IEEE 45th Vehicular Technology Conference, Chicago, USA, July 1995

INFLUENCE OF DATABASES ACCURACY ON RAY-TRACING-BASED-PREDICTION IN URBAN MICROCELLS

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Abstract—The databases required for ray-tracing-based-prediction in urban microcellular environments include those for the building layout, the electrical characteristics of the buildings, and for the base station (locations, antennas, power, etc.). The effects of inaccuracies in these databases are presented and analyzed by comparing the computed results to measurements. The results presented here show that acceptable predictions can be computed but care must be taken a) to use an accurate vector database, b) to precisely place the base station location with respect to the building corners, and c) to adapt the reflection coefficient for the given area.

I. INTRODUCTION

Path loss predictions in urban microcellular environments are required for better planning of emerging high capacity cellular networks. The prediction results presented here are based on ray tracing using the image method. Multiple specular reflections and single perfectly absorbing wedge diffraction are considered. The ray tracing method is briefly presented in Section 2 [1,2].

The predictions require the use of the following data: **1)** the building layout in form of vectors describing the buildings, **2)** the base station location, **3)** the base station antenna characteristics, **4)** the building electrical characteristics (For the ray tracing method used here, the permittivity and the conductivity or a scalar reflection coefficient are required) and, **5)** the frequency.

These data can be stored in databases that may present some inaccuracies. The effects of inaccuracies in the vectored building layout are analyzed in Section 3 where prediction results are compared to measurements which are described in [2]. Then, Section 4 shows by means of an example the noticeable effects due to an inaccuracy in the base station location. Other effects, due for example to the antenna pattern or antenna orientation, are not considered here. The effect of inaccuracies in choosing the proper reflection coefficients is presented in Section 5. Finally, the conclusions presented in Section 6 recall the significance of the various databases required for the predictions in urban microcellular environments.

II. MODEL DESCRIPTION [1,2]

The propagation predictions presented here are based on modeling the radio wave propagation using image theory and ray tracing.

In the results presented, rays including up to 8 multiple reflections or 7 multiple reflections and one diffraction are taken into account. Ground reflections, rays over rooftops, and scattering effects are neglected.

The reflected wave fields are computed according to the well known formula for the Fresnel reflection coefficient for vertical polarisation [e.g., 3]. In the results presented below, unless otherwise noted, the electrical parameters attributed to the building walls were chosen $\varepsilon_r = 5$ for the relative permittivity, and $\sigma = 0.0001$ [S/m] for the conductivity. These values, reasonable for building material, were found to give the best fit between the prediction and the measurements.

The diffracted wave fields are computed using the diffraction coefficient given in [4], which is valid for a perfectly absorbing wedge. Care was taken to saturate in an appropriate manner the discontinuity in the expression.

III. BUILDING LAYOUT DATABASE

The prediction model described above requires the two-dimensional building layout of the urban area by means of vectors describing the building walls. In Switzerland, no such vectored building database readily exits in all cities. Therefore, as a first trial, we manually vectorized a **city map** of the area. We also tried a manual vectorisation of a very precise **cadastre map**. To ease the manual vectorization and to mitigate the difficulties in obtaining the cadastre maps of some cities, a semi-automatic vectorization of **scanned 1:25000 maps** was considered.

A. Vectors from the city map

The vectors obtained by hand digitizing a regular **city map** are presented in Fig. 1. Streets are expected to have a wrong width, since the width of the streets are drawn for clarity, i.e., to represent the importance of the street and to allow the street name to be written in it. Also, details of some buildings are omitted.

Fig. 4 shows a comparison in Wiesen Str. between predictions and measurements. The numerous peaks predicted to appear along the street are due to multiple reflections which do not occur in reality. For example the observation points P1 and P2 in Fig. 1 are considered. The 3-time reflected ray reaching P1 is predicted (peak at d = 370 m in Fig. 4) because of the inaccurate city map representation of the buildings but does not exist in reality. Also, the results presented in the next section shows that this 3-time reflected ray does not exist anymore when the building layout is more accurate (a reflection is replaced by a diffraction). Similarly, the ray reaching P2 exists only in the prediction (d = 110 m) because of the inaccurate representation of the building Bldg. 2 in Fig. 1.

B. Vectors from the cadastre map

The **cadastre map** is available only on paper. The vectors shown in Fig. 2 were obtained using a digitizing tablet. The resulting accuracy is about half a meter on the location of the building corner.

The comparison between predictions and measurements on Wiesen Str. is shown in Fig. 5. The source location is shown in Fig. 2 by a black dot. A reasonable agreement between measurements and prediction is observed. The comparison of the dominant ray reaching P2 in Fig. 1 and 2 explains the differences between Fig. 4 and 5 for d around 100 m. Poor predicted results are obtained for d between 160 m and 280 m. In particular, the peak at d = 240 m is not predicted. These discrepancies have to be further investigated.

The dominant ray reaching P1 in the cadastre map (Fig. 2) is diffracted once and reflected twice. In the city map the ray reaching P1 is reflected 3-times. Thus, much less energy reaches the end of the street (d > 300 m), and a better agreement with the measurements is found for the predictions using the cadastre map.

C. Vectors from 1:25000 Maps

Maps with a 1:25000 scale are available in Switzerland in scanned format. The vectorization presented here used the three following steps[5]: 1) automatic recognition of buildings (to separate text, sidewalk, railways, etc.), 2) manual correction of errors from the automatic recognition, 3) automatic vectorization. Fig. 3 shows the resulting vectored **1:25000 map**.

A comparison between a prediction and measurements is shown in Fig. 6. For d>320 m, the 20 dB discrepancy is due to inaccuracies in the buildings recognition. In fact, because of the representation of the scanned map, the sidewalk could not be separated from the buildings, thus leading to a narrower street (especially for Bldg. 1 to Bldg. 5). Also the prediction for 150 m<d<250 m underestimates the prediction. This is due to the fact that buildings Bldg. 6 and Bldg. 7 are almost joined together because of an error in the automatic building recognition.

D. Effect of passage-way

Fig. 7 shows comparison between predictions and measurements on Rodtmatt Str., i.e., another parallel street. The prediction considers the **cadastre map** (Fig. 2) and the source location indicated by the black dot. The peak which appears in the measurements at d=220 m is due to a passage-way through the building 1 which was detected only when carefully examining the building. This demonstrates the importance of a precise building description and illustrates a required feature for accurate propagation prediction.

IV. Base Station Location

Fig. 8 shows comparison between measurement and two predictions on Wiesen Str. computed with two different source locations. The two source locations are indicated by the black dot and the cross in Fig. 2. Although the two sources are separated by about three meters only, prediction results are noticeably different, especially for d = 100 m. Sensitivity to the source location is due to the fact that the source is surrounded by street openings. This comparison demonstrates the effects of specular reflections, which could be verified in practice in future measurement campaigns.

V. Reflection Coefficient

Fig. 9 compares four predicted results using four different reflection coefficients. It is observed that the best agreement with the measurements are obtained for a relative permittivity of 5 (thick solid line) or for a constant reflection coefficient of 0.5 (thin dashed line). A lower permittivity of 2 (thin solid line) leads to an almost constant shift of about 15 dB away from the peaks. Where this shift occurs, multiple specular reflections dominate. Using a constant reflection coefficients of 0.25 (thick dashed line) and of 0.5 (thin dashed line) leads to prediction results similar to those obtained with an E-polarized reflection coefficients. Further investigations should indicate to what extent such similarities apply in general.

VI. Conclusion

The effects of some inaccuracies in the databases required for ray-tracing-based-prediction in urban microcellular environments have been presented. The databases considered included those for the building layout, the base station location, and the electrical characteristics of the buildings. Predicted results were presented and analyzed by comparison to measurements. Three different maps were used to produce the building vector data used for the prediction, namely **a city map, a cadastre map and a 1:25000 map**. The results improved with the accuracy of the geometry, giving the best results for the cadastre map. However, the remaining discrepancies might be explained either by the fact that the ray-tracing-based-model does not yet consider scattering, or by unidentified errors in the building maps. It was also shown that some building features like passage ways not indicated on any map can influence the propagation.

The effect of the base station location is predicted to be very important when the base station is close to the building corners or close to an opening in a row of buildings. This remains to be demonstrated by additional measurements

The effect of varying the reflection coefficient were briefly presented. It is clear that the value of the reflection coefficient can be used to adjust somewhat the fit between the predictions and the measurements. It remains to determine how local this adjustment should be [2].

ACKNOWLEDGMENT

The authors would like to thank Prof. Carosio, Mr. Stengele, Mr. Nebiker, and Mr. Blaser, from the Swiss Federal Institute of Technology Zürich for their work allowing the automated generation of vectored maps.

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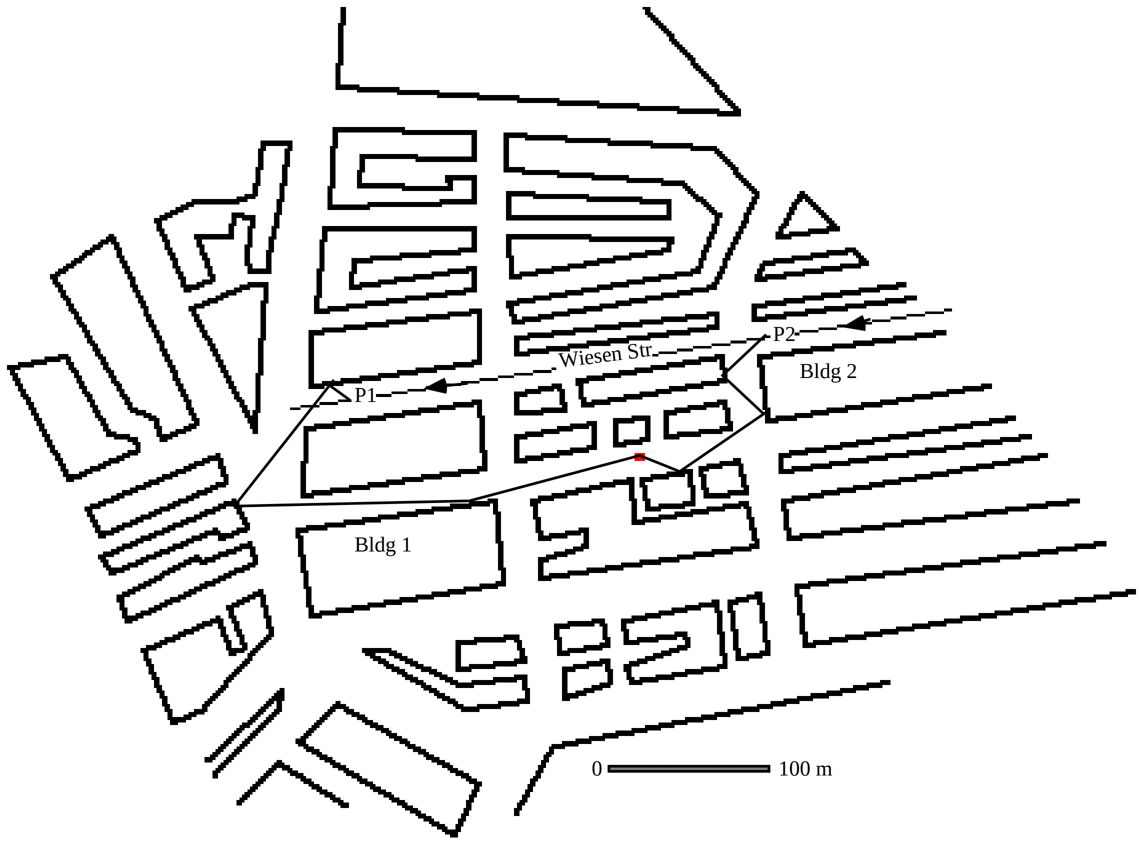

Fig. 1. **City map.** The black dot indicates the source location. The thick line represents the observation route driven in the direction indicated by the arrow. The 3-time reflected rays reaching the two points P1 and P2 are the dominant rays.

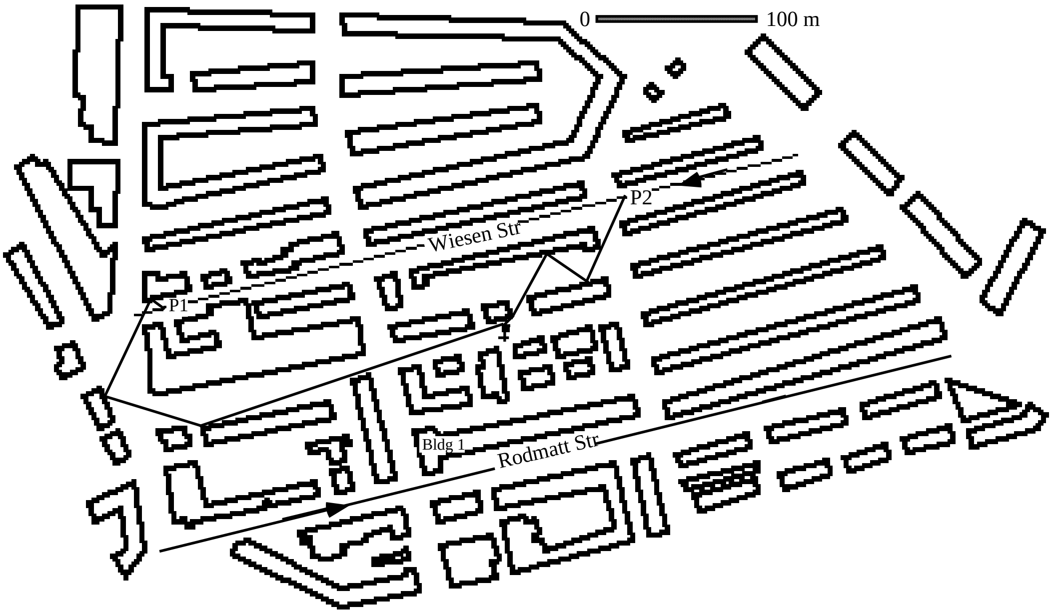

Fig. 2. **Cadastre map.** The black dot and the cross indicate two source locations. The thick lines represent the observation routes driven in the direction indicated by the arrow. Two examples of dominant ray are shown: the diffracted-once and reflected-twice rays reaching P1 and P2.

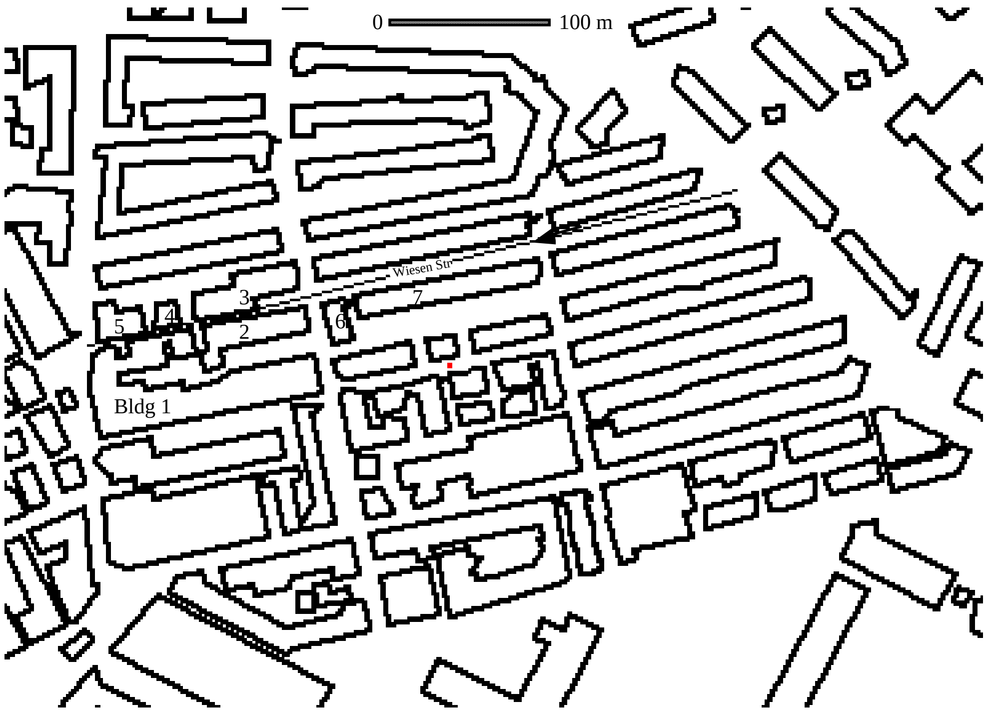

Fig. 3. **1:25000 map.** The source location is indicated by the black dot. The thick line represents the observation route driven in the direction indicated by the arrow.

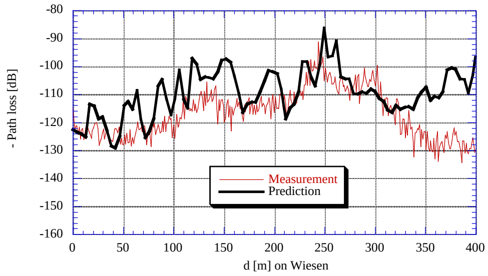

Fig. 4. Comparison **on Wiesen Str.** between measurements (thin line) and predictions (thick line) using the **city map** as the vectors database.

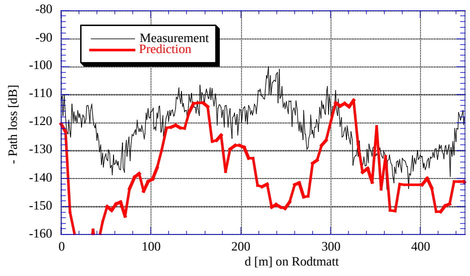

Fig. 7. Comparison **on Rodtmatt Str.** between measurements (thin line) and predictions (thick line) using **cadastre map** as the vectors database.

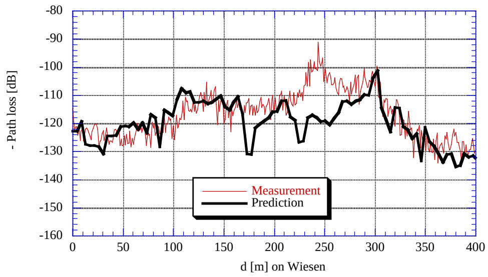

Fig. 5. Comparison **on Wiesen Str.** between measurements (thin line) and predictions (thick line) using the **cadastre map** as the vectors database.

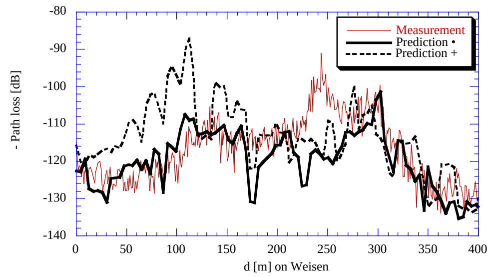

Fig. 8. Comparison **on Wiesen Str.** between two predictions (thick solid line and thick dashed line) for two base station locations (black dot and cross in Fig. 3, respectively). The **cadastre map** is used as the vectors database.

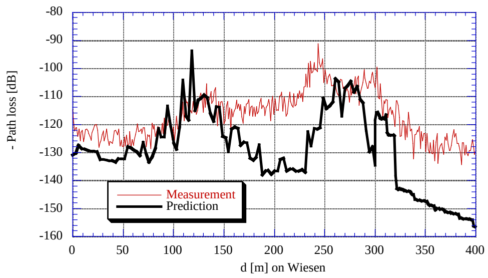

Fig. 6. Comparison **on Wiesen Str.** between measurements (thin line) and predictions (thick line) using the **1:2500 map** as the vectors database.

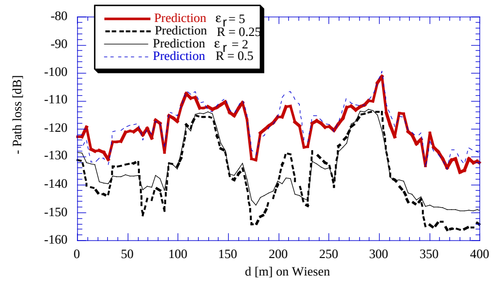

Fig. 9. Comparison **on Wiesen Str.** between four predictions (thin solid line, thick solid line, and thick dashed line, thin dashed line) for four reflection coefficients ($\varepsilon_r = 2$, $\sigma = 0.0001$ [S/m], $\varepsilon_r = 5$, $\sigma = 0.0001$ [S/m], $R = 0.25$ and $R = 0.5$, respectively). The **cadastre map** is used as the vectors database.