Body Posture/Activity Detection: Path Loss Characterization for 2.4GHz On-Body Wireless Sensors

A. Guraliuc(1), A.A. Serra(1), P. Nepa* (1),
G. Manara(1), F. Potortì(2), and P. Barsocchi(2)

(1) Dept. of Information Engineering, University of Pisa, Pisa, Italy
(2) ISTI, CNR, Pisa, Italy

E-mail: anda.guraliuc, andrea.serra, p.nepa, g.manara@iet.unipi.it:
Potortì, paolo.barsocchi@isti.cnr.it

Introduction

On-body wireless sensor networks (WSNs) are gaining an increasing interest in medical, military as well as entertainment applications. Wireless transceiver modules placed on the body and combined with actuators/sensors can communicate between them and with any other node located in the surrounding environment, without any human body movement constraint with respect to wired connections.

A further application of the above on-body WSNs could be in the framework of the human body posture and activity detection. Recognizing people's activities is a key issue in Assisted Living (AL) applications, where it can be required to monitor and detect abnormalities for elderly care, or rate how a person performs routine activities. As an example, in the medical field the patient recovery and rehabilitation can be remotely monitored, controlled and recorded without the presence of a technician [1]. Likewise, in military applications the Soldier Assist System (SAS) that provides recognition of soldier activities can be improved by body activity detection networks [2].

In this context the authors are involved in a research activity aimed at developing algorithms for body posture/activity classification, which are based on RSS (Received Signal Strength) exploiting. Indeed, the RSS indicator is already available in most of low cost transceiver modules designed for WSNs (Smart Dust or Motes). If only a rough classification of body posture/activity is required, additional devices, as for example gyroscopes or accelerometers, could be avoided.

The development of the system architecture (number of transceivers and their best placement on the human body) requires accurate path loss models to characterize radio links between a set of transceivers placed on the human body, for a number of body postures and movements [3]-[6]. Therefore, as a first step of the above mentioned algorithm development activity, on-body path loss properties are being studied. Both numerical and experimental results will be presented in this paper. The analysis of the path loss as a function of the distance between two on-body antennas is performed at 2.4 GHz and results are shown for some radio links.

Path-loss measurements and simulation results at 2.4GHz

Measurement data were obtained by means of MicaZ boards [7], usually used for low-power WSNs, which operate at the 2.4 GHz ISM frequency band and adopt the IEEE 802.15.4 communication protocol (ZigBee network protocol). Path loss measurements have been performed by using two MicaZ modules attached to the human body at a distance of 1cm from the body surface. The transmitting module was at a fixed position while the receiving one was moved along two different paths on the body surface. The first path is along a straight arm, the second one is around the waist. The RX positions are 2cm spaced apart from each other. For each RX position the amplitude of the received power is collected and stored.

For the arm case (see geometry in Fig. 1), samples of measurement results are shown in Fig. 2. In the same figure, the simulated S_{12} parameter for two monopoles on two separate 4cmx4cm ground planes is illustrated, as a function of their distance. In the numerical simulations performed with CST Microwave Studio, a two layer cylindrical model has been used (10mm thick fat layer around a 60mm diameter muscle core). The electrical parameters used in the numerical simulations are ε_r=10.84, σ=0.26 S/m for the fat layer, and ε_r=53.64, σ=1.77 S/m for the muscle tissue. Linear and logarithmic regression fittings of the measured data are also shown for comparison. It is worth noting that the discrepancy between the S_{12} numerical results and the measured power level is due to the fact that the absolute value of the measured path loss should be corrected by an additive term depending on antenna and transceiver characteristics. A logarithmic-law power fitting $PL(d) = PL(d_0) + 10n\log_{10}\left(d/d_0\right)$, where $PL(d_0)$ is the path loss at a reference distance d_0, has been considered. The exponent n derived from measured data and numerical simulations is equal to 2.57 and 2.4, respectively, showing a quite good agreement. Similar results are presented in Fig. 3 for the waist case. This scenario is more complex than the previous one because here both LOS (Line-of-Sight) and NLOS (Non-Line-of-Sight) situations occur while varying the distance between the two transceivers. A logarithmic regression fitting of the measured data is shown for the data relevant to RX locations when the two modules are in LOS condition along the waist. On the other hand, a linear regression fitting gives better results for RX locations in NLOS conditions, in agreement with an expected surface wave propagation condition. For the logarithmic regression fitting, the path loss exponent n derived from measured data is equal to 3.1; the path loss exponent n derived from numerical simulations is equal to 3.9 (homogeneous ellipsoid), 3.07 (homogeneous sphere with a radius equal to 15 cm) and 2.7 (homogeneous sphere with a radius equal to 20 cm). Finally, in Fig. 3b the path loss around the waist is shown, when the receiver is moved symmetrically with respect to the centre of the dorsal area. In both numerical and measured data it is apparent a maximum of the received power at the centre of the back, in a symmetric point with respect to the TX position (which is at the centre of the waist front). The above behavior is related to a constructive interference between two surface waves propagating clockwise and counter clockwise around the waist, which was expected.

The approach here presented follows that one in [5]-[6], where a deep and accurate analysis of the on-body path loss has been performed by considering half-wavelength dipoles parallel to the body surface. On the other hand, the polarization case with the electric field parallel to the body surface is the one giving the higher attenuation due to the conductive properties of the human body. In the present paper we considered monopoles over a small metallic ground plane radiating an electric field normal to the body surface. Although the latter are non-wearable antennas we are using them as they are simple radiators with well-shaped radiation patterns. Work is in progress to repeat the same measurements by changing the antenna of the commercial transceiver with *ad-hoc* planar wearable antennas still radiating a field perpendicular to the body surface (as for example annular ring slot antennas [8]).

Conclusions

In this paper, path loss measurements performed with low cost MicaZ modules used for on-body wireless sensor networks have been shown. By combining the experimental activities with simulation results based on simple canonical geometries, it has been possible to extract some simple path loss models. Time domain properties of the field attenuation are also under investigation. The path loss data will be elaborated to classify a set of typical human postures and activities, and results will be shown at the conference.

References

[1] V. Shnayder, B. Chen, K. Lorincz, T. R. F. Fulford-Jones, M. Welsh, “Sensor Networks for Medical Care”, *Technical Report, Harvard University*, 2005.

[2] D. Minnen, T. Westeyn, D. Ashbrook, P. Presti, T. Starner, “Recognizing soldier activities in the field,” *Int. Workshop on Wearable and Implantable Body sensor Networks*, 2007.

[3] P. S. Hall, Y. Hao, Y.I. Nechayev, A. Alomainy, C.C. Constantinou, C. Parini, M.R. Kamarudin1, T.Z. Salim, D.T.M. Hee, R. Dubrovka, A.S. Owadall, W. Song, A.A. Serra, P. Nepa, M. Gallo and M. Bozzetti, “Antennas and Propagation for On-Body Communication Systems,” *IEEE Magazine on Antennas and Propagation*. vol. 49 (3), pp. 41-58, 2007.

[4] A.A. Serra, P. Nepa, G. Manara, and P.S. Hall, “Diversity Measurements for On-Body Communication Systems,” *IEEE Antenna and Wireless Propagation Letters*, vol. 6 (1), pp. 361 – 363, 2007.

[5] E. Reusens, W. Joseph, Vermeeren, D. Kurup, and L. Martens, “Real human body measurements, model, and simulations of a 2.45 GHz wireless body area network communication channel,” *5th International Workshop on Wearable and Implantable Body Sensor Networks,* China, June 1-3 2008.

[6] L. Roelens, W. Joseph, E. Reusens, G. Vermeeren, and L. Martens, “Characterization of Scattering Parameters Near a Flat Phantom for Wireless Body Area Networks” *IEEE Trans. on Electromagnetic Compatibility*, vol. 6 (1), pp. 361 – 363, 2007.

[7] http://www.xbow.com

[8] A.A. Serra, I. Khan, P. Nepa, G. Manara, and P.S. Hall, “Dual-polarization and dual-pattern planar antenna for diversity in body-centric communications,” *2008 IEEE Antennas and propagation Symposium*, San Diego, CA, USA, 5-11 July, 2008.

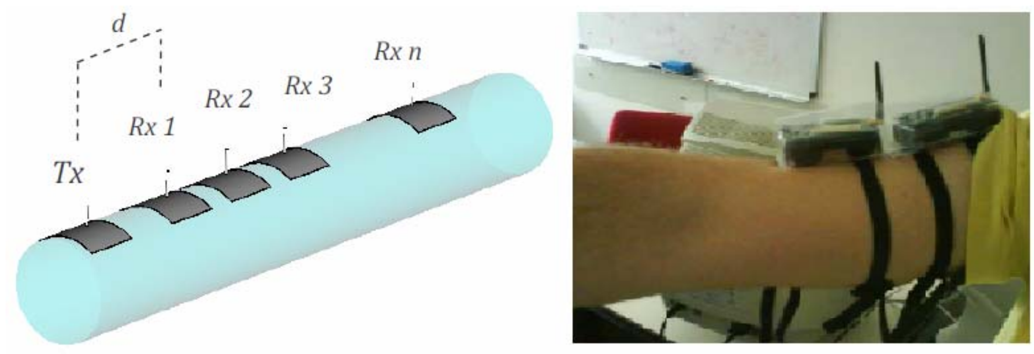


Fig. 1 The cylindrical model used to study the path loss between two antennas located at different distances along a human arm (left) and the photo of the motes during data acquisition (right).

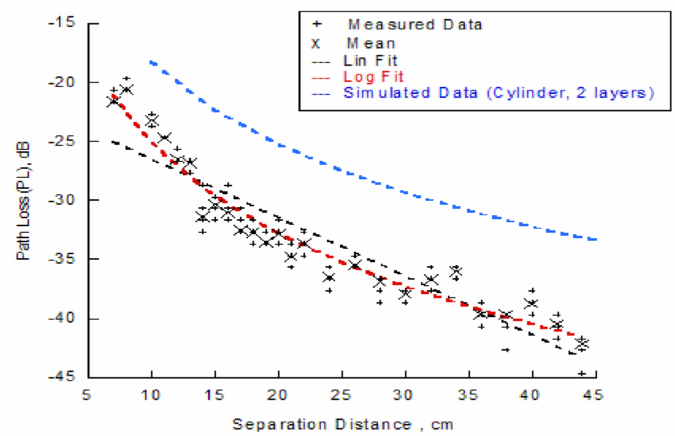
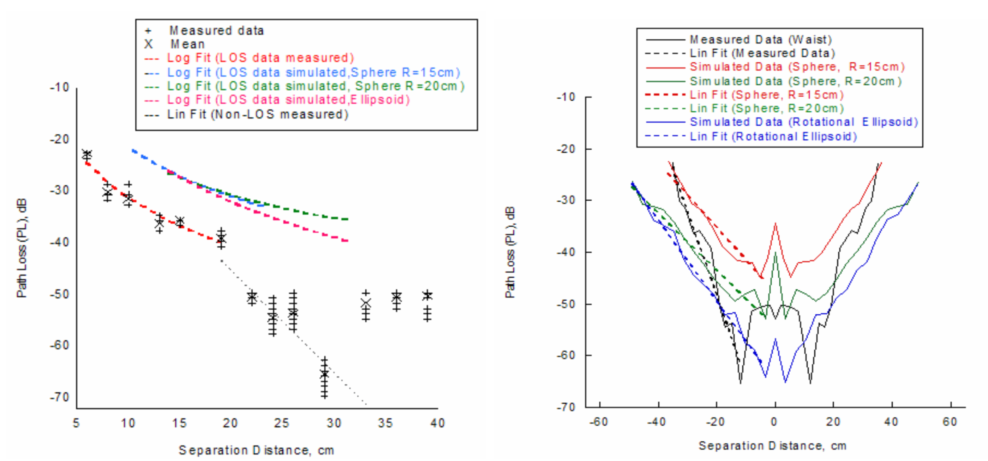


Fig. 2 Path loss *vs*. the distance between TX and RX along a human arm.



(a) (b)

Fig. 3 Path loss *vs*. distance between TX and RX along a human waist when the TX is in the centre of the torso. Note that in Fig.3b the 0-value in the abscissa of the graph corresponds to the position opposed to the TX, right in the middle of the dorsal area.