Wideband propagation measurements for DECT wireless local loop applications

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Appendix D  SCVT’97 Paper

Wideband propagation measurements for DECT Wireless Local Loop applications

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Abstract. Wideband radiowave propagation measurements in the DECT frequency band are performed in a suburban environment. The aim is to analyse the fixed radio link between the subscriber’s premises and the local exchange access unit for different heights and pointing directions of the antenna at the subscriber side. Measured complex impulse responses are used to calculate the path loss and rms time delay spread of this wireless local loop communication channel. For both line-of-sight (LOS) and non line-of-sight (NLOS) links, the lowest path loss and rms time delay spread are found when the antenna points to the access unit at the local exchange side. On the average, no significant decrease in path loss and rms time delay spread is observed when the height of subscriber antennae is increased from 2m to 4m above the ground. However for LOS links and NLOS links which are affected by attenuation due to vegetation, the path loss can be minimized by a proper choice of the antenna height.

II. MEASUREMENT SETUP AND PROTOCOL

The wideband propagation measurements are performed with a channel sounder. The time-domain resolution of the measurements is 20 ns. The measurement technique is based on the correlation properties of a pseudo random binary sequence [2]. This sequence of 511 bits clocked at 50 MHz is used to BPSK modulate a 2 GHz carrier. The modulated signal is then amplified to a power of 30 dBm and filtered with bandwidth of 200 MHz. The transmitted signal is vertical polarised. At the receiver with a noise threshold of -100 dBm, the received signals are correlated with an identical sequence running 6.5 kHz slower than the transmitted one. In fact, the receiver performs a correlation of the autocorrelation function of the pseudo random binary sequence with the impulse response of the channel. The inphase and quadrature signals are then determined and saved in a file. The time needed to measure an impulse response is 78.34 ms.

Two measurement setups were designed which enable variation of the height and pointing direction of the receiver antenna. This antenna as well as the transmitter antenna are directional antennae. Their specifications are given in Table 1.

Table 1 Specifications of transmitter and receiver antennae at 2 GHz

<table>
<thead>
<tr>
<th>Gain</th>
<th>Transmitter antenna</th>
<th>Receiver antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3 dB beamwidth in H-plane</td>
<td>56°</td>
<td>65°</td>
</tr>
<tr>
<td>-3 dB beamwidth in E-plane</td>
<td>53°</td>
<td>83°</td>
</tr>
</tbody>
</table>

A setup to investigate the dependence of behaviour of the channel on the receiver antenna pointing direction is shown in Figure 1. The receiver antenna is fixed on a motor which rotates the antenna in the horizontal plane. The motor is mounted on a mast with a variable height between 1.5m and 5m. The antenna is rotated over an angle of 3.524° during the measurement of an impulse response. At each measurement site the start position and rotation direction are documented.

1. INTRODUCTION

Wireless Local Loop (WLL) [1] uses a DECT radio interface instead of copper wires to create a link between antennae at residential subscribers and at the local exchange side. In the WLL configuration as studied in this paper, the antenna at the subscriber's premises is installed below rooftop while it is installed above average rooftop level at the local exchange side. Consequently, in built-up areas beside line-of-sight (LOS) also non line-of-sight (NLOS) condition will occur which could lead to a degradation of the link performance. It is expected that this can be reduced by investigating favourable mounting positions for the deployment of antennae at the subscriber side. Therefore, experimental data are acquired to analyse the effect of both the height and the pointing direction of the antenna on the transfer function of WLL radio link. The behaviour of the radio channel will be characterized by the wideband path loss relative to free space loss and the rms time delay spread. These two parameters are deduced from the measured complex impulse response. For convenience, the antennae at the local exchange side and the subscriber side will be named 'transmitter' and 'receiver' respectively.
Figure 81 Measurement setup to rotate the receiver antenna

After having determined the best receiver antenna pointing direction, the dependence of the channel's behaviour on the receiver antenna height can be investigated using the setup shown in Figure 2.

Figure 82 Measurement setup to vary the height of the receiver antenna

The receiver antenna is fixed on a carriage which is moved over a rail by a motor in vertical direction. During the measurement of an impulse response, the antenna is displaced over a distance of 2.45 cm along the rail. This distance which agrees with $\lambda/6$, is small enough to obtain a detailed field pattern. The height can be varied between 1.5m and 4m.

The wideband path loss relative to free space loss and the rms time delay spread which are used to characterize the radio channel, are calculated from the power delay profile given by

$$P(\tau,d) = |h(\tau,d)|^2$$

with $h(\tau,d)$ the measured complex impulse response as function of the excess delay time $\tau$ and the distance between transmitter and receiver antenna $d$. The wideband path loss relative to free space loss is given by

$$L = \frac{P_{\text{real}} G_T G_R L_A}{P_R L_A} \left( \frac{\lambda}{4\pi d} \right)^2$$

where $G_T$ denotes the gain of the transmitter antenna and $G_R$ the gain of the receiver antenna and $P_{\text{real}}$ and $P_R$ are the measured signal power during a calibration and a field measurement respectively. These powers are calculated by integrating the measured power delay profiles. The calibration of the channel sounder is performed previously to the data acquisition. Then, transmitter and receiver are connected back-to-back with a variable attenuator. The attenuation setting of the attenuator during a calibration and a field measurement is denoted by $L_A$ and $L_{\text{cal}}$ respectively. Furthermore, the rms time delay spread given by [3]

$$\sigma = \sqrt{\frac{\int_0^\infty \tau^2 P(\tau,d) d\tau - \left( \frac{\int_0^\infty \tau P(\tau,d) d\tau}{\int_0^\infty P(\tau,d) d\tau} \right)^2}{\int_0^\infty P(\tau,d) d\tau}}$$

is calculated.

III MEASUREMENT ENVIRONMENT

In the DECT WLL application considered here the antenna at the local exchange side is installed well above average rooftop level while it is installed below rooftop at the subscriber's premises. An area where this configuration can be investigated is Deppenbroek in Enschede. In this area the transmitter antenna was placed on top of a high building at a height of 37m above the ground. The area seen by the transmitter antenna within its -3 dB beamwidth is for 13% occupied by buildings while the other 87% is open area which is partly covered by vegetation.
IV MEASUREMENT RESULTS

Measurements with a rotating receiver antenna at a height of 2m and 4m above the ground were done at a number of sites on trajectory along a row of buildings. Two categories of trajectories are considered, namely trajectories that are oriented parallel to the straight line between the receiver and transmitter antenna (LOS-line) and trajectories that are perpendicular to this LOS-line. For each trajectory the average angle dependence of the normalized wideband path loss and the normalized rms time delay spread are calculated according to

\[ L_w(\varphi_n) = 10^{10} \log \left( \frac{1}{N} \sum_{n=1}^{N} \frac{L(\varphi_n, n)}{L_{\text{min}}(n)} \right) \]  \hspace{1cm} (4)

and

\[ \sigma_w(\varphi_n) = \frac{1}{N} \sum_{n=1}^{N} \frac{\sigma(\varphi_n, n)}{\sigma_{\text{min}}(n)} \]  \hspace{1cm} (5)

respectively with \( \varphi_m = m \times 3.524^\circ \) and \( n \) the \( n \)-th measurement site and \( N \) the number of sites.

A street in Deppenkoek with buildings oriented almost parallel to the LOS-line is Jan van Zutphen straat shown in Figure 3. In this figure the height of the buildings and the rotation direction of the receiver antenna are indicated. Furthermore, it shows that for the sites on the measurement trajectory the angle of the LOS-line is between 21° and 25°. NLOS condition occurs for about 70% of the trajectory.

The average angle dependence of the normalized rms time delay spread and the normalized wideband path loss for this trajectory are shown in Figures 4 and 5 for an antenna height of 4m. Similar results were obtained for an antenna height of 2m.

![Figure 4 Average angle dependence of the normalized path loss for an antenna height of 4m](image)

![Figure 5 Average angle dependence of the normalized rms time delay spread for an antenna height of 4m](image)

It can be seen from these figures that the lowest path loss and rms time delay spread were measured when the receiver antenna was pointing to the transmitter antenna position. This means that the dominant propagation mode is either LOS or diffraction at the rooftops of the buildings that intersect the LOS-line. No significant tunneling of the radio wave through the street was observed.
A street with buildings oriented almost perpendicular to the LOS-line is the Roerstraat shown in Figure 6. NLOS condition occurs for about 90% of the trajectory.

For this street, the average angle dependence of the normalized rms time delay spread and the normalized wideband path loss are shown in Figures 7 and 8 for an antenna height of 4m. Similar results were obtained for an antenna height of 2m.

Again the lowest path loss and rms time delay spread occur when the receiver antenna points to the transmitter antenna position. This means that also for this orientation of the trajectories, the dominant propagation mode is either LOS or diffraction at the rooftops of the buildings that intersect the LOS-line.

Similar measurements were done for other streets in the illuminated area of Deppenbroek. All trajectories run along buildings and are oriented either parallel or perpendicular to the LOS-line. Now distinction is made between the situation that the receiver antenna points to the transmitter antenna and the situation that the receiver antenna aperture is parallel to the wall of the building near the measurement site. For both situations cumulative distributions are determined for the measured path loss relative to free space loss and for the rms time delay spread. These distributions are shown in Figures 9 and 10.
They show that what was found for the Jan van Zutphen straat and the Roerstraat also holds for the other streets in the illuminated area, namely that the lowest path loss and rms time delay spread occur when the receiver antenna points to the transmitter antenna position. Furthermore, it can be seen from these figures that for this optimal antenna pointing direction the path loss is about 5 dB smaller than for an antenna pointing perpendicular to the building walls. Also the rms time delay spread is less than 100 ns for 90% of the measurement sites which implies that no significant signal distortion occurs due to time delay spread [4]. Again similar results were obtained for an antenna height of 2m.

For this optimal pointing of the receiver antenna, the antenna height dependence of the rms time delay spread and the path loss relative to free space loss is experimentally investigated with the setup shown in Figure 2. A large number of LOS and NLOS measurements were done on various sites in Dappenbroek. First, a statistical approach is chosen to analyse the measured data. The 10%, 50% and 90% percentile were calculated for the path loss relative to free space loss and the rms time delay spread measured at each receiver antenna height.

The 50% percentile in Figure 11 shows a 4 dB decrease in path loss when increasing the receiver antenna height from 1.5m to 4m. However, there is also a large spread of 20 dB. So, on the average no significant decrease in path loss is achieved when increasing the receiver antenna height from 1.5 to 4m.

The results for the rms time delay spread in Figure 12 show the same behaviour. It appears that the conclusion drawn for Figure 10 for an antenna height of 4m, namely that for 90% of the measured sites the rms time delay spread is less than 100 ns, also holds for antenna heights between 2 and 4m.

This statistical analysis shows that on the average no significant gain is obtained by increasing the receiver antenna height from 2m to 4m. However, a more detailed analysis of the measured data indicates that for some specific configurations significant improvement can be obtained by a proper choice of the antenna height. This will be illustrated with two examples.
Figure 13 shows the measured path loss relative to free space loss for a typical LOS situation. By using a simple two-ray model it was found that the measured pattern is due to interference of the direct and ground reflected wave. Because this interference pattern can be predicted very well, it is possible to determine the optimal antenna height. Figure 13 shows that this can result in a significant decrease in path loss.

![Figure 13](image)

**Figure 13** Measured path loss relative to free space loss as a function of antenna height for LOS situation.

A second example, Figure 14 shows that the measured path loss relative to free space loss for a NLOS situation where the wave, after being diffracted at the rooftop of a building, is attenuated by trees near the receiver. The increase of the path loss with increasing antenna height is due to the fact that the foliage of the trees introduces a larger attenuation than their trunks. Figure 14 shows that also for this situation the path loss can be reduced significantly by placing the receiver antenna in the shadow of the trunks instead of in the shadow of the foliage.

![Figure 14](image)

**Figure 14** Measured path loss relative to free space loss as a function of antenna height for NLOS situation with vegetation.

V CONCLUSIONS

A DECT wireless local loop (WLL) application in an suburban environment has been investigated where the antenna at the subscriber side is installed below rooftop while it is installed well above roof level at the local exchange side. The effect of the pointing direction and the height of the antenna at the subscriber side on the transfer function of the WLL radio link is analysed by calculating the wideband path loss relative to free space loss and the rms time delay spread from a large set of measured data. It was found that for both line-of-sight (LOS) and non line-of-sight (NLOS) links the lowest path loss and rms time delay spread occur when the antenna at the subscriber side points towards the antenna at the local exchange side. On the average, no significant decrease in path loss and rms time delay spread was observed when the antenna height is increased from 2 to 4m. However, for individual LOS links and for NLOS links which are affected by attenuation due to vegetation, the path loss can be minimized by a proper choice of the antenna height.

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REFERENCES


