Study of Ultra Wideband Wireless Sensors for Body Area Networks

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Abstract— **In this paper, experimental characterisation of on-body radio channel using ultra wideband (UWB) wireless tags is presented. The performance of wearable wireless tags on the UWB on-body radio channel characterisation has been investigated. Measurement campaigns are performed in the chamber and in an indoor environment for comparison. Statistical path loss parameters of nine different on-body radio channels for static and dynamic cases are shown and analyzed. The path loss was modeled as a function of distance for 34 different receiver locations for propagation along the front part of the body.**

Keywords—on-body radio channel, body-centric wireless communications, ultra wideband (UWB), path loss, received signal strength indicator (RSSI).

I. INTRODUCTION

Ultra wideband (UWB) communication is a low-power, high data rate technology that minimizes multipath interference due to late time-of-arrival. Its low power requirement due to control over duty cycle allows longer battery life and also introduces green radio system. One of the most potential areas of UWB applications is the body-centric wireless networks where various units/sensors are scattered on/around the human body to measure specified physiological data i.e. patient monitoring for healthcare applications [1-3].

In the past few years researchers have been thoroughly investigating narrow band and ultra wideband on-body radio channels. In [4-7], on-body radio channel characterisation was presented at the unlicensed frequency band of 2.45 GHz. UWB on-body radio channel characterisation and system level modelling for body-centric wireless networks have been presented extensively in the open literature [2, 8-18]. In [8-18] UWB on-body radio propagation channels have been characterised and their behaviour have been investigated in indoor and chamber for stand-still, various postured and dynamic human body based on different antennas.

Most UWB on-body radio channel measurements are performed using two standalone antennas and cables connecting to a vector network or spectrum analyzer which is more a controlled environment and restrictive; however, in real life scenarios potential UWB body-centric wireless network needs to be integrated with compact sensors and provides efficient and reliable communication channels. Critical issues remain with regards to indoor propagations, radio channel characterisation and human body effect which need to be addressed before the concept can be deployed for real life applications.

In this paper measurement campaigns were performed in the chamber and indoor environment using commercially available UWB wearable active tags and reader. The main aim of this study is to investigate the performance of the commercially available wireless tags on the UWB on-body radio channel characterization. Nine different UWB on-body radio channels are investigated and the effects of the body movements on the path loss are analysed. The results reported here provide information on optimum sensor locations on the body considering efficient and reliable communication links for various applications, e.g. healthcare and performance monitoring.

The rest of the paper is organised as follows; section II illustrates the measurement settings and it briefly introduces the UWB tags, Section III presents the measurement results and on-body radio channel parameters and modelling aspects, and finally section IV draws the main conclusion of the presented study.

II. MEASUREMENT SETTINGS

In this study, measurement campaigns were performed using UWB wearable active tags and reader provided by Time Domain PLUS™ [19]. For this measurement purpose a real human subject was used. The test subject was an adult male of mass 90 Kg, height 1.68 meter and chest circumference 114 cm. Nine different ultra wideband wireless active transmitter tags were attached at different locations on the human body: left/right chest, left/right thigh, left wrist, left/right ankle, left elbow, left ear, as shown in Fig. 1, while the UWB antenna connected with the reader was placed on the left waist of the human subject for tag's signal reception. Two measurement scenarios are considered: as static and dynamic human body. For static case, subject was standing still for a period of 60 seconds wearing nine tags on the body and, for the movement case, the subject was walking 5 steps ahead and 5 steps back, starting with the left leg and right arm as a normal walking speed. For the dynamic case, the measurement duration was again 60 seconds while the subject was doing the same walking movement for the measurement duration. Location-based software was used to save the tags transmission ID, received signal strength (RSSI) and time of arrival data from the reader. The UWB tags are battery powered and the duration of the battery life is four years since the tags only transmit UWB pulses every one second. The tag's transmit power is -13.01 dBm which is around 40 dB less than mobile phone transmit power. The operating frequency of the tags used for this measurement is 5.9~7.25 GHz with a centre frequency of 6.6 GHz. The UWB tag is small and durable, with a plastic housing that allows it to be attached to assets or people. The dimension of the tag is (13 mm x 36 mm x 33 mm) and the weight is 0.74 oz (22 g). Figs. 2(a) and 2(b) show the UWB tag encased inside the plastic housing and the bottom view of the tag without plastic housing [19].

The measurement was first performed in the anechoic chamber to eliminate multipath reflections from surrounding environment and then repeated in the Body-Centric Wireless Sensor Laboratory at Queen Mary, University of London to consider the effect of the indoor environment on the on-body radio propagation channels. Fig. 3 shows the dimensions and geometry of the Body-Centric Wireless Sensor Lab. The total area of the lab is 45 m^2 which includes a meeting area, treadmill machine, workstations and a hospital bed for healthcare applications. The measured Received Signal Strength Indicator (RSSI) level for each transmitter tag is recorded over the measurement duration of 60 seconds for each different location.

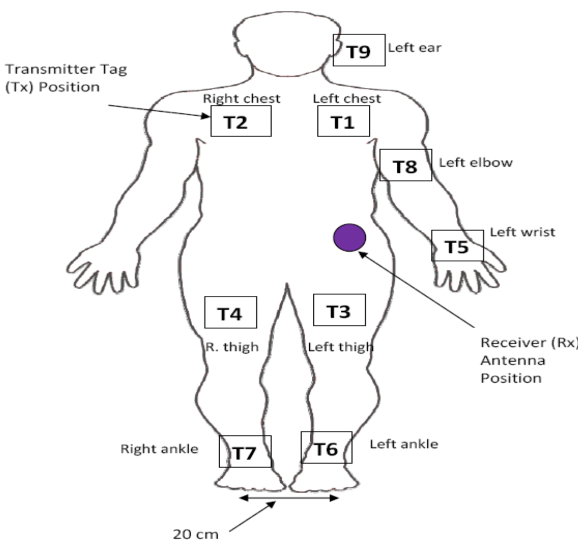

Fig. 1 On-body measurement settings showing the receiver antenna is on the left waist and nine transmitter tags are on different locations of the body (nine static and dynamic channels cases analysed).

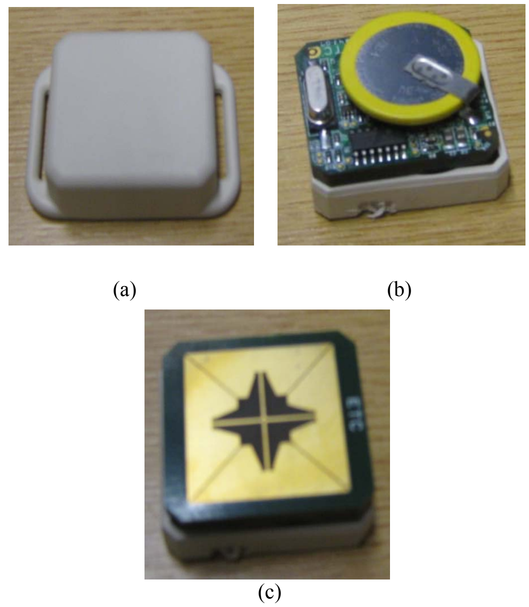

Fig. 2 (a) UWB active transmitter tag encased inside the plastic housing, (b) Tag without plastic housing and bottom view, (c) Top view of the tag showing the transmitter tag antenna.

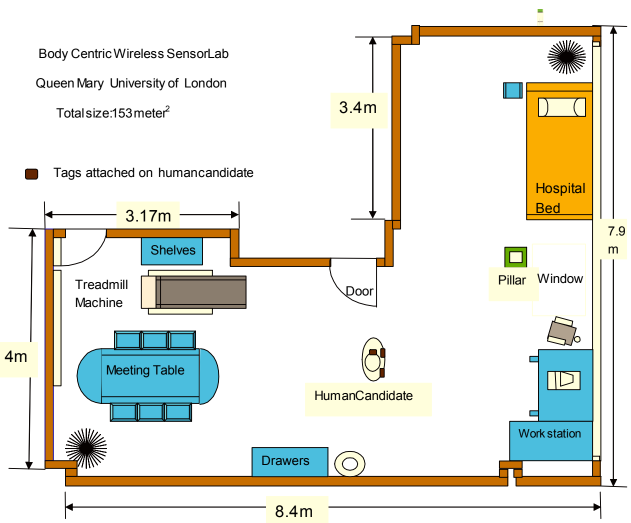

Fig. 3 Dimensions and geometry of the Body-Centric Wireless Sensor Lab (housed within the Department of Electronic engineering, Queen Mary University of London, London, U.K) where the indoor on-body radio propagation measurements for the presented work is performed.

III. UWB On-Body Radio Channel Parameters

A. *On-Body Radio Channel Characterisation*

In this work, the path loss for nine different on-body channels was calculated from the measured RSSI for each transmitter tag. The cumulative distribution function (CDF) of the path loss variations both in the chamber and indoor environment for static and dynamic scenarios of nine different on-body radio channels is compared to well-known distributions such as Normal, Lognormal, Nakagami, Rayleigh, Weibull, Gamma and Rician. Based on the maximum likelihood test results, the lognormal distribution provides the best fits these measured results (Fig. 4). Figs. 5

and 6 show a comparison of the measured average path loss (μ) and standard deviation (σ) of the fitted lognormal distribution that are applied to model the path loss variations for the nine on-body radio channels, for the static and walking scenarios, respectively.

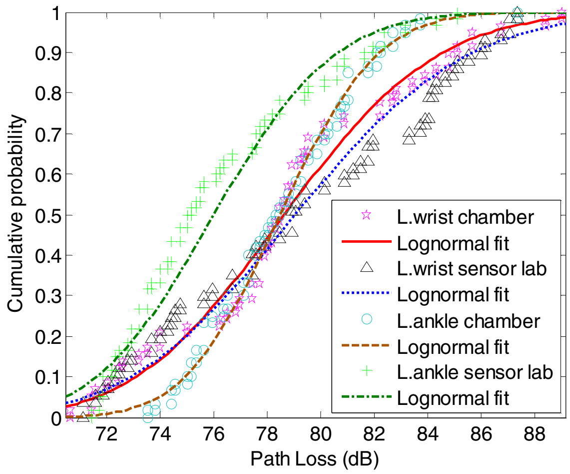

Fig. 4 Cumulative distribution function of the left wrist and left ankle on-body radio channels when subject was walking measured in the chamber and in indoor environment.

In the chamber, for both standing and walking cases, the highest path loss is noticed for the receiver to left-ear link, while the lowest is the receiver to left-thigh link (Fig. 5). For the reader to left-ear link the communication distance between the reader antenna and the transmitter tag is larger; in addition, due to the different orientation of the tag located on the left ear, non-line-of-sight (NLOS) communications exist, which cause the highest path loss value for this channel. For the left thigh link there is a clear line-of-sight (LOS) communication and the lowest communication distance between the reader and the transmitter tag.

In the indoor environment due to reflecting area and contributions of multipath reflection the right chest and left-ear (for static case) and right thigh and chest channels (for movement cases) experience the highest path loss value, while the left thigh channel experiences the lowest. Most of the on-body channels experience higher path loss value when measurements are made in the chamber, due to the non-reflecting environment. The average path loss of all nine channels in the chamber, for static and walking case, is 81.44 dB and 80.68 dB, whereas 79.22 dB and 80.00 dB are found in the indoor environment, respectively.

The variation of the path loss for the nine different on-body channels is also compared for standing and walking cases, to study the trend of the changes of path loss for each channel in these two different scenarios. For the two different scenarios (i.e. standing and walking) a maximum of 8.23 dB and 6.88 dB variation of average path loss of a channel is noticed, which occurred for the left wrist channel both in indoor environment and chamber, respectively (Fig.5). During walking scenarios, the tag located on the wrist moves between to LOS and NLOS communications scenarios and the communication distance between the receiver and the transmitter is also changes greatly, causing the path loss data to vary the most with respect to the standing case for this channel.

The highest standard deviation σ value for the dynamic case is noticed for the left wrist and right ankle channels, which are considered the least stable (data spreads the most from the average path loss) channels, whereas the lowest is noticed for the left thigh and chest channels; these channels are considered the most stable (see Fig.6). Movement of the human body has the highest effect on the wrist and ankle channels and the least on chest and left thigh channels. In comparison to the chamber, the standard deviation value is found to be higher in the indoor environment due to the effects from the indoor reflecting multipath environment.

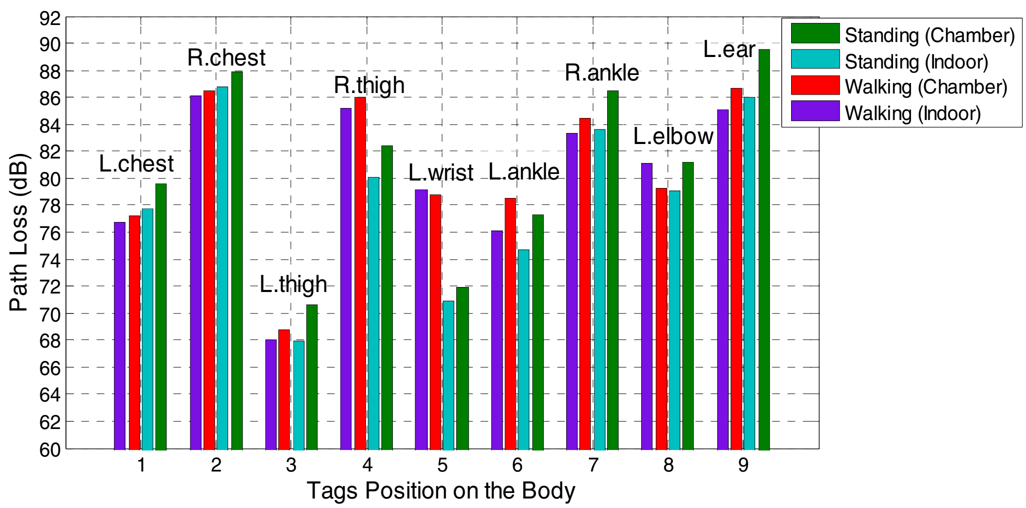

Fig. 5 Comparison of average path loss of nine UWB on-body radio channels for standing and walking scenarios measured in the chamber and in indoor.

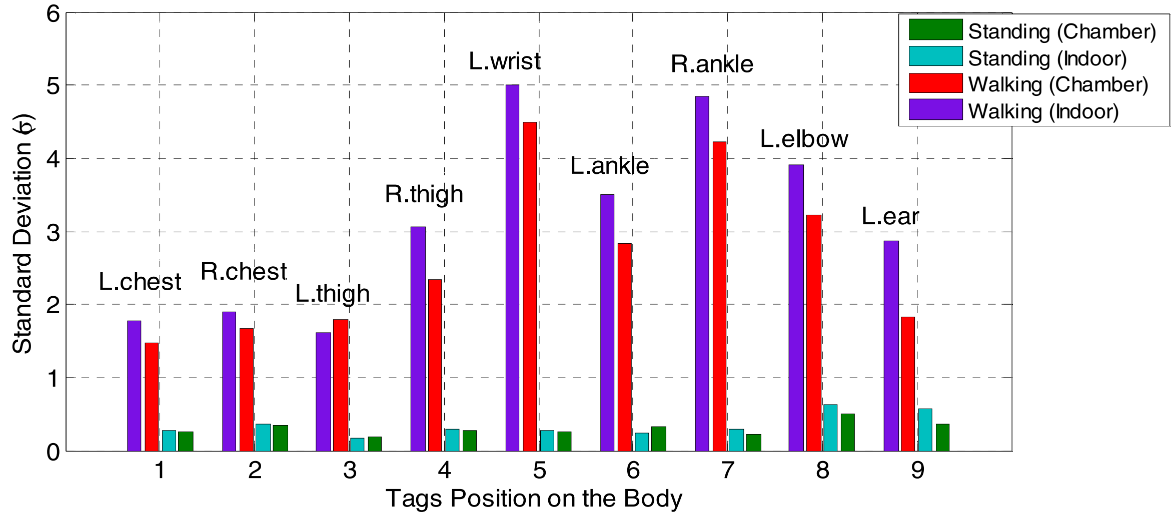

Fig. 6 Comparison of standard deviation (σ) of nine different on-body radio channels for standing and walking scenarios measured in the chamber and indoor.

I. CONCLUSION

UWB on-body radio propagation channel measurements were performed using ultra wideband (UWB) wireless tags and reader in the chamber and indoor environment. Nine different UWB on-body radio channels were investigated for static and movement scenarios. Results demonstrated that lognormal distribution provides the best fits for on-body propagation channels path loss model. In this study, left thigh link shows the lowest path loss, whereas the left ear and right chest show the highest. Study shows that due to different scenarios (i.e. standing and walking) an on-body link experiences up to 8.23 dB variations in path loss.

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