Investigation of Knee Flexion Angle Influences on Intra-Body Communication's (IBC) Signal Attenuation

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ABSTRACT

Galvanic coupling method is one of the methods introduced in intra-body communication (IBC). IBC uses human body to as the communication medium for data transmission. In this paper, the investigation focuses on signal attenuation performance across knee joint using the galvanic coupling analysis. The signal attenuation was determined by implementing the galvanic coupling analysis at specific knee flexion angle. The galvanic analysis initiated by deciding the operating frequency in between 40 to 60 MHz in order to analyze the signal attenuation between the knee flexion angles. This paper found that the lowest signal attenuation at the operating frequency was 47.25dB, while the highest one was 52.63dB where the knee flexion angle is 0o and 155o respectively. It was concluded that the signal attenuation decrease with the increasing of knee joint existence at the specific flexion angle. However, a wider experiment must be conducted for various data that will correspond to signal attenuation for various influenced human data characteristics.

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1. INTRODUCTION

Leading to Industry 4.0, the biomedical engineering field rapidly improves the data analyzing and monitoring system using the new channel of communication. The help of advancement in electronics technology introduces a set of diseases self-monitor system that built-up from specific miniature sensors and wireless communication in which integrated together. Due to the development of biomedical communication channel, a new standard of wireless body area network (WBAN) or IEEE 802.15.6 was ratified in 2012. This standard allows a low power wireless communication protocol through human body using radio frequency (RF) wave and also non-RF. Compared to RF, the IBC consume very low power which is very important for the wearable device [1]. WBAN can be apply in many application including medical and non-medical application such as ubiquitous healthcare, cancer detection , monitoring blood glucose , asthma detection application, military, monitoring battlefield activity and many others [2].

In 1995, intra-body communication (IBC) that is a kind of non-RF protocol proposed by Zimmerman [3] to introduce the cable-free concept in biomedical engineering. IBC was defined as wireless communication that using body tissue as propagation medium or electrical channel [4]. Figure 1 illustrates the IBC technology in biomedical application [5].

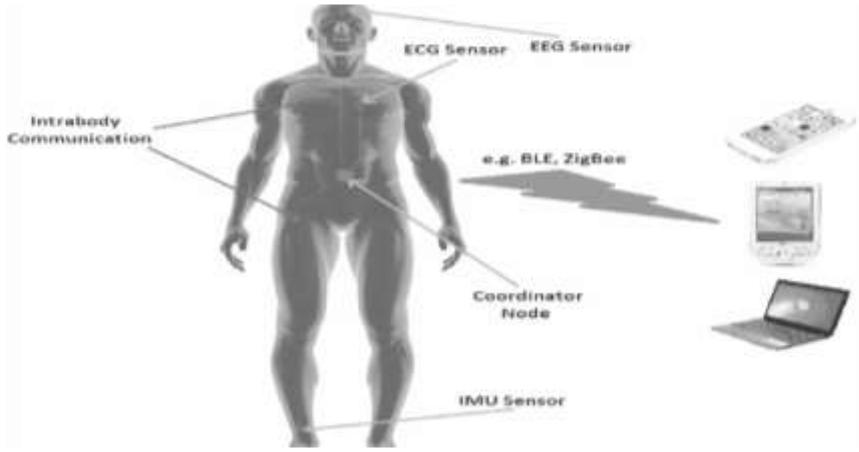

Figure 1. IBC Illustration of Transmission Line

In general, there are two main coupling techniques used in IBC: galvanic coupling and capacitive coupling. By definition, both of these techniques differentiated by the connection from transmitter to receiver component as shown in Figure 2 [6]. In galvanic coupling, two set of transmitter and receiver electrodes that attached to human skin will operate to process the applied signal [7] while capacitive coupling technique provides the signal processing by current loop between the transmitters and receiver electrode that form a return path through the external ground [8].

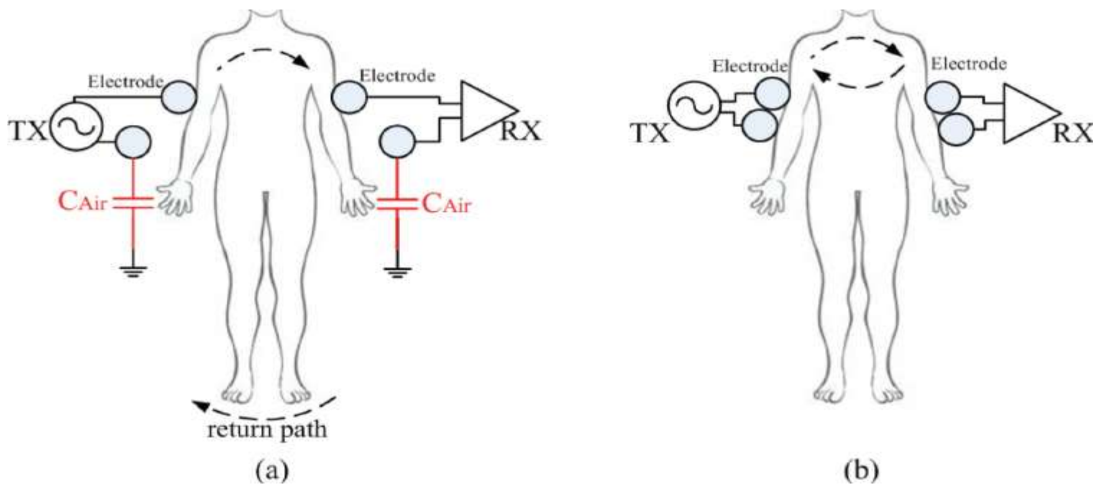

Figure 2. a) Capacitive Coupling Technique b) Galvanic Coupling Technique

A lot of researches had been conducted before in order to select the best modeling method for both of IBC's techniques. In 2013, H. liu *et al.* was proposed a low-cost remote healthcare monitor system designed based on embedded system [9]. However, the effect of existing limb joint to the system design was not discussed. Home Health monitoring system using Internet Of Thing (IOT) also proposed by Y. JingJing *et al.* [10]. In order to apply human body as a communication medium in IBC system, the characteristic of human body must be study. The human body contain of many limb joint that may affect the quality of signal transmitted. Therefore, this paper investigates the signal attenuation during the knee joint existence by using static adjustment of knee flexion angle. However, this paper focused on galvanic coupling approach in assessing the signal attenuation in three different static conditions of knee flexion angle. Other than that, the signal attenuation at the specific angle during movement was compared on previous paper (I W Ibrahim 2015)[11] based on gait cycle analysis.

2. METHOD

2.1. IBC Technique Approach
Even though IBC technique has two different approaches, this paper focused on galvanic coupling technique. Galvanic coupling is the method where the signal applied to both of transmitter electrodes. The human skin will transmit the signal like a wire to appear as an output voltage at the receiver electrodes on the body. The selection of galvanic coupling technique in the paper was influenced by the determination reported by Ryan G. and A H A Razak *et al.*[12] that concluded the signal for this approach technique is contained completely in the body and significant in data transmitting. The implementation of this IBC technique is shown in Figure 3 [13].

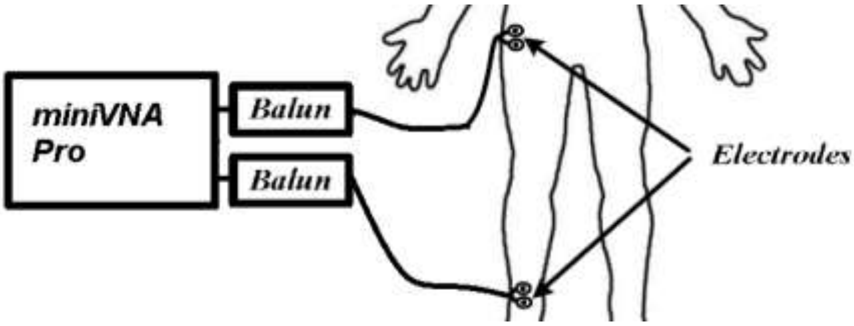

Figure 3. Galvanic Coupling Setup

2.2. Experimental Design
Referring to Figure 3, the signal attenuation analysis used a portable vector network analyzer (miniVNA Pro) and a pair of baluns to create a full transmission path from transmitter to receiver though the human body. The placement of transmitters and receivers were setup at the subject's right ankle and waist consecutively with a distance of 90cm calculated from the center of the electrodes. This simple connection used to pump the signal and read it at the receiver electrode. The function of portable vector network analyzer is to generate the signal in form of frequency wave at the transmitter electrodes and read the signal attenuation at the receiver electrodes.

This experiment started by varying the frequency in range from 0.3 to 200MHz at the transmitter electrodes that attach to the subject's skin. The analysis of signal attenuation was done by three knee flexion angle conditions. Each angle was statically adjusted until reached the required angle as show in Figure 4. The selection of knee flexion angle was determined by considering the clinical report from UKM specialist center. The orientation of knee flexion angle is from 0^{o} to the maximum flexion of 155^{o}. This knee flexion angle represents the knee joint existence to relate the condition of knee joint existence to signal attenuation in galvanic coupling technique.

Table 1: Knee Flexion Angle for Subject Testing

0^{o} of knee flexion angle	90^{o} of knee flexion angle	155^{o} of knee flexion angle
		

For each angle stage, the experiment was repeated up to three times to get the mean of the loss signal. A simple mathematical equation was carried out to determine the mean and data comparison. The specific operating frequency was decided based on previous paper by M. Seyedi and L. Daniel [14] to prove the relationship between the signal attenuation for knee joint existence in static condition and the surface of standing factor. The initial hypothesis was assumed as the greater of knee joint existence, the smallest the signal attenuation recorded.

2.3. Protocol

Three male subjects from UiTM was a volunteer that fulfill the requirement by the Universiti Teknologi Mara Research Ethics. The signal attenuation analysis was tabulated for the frequency from 0.3 to 200MHz. Nevertheless, the operating frequency was decided at 40 to 60 MHz based on previous paper as mentioned before. On the other hand, the mean readings of the signal attenuation focused on 40 to 60 MHz of operating frequency for all of knee joint existence angle. A generated input power from miniVNA was kept at very low power which is 1.0mW. To be mentioned, this input power follow the guideline of maximum allowed contact current by International Commission on Non-ionizing Radiation Protection (ICNIRP) and it does not affect the health risk to the subject.

2.4. Subject Testing

Before the experiment initiated, the volunteer subjects was explained the details about on-going procedure in order to ensure the accurate result could be obtained. The subject required to undergo three set of tests which include three angle position of knee joint existence. During the data analysis stage, subject was asked to not stretching the legs and not to move them until it was adjusted to specific angle that represent the knee joint existence. Each of data was analyzed by varying the frequency range from 0.3 to 200MHz as mentioned previously.

3. RESULTS AND DISCUSSION

This paper investigates the signal attenuation in galvanic coupling technique by testing the knee joint existence. Three specific angle was determined and adjusted from 0^o (no knee flexion), 90^o (medium knee flexion) and 155^o (maximum knee flexion). Theoretically, during the knee joint existence, the signal attenuation decrease as the resistance inside the galvanic coupling increase at that specific flexion angle. Thus, this section revealed the significant of the theory concept.

M. Seyedi and L. Daniel [12] reported that the focus operating frequency is in between 40 to 60 MHz due to the less signal attenuation compared to other region of the supplied frequency. Thus, this paper used the average of 50 MHz to measure the signal attenuation at the specific existence knee angle. Figure 6 to Figure 8 show the signal attenuation measured for frequency in range of 0 to 180 MHz for the knee flexion angle. As mentioned before, three readings captured for each angles to obtain the accurate mean at the final analysis.

Figure 6. Signal Attenuation Captured at 0^o Knee Flexion Angle (No Knee Joint Existence)

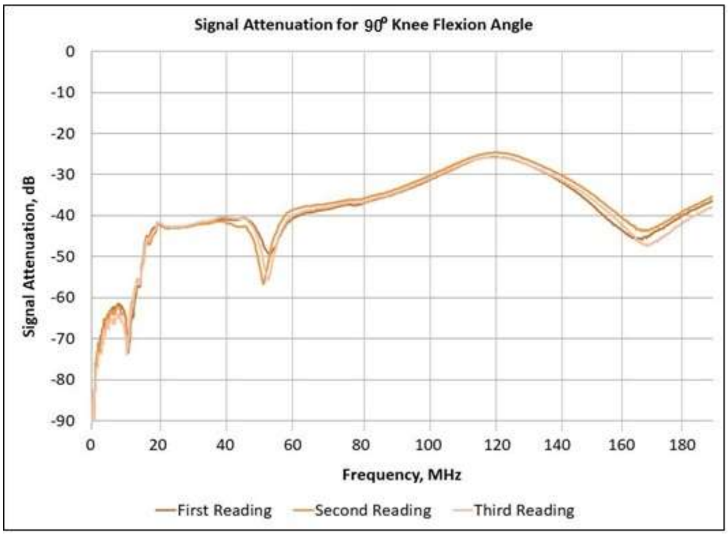

Figure 7. Signal Attenuation Captured at 90° Knee Flexion Angle (Medium Knee Joint Existence)

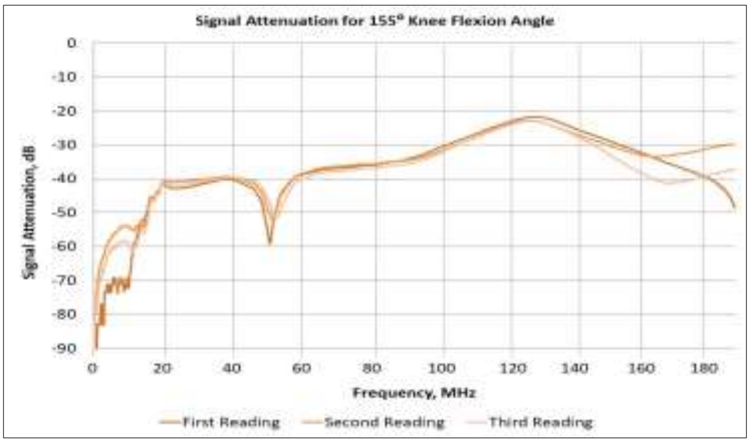

Figure 8. Signal Attenuation Captured at 155° Knee Flexion Angle (Maximum Knee Joint Existence)

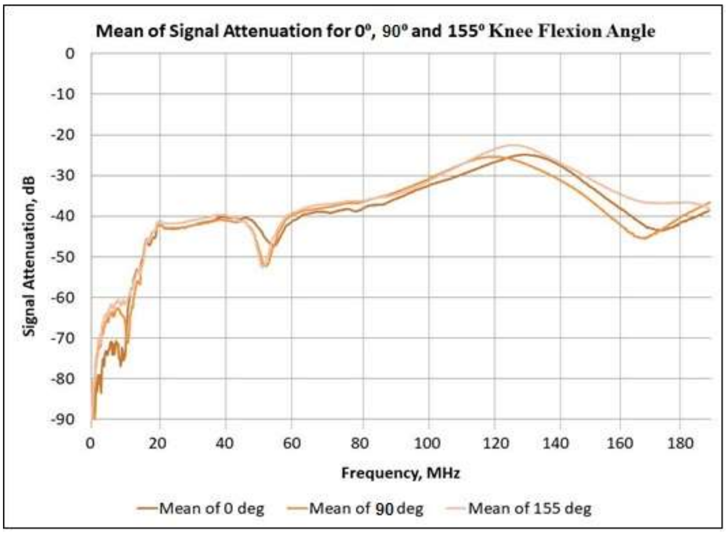

Figure 9. Mean of Signal Attenuation for 0°, 90° and 155° Knee Flexion Angle

Figure 9. shows the mean of signal attenuation for 0º, 45º and 155º of knee flexion angle. As plotted, the signal attenuation during the different of knee joint existence shows the maximum of 90dB in each angle at starting point. However, during the sweeping process of the signal applied, the signal attenuation started to follow the angle position. As expected, the signal attenuation recorded at the highest knee flexion angle of 155º is the lowest one. The highest signal loss at this angle is only 52.63dB at the frequency of 50 MHz, while the rest is lower than 40dB compared to flexion angle of 0º and 45º.

The maximum signal attenuation at the 40 to 60MHz frequency is tabulated in Table 2. The signal attenuation at 0º is 47.25, followed by 52.33 at 90º and 52.63dB at 155º. The obtained result concluded the relationship between the knee joint existence and the signal attenuation. The earlier hypothesis was confirmed that the signal attenuation decrease as the angle of knee flexion increase.

Table 2. Signal Attenuation for Knee Flexion Angle at 40 to 60MHz

Knee Flexion Angle (deg)	Signal Attenuation (dB)
0	47.25
90	52.33
155	52.63

4. CONCLUSION

The paper studies the effect of human limb posture on IBC signal attenuation. It could be concluded that the dynamic body channel characteristic in significant for choosing the optimum frequency range for data communication in IBC. In general, this study focused on signal loss at the knee joint. The signal attenuation affected by the knee flexion. It can be reserved that the signal attenuation increased when the knee joint flexes. The lowest signal attenuation recorded at 0º or at the minimum point of knee angle. As a conclusion, it shows that the transmission loss presence by the knee flexion angle presence. The increase in attenuation was proportional to the joint angle. The effect of environment on IBC measurements can be neglected. These findings suggest that more advanced and motion-adaptable IBC systems are required for improved IBC BAN applications.

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