Analysis of measurements on urban models in anechoic chamber and comparisons with propagation predictions

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Abstract— **A time-domain analysis of measured data is acrried out to identify the multipath components that are mixed in the overall received signal. The theoretical multipath components are predicted by a ray-tracing electromagnetic wave propagation simulator. The predictions are compared with the measured data and the results confirm the goodness of the theoretical approach. The application of this research lies in the modelling of the urban channel for wireless communication systems of the third generation (UMTS) and beyond.**

I. Introduction

The time-domain (TD) analysis presented herein completes the investigation started in the companion paper [1]. The TD analysis is carried out to compare measurements with theoretical predictions about propagation in urban environments. The TD analysis identifies the multipath components that actually contribute towards the received field. The measurements are conducted inside an anechoic chamber facility, using scaled models of urban environments and appropriate antennas. Details of the experiment are given in [1] and are not repeated here. The theoretical predictions are obtained from the Polygonal Line (PL) simulator, a 2D ray-tracing program for electromagnetic wave propagation prediction in urban environments, which is fully described in [2], [3], [4]. Preliminary results of this investigation were given in [5], [6], [7].

II. Time-Domain Analysis

Given a certain configuration in input, the PL simulator computes the complex value of the EM field for a pre-determined set of frequencies. Similarly, in the experiments pulses that are launched from T_x and measured at R_x. The pulses are generated by a Hewlett-Packard HP8510 Network Analyzer (NA) and their bandwidth, determined by the radiation characteristics of the antennas, is in the range from 19 GHz to 27 GHz. The *response resolution* (i.e.the minimum distance between two impulses in order to distinguish them) is 0.25 ns, whereas the *range resolution* (i.e. the ability to pinpoint the peak of an impulse) is $\pm$ 0.0625 ns. The TD analysis is accomplished using MATLAB. The measured bandwidth is artificially enlarged by adding zeroes before and after the original interval in the frequency domain. This results in a less abrupt shape in the TD and has the important effect of improving the time-resolution. The artificial enlargement corresponds to 4 times the original frequency interval. The TD analysis is carried out for three scaled models of urban profiles in the sections to follow.

III. Single-Building Profile

Starting with a simple profile, comparisons with the measured data are made to verify the accuracy of the predictions of the PL simulator. The TD analysis is plotted in graphs where the blue line represents the measured data and the black one the PL simulator prediction. In addition, the details of each multipath component are presented in a series of tables.

A. Transmitter above Rooftop

Let us consider the configuration shown in Figure 1 for soft polarization.

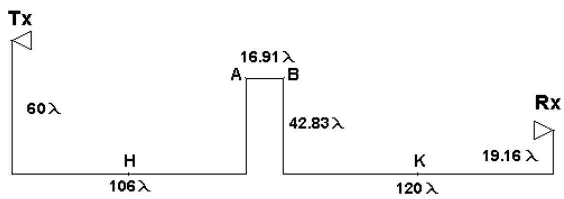

Fig. 1. Configuration 1: T_x above rooftop

The possible trajectories found by the polygonal line simulator are:

1. $T_x \to B \to R_x$
2. $T_x \to A \to B \to R_x$
3. $T_x \to B \to K \to R_x$
4. $T_x \to A \to B \to K \to R_x$

5. $T_x \rightarrow H \rightarrow A \rightarrow B \rightarrow R_x$
6. $T_x \rightarrow H \rightarrow A \rightarrow B \rightarrow K \rightarrow R_x$

The results of the comparisons are shown in in Figure 2.

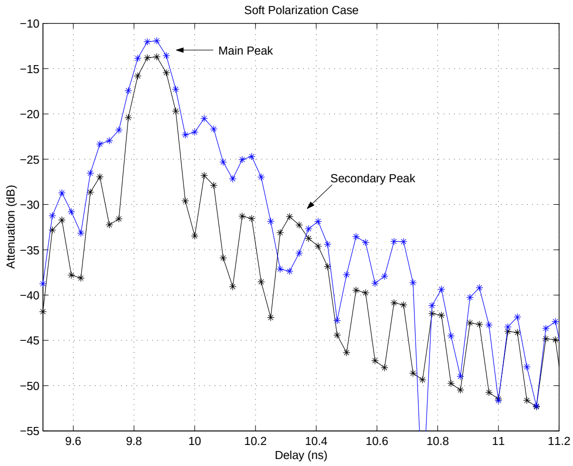

Fig. 2. Configuration 1: Time-domain analysis

TABLE I
CONFIGURATION 1

Trj	Measured Data Delay (ns)	Attn (dB)	PL Simul Delay (ns)	Attn (dB)
1	9.860	-11.95	9.863	-13.19
2	”	”	9.871	-41.32
3	10.390	-32.87	10.375	-32.34
4	”	”	10.382	-55.71
5	x	x	11.484	-67.04
6	x	x	11.994	-81.12

Referring to Table I, the main peak of the response is due to trajectory 1; trajectory 2 does not contribute to it because it is weaker of about 28 dB. For the secondary peak, a similar situation applies. Trajectories 3 is the only contributor because trajectory 4 is about 23 dB below the level of trajectory 3. Trajectories 5 and 6 are too weak to be detected. The overall behavior of the PL prediction in Fig. 2 is in close agreement with the measured data for this configuration.

B. Transmitter and receiver at grazing aspects of incidence and observation

This configuration is shown in Figure 3 and is of a particular importance because it challenges the ray-tracing algorithms by containing two transition zones. Also, it has the characteristic of being perfectly symmetrical. The experiments were carried out by actually keeping both the transmitter and the receiver slightly below the building rooftop to avoid direct ray contributions. The possible trajectories trajectories are:

1. $T_x \rightarrow A \rightarrow B \rightarrow R_x$
2. $T_x \rightarrow A \rightarrow B \rightarrow K \rightarrow R_x$
3. $T_x \rightarrow H \rightarrow A \rightarrow B \rightarrow R_x$
4. $T_x \rightarrow H \rightarrow A \rightarrow B \rightarrow K \rightarrow R_x$

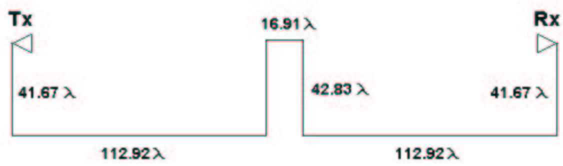

Fig. 3. Configuration 2: T_x and R_x at grazing incidence

The TD analysis for this configuration is shown in Figure 4. Referring to Table II, the main peak is associated with trajectory 1. The second peak is due to a combination of both trajectories 2 and 3. In fact, because of the symmetry of the present configuration, trajectories 2 and 3 have the same delays and roughly provide the same contributions.

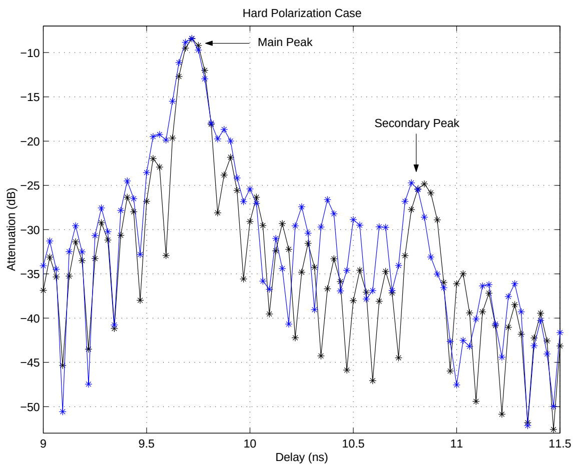

Fig. 4. Configuration 2: Time domain analysis

TABLE II
CONFIGURATION 2:

Trj	Measured Data Delay (ns)	Attn (dB)	PL Simul Delay (ns)	Attn (dB)
1	9.720	-8.40	9.724	-8.42
2	10.795	-24.72	10.839	-29.60
3	”	”	10.839	-31.99
4	x	x	11.953	-48.43

IV. Two-Building Profile

This profile represents the simplest case of rows of parallel buildings and provides a way to challenge the ray-tracing algorithm because of the intrinsic grazing incidence condition created by the two buildings.

A. *Transmitter and receiver at grazing aspects of incidence and observation*

This configuration is shown in Fig. 5 and is the most challenging for the ray-tracing simulator. The experiments were carried out by actually keeping both the transmitter and the receiver below the building height to avoid direct ray contributions. The TD analysis of Fig. 6 shows two peaks . Referring to Table III, both the main and the secondary peaks are predicted by the polygonal line simulator. Notice that the two secondary peaks due to trajectories 2 and 3 are merged together in a single contribution.

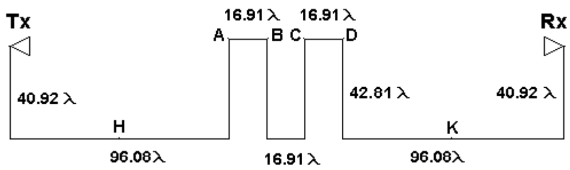

Fig. 5. Configuration 3

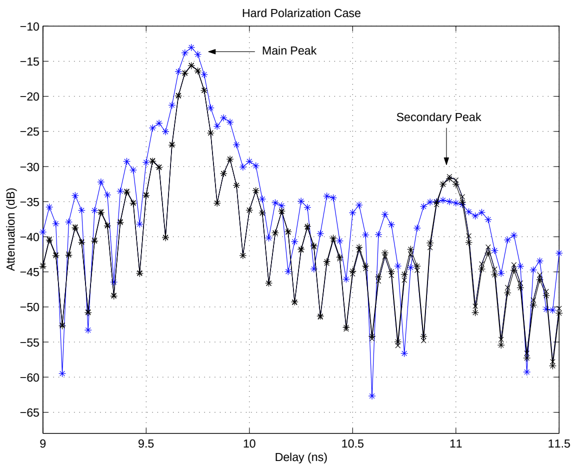

Fig. 6. Configuration 3: Time domain analysis

Under conditions of grazing aspects of incidence and

TABLE III
CONFIGURATION 3

Trj	Measured Data Delay (ns)	Attn (dB)	PL Simul Delay (ns)	Attn (dB)
1	9.720	-13.05	9.724	-15.49
2	10.970	-34.80	10.971	-36.84
3	"	"	10.973	-38.15

observation, diffraction past the edges A, B, C, D of Fig. 5 requires a diffraction coefficient of order higher than the second. However, the polygonal line simulator computes the diffraction past the two buildings by cascading the diffraction past A, B with the diffraction past C, D. Each diffraction past a single building is computed using the diffraction coefficients described in [8].

V. Three-Building Profile

The three-building profile is introduced to analyze a more complex situation where there are buildings with different heights and not all surfaces are either horizontal or vertical. The configuration that is examined is shown in Fig. 7. The height of the trans-

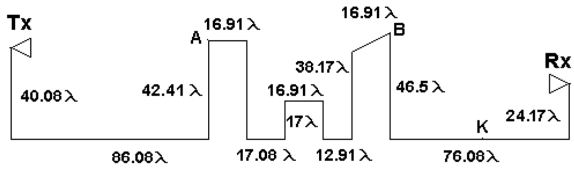

Fig. 7. Configuration 4

mitter is chosen to illuminate B while, at the same time, almost creating grazing incidence over the roof of the left building. For this configuration the main trajectories are:

1. $T_x \rightarrow A \rightarrow B \rightarrow R_x$
2. $T_x \rightarrow A \rightarrow B \rightarrow K \rightarrow R_x$
3. $T_x \rightarrow H \rightarrow A \rightarrow B \rightarrow R_x$

The results of the time-domain analysis are shown in Fig. 8 for the case of soft polarization. There is

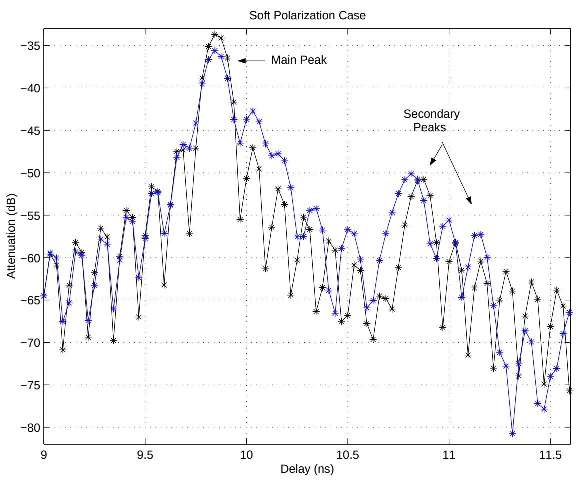

Fig. 8. Configuration 4: Time domain analysis: soft polarization

good agreement for the prediction of the main and secondary peaks, as shown in Table IV. The results for the time-domain analysis for hard polarization are given in Fig. 9 and in Table V. As expected, soft polarization provides weaker fields than hard polarization. This explains why the secondary peaks of Fig. 8 are not so evident as in the case of Fig. 9. For both polarizations, the secondary peaks are due to trajectories 2 and 3, whereas the main peaks are due to trajectory 1. Additional trajectories are not presented here because their contributions are weaker than the noise.

TABLE IV

Configuration 4: Soft Polarization

Trj	Measured Delay (ns)	Data Attn (dB)	PL Delay (ns)	Simul Attn (dB) (dB)
1	9.845	-35.55	9.850	-33.68
2	10.815	-50.10	10.832	-50.76
3	11.150	-57.25	11.179	-60.40

TABLE V

Configuration 4: Hard polarization.

Trj	Measured Delay (ns)	Data Attn (dB)	PL Delay (ns)	Simul Attn (dB)
1	9.875	-25.40	9.850	-24.29
2	10.785	-31.90	10.832	-33.76
3	10.110	-45.55	11.179	-45.39

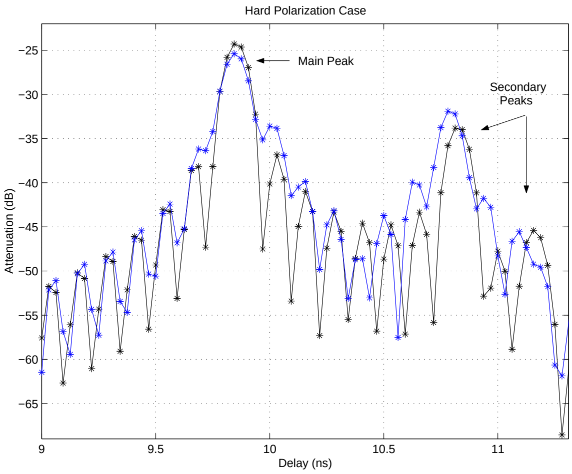

Fig. 9. Configuration 4: Time domain analysis: hard polarization

VI. Conclusions

This article presented an experimental study of propagation past buildings focusing on the different contributions due to multipath propagation. This study has been carried out to further validate a two-dimensional ray tracing model for propagation in urban environment described in [2] [3] [4]. The predictions obtained with the PL simulator are in very good agreement with the measurements for all the configurations that were examined. In particular, this research has isolated the components of the received signal which are most important according to the configuration of the examined profile with respect to the Tx and Rx.

The limitations of this analysis are mainly due to the fact that it was performed on metallic models. On the other hand the advantages of carrying out such a set of measurements in an anechoic chamber are evident, as opposed to field measurement that are influenced by a series of factors, most of which are not easily quantifiable. Therefore, with field measurements, it would be difficult to determine the causes of any disagreement with the predictions. To the best of the author's knowledge, this is the first time that a study of propagation over buildings is performed in an anechoic chamber, and in literature there is only a single paper on measurements on scaled buildings [10], which however is not performed in an anechoic and addresses propagation among buildings instead of over buildings.

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