Body-Centric WLANs for Future Wearable Computers

A. Alomainy[1], A. S. Owadally[1], Y. Hao[1], C. G. Parini[1]
Y. I. Nechayev[2], C. C. Constantinou[2] and P. S. Hall[2]

[1]Department of Electronic Engineering, Queen Mary University of London, UK
[2]School of Electronic and Electrical Engineering, University of Birmingham, UK

Abstract – Wearable computers are expected to provide personalised assistants to the user anywhere at anytime with the user being the centre of attention in order to be a true extension of the human's mind and body. Current wearable computer systems include wired connections between the various distributed network components. Replacing the scores of cables with wireless communications will enable enhanced performance of the system regarding the user's information needs and environment. The paper presents preliminary results of on-body communication channel characteristics and measurements highlighting the effects of the body and surroundings on path loss. System-level modelling of possible low-power and low-cost radio transceivers to be employed within the wearable system, creating the body-centric WLAN, and their performances under the measured path characteristics is also presented.

Key words – Wireless Wearable, Body-Centric, On-body Communication Channel, Transceiver

I. INTRODUCTION

Computers initially were made with people behaviour and environment not in consideration. This urged technologists to search and explore alternative flexible technologies and systems that adapt with the human behaviour and provide technical and personal assistant. This was the climate to which wearable computer was born. Wearable computing nowadays is more than a concept with many products and prototypes are available by many industrial sectors providing the functionality promised such as mobility, flexibility, availability and contest awareness. A typical wearable computer system will consist of a number of modules distributed around the wearer's body wit, e.g. a small keyboard mounted on the wrist/arm, head mounted display and belt mounted central processing unit and in addition power units [1, 2].

Currently, wearable computers are limited in the functions and tasks that they perform due to restriction in size, power and cost. Cable connection between the various system parts also introduces another obstacle in the freedom provided to the user in using the system and also in the flexibility of altering and maintaining the system. Ideally, each unit of the system will include integrated powering mechanism with long battery life expectancy and high efficiency wireless link will be provided for data transfer between required parts with respect to power level and bandwidth capacity of applied wireless technology. Characterisation and modelling of the propagation channel available on the human body is important in understanding the major aspects of effects and interference that could be due to the special body properties and the multi-reflection of various body parts in addition to the multi-path and out-of-band signals due to surroundings and other operating systems.

Understanding the communication channel attributes and behaviour is fundamental in designing suitable radio interface systems and wireless protocols. The paper presents a system-level modelling of possible RF transceiver system that follows existing wireless technologies standards in providing the radio link between some of the wearable system units. The main requirements of the proposed system and performance of the transceiver in ideal environment and under measured path changes are discussed and analysed in the presented work.

II. ON-BODY PROPAGATION CHANNELS MEASUREMENTS AND MODELLING

Preliminary experimental results inside and outside an anechoic chamber have been obtained using patch antennas at the frequency of 2.4GHz. A pair of patch antennas were attached to the body, Fig 1. In the case in Fig 2 below, one was placed on the belt (left) and the other one on the left wrist. Various body postures were investigated such as standing, sitting, reaching forward, bending and changed every 20 seconds. Also various transmitter (Tx)/receiver (Rx) orientations were investigated. It is concluded that, in this case, for trunk movements, the channel loss is steady, but when the arms and hands are moved changes of more than 30dB can be experienced.

To complement the measurement campaign a simulation approach is used. The human body will be modelled and the field distribution over it will be evaluated using a conformal FDTD technique. Since the body is essentially acting as a surface wave guiding structure, a simplified homogeneous model is used to characterise the radio propagation over the body. The human body can be modelled according to the various positions tried out during the measurement campaign. Simulation results will be presented at the conference.

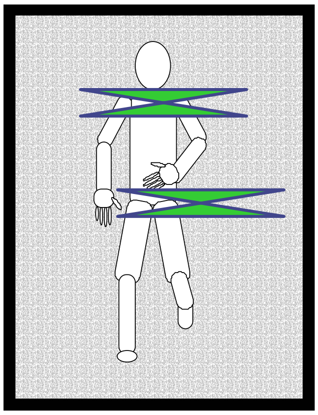

Figure 1. Antennas on the body for radio propagation measurement campaign

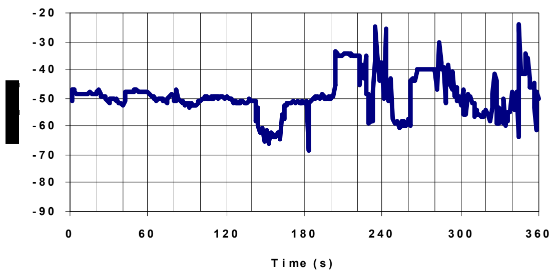

Figure 2. Path Loss for Belt to Hand Path (body posture changes every 20seconds)

III. Radio Transceivers Modelling and Performance Analysis

The radio link systems of the Body-centric WLAN has to be ideally miniaturised, lightweight, low-power operation for longer lifetime and easy to integrate with daily life clothes. The different parts in the system need to share a common wireless protocol to enable the establishment of understandable and re-configurable communication medium. Sufficient data rates and controlled power levels are required by the radio transceivers to enable flawless connectivity between body-distributed networks.

Many short-range wireless technologies exist currently providing communication medium and cable replacement technologies for different transmission types. To design the suitable efficient radio interface for the wireless wearable computer system, understanding and integration of existing standards are required in order to bring to light the main areas in which new techniques (in modulation, amplification or conversion) is required to meet the hash and demanding environment of the wearable system. Many prototypes are available for such integration of current wireless protocols in specific-tasks wearable systems [3, 4] but not for the fully PC functional version. As the first stage in this investigation, transmitter and receiver architectures for data and voice communication were modelled according to Bluetooth requirements [5]. Figure 3 shows a block diagram of the modelled system.

The system-level modelling architecture of the system was simulated using Agilent RF Designer™ and the RF frequency of the system was set to 2.4 GHz (Bluetooth and wearable computing). The input power level was set –60 dBm with various components parameters meeting commercially available RF parts specifications. The system can provide connectivity between keyboard, mouse and voice units and the main processor. The data rate is theoretically 1 Mbit/s, which provides efficient transfer rate for such information. The antennas gain were set 0 dBm for ideal communication channel requirements and the simulation of the model were performed first with no variation in the radio channel (mainly path length loss is accounted for). Bluetooth specification for the modulation index requires BT (Bandwidth × Period) of 0.5 of the Gaussian Low Pass Filter prior to data being modulated into the carrier. For demodulation same requirements apply with addition of sampling and threshold actions with respect to the whole system delay. Receiver sensitivity of around –74 dBm (within Bluetooth minimum requirements) and excellent recovery of original data was achieved with delay time of about 1.3 μsec.

As a measure of performance the Bit Error Rate of the system is simulated with regards to sensitivity level and the effect of signal to noise ratio on system performance. As mentioned earlier, the effect of the indoor environment and human body characteristics is taken into consideration, resulted from the measurement campaign discussed above. However, the BER was first calculated when no additional path loss variation is encountered for and was found to be 4.3E-6, which easily meets Bluetooth requirements with input power of -60 dBm .

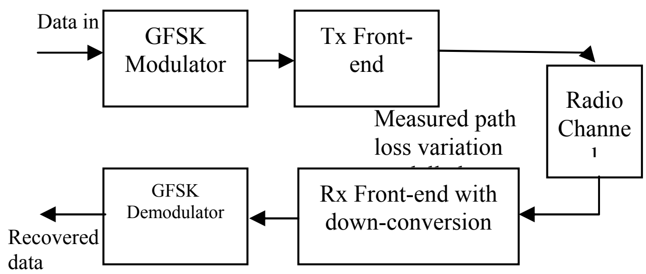

Figure 3. Block diagram of the transceiver architecture modelled for Body-Centric WLAN

However, the simulation does not provide the full picture of the hash environment outside which means that the BER could vary when measured for the real system. Figure 4 presents the SNR performance of the system and BER sweep over Eb/No (Bit energy to noise power ratio) values. The SNR

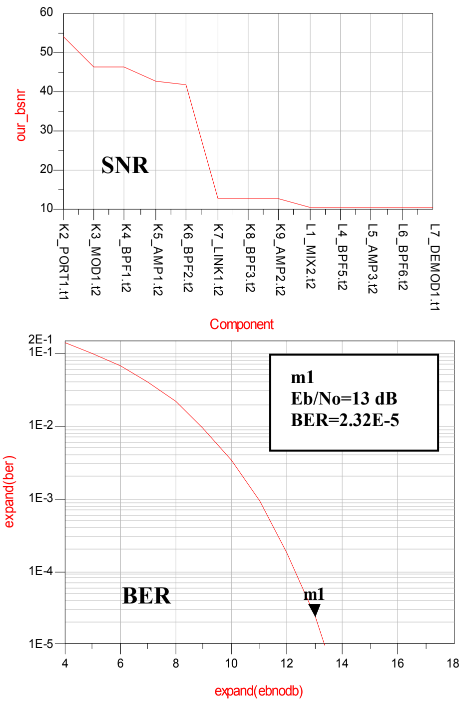

Figure 4. Radio System Performance Measures, above Signal-to-noise ratio and below Bit Error Rate

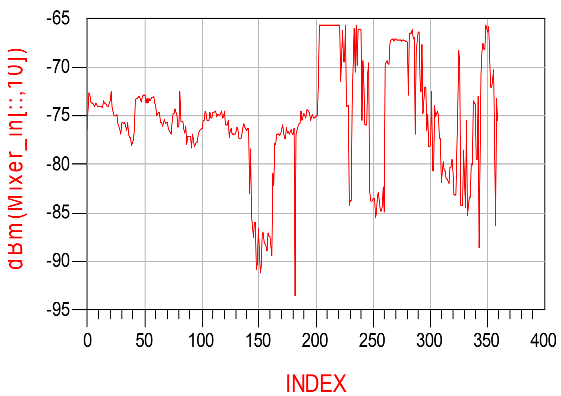

Figure 5. Receiver sensitivity variation due to path loss variation

performance figure shows the internal components noise in addition to the noise added from the radio link effects on the propagating signal. The environment and channel noise can be noticed on the SNR value drop from 40 dB to around 13 dB. BER performance measurements show the inverse proportional relation between the Eb/No and error probability of the system. Good performance was achieved, as can be noticed from the reduced values of BER for large Eb/No values.

To evaluate the system with channel characteristics similar to the real environment, the path loss variation is included within the radio link component in the modelled architecture. This causes the receiver sensitivity to vary between –66 dBm to –94 dBm which agrees with Bluetooth requirements. Due to these changes, the BER of the received signal also varies, which causes BER sensitivity levels to decrease adding more restrictions on system parameters, however, with advanced chip products available now, most of these effects can be minimised and stable gain achieved.

IV. Discussion and Conclusions

In this paper, the use of the human body as a communication channel between wearable wireless devices was investigated. It was concluded that, in this case, for trunk movements, the channel loss was steady, but when the arms and hands were moved changes of more than 30dB can be experienced.

System-level modelling of possible transceiver architecture for Body-Centric WLANs was analysed and simulated to evaluate the possibilities of using Bluetooth standards for data and voice transmission. Good SNR and BER performance was achieved, even with the existence of around 30 dB of path loss variation. For body-centric wearable system, radio links for video and image transmission is required with data rates sufficient enough for real time transfer between main CPU unit and head-mounted display. Ultra Wide Band (UWB) technology currently offers short-range wireless communication with theoretical data rat of around 1 Gbit/s with the lowest power-level requirement for wireless system. This will enable the design and development of radio systems that will perform efficient enough for all different tasks even the heavy duty ones. However, UWB specification has not yet been widely studied and due to its wide bandwidth some new techniques need to be investigated for modulation and front-end technologies.

V. References

1. Lukowicz P, Anliker U, Ward J, Troster G, Hirt E and Neufelt C; AMON: A WEARABLE MEDICAL COMPUTER FOR HIGH RISK PATIENTS, Proceedings of Sixth International Symposium on Wearable Computers, 7-10 Oct. 2002; pages: 133-134
2. Xybernaut's MA TC Wearable Computer System, Xybernaut Europe: http://www.xybernaut.de
3. Soichiro Matsushita, A HEADSET-BASED MINIMIZED WEARABLE COMPUTER, IEEE Intelligent Systems, May/June 2001, Vol. 16, Issue 3, Pages 28-32.
4. Fishkin, K.P.; Partidge, K.; Chatterjee, S., WIRELESS USER INTERFACE COMPONENTS FOR PERSONAL AREA NETWORKS, IEE Pervasive Computing, October/December 2002, Vol. 1, Issue 4, Pages 49-55.
5. Bluetooth Specifications, Bluetooth Members Website: http://www.bluetooth.org