Radio channel dynamics for wireless body area networks

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Abstract – Recent results about body area radio channel dynamics are analyzed, considering on-body and body-to-body transmissions. Investigations are based on experimental data around 4 GHz. Regarding the on-body case, the dynamics of cross-channel correlation are measured and analyzed for stationary periodic and non-stationary motions, with a clear impact of the walking mode being observed. For body-to-body scenarios, measurements conducted in room-to-room environments show again some strong non-stationary behaviors. In both cases, Markov chain-based models are developed to represent transitions between fading states.

Wireless Body Area Networks (WBANs) typically consist of transceiver nodes placed on or in the vicinity of the human body and encompass a large number of applications, such as e-health, remote monitoring, sports and entertainment. Understanding the radio channel behavior is critical to develop efficient body-area communications systems, especially when relay and cooperative techniques are considered to overcome the severity of on-body path-loss and/or body shadowing. In particular, the prediction and modeling of channel dynamics may strongly differ from classical wireless transmissions.

In a first part, we characterize the Doppler spectra for on-body channels with transmit and receive sensors located on the torso [1, 2], the transmission being impacted by the regular motion of the arms. In this case, the Doppler spectrum is very peaky around 0 Hz, as none of the nodes are moving with respect to each other, but exhibits strong harmonics resulting from the swinging of the arms. When the walking mode is non-regular, the channel becomes highly non-stationary. This implies first that the Doppler spectrum can only be defined over very short periods of time, but most importantly, that cross-channel correlation properties also change rapidly between successive stationary states. To illustrate this observation, let us compare two experimental results [3]. In both cases, one is interested in the correlation between two links, from the chest to the right hand (CRH) to the left hand (CLH) respectively. In the first measurement setup, the subject walked uniformly along a straight line with periodic arm swing, whereas in the second setup, the trajectory and the arm swings were completely random, likely representing a more realistic type of walk. In the first scenario, Fig. 1 (top) highlights that both links exhibit strongly anti-correlated fading behaviors. This is the direct consequence of the regular (soldier-like) swinging of the arms. This pattern is expected to result in high anti-correlation values that could be exploited in multi-hop approaches. By contrast, the bottom graph shows that the correlation behavior varies strongly over time in the second set of measurements.

The second part deals with body-to-body communications, which are emerging as a key component of future 5G networks. Most studies usually assume that the channel is stationary: while this is justified in some cases by the careful choice of experimental scenarios, it is likely that typical body motion and shadowing will induce non-stationary conditions. In [4], a body-to-body measurement campaign was carried out in two environments: subjects were either grouped in a large room or isolated in different rooms. In both cases, they moved freely on their own, avoiding regular motions. The experimental set-up relied on the UCL PropSound MIMO channel sounder, used in a distributed fashion at the frequency of 3.8 GHz. The distributed body nodes were connected to the sounder by long cables. Based on this experimental campaign, small-scale fading was found to strongly differ from one stationarity period to the next one, and its distribution ranged from double-Rayleigh to highly Ricean.

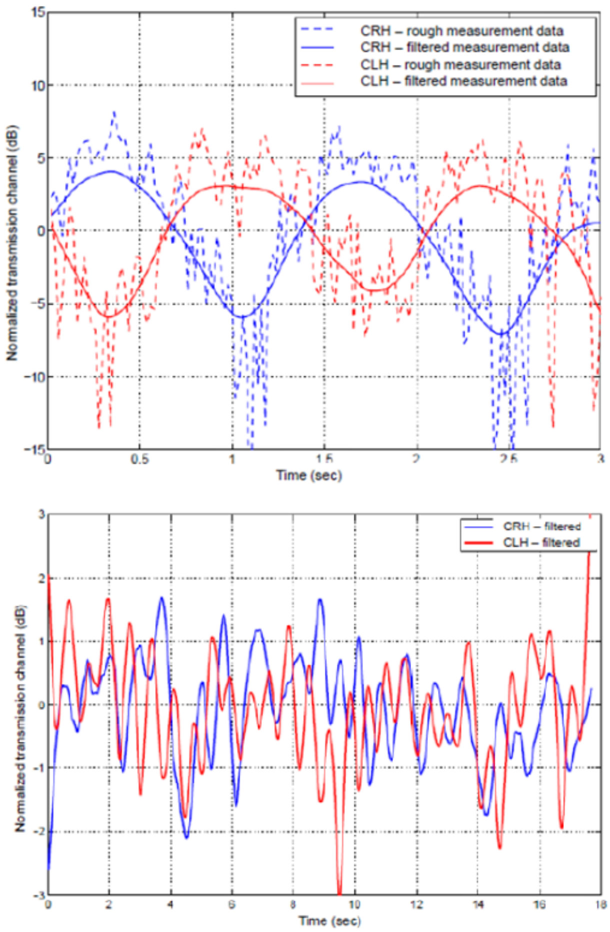

Figure 1: Comparison of correlation behaviors for two links and two walks: regular (top) and non-regular (bottom).

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