Path Loss Model for Wireless Applications at 3500 MHz

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Introduction

Fixed Wireless Access (FWA) systems such as WiMax (Worldwide Interoperability for Microwave Access) – based on the standard IEEE 802.16 [1] – gain popularity as "last mile access technology" as an alternative to DSL (Digital Subscriber Line) and cable technologies. When planning a FWA (Fixed Wireless Access) network, the operator has to make a choice among the available frequency bands. The selection of the frequency band to be used has a major effect on the dimensioning and planning of the FWA network. In a lot of countries (also Belgium) the 3.5 GHz FWA band will be used because the band is licensed and interference is under control. Furthermore, higher transmission powers are allowed and a better range and coverage than at 5.8 GHz can be obtained.
Therefore we discuss in this paper a path loss model based on propagation measurements performed at 3500 MHz in a suburban office park in Ghent, Belgium. From the experimental data a statistical path loss model is derived. This model can be used for coverage estimation for FWA networks.

Measurements

The measurement site is located at the Gaston Crommenlaan in Ghent, Belgium. The base station (BS) antenna is located on the roof of a building with three stories. The height of the BS is h_{BS} = 15 m. The height of the receiving antenna (Rx) is varied from h_{Rx} = 2.5 to 4 m. Fig. 1 shows an aerial picture of the environment near the BS antenna. This suburban area consists of buildings with 3 to 7 stories, and houses. Also trees are present in the environment.

The BS antenna is an omnidirectional Jaybeam antenna type MA431X21. The gain of this antenna is 10 dBi. We inject a continuous wave (cw) signal in the transmitting antenna (Tx) with a Rohde & Schwarz signal generator (SMP 22). Using an amplifier of type 5S1G4 of AR Worldwide (frequency range of 0.8 - 4.2 GHz) we can obtain an input power of 6.5 W.
The same type of antenna is used for the Rx as for the BS. For the adjustment of the height of the Rx we use a telescopic mast. The measurements are performed with a Rohde & Schwarz FSEM30 spectrum analyser (SA) with a frequency range

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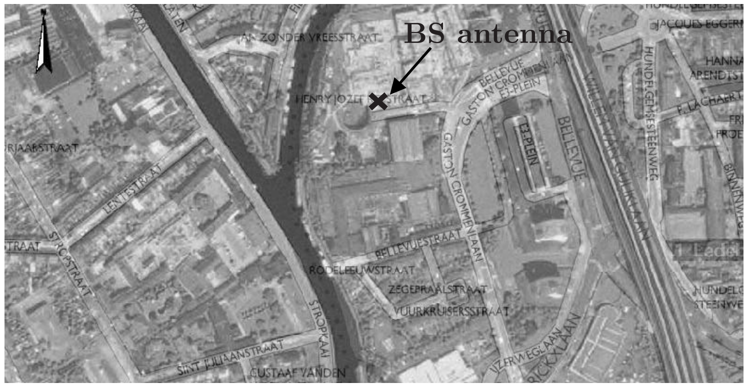


Figure 1: Aerial picture of the environment of the base station antenna.

from 20 Hz up to 26.5 GHz. The output of the SA is sampled and stored on a laptop. The center frequency is 3500 MHz, the frequency span is 200 kHz and the resolution bandwidth is 5 kHz. The noise floor for these settings is about -105 dBm. The measurement positions are acquired with a GPS. Using a car, the Rx is moved in the environment with constant speed.

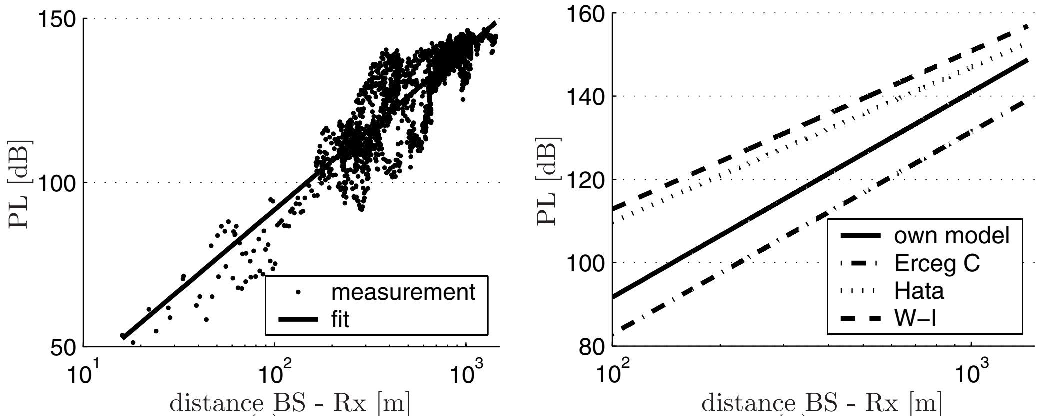
First, the noise floor is determined for each measurement track. Samples which are below the noise floor plus 10 dB (additional margin) are discarded. To remove the fluctuations of the fast fading, the received signal strength is averaged and sampled according to the Lee criterium [2] i.e., 50 samples for each 40 wavelengths. The sampling of the measurement points depends upon the velocity of the car and the investigated frequency. Furthermore, for each point we determined whether it was located line-of-sight (LoS) or non-line-of-sight (NLoS). For each Rx height (we consider here 4 heights) about 90,000 samples are maintained for averaging and further data processing. We consider distances from about 30 m to 1500 m from the antenna and develop a microcell model.

Path loss results

Path loss (PL), is defined as the transmit power times the antenna gains divided by the mean received power. The path loss is modeled according to a log-normal shadowing model. In this paper the median path loss is modeled as:

$$\mathrm{PL} = \mathrm{A} + 10\ \mathrm{n} \cdot \log(\mathrm{d}/\mathrm{d_0}) + \chi \qquad (1)$$

where $\mathrm{A} = 20\log10(4\pi \mathrm{d_0}/\lambda)$ and λ is the wavelength in m, d is the distance in m, $\mathrm{d_0}$ is a reference distance in m, and n is the path-loss exponent. Furthermore, χ is the shadowing fading variation and has a standard deviation σ.
Fig. 2 (a) shows the PL at $\mathrm{h_{Rx}} = 2.5$ m as a function of the distance BS - Rx. A



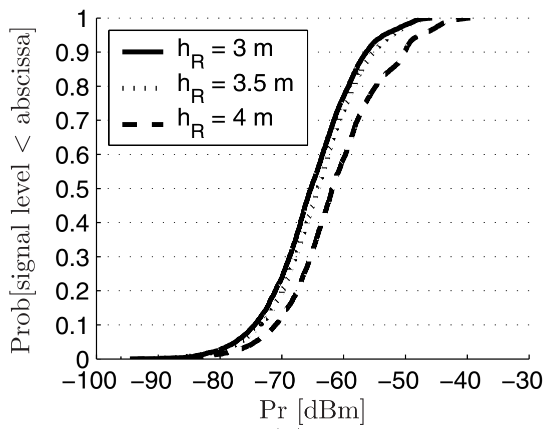
(a) (b)

Figure 2: (a) Scatter plot and linear regression fit of path loss at 3500 MHz as function of the distance BS - Rx and (b) comparison of PL of own model to other models ($h_{BS} = 15$ m and $h_{Rx} = 2.5$ m).

linear fit is made on the measurements. The root mean square (rms) deviation of the points of the figure with respect to the straight line is minimized. At 2.5 m we obtain a path loss exponent n = 4.9 and a standard deviation of 7.7 dB. The parameter A equals 77.6 dB. In Fig. 2 (b) (log-log scale) our model at $h_{Rx} = 2.5$ m is compared to the Erceg model (terrain C, flat terrain with light tree densities) [3], the cost231 Walfish-Ikegami (W-I) model, and the cost231 Hata model [4]. The PL is higher than the Erceg model for the considered range. The PL exponent of our model (about 4.9) is higher than for the other models. These higher losses could be explained by the fact that the European houses contain more brick material than the houses (more wood) in the United States.

We investigate the influence of the receiver height $h_{Rx} = 2.5$, 3, 3.5 and 4 m. For each height we perform the same analysis as described above. Fig. 3 (a) shows n, A, and the standard deviation σ for the different heights. The path loss exponent and parameter A decrease with increasing receiver height. This could be expected because the higher the receiver is located, the fewer objects that can block the signal are present. This table also shows that at $h_{Rx} = 4$ m, the path loss exponent n and parameter A are much lower than at other heights. In European countries the rooftops of houses are often reached at about 4 m. Thus the signal will be less attenuated (due to quasi LoS and diffraction) and the received power will be higher. Therefore the path loss exponent n and parameter A will be lower. This can also be seen in Fig. 3 (b). In this figure the cdf (cumulative distribution function, i.e., Prob[signal level $<$ abscissa]) of the received power P_r for $h_{Rx} = 3$, 3.5 and 4 m is shown. The values at 3 and 3.5 m (median value of -65.3 and -64.1 dBm) are closer together than those at 4 m (median value of -61.4 dBm). The received power at

	h_{Rx} [m]			
	2.5	3	3.5	4
n	4.9	4.8	4.6	3.7
A [dB]	77.6	77.1	76.2	69.2
σ [dB]	7.7	8.4	9.0	9.6



(a) (b)

Figure 3: (a) Parameters of the model for different receiver heights h_{Rx} and (b) cumulative distribution of the received power P_r for three measurement heights in NLoS environment at about 170 m from the BS.

4 m is considerably higher than at lower receiver heights.

Conclusions

In this paper propagation measurements for fixed wireless systems operating at 3.5 GHz are analysed and discussed. A statistical path loss model for a suburban Belgian environment is proposed and different receiver heights are analysed. The path loss exponent depends upon the receiver height. This was not yet investigated in other models.

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