a unique power source, i.e., the so-called personal area network (PAN) devices that can be embedded in shoe insert that extract power from walking. An adult dissipates several hundred milliwatts while walking, can provide enough power for some devices.

As electronic devices become smaller, lower power, and less expensive, we have begun to adorn ourselves with personal information and communication appliances. These devices include cellular phones, personal digital assistants (PDAs), pocket video games, pen-based computer pads, palm top computer, and pagers. Currently, there is no standard method to interconnect these personal electronic devices. The personal area network is a means to interconnect these personal devices in a manner appropriate to the power, size, and cost of these devices.

A person who carries a watch, pager, cellular phone, cassette/FM player/recorded, PDA, and notebook computer is carrying five displays, three keyboards, two speakers, two microphones, and three communication devices. The duplicity of input/output (I/O) devices is a result of the inability of the devices to exchange data. All of these networking structure these devices can share computational resources, either performing distributed computation or relying on neighbors with more specialized and higher capacity processing power to perform functions that are too intensive for the resident processor. The ability to share resources is tempered by inter-communication channel capacity and system complexity [1].

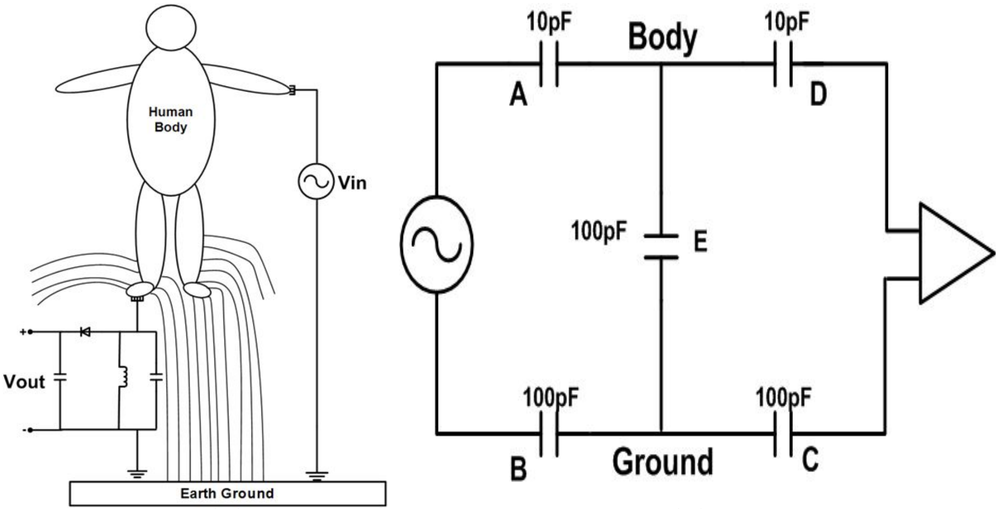
A. State of the Art

1. Zimmerman, MIT Media Laboratory, 1995

Personal Area Network, one of the first Human Body Communication (HBC) system was firstly proposed by Zimmerman [1]. In his study, the capacitive coupling approach was used, and the communication system consisted of a Tx and a Rx, which are battery powered devices. Also, the Tx and Rx were electrically isolated from each other, so they did not share a common electrical ground. Both Tx and Rx were connected to a pair of vertically structured electrodes. The size of the electrode was on the order of a few centimeters. Data were transmitted by modulating electric fields and by capacitively coupling very small currents to the body. The body conducted the tiny signal to the Rx, which demodulated the signal. The environment provided the return path. Zimmerman also had developed an electrical model of the body-coupled communication (BCC) system that includes the most important electric field paths in the system. In this model, the human body was modeled as a perfect conductor, and the electric coupling among the electrodes of the transceiver, body and environment were modeled as capacitors. Several experiments and measurements were performed by using different electrodes with different sizes and different positions on the body. The sizes and positions were selected based on the possible applications grouped in commonly worn objects such as a watch face, credit card, shoe insert and belt and head mounted personal area network (PAN) devices like headphones. The results showed that placing a large area environment electrode close to the physical ground maximizes the magnitude of the received signal, so the feet are the best location for PAN devices. Moreover, devices with larger electrode area and smaller intra-electrodes capacitance improve the communication performance.

2. E. R. Post et.al., MIT Media Laboratory, 1997

E. Rehmi post *et.al,* [7], proposed a system that transmitted and received both data and power, they were working to combine the two. In order to transmit power and data by using the human body, the new version of personal area network (PAN) and a "body modem" was built. In Figure 2.1, the capacitive junction A, B, C, and D correspond to regions of increased electric field strength, induced by the presence of conductive electrodes. The fifth junction, labeled E, represents all other electrostatic coupling between the body and the surrounding electrical environment. The transmitter for this model is represented by an oscillator, and the receiver is represented variously in the Figure 2.1, e.g., as a simple tuned circuit and detector or as differential amplifier.



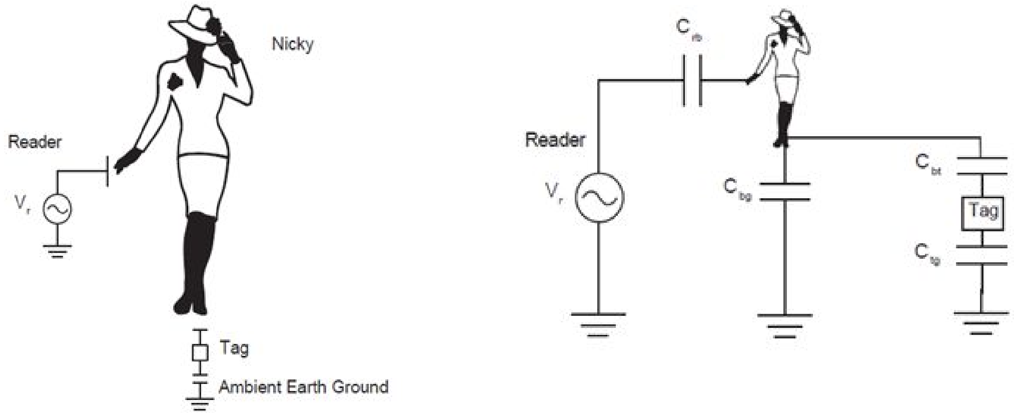
(A) (B)

Figure 2.1. New version of personal area network (PAN): (A) Intrabody electrostatic coupling that subject is floating above ground, (B) Capacitive bridge formed in A.

This system distributes electrical power as an alternating current at a voltage much higher than what ultimately appears at wall socket. This reduces the ohmic losses inherent in long-distance transmission and facilitates the transformation from higher to lower voltage (or vice-versa) using inductive devices. Also, the frequency of alternation is regulated to provide a simple timing reference for motors, clocks, and video signals. Finally, to generate direct current (DC) power from the alternating current (AC) power available at a wall socket, a power supply must rectify, filter, and regulate the AC signal. So, AC power appears at a single-phase wall socket appears as the difference in electrical potential (or voltage) between the "hot" and "neutral" leads. By convention, current is said to flow from higher to lower potentials, and the available power is simply the product of the potential difference and the amount of current flow. This somewhat pedantic explanation underscores the fact that power transmission relies upon the flow of current across a potential difference. Under reasonable conditions, an available power of 200 mW at 1.0 MHz applied at one hand leads to the recovery of about 20 mW of rectified, filtered DC power at one foot. This system of 10% roughly reflects the proportion of the body's electrostatic coupling available at one foot in the presence of an electrode.

3. Babak Nivi, et.al., MIT Media Laboratory (1997) [15]

Babak Nivi *et.al.* [15] proposed how data and power can be wirelessly (and safely) transmitted through the human body. They applied a new type of *radio frequency identification* (RFID) tag, i.e., the so-called *bodytag*. The bodytag is a passive wearable electrostatic tag that exploits the human body’s natural ability to guide electric field, and allows the wearer to present tags to tag readers through various motions, such as grasping of a doorknob or pushing of a button.



(A) (B)

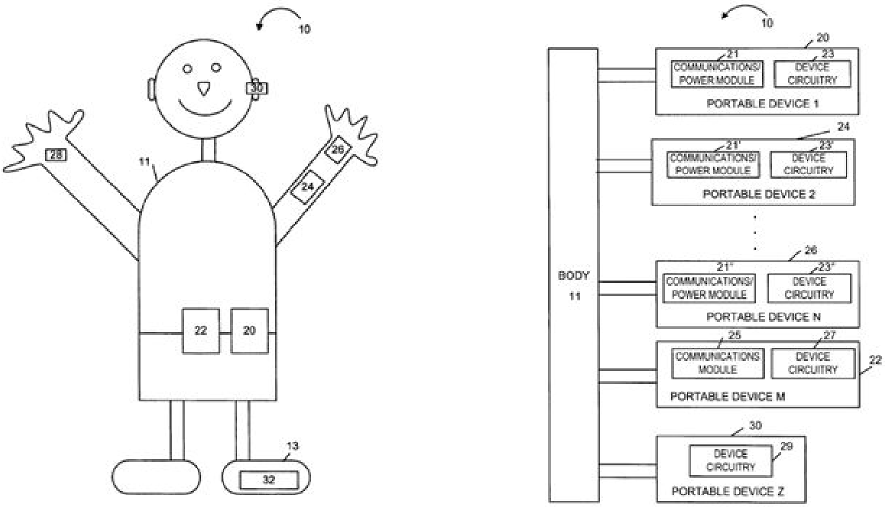
Figure 2.2. Passive Wearable Electrostatic Tags: (A) Model of tag and reader exchanging data and power through Nicky's body, (B) Equivalent circuit of A.

As it is shown in Figure 2.2, the human body acts as a poor conductor connecting the tag and the reader. Where displacement current (not DC current) is passing through the user's body, the tag and reader can exchange data and power through the body via so-called *intrabody signaling*. The tag readers operate at fixed frequencies below 1 MHz and use single electrodes (monopole) as antennas. The wavelength of a 1 MHz uniform plane wave in free space is approximately 300m. Such waves send power and data through the body by capacitively coupling displacements current into the body and using the ambient ground reference provided by the environment as the return path for the current. Also, Babak Nivi *et al.,* modeled the human body as a solid ideal conductor surrounded by an ideal insulator (the skin). They did not send DC current through the body due to the fact that it is surrounded by an insulator and because it could be hazardous to present a constant voltage drop across the interior of the body. Instead, they send AC current through the body by capacitively coupling to its interior and using it as a single, low-impedance node in a network of capacitors. When the current entered the body, the only other thing that was needed to complete the circuit was a place for the current to go. Eventually, they used the ambient ground reference as a return path for the AC current. Figure 2.2(A) is circuit diagram of Nicky's interaction with the tag and reader, with several electrostatic links shown explicitly as capacitor. These capacitance are represented by C_{rb} between the tag reader and the body; C_{bg} between the body and ambient ground; C_{bt} between the body and the tag; and C_t between the tag and ambient ground.

4. L. Williams et.al., Microsoft Corporation

L. William *et.al.* [16], proposed a method and an apparatus for distributing power and data to coupled devices and the human body that was used as a conductive medium. Power was distributed by coupling a power source to the human body via a first set of electrodes. One or more device to be powered, e.g., peripheral devices, also were coupled to the human body via additional set of electrodes. The devices may be, e.g., a speaker, display, watch, keyboard, etc. For power source, they may use a pulse DC signal or AC signal. By using multiple power supply signals of differing frequencies, different devices can be selectively until fifteen devices powered. For example, a 100 Hz signal may be used to power a first device, while 150 Hz signal may be used to power the second device. The power source and peripheral devices can interact to form a complete computer network in which the body serves as the bus that couples the devices together. The devices can include optional batteries, one or more CPUs, transmit/receive circuitry, and/or input/output circuitry. For exemplary network implementation, the first device to be placed on the body operates as master, e.g., bus mater, and the second devices working as slaves. And then the power and/or communication signals may also be transmitted from one body to another by touch.

The devices for power and data transmission using the human body are networked; the devices can be recharged and powered by other devices on the network. Kinetic converters or power converters can be used in this network. Kinetic converter to power converters can be used in this network to sustain this network's power. Kinetic converters in shoes and on wrist watches can be used and distributed power to the rest of the network, as it is shown in Figure 2.3.



(A) (B)

Figure 2.3 Method and apparatus for distributing power and data to devices coupled and the human body: (A) Illustrates an exemplary system that used as a bus for distribution power and information between various devices coupled to the person's body, (B) Block diagram of the exemplary system illustrated in A.

B. Wireless Power Transmission (WPT) on Implantable Medical Devices (IMD)

The wireless power transmission (WPT) concept was first proposed by Tesla [17], WPT devices can be defined as devices that efficiently transmit electric power from one point to another through the vacuum of space or the Earth's atmosphere without the use of wires or any other substance. Wireless power transmission is also often referred to often as "beamed power transmission".

In the early 1960s, resonant inductive wireless energy transfer was used successfully in implantable medical devices [18], including such devices as pacemakers and artificial hearts. While the early systems used a resonant receiver coil, later systems [19] implemented resonant transmitter coils as well. These medical devices were designed for high efficiency using lower power electronic, while efficiently accommodating some misalignment and dynamic twisting of the coils. The separation between the coils in implantable applications is commonly less than 20 cm. Today, resonant inductive energy transfer is used routinely for providing electric power in many commercially-available medical implantable devices [24] [25].

The most efficient way to transmit the power and data signals over a small current is to use inductive coupling [20]. With this type of setup, the link can be modelled as a weak transformer (e.g., a transformer with a low coupling coefficient). Also, this means the transmitting voltage must be inversely proportional to the coupling coefficient to induce an arbitrary voltage amplitude in the receiving coil, implying that the transmit voltage will be very large. This brings the concern about the amount of power absorbed in the tissues. The power absorbed in the tissues is a function of both amplitude and frequency.

Many implantable medical devices (IMDs) have been proposed in recent years [26] [27] for various functions and applications. The implantable system is one the prospective approaches, since it can detect vital signals more accurately without pain. While numbers of component are required to construct an implantable system, the power supply is the major technical challenge. If a battery-type power source is to be used, surgery would be required to replace the battery. To avoid this invasive operation, it is necessary to develop a method to transmit power wirelessly from outside of the body [28].

Safety is also one of the major issued in the design and application of wireless power transmission on implantable medical devices. So, in this study, we focus exclusively on wireless power transmission for implantable medical devices that have relatively smaller power requirement and lower performance i.e., tens microwatts to a milliwatt.

III. Measurement Methodology

In this thesis, we report the results of our investigation and analysis of the optimum distance and frequency of power transmission through the human body based on ICNIRP's regulations [10]. The analysis is used to design an effective modulation scheme for transmitting power through the human body. In order to determine the optimum distance and frequency, we have to define the basic regulations, such as basic restriction (e.g., current density) and reference level (e.g., current). Both basic restriction and reference level are intended to limit the electromagnetic field (EMF) emissions under specified test conditions by measuring the physical quantities that characterize electric, magnetic, and electromagnetic fields. First, we examine the performance (i.e., available power) of PTS through the human body by reducing transmission distance until the efficiency is higher than that of wireless power transmission.

The human body has unique characteristic compared to the other common transmission media, such as air i.e., wireless transmission and wired transmission. The human body has high signal loss that increases exponentially as distance increases, but the amount of signal loss for short distance is acceptable. Further, we examine the reasonable current density (basic restriction) and current (reference level) by defining the maximum exposure allowed for biological tissue e.g., human body, according to frequency range in the ICNIRP regulations. This information is useful for determining the optimum frequency for power transmission system through the human body. From both power performance of power transmission (human body and wireless) and the regulation (basic restriction and reference level) perspective, we design an effective modulation scheme to transmit signal and power simultaneously. The parameter (i.e., distance and frequency) are applied on the human body communication (HBC) channel model. Therefore, when we measure the HBC channel model, distance (i.e., distance between a transmitter and a receiver on both air and body) and the size of ground plane must be considered.

A. Modulation Scheme

In order to define the modulation scheme for PTS through the human body, first, we show the HBC channel model, by defining this channel model, we are able to measure an impulse response in the time domain and then transform it to get the signal loss information in the frequency domain.

1. Model Structure

Electronics and Telecommunications Research Institute (ETRI) proposed the HBC channel model that can be used for either transmitting data (Human Body Communication) [21] and transmitting power (power transmission system through the human body) [22], as it is shown in Figure 3.1.

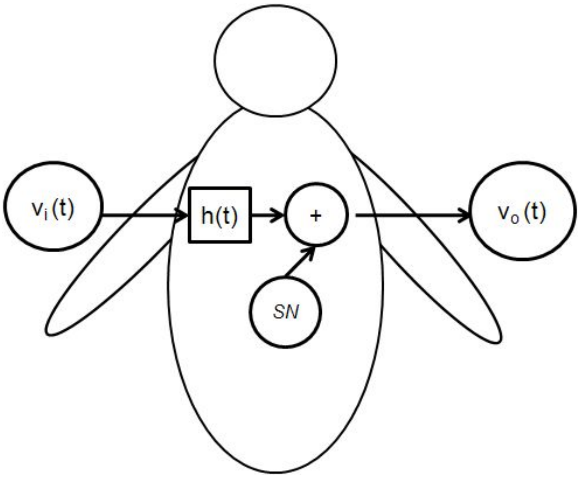


Figure 3.1. Human body communication (HBC) channel model.

The HBC channel model consists of channel input ($v_i(t)$), channel filter or channel on human body ($h(t)$), additive noise source (SN), and channel output ($v_o(t)$). Channel filter ($h(t)$) represents a signal loss by the human body. In the channel model of PTS, the human body and its characteristic are represented by an impulse response to simultaneously model changes of transmitting signal's amplitude and phase by the channel filter. The frequency components of the impulse response are valid only between 0 MHz and 50 MHz, an input should be filtered with a low-pass filter to remove the frequency components that are out of the range. When sampling the impulse response, the sampling rate should be over 250 MHz to model the impulse response accurately. Concerning channel noise SN, the electromagnetic waves are generated from various electronic devices cause the nose inside body to an antenna effect of the human body, so the noise is added to the transmitting signal. In the HBC channel model, the power spectral density is used to represent level of the noise.

In HBC, there are two kinds of the parameter that affect the HBC channel, i.e., distance and the size of the ground plane.

2. Distance

When we measure the PTS through the human body using near-field coupling, there are two coupling media between the transmitter and receiver, i.e., air and body. The media will affect channel model in combination, so two distances at each medium should be defined, respectively, as shown in Figure 3.2. First, distance through body (d_{body}) is defined as a minimum distance along the human body between a transmitter and a receiver. Second, distance through air (d_{air}) is defined as a minimum distance in air between a transmitter and a receiver.

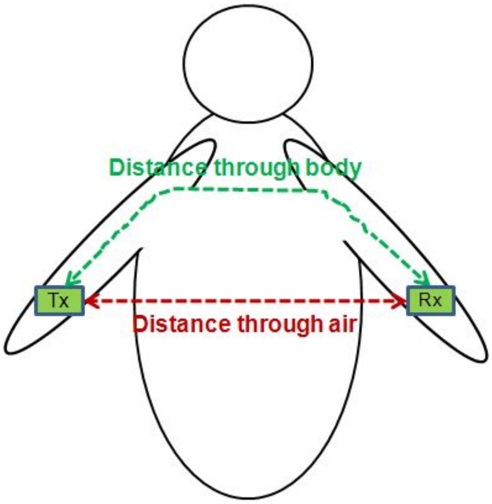


Figure 3.2. Distance on HBC channel model.

3. Size of ground plane

The level of the near-field coupling is affected by sizes of ground planes in a transmitter (Tx) and a receiver (Rx), because the near-field is coupled with the air and the human body more and more as the sizes of the ground planes increase. It is impossible to define the size of the ground plane because the ground plane is inside a device, but the maximum size of the device's outline should be defined as the size of the ground plane. The ground size can be divided into parts, i.e., the transmitter's ground size (G_T) that is defined as a size of a ground plane in the transmitter's device and receiver's ground size (G_R) that is defined as the size of a ground plane in a receiver's device. Like the distance, the channel noise is not affected by ground size in the current channel model.

B. Modulation Scheme on PTS through the Human Body

1. Mathematical Equation

As explain above, the channel filter is represented by an impulse response and can be shown in a mathematical equation [21]:

$$h(t) = h_R(t)C_h \tag{1}$$

where, $h_R(t)$ is a reference impulse response and C_h is a coefficient related to the sizes of ground planes and distances between Transmitter (Tx) and Receiver (Rx). The impulse response is valid only between 0 MHz and 50 MHz, and its sampling should be more than 250 MHz.

$$h_R(t) = A_V A exp(-(t-t_r)/t_0)\sin(\pi(t-t_r-x_c)/w) \tag{2}$$

where the A_V is a coefficient to represent fluctuation of signal loss, which has a Gaussian distribution as follows:

$$A_V \sim N(1, 0.16^2) \quad (3)$$

where A, t_r, t_0, x_c, and w has constant as follows:

Table 3.1. Constant values for HBC channel model

Time range	A	t_r	t_0	x_c	w
$0 \le t < 0.025$	0.00032	0.00000	0.00621	-0.00097	0.00735
$0.025 \le t < 0.058$	0.00003	0.02500	0.01684	-0.01225	0.00944
$t \le 0.058$	0.00002	0.05800	0.05610	0.00100	0.01109

The constant C_h can be defined as shown in equation below:

$$C_h = (0.0422G_T - 0.184)(0.0078G_R + 0.782)\left(\frac{120.49}{d_{body} + d_{body}(d_{air}/d_{body})^5}\right)^2 \quad (4)$$

where G_T and G_R are the sizes of the ground plane at Tx and Rx, respectively, in cm^2 and the d_{body} and d_{air} are distance between Tx and Rx through air and body, respectively, in cm. Also, the four value are limited for the validity of the channel model as follows: $10cm^2 \le G_T$, $G_R \le 270cm^2$, $10\mathrm{cm} \le \mathrm{dair}$, $\mathrm{dbody} \le 200\mathrm{cm}$.

2. Convolution (De-Convolution)

In frequency domain, the output is the product of the input and the transfer function. In case of PTS through the human body, with a system and the corresponding transfer function in HBC channel model (Figure 3.1), here we delete the channel noise, and the system output become:

$$V_o(f) = V_i(f)H(f) \quad (5)$$

in time domain, the convolution operation is shown in Equation (6):.

$$v_o(t) = v_i(t) * h(t) \tag{6}$$

In order to obtain $H(f)$, divide the output $V_o(f)$ by the input $V_i(f)$. Such an operation in time domain is called de-convolution.

$$H(f) = \frac{V_o(f)}{V_i(f)} \tag{7}$$

by defining $H(f)$ we may obtain the information about signal loss, and we may also measure the efficiency of PTS through the human body with various grounding conditions as explained before. And also $H(f)$ is used as one of parameter for modulation scheme of PTS through the human body. Using this parameter, we can calculate the performance of PTS through the human body. In addition, one of the advantages of this system is that we can use the simple modulation, such analog modulation i.e., amplitude modulation (AM), to transmit power through the human body. We use AM to simulate the performance (efficiency) in which the performance is evaluated from signal loss. By knowing the signal loss, we can obtain the performance of PTS through the human body, where the performance (efficiency) is defined as the ratio of channel output (i.e., output power) to the channel input (i.e., available/input power).

C. Measurement Method

Ideally, sinusoidal waveform of different frequencies would be applied to measure the channel's frequency response. However, generating a high quality sinusoidal waveform is difficult, especially in a ground-free environment. Thus, in this thesis, we propose the use of a signal wave as the input signal that contains multiple frequency components, and use convolution (de-convolution) concept to extract the frequency response of the HBC system. Subsequently, this frequency response is used to get the signal loss of the human body channel, so with this signal loss, we are able to define the optimum distance and frequency on PTS through the human body. Futhermore, we are able to design and select an effective modulation scheme of PTS through the human body.

In order to obtain sufficiently accurate output channel results in the HBC channel model, the measurement taken must consider noise effect. A human body can be modeled as an impulse response h(t) with a channel noise source *SN*, as shown in Figure 3.1. In the case of PTS through the human body, there is no need to consider the noise effect. Instead, we merely use HBC channel model to transmit electric signal for power transmission instead of data transmission. This is illustrated in Figure 3.3.

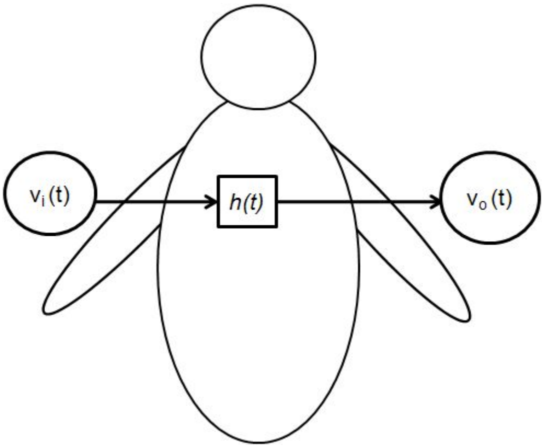


Figure 3.3. Modulation scheme on power transmission system (PTS) through the human body.

Figure 3.4 shows the experimental setup. An Agilent wave generator and Agilent oscilloscope were employed to generate and receive the channel input, e.g., input power, respectively. In the measurement, we use two electrodes with various surface ground size to connect the measured human body directly to the waveform generator and oscilloscope. The MATLAB tool is utilized to transfer the channel input $v_i(t)$ and the channel output $v_o(t)$ from time domain to frequency domain $V_i(f)$ and $V_o(f)$. Then, using the de-convolution of $V_o(f)$ by $V_i(f)$ is performed to obtain the impulse response i.e., channel filter $H(f)$ in Equation (7).

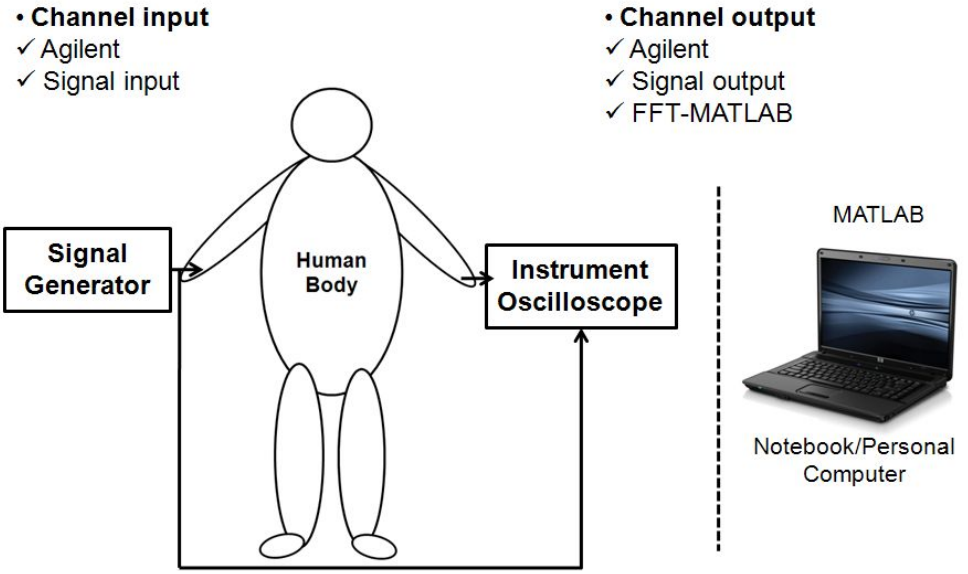


Figure 3.4. Block diagram of measurement setup.

D. Grounding Conditions

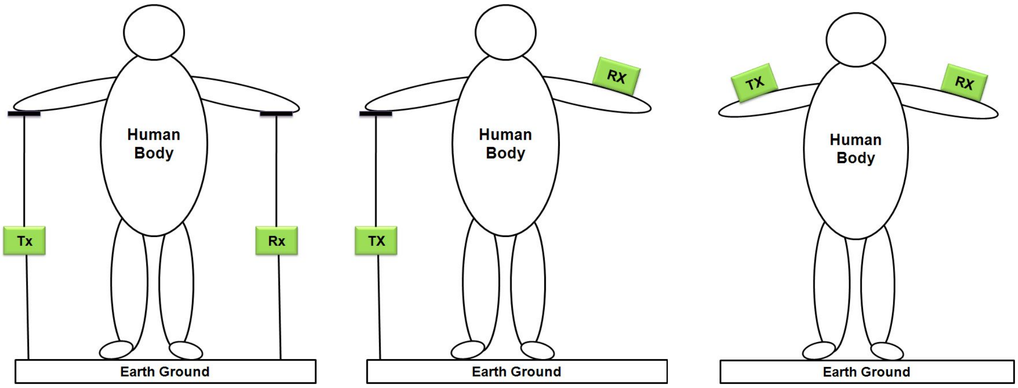
We define the characteristic of PTS through the human body by comparing three types of transmitting power from a Transmitter (Tx) to a Receiver (Rx). Those three types can be categorized as follows:

1) transmission power between Tx and Rx by using the same ground as shown in Figure 3.5(A)

2) transmission power between Tx with ground and Rx without ground as shown in Figure 3.5(B), and

3) transmission power between Tx and Rx by both using no ground as shown in Figure 3.5(C).

Type 1 is widely used in Intra-body communication. A Tx and a Rx in type 1 are connected with two lines, i.e., a signal line and a ground line. The human body is the signal line, and the Earth is the ground line. That is why type 1 will be less difficult to implement. On the other hand, type 2 and type 3 will be more difficult than type 1 to implement. This is because both a Tx and a Rx without ground or a Tx with ground and a Rx without ground are not common. Under these situations, the transmitted power might capable of harming the user and also, in transmitted data case, might be distorted, resulting the degradation of the quality of the communication system[23]. However, most applications for HBC will be type 2 or type 3, especially for mobile devices. As we mention above, either Tx or Rx will be applied in three different treatments. The first treatment is a Tx with ground, which means a Tx will be driven by an AC power supply that earthed to ground, and the second treatment is a Tx without ground, which means the Tx will be driven by a charged battery. And the last treatment is a Rx without ground which means Rx will be driven by the battery is floating. Therefore, we use the different aforementioned treatments to clarify the characteristic of PTS through the human body.



(A) (B) (C)

Figure 3.5. Block diagram of the proposed grounding procedures: (A) Tx and Rx are both connected to ground, (B) Tx is connected to ground, Rx is connected without ground (floating), and (C) Tx and Rx are both connected without ground (floating).

IV. Result and Discussion

A. Initial Results

1. Initial Measurement and Results

To define the initial characteristic of the power transmission system through the human body, we first perform the measurement in our lab, as shown in Figure 4.1. The transmitter (Tx) and receiver (Rx) are attached to the human body (i.e., left arm) with a constant distance between two electrodes(d = 20 cm). In real measurement, the Tx and Rx are connected with the human body through electrode. A signal generator is used as Tx, and spectrum analyser is used as Rx, respectively. The signal generator generate signal with power level at 0.01 mW (-20 dBm) that is transmitted to the human body. Then, the received signal is evaluated by spectrum analyzer. In this measurement we use digital modulation i.e., amplitude-shift keying (ASK), frequency-shift keying (FSK), and phase-shift keying (PSK) as modulation to transmit power through the human body.

To select the modulation and arrange the channel frequency for each modulation we use signal generator. We use the channel frequency of 10 MHz, 20 MHz, 30 MHz, 40 MHz, and 50 MHz, respectively. The measurement result show that the three modulations relatively have low efficiency and, for each of frequencies, deviation of less than 1%, as shown in Figure 4.2. The optimum performance (efficiency) occurs when frequency was 40 MHz using ASK as a modulation. This happen because the signal loss on human body is relatively constant when we use the digital modulation. From this measurement result, it is apparent that we still must define a better modulation scheme for power transmission system through the human body to get better performance. In other words, digital modulation is not well suited for use in power transmission system through the human body.

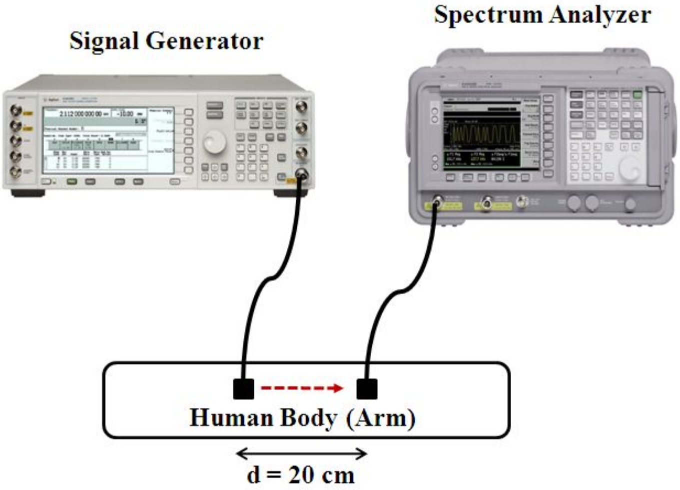


Figure 4.1. Measurement setup for power transmission system through the human body.

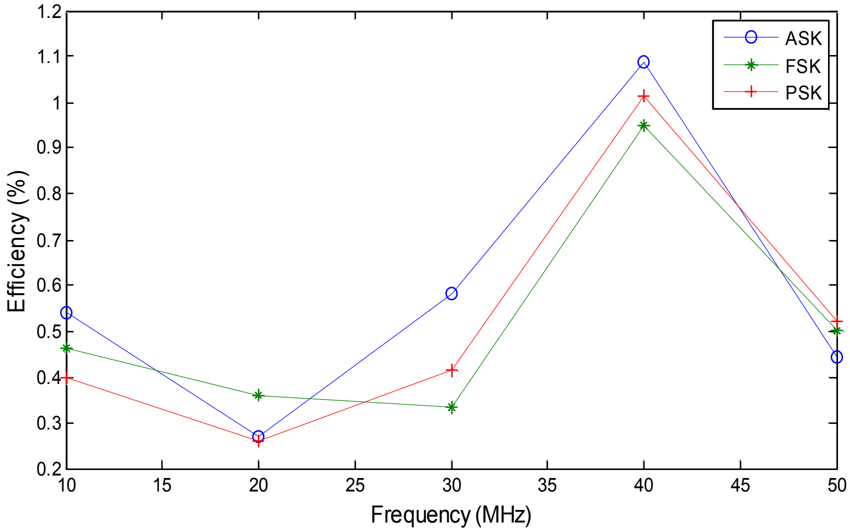


Figure 4.2. Performance result of power transmission system through the human body using digital modulation.

2. Result of Experimental Evaluation of a Power Transmission through the Human Body

In this part, first we examine the HBC channel model by measuring channel input that is represented by impulse response *h(t)* as shown in equation (1). Before we simulate it using MATLAB, we set the value of C_h constant as a reference for the other measurements. As shown in equation (4), C_h is a coefficient related to the sizes of ground planes and distances between Tx and Rx. To evaluate the impulse response in time domain by using MATLAB, we arrange the ground size and distance in the HBC channel model to be at G_T = 10 cm^2, G_R = 270 cm^2, d_{air} = 100 cm, and d_{body} = 100 cm, respectively, as shown in Figure 4.3. In this simulation, we set the time range from 0 to 1 μs and time sampling is 0.001 μs. The impulse response has the response that tend to be decreased from 0 microsecond to 0.3 μs, and, finally, the response is relatively constant over 0.3 μs.

After we obtain the impulse response in the time domain, we transform it to the frequency domain in order to get the signal loss, as shown in Figure 4.4 which we set up a sampling frequency range from 0 MHz to 500 MHz, since sampling should always be over 250 MHz to model the impulse response accurately. From the simulation, it can be seen that the optimum performances occur at a frequency range of 0 MHz to 50 MHz, with the best performance at 41.93 MHz. This result is in good agreement with the HBC channel model, for which the frequency components of the impulse response are valid only between 0 MHz to 50 MHz. In addition, this result is considered further as reference (i.e., frequency at 41.93 MHz) for the other measurements with different ground sizes and distance between Transmitter (Tx) and Receiver (Rx).

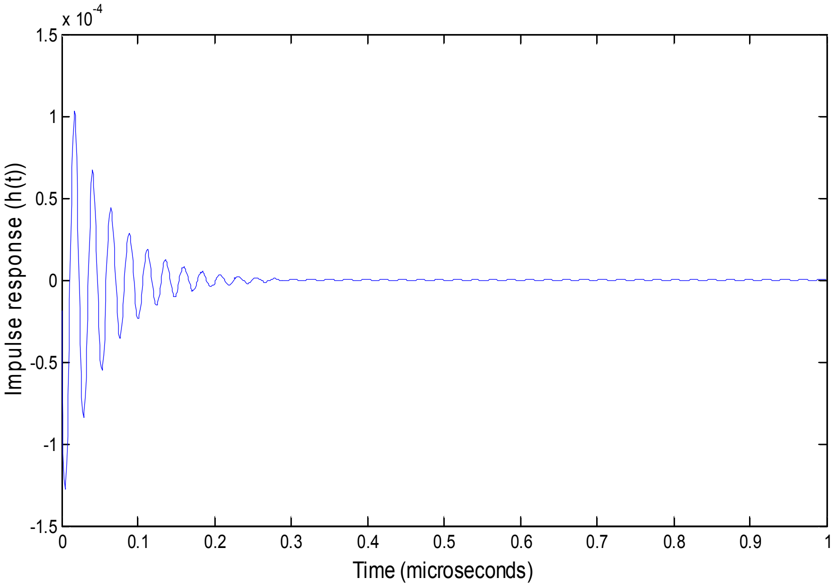


Figure 4.3. Impulse response (time domain).

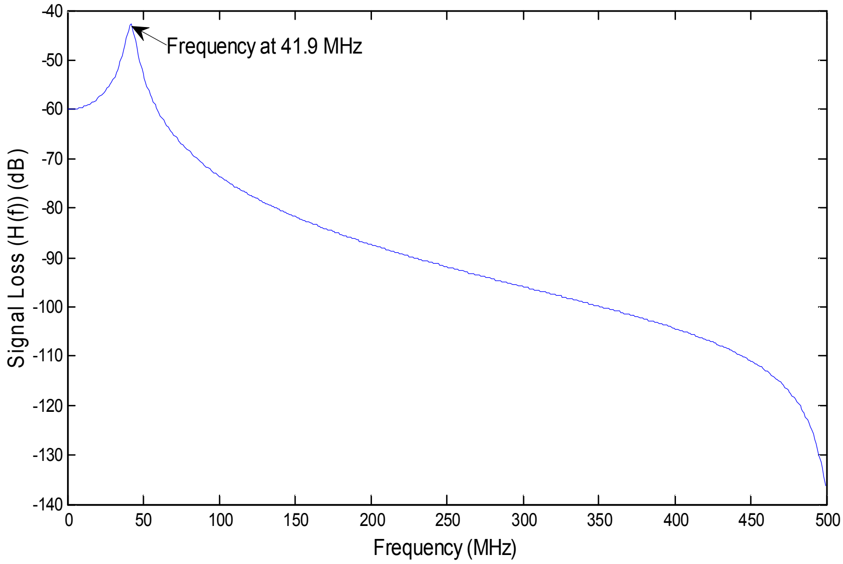


Figure 4.4. Signal loss (frequency domain).

3. Results

In the next measurement, we focus on the performance (efficiency) of power transmission system through the human body. The performance is defined as the ratio of channel output (output power) to the channel input (available/input power). Signal loss is defined as the logarithm of performance (efficiency). Thus, lower signal loss will result in higher performance, which means that signal loss is inversely proportional to the logarithm of performance. Finally, we simulate the variation parameters for different ground size (G_T and G_R) and distances (either through the body or the air).

a) G_R and G_T are Constant

In this simulation, we arrange the condition of HBC channel model at G_R (=260 cm^2) and G_T (=110 cm^2), both of which are essentially constant. The terms d_{air} and d_{body} are set from 10 cm to 100 cm, which, in this simulation, operates at frequency 41.93 MHz. This distance (i.e., distance between Tx and Rx) refers to the reasonable distance for measuring the performance of HBC channel model. As d_{air} and d_{body} increase in length, performance diminishes, i.e., it rapidly increases the signal loss. Figure 4.5 shows the simulation result based on the variation of distance between Tx and Rx (d_{air} and d_{body}). The length of d_{body} must be equal to the length of d_{air} because d_{body} cannot be less than d_{air}, since d_{air} is defined as the shortest distance through the air. Figure 4.5 shows that the efficiency of d1 (i.e., d_{body} = d_{air} = 10cm) is significant compared to that associated with d_2 (=20cm), with a difference of about 8.2% of their efficiencies. In addition, the longer the values of d_{body} and d_{air} are used, the lower the efficiency becomes between Tx and Rx. Therefore, we use the shorter distance between Tx and Rx (i.e., d_{body} = d_{air} = 10cm) in order to get the optimum efficiency. However, the G_T and G_R in this simulation should be examined further to make the current structure reasonable, since the Tx ground (G_T) is too large to be used.

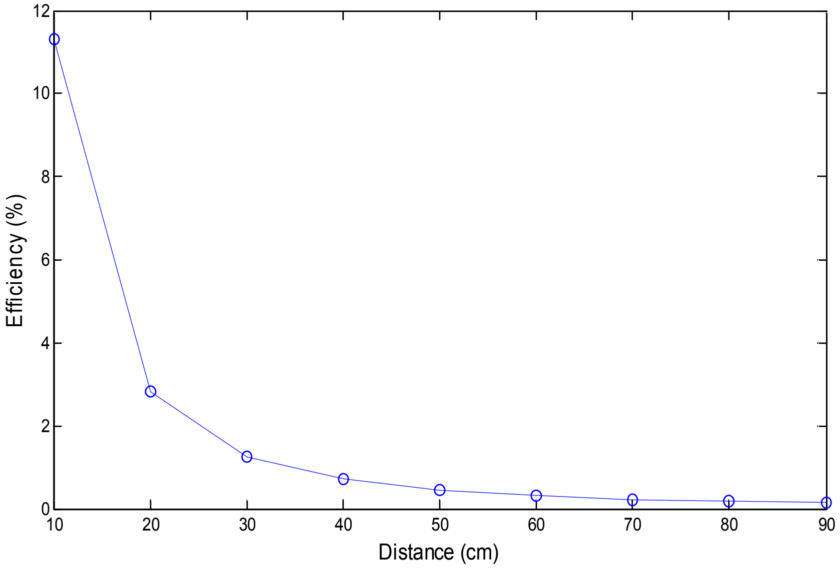


Figure 4.5. Performance (efficiency) on various distance at G_T = 110 cm^2 and G_R = 260 cm^2

b) G_T, d_{body}, and d_{air} are constant

We choose the parameters of HBC channel model as G_{T1}, $G_{T2,}$ and d_{body} = d_{air} are 50 cm^2, 60 cm^2 , 10 cm, and 10 cm, respectively. G_R is set from 10 cm^2 to 260 cm^2. The corelation between ground size and performance (efficiency) is linear, and the slope of the line increases when G_R increases, as shown in Figure 4.6. The best performances occur at G_R 260 cm^2, which indicates that larger G_T become, the better the performance is. It can be seen that when G_{T2} is 60 cm^2, the difference between two different G_R values, e.g., G_{R2} = 160 cm^2 and G_{R1} = 110 cm^2, is greater than G_T has 50 cm^2. This occurs because the value of G_T affects the performance of the power transmission system through the human body to a greater extent than does the value of G_R. By examining different ground size of Rx (G_R), we can determine reasonable parameter for obtaining the optimum performance of the system.

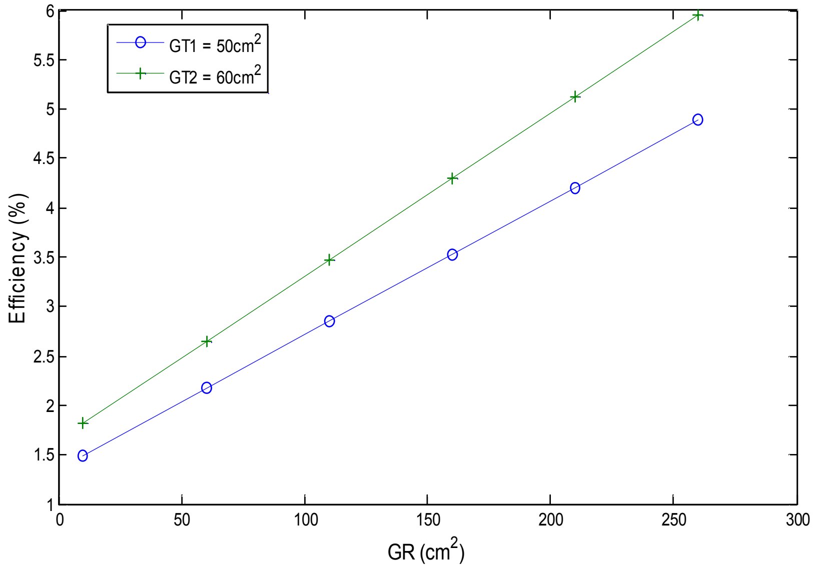


Figure 4.6. Performance (efficiency) on various G_R at G_{T1} = 50 cm^2, G_{T2} = 60 cm^2, and d_{body} = d_{air} = 10 cm.

c) G_R, d_{body} and d_{air} are constant

In this part, we examine the ground size of Tx (G_T) that is arranged from 10 cm^2 to 110 cm^2 with four different G_R values, i.e., 260 cm^2, 210 cm^2, 160 cm^2, and 110 cm^2, as shown in Figure 4.7. This is done to check the effect of each G_R and G_T. In Figure 4.7 shows the changes of G_R have relatively less effect on the performance than does G_T. In case of the change of G_T as shown in Figure 4.6, the difference in performance is about 1.1%, even when there is only a difference in ground size between them of 10 cm^2. In contrast with G_R, the difference performances shown in Figure 4.7 are about 1.56% at a difference of 50 cm^2 between them. Therefore, in the future, we must give careful consideration to choosing a reasonable structure of ground size for Tx.

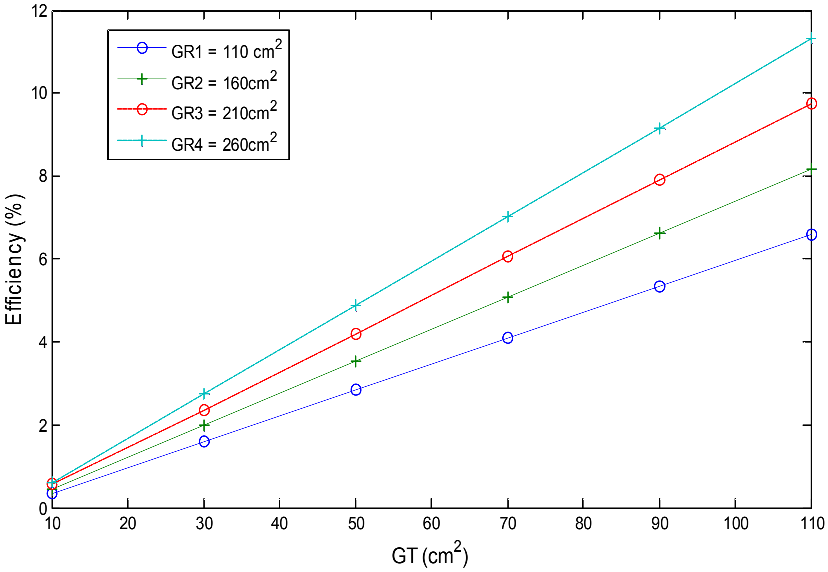


Figure 4.7. Performance (efficiency) on various G_T at G_{R1} = 110 cm^2, G_{R2} = 160 cm^2, G_{R3} = 210 cm^2, and G_{R4} = 260 $cm^{2.}$

4. Wireless Power Transmission on Implantable Medical Devices (IMD)

For Tx and Rx, we examined several ground sizes, i.e., G_T and G_R, and distances i.e., d_{body} and d_{air}. Then, we compare the results with the results acquired and the previous wireless power transmission (WPT) approach. This WPT result should be required to have a similar frequency and power requirement characteristics as the power transmission system through the human body both the frequency and power requirement i.e., a maximum 1mW. In this study, we use WPT on implantable medical devices (IMD), which could be applied either outside or inside human body [29]. This WPT on implantable medical devices has two important components, i.e., power transmitter coil and power receiver coil. The power transmitter coil is attached to our body and wirelessly transmitted power to devices implanted din the body. Thus, the implanted device, the so-called power receiver or load is able to receive power from the power transmitter. To test the coupling and determine the maximum power transfer, the transmitter and receiver coils are placed close together and moved apart (Figure 4.8). The distances are set between 1 cm and 10 cm, as shown in Figure 4.9. This system produces a steady 3.3 V output and can supply 2 mA. The implanted coil received power of less than 1mW at distances between 6 cm and 10 cm. These distances are used as reference for the power transmission system through the human body. However, HBC channel model can only be used at distance of 10 cm or more. So, we compared the power transmission system through the human body with wireless power transmission with both sources located at a distance of 10 cm from the coil.

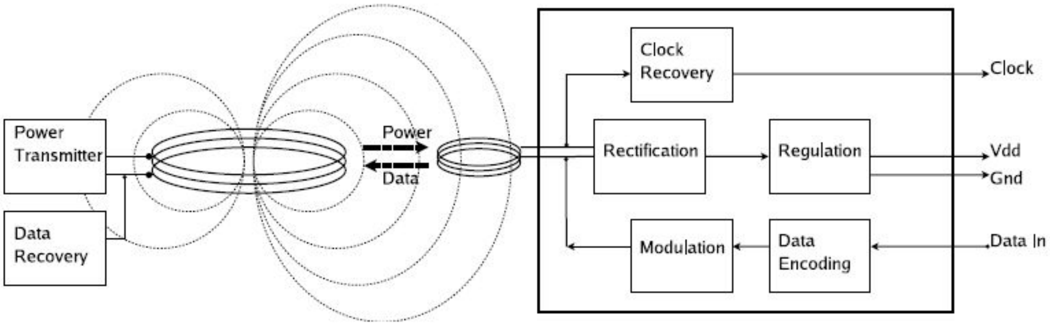


Figure 4.8. Block diagram of the wireless power transmission on implantable medical devices (IMD).

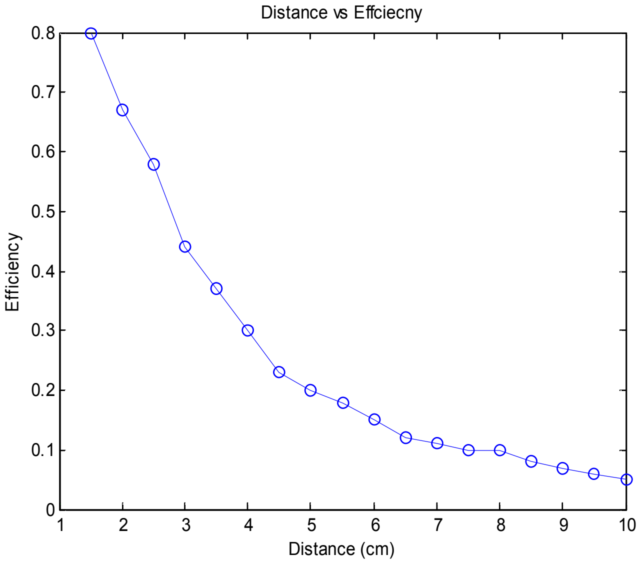


Figure 4.9. Performance (efficiency) of wireless power transmission on implantable medical devices (IMD).

5. Comparison WPT on IMD with PTSTHB

In this part, we compare the wireless power transmission on implantable medical devices (IMD) with power transmission system through the human body (PTSTHB). The various simulation results, as shown in previous part, are compared to Figure 4.10. Since the shortest distance between Tx and Rx is 10 cm ($d_{body}=d_{air}$), in order to get the better performance, we use d_{body} and d_{air} vales of 10 cm, respectively, as the reference parameter for distance between Tx and Rx. We examine the various G_T size over several values of G_R, i.e., from 110 cm^2 to 260 cm^2, as shown in Figure 4.10. In the case of G_T 50 cm^2, the performance is still below the performance of WPT (as shown in the dashed, black line), even for the largest value of G_T i.e., 260 cm^2. Then, for G_T 60 cm^2, the performance is better than the WPT when G_R is 210 cm^2 and 260 cm^2. And G_T values of 70 cm^2 and 80 cm^2 produces better performance than WPT when G_R values are 160 cm^2, 210 cm^2, and 260 cm^2, respectively. G_R values from 110 cm^2 to 260 cm^2 have better performance when G_T value is greater than 85 cm^2 (e.g., 90cm^2 to 110 cm^2). From the simulation results describe above, it was concluded that, when measurements are taken, we consider the reasonable size of G_T because the effect the size of G_T improves the performance of the PTTHB to a greater extent than does the size of G_R. Therefore, in order to design HBC channel model to get the better performance than WPT, we must consider the realistic structure (size) of G_T and use the shortest distance between Tx and Rx wherever possible.

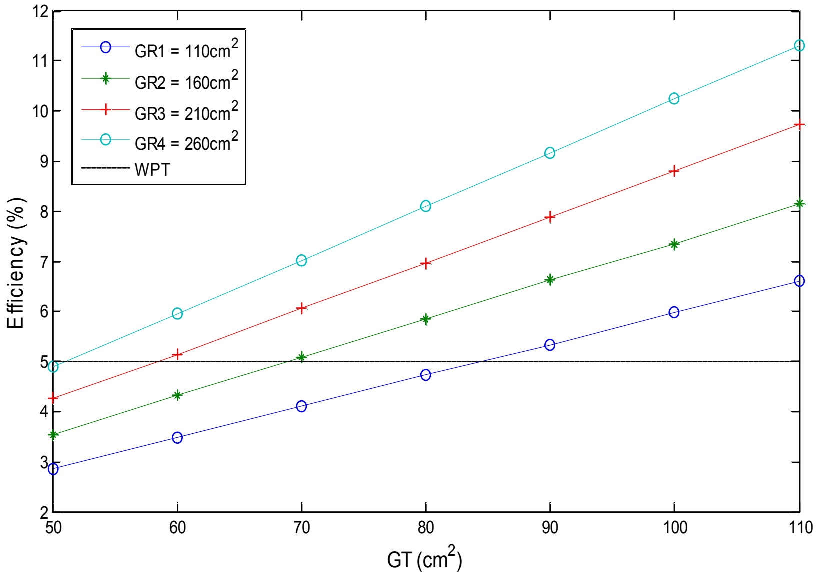


Figure 4.10. Comparison Power transmission system through the human body (PTSTHB) and wireless power transmission (WPT) at distance 10 cm.

6. The reasonable Ground Size of Transmitter and Receiver

From the comparison of the performance between power transmission system through the human body (PTSTHB) and wireless power transmission (WPT) on implantable medical sensor, the ground size (either ground size of transmitter or receiver) is still big enough to be applied in the real case e.g., medical sensor or implantable devices. Therefore, we should consider the smaller ground size, even though the performance (efficiency) is very low. In this part, we evaluate the reasonable ground size for medical application by re-simulating the performance based on the ground size (G_T and G_R). The simulation is done with two conditions of ground size of transmitter (G_T) and ground size of receiver (G_R). First, both ground size (G_T and G_R) are equal at values between 10 cm^2 until 30 cm^2 (green line), which means G_T should be equal or larger than 10 cm^2. Second, we arrange G_T from 10 cm^2 to 30 cm^2 and G_R from 1 cm^2 to 21 cm^2 (blue line) as shown in Figure 4.11 which that the deviation range between the two condition are less than 0.1 % (dashed, red line). Thus, when we manufacture the transmitter and receiver, we must ensure that the ground size of receiver (G_R) is smaller than ground size of transmitter (G_T) without decreasing the efficiency significantly. However, this performance should be considered for certain application, such as small medical sensors, which commonly have transmitter or receiver sizes of less than 30 cm^2 [30]. Last, a reasonable ground size depends on the application. To apply this system on implantable devices or medical sensor i.e., Biomedical Sensor Network (BSN) [31], we must use a small ground size, and vice versa, if we use this system to charge portable devices, we must use a larger ground size than would be used on medical sensor.

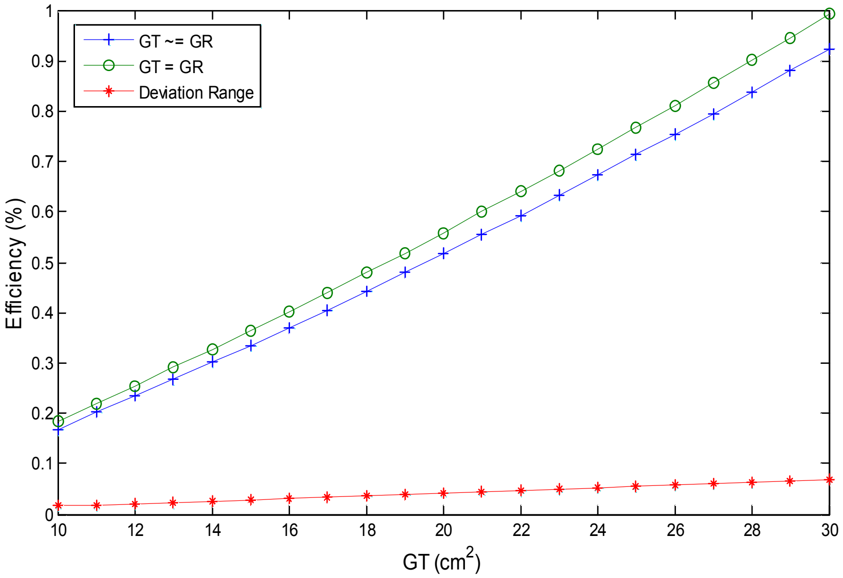


Figure 4.11. Performance of power transmission system through the human body based on ground size when the system is applied to medical application (medical sensor).

V. Conclusion

At the current time, significant amounts of the data are handled on various types of mobile terminal, such as cellular phones, personal digital assistants (PDAs), pocket games, and other small portable devices. Therefore, the importance of intra-body communication is increasing as a common tool for communication among mobile terminal. At the same time the power resource among mobile terminal must be considered. In this study we will investigate the need of power transmission system (PTS) through the human body by transmitting reasonable power (i.e., maximum of 1mW).

The study is conducted by defining the characteristic of power transmission system through the human body in order to simulate its performance according to ground conditions. So, we determine the optimum efficiency by comparing the various ground conditions (i.e., using three different treatment).

In order to get better performance compared to wireless power transmission on implantable medical devices (WPT on IMD), we use the distance between Tx and Rx while considering the what a reasonable ground size of Tx (G_T) should be. Based on the simulation results of power transmission system through the human body (PTSTHB) and the result of wireless power transmission on implantable medical devices (IMD), we conclude that power transmission system through the human body is improved as the transmission distance decreases and ground size of Tx and Rx increases. From simulation results, we determine that PTSTHB have a better performance than WPT when the parameters of HBC channel model are chosen such that the distance between Tx and Rx (d_{body} and d_{air}) is 10 cm, G_T is greater than 70 cm^2 and G_R greater than 110 cm^2, and the operational frequency is about 42 MHz. However, this ground size is still large enough for real implementation e.g., as a medical sensor (Body Area Network). Therefore, in future research, we should consider using a smaller ground size to enhance the possibility of using the system for medical applications that require small levels of power consumption (e.g, efficiency less than 5%).

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List of Publications

Rudi M. Siagian, Thanh V. Pham, Jung Hwan Hwang, Sung-Weon Kang, and Youn Tae Kim, "A Study of Power Transmission System Through The Human Body," Proc. IEEE APS/URSI, Toronto, July. 2010.

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Rudi M. Siagian, Jung Hwan Hwang, Sung Weon Kang, and Youn Tae Kim, "Ground Effect on Power Transmission System Through The Human Body," Proc. IEEE APS/URSI, Spokane, WA, USA, July. 2011 (Accepted).

ABSTRACT

A Study of Ground Effect Based on the Analysis of Optimum Distance and Frequency for Power Transmission System through the Human Body

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Currently, significant amounts of data are handled on various type of mobile terminal, such as cellular phones, PDA, pocket games and other small portable devices. Therefore, the importance of Intra-body communication is increasing as a common tool for communication among mobile terminal. At the same time the of power resource among mobile terminal should be considered. In this study, we investigate the need of power transmission through the human body by transmitting the reasonable power (i.e., maximum 1 mW).

In the research reported in this thesis we investigate and analyze the optimum distance and frequency of power transmission system through the human body based on established the regulation i.e., regulations established by International Commission on Non-Ionizing Radiation Protection (ICNIRP). Our analysis is used to design an effective modulation scheme for transmitting power through the human body. In order to determine the optimum distance and frequency, we define the basic tenets of the regulation, such as basic restriction (e.g., current density) and reference level (e.g., current). Both basic restriction and reference level are intended to limit the effects and influences of the electromagnetic field (EMF) under specified test conditions by measuring the physical quantities that characterize electric, magnetic, and electromagnetic fields. First, we examine the power performance (i.e., available power) of power transmission system through the human body by reducing transmission distance until the transmission could occur with a higher efficiency than transmitting power via wireless media.

From the simulation with MATLAB and the regulation (i.e. ICNIRP), we determine that the optimum frequency for power transmission system through the human body is in the range 100 kHz to 50 MHz, and it is important that the frequency not exceed the upper of this range. Also, we obtain good agreement between distance (d_{body}), ground size (i.e., a transmitter Tx and a receiver Rx). The shorter the distance between Tx and Rx, the better performance of system becomes. In addition, as we increase the ground size, performance improve.

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During this work, I collaborated with all my colleagues in the laboratory and I have great regard for all of them and wish to extend my sincerest thanks to all those in the Department of IT Fusion Technology who helped as I conducted my work.

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저작물 이용 허락서

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논문제목	한글 : **인체를 통한 전력전송체계를 위해 접지 효과를 기본으로 한 최적의 거리 및 주파수 분석에 대한 연구** 영어 : A Study of Ground Effect Based On The Analysis of Optimum Distance and Frequency For Power Transmission System Through The Human Body				

본인이 저작한 위의 저작물에 대하여 다음과 같은 조건아래 조선대학교가 저작물을 이용할 수 있도록 허락하고 동의합니다.

- 다 음 -

1. 저작물의 DB구축 및 인터넷을 포함한 정보통신망에의 공개를 위한 저작물의 복제, 기억장치에의 저장, 전송 등을 허락함
2. 위의 목적을 위하여 필요한 범위 내에서의 편집・형식상의 변경을 허락함. 다만, 저작물의 내용변경은 금지함.
3. 배포・전송된 저작물의 영리적 목적을 위한 복제, 저장, 전송 등은 금지함.
4. 저작물에 대한 이용기간은 5년으로 하고, 기간종료 3개월 이내에 별도의 의사 표시가 없을 경우에는 저작물의 이용기간을 계속 연장함.
5. 해당 저작물의 저작권을 타인에게 양도하거나 또는 출판을 허락을 하였을 경우에는 1개월 이내에 대학에 이를 통보함.
6. 조선대학교는 저작물의 이용허락 이후 해당 저작물로 인하여 발생하는 타인에 의한 권리 침해에 대하여 일체의 법적 책임을 지지 않음
7. 소속대학의 협정기관에 저작물의 제공 및 인터넷 등 정보통신망을 이용한 저작물의 전송・출력을 허락함.

동의여부 : 동의(○) 반대( )

2011년 8월

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