Experimental Characterization of In Vivo Radio Channel at MICS and ISM Bands

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Abstract— This paper presents an experimental study for the propagation losses and wave attenuation inside human body for implanted antenna at different body organs. The experimental study discusses the commonly used frequency bands: 402–405 MHz MICS (Medical Implant Communication Service) band, and the industrial, scientific and medical (ISM) band frequency at 915 MHz. The path loss is calculated for different positions of implant at different organs i.e., heart, stomach, and intestine. In addition, the effect of frequency change is discussed and analyzed.

1. INTRODUCTION

Wireless communication and channel modeling for implantable biomedical devices have received more attention in recent years for diagnosis and therapy. The patients can be monitored remotely without direct physical communication and schedules. Biomedical implantable devices play an important role in remote monitoring of various important parameters such as concentration of glucose, and blood flow pressure and rate, etc. [1].

Mutual communication between the implantable medical devices and the ex-vivo devices is commonly performed in the medical implant communications service (MICS) band (402–405 MHz) as it represents reasonable signal propagation characteristics in human body [2]. MICS has wide range of applications such as stimulatory devices including pacemakers and implantable cardioverter/defibrillator. Moreover, ISM band is intended for start-up signal, thus saving the total power consumption [2]. It is crucial to analyze the signal attenuation in the lossy human tissues and the propagation around the human body. The radiation performance of human vaginally implanted 418 MHz and 916.5 MHz radio sources was examined, and it was shown that as the frequency increases, losses in human tissues increase also [3, 4]. Moreover, the path loss characterization of in-vivo communication channel at 2.45 GHz was investigated inside the human body chest, and it was shown that there was almost 10–15 dB variation in path loss in case of in-vivo channel as compared to free space, which reflects the importance of carefully considering the location of on-body receiver for optimal system performance [5].

Experimental measurements used to confirm the validity of the simulation results done using human body models are usually performed inside phantoms. Phantoms are relatively easy to be analyzed and implemented; however, real time in-vivo measurements of implantable devices are essential to verify the performance in a real environment that has many and different tissue layers. These multitissues have different electrical properties such as conductivity and signal attenuation depending on the used frequency as well as age, size, sex, etc. [6]. In addition, the most widespread solution is the use of liquids, simulating the electrical properties of the body tissues, that fill a container with predefined shape [7]. A comparison between a single equivalent layer of a body model and a three layer structure was presented showing the advantages and limitations of each one [8]. Numerical electromagnetic analysis was applied to model in/on body radio propagation channels which clarified the importance of digital phantom accuracy [9].

In this study, experimental analysis of implantable antennas for biomedical telemetry in the ultrahigh frequencies MICS (402–405 MHz) and the industrial, scientific and medical ISM (902–928 MHz) bands is presented. Measurements are performed on adult cadaver. For measurement studies, an antenna is placed at different organs inside the body (keeping in view the most promising implantable applications) i.e., heart, stomach and intestine. The ex-vivo antenna is placed at a distance of 20 mm from the body. In addition, different depths of implant antenna are considered as well. Path loss is calculated for all scenarios. The study enables better understanding of losses inside the body for different organs, which will help in developing better implantable devices.

The paper is organized as follows: Section 2 discusses the experimental setup and the positions of both the implanted and ex-vivo antennas. Section 3 discusses the results. Finally, conclusions are given in Section 4.

2. MEASUREMENT SETUP

The measurement setup were performed using a medium height adult cadaver in Medipol University, Turkey (IRB approval was obtained for this study). Two dipole antennas were used in this study, one was implanted inside the body and the ex-vivo antenna was placed outside the human body at the distance of 20 mm from the surface of the body. The measurements were taken at different body locations. The implanted antenna was placed at three different organs inside the body i.e., heart, stomach, and intestine. Moreover, the measurements were done for different implanted antenna organ positions. For the heart, the implanted antenna was placed at two positions, top and bottom of heart, represented by hrt1 and hrt2; respectively. For the intestine, the implanted antenna was placed at two positions, top and bottom of intestine, represented by int1 and int2; respectively. Finally, for the stomach, the implanted antenna was placed at three difference positions, top, bottom and inside the stomach, represented by st1, st2, and st3; respectively. The study was done at two frequency bands: 402–405 MHz MICS (Medical Implant Communication Service) band, and the industrial, scientific and medical (ISM) band frequency at 915 MHz.

The ex-vivo antenna was placed outside the body at distance 20 mm away from the body. Moreover, the losses inside the human body were investigated for different ex-vivo antenna positions regarding the body. The ex-vivo antenna was placed in 3 positions: at center of the body, at right side of the body, and at left side of the body, represented by c, s_1, and s_2; respectively. Ex-vivo antenna was oriented parallel to the implanted antenna throughout the measurement. Consequently, the polarization loss and the effect of the polarization on the performance were not encountered. For all cases, path loss was calculated from the measured transfer function S_{21} using Rohde & Schwarz portable vector network analyzer, which was calibrated to remove any cable losses.

3. ANALYSIS OF MEASUREMENT RESULT

The effect of the human body on the in-vivo device signal must be understood for successful design and reliable operation. Unlike the usual communication through constant air, the various tissues and organs within the body have their own unique conductivity, dielectric constant and characteristic impedance. Table 1 represents a comparison between the values of the path loss for different organs at different implantable antenna positions. The effect of the ex-vivo positions regarding to the human body is also clear from the table. All these values are measured at a distance of 2 cm from the human body. Table 1 shows the measurement results at the two chosen frequency bands. The losses through the body come from the attenuation by the weakly conductive tissues and the reflection at each of the boundaries of dissimilar tissues.

Table 1: Path Loss (dB) for different body tissues at different ex-vivo positions measured at the two specified frequency bands.

		402 MHz			915 MHz		
		c	s_1	s_2	c	s_1	s_2
Heart	hrt1	−67.06	−67.062	−40.65	−42.08	−55.72	−40.99
	hrt2	−40.99	−40.99	−40.99	−46.5	−56.74	−63.9
Stomach	st1	−40.99	−40.99	−40.99	−57.52	−39.93	−41.51
	st2	−40.99	−40.99	−40.99	−58.75	−51.71	−50.4
	st3	−38.78	−38.78	−38.78	−67.39	−58.34	−69.34
Intestine	int1	−38.78	−38.78	−38.78	−73.3	−42.59	−47.05
	int2	−26.81	−26.81	−35.84	−41.12	−68.1	−46.06

Table 2: Average Path Loss (dB) at the two specified frequency bands.

		402 MHz		915 MHz	
		Average 1	Average 2	Average 1	Average 2
Heart	hrt1	−58.26	−49.62	−46.26	−50.99
	hrt2	−40.99		−55.71	
Stomach	st1	−40.99	−40.25	−46.32	−54.99
	st2	−40.99		−53.62	
	st3	−38.78		−65.02	
Intestine	int1	−38.78	−34.30	−54.31	−53.03
	int2	−29.82		−51.76	

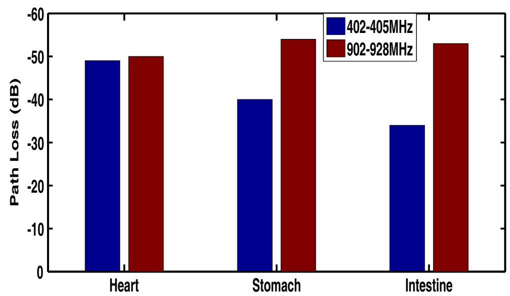

Figure 1: Average Path loss at the two specified frequency bands.

In order to ease the comparison between the different path loss values, Table 2 summarises Table 1 by representing the average values for the path loss at different implantable antenna positions, and ex-vivo positions. "Average 1" represents the average value of the path loss resulting from the different ex-vivo positions regarding to the human body. While "Average 2" represents the average value of the path loss resulting from measuring the losses at the different organs inside the body.

From the results, it can be concluded that as the frequency increases, losses also increase for the all body organs due to the high conductivity of the tissues and the increase of the free space propagation losses. For 402 MHz frequency band, losses from the intestine is the lowest, while losses from the heart is the highest. On the other hand, for 915 MHz frequency band, losses from the heart is the lowest, while losses from the stomach is the highest. These results are indicated in Fig. 1.

4. CONCLUSION

The paper presented an experimental study of in-vivo radio propagation at 402 MHz, and 915 MHz bands. The effect of the position of the implanted antenna inside a human body is analysed. The position of both the implanted antenna and the ex-vivo is shown to have a great effect on the path loss. Different body tissues have an effect on the path losses. Consequently, it is important to consider the real effect of the different body tissues, when designing an implanted antenna to get reliable and practical situation. It is clear from the investigation that the losses increase as the frequency increases due to the high conductivity of the tissues.

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