

The effect of body shape and gender on Wireless Body Area Network on-body channels

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Abstract – *Technological advancements have made possible the emergence of Body Area Networks (BANs). There are numerous on-body channel characterizations in the literature performed on a phantom or a single human subject. In this paper, using multiple subjects, we consider the effect of body shape and gender on the on-body channel.*

A characterization of a narrowband on-body to on-body channel among different subjects is presented. The paper investigates the relationship between the propagation and the subject's physical characteristics. The investigation is performed at 2360 MHz; the new medical band undergoing FCC approval. Our results show that the path loss in women is less than that in men. They also show that involuntary movements along with respiration cause small-scale fading that follows the Rice distribution.

1. INTRODUCTION

Body Area Networks (BAN) have attracted significant attention in medical and consumer applications. The IEEE 802.15.6 task group is defining the physical and the data link layer for BANs. The task group identified four distinct communication scenarios between devices: implantable to implantable, implantable to on/off body, on-body to on-body and on-body to off-body [1].

Much research has been devoted to characterize on-body to on-body channels at different frequencies [2], with nodes at different positions on the body [3][3], different postures, different surrounding environments and different antennas [3]. Oliveira et al. [4] performed a study on two male and female subjects and concluded that there is no significant difference between female and male subjects. However the authors recognise that their study does not provide statistical confidence. In this paper we extend their work by performing the study on sixteen subjects and we argue that this provides higher confidence in results.

This paper characterizes the on-body to on-body channel of different subjects and identifies a relationship between physical characteristics and signal propagation.

2. MEASUREMENT SETUP

The on-body channel was characterized measuring the path loss between 2 printed inverted F antennas with a ZVB-8 vector network analyzer (VNA). Each antenna was designed in a printed circuit board (PCB) that also includes a SMA connector. The PCB characteristics and size were chosen to be

similar to the one used in body-worn devices (1.6mm-thick 2-layer FR4 PCB of 3 cm x 2.5 cm dimension with a solid ground on the bottom layer).

The two PCBs were attached to 5 mm plastic support, which were then attached to the body: the first PCB was mounted on the chest with an adhesive tape and the other on the left wrist using a tight elastic band. Accurate orientation and placement of the PCB was kept during each experiment.

Taking into consideration the effect of the resonance frequency shift caused by the body, the antenna was designed to have central frequency at 2360 MHz and bandwidth of 15%. The inverted F antenna is a realistic option in BAN for its low profile, cost-effectiveness and simple integration.

The vector network analyzer was set to measure the S21 response at 2360 MHz for 30 seconds every 10 ms. Each measurement included 3000 samples and it was repeated three times for validation purposes. The measurements were made on sixteen people who had the PCBs fitted at the same anatomical location on the body. The subjects were instructed to stay motionless on a marked spot at the centre of an empty office room (10.5 x 6.7 x 3 m).

3. RESULTS

The propagation path loss was measured on 16 people with different physical characteristics as shown in Table 1: age (from 20 to 63), gender (8 males and 8 females), weight (from 51 to 119 kg) and height (160 to 185 cm).

The results were analysed independently for each subject, in terms of: first order statistics (average and standard deviation), small scale fading, level crossing rate (LCR) and average fade duration (AFD).

The time series of the measurements indicated a periodicity of approximately 2 to 5 seconds and its existence was verified with the FFT of the signals. This frequency component is due to the respiration of the subjects.

The results showed that the average path loss varies between 60 dB and 80 dB depending on the subject. Additionally, it was observed that females suffer less path loss in comparison to men. This could be justified by the reduced distance between the torso and the wrist in women. However, weak correlation was found between average path loss and distance. This suggests that physical characteristics of the

Subject	Gender	Age (year)	Height (cm)	Chest size (cm.)	Waist size (cm.)	Distance between 2 sensors (cm)	Weight (kg)	Average Path Loss (dB)
1	female	20	166	91	81	47	60	64.3
2	female	30	167	94	83	47	65	69.7
3	female	31	162	98	98	52	72	67.7
4	female	31	165	90	85	50	51	66.4
5	female	37	168	98	94	50	77	60.4
6	female	39	168	80	84	48	53	66.9
7	female	52	168	90	78	46	69	67.9
8	female	58	160	100	89	52	67	65.3
9	male	20	185	115	110	49	119	75.8
10	male	21	185	97	89	55	87	71.6
11	male	25	180	92	84	52	65	72.1
12	male	29	175	104	95	49	90	75.3
13	male	33	183	100	96	52	91	69.4
14	male	34	172	89	80	49	68	69.5
15	male	48	167	108	102	50	87	79.7
16	male	63	168	130	125	55	112	74.9

Table 1 Characteristics of the persons and Average path Loss

subjects are more influential in the path loss, compared to the difference in distance for each subject.

On body signal propagation consists mainly of a creeping wave diffracted from the human tissue and trapped along the body surface [6]. From the results obtained in all male subjects, it was observed that the path loss was higher for larger chest sizes. This can be justified by the fact that larger chest size increases the diffraction of the creeping wave; this was validated by the analysis of the K-factor in the Rice distribution as discussed later in this paper.

To understand this phenomenon better we used a statistical analysis of the small-scale fading to take into account the involuntary movements and the environment where the experiments were conducted.

The received signal amplitude was normalized with respect to the global median and seven commonly used probability distributions were chosen in order to fit the empirical distribution using the maximum likelihood estimates (mle) function in Matlab. Subsequently, the second order Akaike Information Criteria (AIC) [3] was used to choose the best distribution among the seven with the minimum loss of information.

The AIC reveals that the Rice distribution is best suited for 14 out of 16 subjects while Weibull distribution is the best fit for the remaining 2 subjects. The Rice distribution is often expressed in terms of a parameter K defined as the ratio of the power in the line of sight (LOS) component to the power in the diffuse component. The diffuse component consists of the energy that is diffracted, reflected, scattered from the body or from the surrounding environment. Figure 1 shows that for high path loss the K is lower, which means that the ratio of LOS and multipath in the received power is lower.

Level crossing rate (LCR) and Average Fade Duration (AFD) indicate the occurrence rate and duration of fading dips respectively. Our results for 5 subjects show that the received signal is 10 dB below the median with a LCR between 0.4 Hz and 5 Hz and an average fade duration between 10 and 15 ms.

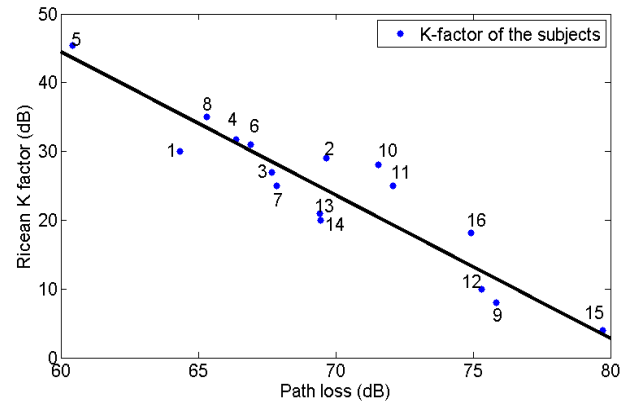


Fig. 1 Path loss against Ricean K-factor with identified subjects.

4. CONCLUSION

On body channels are challenging due to the effects of the body which detunes and distorts the radiation pattern of the antenna and acts as a bulk absorber. The measurements presented in this paper show that the additional critical parameters in channel models are the shape of human body and the involuntary movements of the subjects. In particular, it was shown that men suffer higher path loss than women and that men's chest size is a parameter that affects signal propagation. We argue that using a phantom instead of humans, who were instructed to stay motionless, ignores phenomena like respiration and involuntary movements that we show to be significant. The weak correlation observed between distance and path loss indicates that the shadow effect due to different body shapes has much more influence in the path loss. The statistical analysis of the small scale fading reveals the Ricean distribution is the best for 88% of the cases. The Ricean K factor decreases with increasing path loss indicating the contribution of the creeping wave in the received signal is affected by the body shape. Finally, the paper estimates the level crossing rate and the average fade duration on all the subjects.

5. REFERENCES

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