

Wideband Channel Characterisation for Body and Personal Area Networks

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Abstract – Indoor channel measurements for body and personal area network applications have been conducted between a number of on-body positions and to three nearby-peer locations. Particular attention has been paid to the relation between the channel characteristics and the user’s motion. The results demonstrate how the channel characteristics in BANs/PANs are dominated by the effects of body blocking. With body shadowing losses reaching 40 dB, non-LOS links rely on multipath propagation in the surrounding environment.

Key words – personal area networks (PAN), body area networks (BAN), propagation measurements, channel characteristics.

I. INTRODUCTION

Many exciting scenarios for future use of communications technology around the house and in the personal sphere have been proposed by a variety of organisations. The Wireless World Research Forum’s (WWRF) Book of Vision’s [1] is an important example where the term Body Area Network (BAN) was first defined. Scenarios to guide research into the interworking of broadcast and personal communications have been developed as part of the Core 3 programme of the Virtual Centre of Excellence in Mobile and Personal Communications (Mobile VCE) [2]. Within this programme, the work presented here focuses on the characterisation of the wireless channel.

The development of efficient radio systems relies on a thorough understanding of the wireless channels in which these systems are to operate. However, despite the development of Bluetooth™ and various IEEE 802.15 WPAN standards, research into the propagation characteristics within a personal area network is lacking, except when focused on ultrawideband (e.g. [3],[4]). To our knowledge, [5] and [6] are the only reports of conventional propagation measurements for on-body channels. They consider narrowband path losses for a shoulder to belt link at three microwave frequencies. The results show the dependence of the channel on the posture of the user.

This paper reports on wideband channel measurements carried out for personal and body area networks.

II. MEASUREMENTS

Wideband channel frequency responses have been registered by recording the forward transmission coefficients, S_{21} , with

a network analyser between two ultrawideband antennas at frequencies spaced 1 MHz apart in four frequency bands (table 1). The antennas were placed in various on-body positions and at three nearby-peer locations, as listed below.

In the case of measurements involving a nearby-peer, both line-of-sight and non-line-of-sight scenarios have been included, where the obstruction was caused by the user’s body and/or other objects in the environment.

On-body antenna positions:

- Next to head, right hand side
- On chest, right hand side
- Around wrist, left hand side
- Back of the waist, left hand side
- Around the ankle, left hand side

Nearby-peer antenna positions:

- In front of the network analyser, on desk
- At the back of the network analyser, on desk
- In a backpack, on ground

Band	Frequency
UMTS FDD UL	1.91-1.93 GHz
UMTS FDD DL	2.11-2.13 GHz
2 GHz ISM	2.4-2.483 GHz
5 GHz UNII	5.14-5.26 GHz

Table 1. Frequency bands

The measurements were repeated at a variety of larger and smaller indoor locations and for several user actions. In addition to these, a set of measurements was taken in an anechoic chamber. The resulting set of channel data allows a comparison of the channel characteristics between antenna locations, frequency bands and environments. Particular attention has been paid to the relation between the user motion and the resulting channel.

Calibration routines correct the frequency domain information for cable losses and differences in the antenna gain between the frequency bands. A Hanning window is applied to the result before converting it to the time domain using the inverse Fourier Transform. The resulting power delay profiles are passed through a 30 dB power window, eliminating all multipath components whose power is more than 30 dB below the power of the dominant ray. These power delay profiles are then used to calculate the instantaneous RMS delay spread and Rician K factors. The

effect of spectral leakage on the RMS delay spread is minimised using the technique proposed in [7].

III. RESULTS

The main results of the analysis are discussed using a link from wrist to chest as an example. During the measurement period, which lasts about 37 seconds, the arm was swinging from behind the body in front of the chest, causing cyclic changes between non-line-of-sight and line-of-sight.

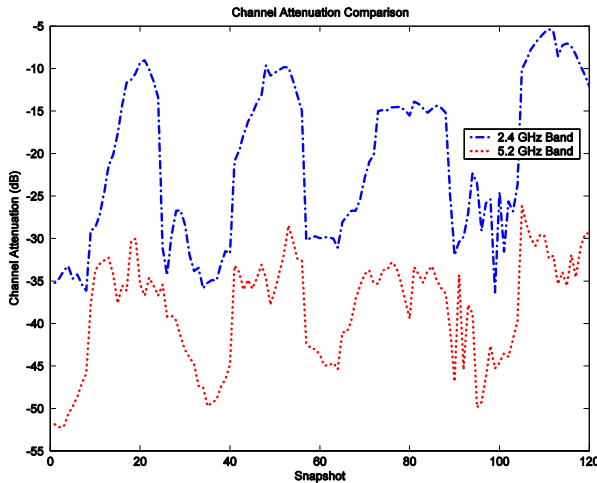


Figure 1. Channel attenuation, swinging wrist to chest

Figure 1 shows how this cyclic behaviour is clearly reflected in the variations of the channel attenuation. As can be seen, body obstruction leads to shadowing depths of around 30 dB in this particular case. Similar measurements in an anechoic chamber have shown that fluctuations over 40 dB can occur within a few seconds. These extreme variations, which also appear in the other channel parameters, will pose serious challenges to BAN radio designers.

Figure 2 contains a plot of the RMS delay spread as a function of the channel attenuation. Signal attenuation due to body obstruction now appears as shifts towards the left of the graph. Higher RMS delay spread values occur at lower signal levels, indicating that more time dispersion occurs in non-line-of-sight channels. For those cases where a line-of-sight was available, the RMS delay spread reaches extremely low values.

Equivalent observations have been made during the analysis of the Rician K factors. Lower K factors, indicating the absence of a dominating multipath component, occur at the lower received power levels. High K factors, on the other hand, are concentrated in those regions where the channel attenuation is low.

The lower path loss in the 2.4 GHz band explains why the channel attenuation is lower than in the 5.2 GHz band. Multipath components, most of which have to travel longer

distances than the main beam, are less weakened in the lower frequency band, resulting in relatively higher RMS delay spreads, as observed in figure 2. However, the relative changes in characteristics as a result of the user motion remain the same and are indeed observed in all four frequency bands.

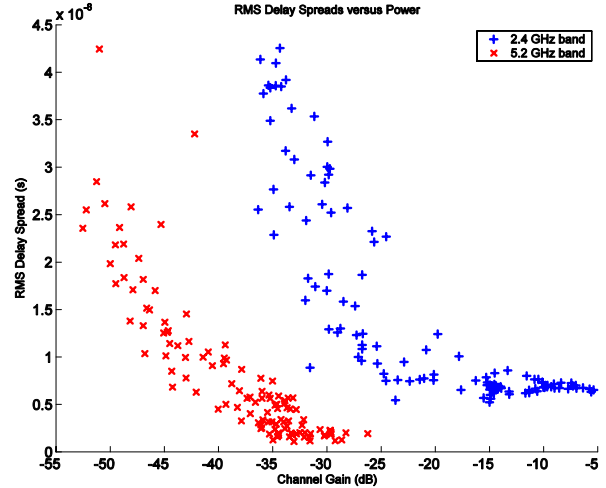


Figure 2. RMS delay spread versus channel attenuation, swinging wrist to chest

Similar phenomena to those highlighted using figures 1 and 2 have been observed for all the on-body links. When a line-of-sight is present between transmitter and receiver, this dominates the propagation characteristics. Channel attenuation and RMS delay spreads are low, while the Rician K factors are high. For those links where the body obstructs the line-of-sight, the channel characteristics become a function of the multipath characteristics of the surrounding environment. This can lead to significant signal attenuation, increased RMS delay spread and low K factors. As demonstrated by the figures, for some links several changes between these extremes can occur within very short time periods.

Analysis of the links to the nearby-peer locations leads to similar conclusions. The channel attenuation in this case depends on the distance to the transmitter and the presence of a line-of-sight. Beyond this characterisation, the actual position of the receiving antenna on the body is only of minor importance.

IV. CONCLUSIONS

Wideband channel measurements for BAN and PAN applications have demonstrated the dependence of the channel characteristics on the user's actions in all frequency bands considered. Particularly in the case of on-body links, differences can be huge depending on whether the location of the antennas allows a line-of-sight. With body shadowing depths reaching up to 40 dB, non-line-of-sight links are

entirely dependent on the multipath characteristics of the surrounding environment.

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