On obtaining wideband directional channel realizations from single-antenna channel sounding and simple ray-tracing
Martijn, E.F.T.; Herben, M.H.A.J.

Published in:
IEEE Antennas and Wireless Propagation Letters

DOI:
10.1109/LAWP.2005.860209

Published: 01/01/2005

Document Version
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain.
• You may freely distribute the URL identifying the publication in the public portal?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 27. Dec. 2018
On Obtaining Wideband Directional Channel Realizations From Single-Antenna Channel Sounding and Simple Ray Tracing

Ewart F. T. Martijn and Matti H. A. J. Herben, Senior Member, IEEE

Abstract—In this letter, it is demonstrated that the dominant multipath radio waves predicted with simple ray tracing show a good match in the time domain with those obtained from complex impulse response measurements along outdoor trajectories. By combining the measured intensities and delays of these dominant multipath components with their angles-of-arrival and angles-of-departure obtained from the ray tracer, good wideband directional channel realizations can be derived.

Index Terms—Modeling, multipath channels, ray tracing, UHF radio propagation.

I. INTRODUCTION

WIDEBAND directional channel modeling (WDCM) is indispensable for the development and deployment of broadband radio communication systems using antenna arrays at one or both ends of the communication link. The performance of the multiantenna modes, often denoted as smart-antenna or multiple-input–multiple-output (MIMO) wireless stations, depends on the dispersion of radio waves both in time and space in the environment where they are employed.

In principle, all temporal and spatial radio channel characteristics needed for the evaluation and planning of these systems can be derived from the channel’s power-delay-angle spectra. From the experimental point of view, high resolution angle-of-arrival measurement systems have been proposed for the measurement of power-delay-angle spectra of the mobile radio channel [1]. Although they provide very accurate channel estimations, the drawback of these measurement systems is that complex multidimensional antenna arrays and complex signal processing algorithms are needed to obtain the desired spectra. On the other hand, ray-tracing propagation models based on geometrical optics (GO), the uniform theory of diffraction (UTD) and scattering models can be an effective tool to obtain location-specific predictions of the power, delay, and angles of transmitted and received radio waves. The accuracy, however, may heavily depend on the modeling of buildings and the choice of dielectric properties of the building materials. Furthermore, when wideband directional channel realizations along outdoor trajectories are desired, the above mentioned methods generate substantial amounts of data which results in tedious data analysis. Therefore, both of the mentioned approaches are not easy-to-handle tools that cannot quickly provide radio system designers and/or radio network planners with the wideband directional channel realizations needed.

In this letter, it is shown that the combination of single-antenna wideband channel sounding and simple ray tracing along a vehicle trajectory is a simpler method to obtain good wideband directional channel realizations. By combining the measurement and prediction results in the time domain, it is possible to identify dominant multipath contributions and determine the corresponding angles-of-departure and angles-of-arrival in an indirect manner.

First, the measurement system, prediction tool, and scenarios investigated are presented. Then, the match of simple ray tracing with the measurement results is shown. Finally, the conclusions will be summarized.

II. MEASUREMENT SYSTEM

For the measurements, a sliding correlator radio channel sounder, which is based on the well-known pseudo noise (PN) correlation method [2], [3] was used. The system is capable of measuring complex impulse responses (CIR) with a time resolution of 20 ns and a dynamic range of 40 dB. The most important specification figures are given in Table I.

For quasicoherent measurements, the frequency synthesizers at both the transmitter and the receiver were locked to highly stable rubidium clocks (short-term stability better than $5 \times 10^{-11}$). In order to obtain accurate power density the choice of dielectric properties of the building materials.

Manuscript received July 1, 2005; revised October 7, 2005. This work was supported by the Dutch Ministry of Economic Affairs within the framework of the BraBant BreedBand (B4) Project.

E. F. T. Martijn was with the Radiocommunications Group, Eindhoven University of Technology, 5600MB Eindhoven, The Netherlands. He is now with Ericsson BV, 5120AA Rijen, The Netherlands (e-mail: ewart.martijn@ericsson.com).

M. H. A. J. Herben is with the Radiocommunications Group, Eindhoven University of Technology, 5600MB Eindhoven, The Netherlands (e-mail: m.h.a.j.herben@tue.nl).

Digital Object Identifier 10.1109/LAWP.2005.860209

TABLE I

<table>
<thead>
<tr>
<th>Channel Sounder Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>System parameter</td>
</tr>
<tr>
<td>center frequency</td>
</tr>
<tr>
<td>bandwidth</td>
</tr>
<tr>
<td>output power</td>
</tr>
<tr>
<td>excitation</td>
</tr>
<tr>
<td>chip rate</td>
</tr>
<tr>
<td>modulation</td>
</tr>
<tr>
<td>unambiguous range</td>
</tr>
<tr>
<td>time resolution</td>
</tr>
<tr>
<td>acquisition rate</td>
</tr>
<tr>
<td>dynamic range</td>
</tr>
</tbody>
</table>
measurements, back-to-back calibrations with a fixed known attenuation were performed before the actual measurements.

At the transmit and receive side a vertically polarized 2 dBi omnidirectional antenna was used. Both antennas were positioned below the rooftop of the surrounding buildings; the transmit antenna was positioned at 4.5 m height and the receive antenna was mounted on top of the measurement vehicle at 2.5 m.

III. PREDICTION TOOL

In urban areas, microcells can be deployed to provide high capacity in a local coverage area (approximately up to 1 km). The base station (BS) antennas in these microcells are usually mounted below the rooftop level in order to confine the radiated power. The communication between BS and the user’s wireless devices is established via a direct path (if present) and multipath propagation resulting from reflection, diffraction and scattering of radio waves at various objects. In these types of scenarios, deterministic ray-based prediction models can provide location-specific predictions of the channel impulse response based on the composition of multipath waves.

The μFiPRe ray-tracing tool used in this work is a two-dimensional model suitable for the prediction of impulse responses and azimuth angle-of-arrival spectra in microcell type of scenarios [4]. It is a ray-tracing model based on GO to model free-space propagation and reflections, and UTD to describe diffraction effects. Transmission through buildings can be an important propagation mechanism in microcell scenarios. Therefore, transmission through buildings is modeled by means of reflection losses at the exterior walls and an empirically determined building attenuation factor to account for the interior losses [5]. In addition, a model for scattering from trees is included in the tool [6].

Our purpose is to show the effectiveness of simple ray tracing by using a limited number of simulation parameters with typical values and a limited number of multipath contributions. The contributions taken into account were the direct wave (either line-of-sight or transmitted through a building), single reflection, single scattering, and combinations of two of these wave interactions.

Commercial ray-tracing tools provide the possibility to model the material dielectric properties of individual buildings separately. In our more simple simulations, however, the relative permittivity $\varepsilon_r = 5$ and conductivity $\sigma = 10^{-4}$ were chosen for all buildings. These parameters correspond with simulations and measurement results obtained in microcell type of scenarios [7]. For the estimation of transmission through buildings, an average building attenuation factor of 2.1 dB/m was chosen, as found in [5].

IV. COMPARISON OF MEASUREMENTS AND PREDICTIONS

CIR measurements and predictions were performed along various trajectories on the campus of Eindhoven University of Technology. The experiments were performed in two different areas, with both areas containing multifloor buildings. In this letter, results for one trajectory in each area will be shown. The first area is situated around the Traverse building as shown in Fig. 1. The dashed line indicates the trajectory. The direct path between transmitter and receiver is obstructed by the Traverse building.

The second area is situated in the vicinity of the ST-building as shown in Fig. 2. The results shown for this area are obtained for the line-of-sight trajectory depicted by the dashed line.

Fig. 3 shows the measurement results for the Traverse case. The figure illustrates a top view of the power-delay-profile consisting of multipaths arriving at a time delay indicated along the vertical axis and with an intensity indicated by the gray-scale palette. The horizontal axis indicates the measurement position on the trajectory (traveled from left to right) as the distance from the starting point. When the vehicle starts a drive with constant speed, the path lengths of the multipath contributions coming from behind of the vehicle become longer resulting in longer delay times. These contributions appear as patterns with a positive slope. On the other hand, the path lengths of the multipath contributions originating from in front of the vehicle become...
shorter resulting in shorter delay times, which appear as patterns with a negative slope. In the figure, the contribution arriving via transmission through the Traverse building (1) and multipath contributions arriving from the right (3, 4, 5) and left side (2) of the building can be clearly distinguished.

In the prediction results shown in Fig. 4, the same dominant contributions can be observed. The evolution of the dominant waves along the trajectory provides enough information for comparison. These figures indicate a good match of measured and predicted dominant contributions.

Figs. 5 and 6 show the measured and predicted power-delay profiles along the trajectory for the ST-building case. In these figures the reflections from obstacles along the street are clearly visible (4, 5, 6). Again, a good match can be observed between the arrival time of the measured and predicted dominant contributions. For matching dominant contributions, the measured signal intensity and time delay of a particular contribution can be combined with the predicted angles-of-departure and angles-of-arrival to obtain complete wideband directional channel realizations.

In order to determine the significance of the dominant contributions to the total power-delay profile, the narrowband received power

$$P_r = \left| \sum_{n=1}^{N} a_n \exp(j\phi_n) \right|^2$$

is calculated. The amplitudes $a_n$ and phases $\phi_n$ are obtained from all samples $n$ above noise level. Figs. 7 and 8 show the received narrowband power along the trajectories. The instantaneous values in the figures are dotted, while the solid lines indicate running mean values using a window of 40 samples. The line indicated with “Match” is obtained by selecting the measured signal intensity and time delay of only those points in time and space (i.e., along the trajectory) that match with the predicted points. If either a measured or predicted result for a given trajectory position and time delay is equal to or below noise level, this result is not considered for the Match results. Since the predicted power-delay profiles are equal to the noise
level with the exception of only the most dominant contributions, the Match lines give a good indication of the significance of these dominant contributions for the total received power. The received power figures indicate that the majority of the signal intensity is concentrated in the dominant contributions.

A similar analysis of the r.m.s. delay spread showed significantly lower matched values than the measured ones, indicating that weaker contributions can have a more pronounced effect on the delay spread than on received power. This is more noticeable in the line-of-sight case where the tunneling effect of the buildings causing many multiple reflections is not included in the predictions. One method to solve this is to allow more interactions during ray tracing or to model the large number of weaker contributions stochastically.

V. CONCLUSION

In this letter, a method has been presented to obtain wideband directional channel realizations from single antenna channel sounding and simple ray tracing in microcell scenarios. In the time domain, the dominant radio waves predicted with simple ray tracing show a good match with dominant radio waves obtained from complex impulse response measurements along outdoor trajectories. By combining the realistic intensity and delay of the dominant multipath components from the measurements with the angle-of-arrival and angle-of-departure from the ray tracer, the power-delay-angle spectra of the mobile radio channel can be obtained. These wideband directional channel estimations are suitable for the evaluation of broadband communication systems using antenna arrays at one or both ends. Finally, as shown in [5], [6] the way of comparing measurements with predictions, as presented in this letter, can also be used for the estimation of interaction coefficients with the environment in order to improve the modeling of specific propagation mechanisms used in the ray tracer.

ACKNOWLEDGMENT

The authors would like to thank L. A. Colin for his assistance in the experiments.

REFERENCES