

Characterization of WiMAX propagation in microcellular and picocellular environments

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Abstract— In this paper different propagation models for coverage prediction of WiMAX microcellular and picocellular urban environments and for WiMAX indoor femtocells at 3.5 GHz are compared with experimental data. Results obtained for different urban and indoor environments show that statistical models are quite far from good agreement with experimental data while deterministic ray-tracing models provide appropriate prediction in all different complex analyzed environments.

I. INTRODUCTION

The design and the deployment of wireless broadband access systems, and notably of WiMAX [1], represents nowadays one of the main challenges for telecommunication service providers, which need to perform cost/performance analyses, the costs being related to infrastructure deployment, required bandwidth and power consumption and the benefits to offered bit rate and coverage.

Different coverage strategies are envisaged to guarantee higher bit rates both in outdoor and indoor environments. In order to support WiMAX broadband mobile access also in indoor environments the introduction of WiMAX picocells and femtocells is needed in addition to conventional macrocellular and microcellular base stations. Due to the high penetration loss at the 3.5 GHz WiMAX frequency operation, pico- and/or femtocells base stations are likely to be essential to provide good indoor service quality.

Therefore, a layered cellular structure is foreseen for WiMAX coverage. This implies that propagation phenomena will be very different for each cellular layer and a suitable and adaptable propagation model will be required to correctly evaluate WiMAX coverage in all different propagation conditions.

The basic aim of this paper is to investigate propagation characteristics at WiMAX frequencies in microcellular and indoor environments and to characterise the multi form propagation phenomena involved which include street-corner effect and indoor penetration loss.

Different sets of WiMAX propagation measurements have been performed in both outdoor and indoor environments. These experimental data have been already analysed and discussed in the framework of COST 2100 action [2].

In this study we compare different propagation models with experimental results by means of mean error value and error standard deviation in order to identify the most suitable

prediction model which well fits measurements results in the different propagation conditions. For the comparison we considered statistical models available in literature for WiMAX systems, such as the COST 231 model [3] and the Stanford University Interim (SUI) model [4], and with ray-tracing deterministic models developed in our laboratory ([5], [6]).

In section II the measurement methodology and the different instrument equipment used to perform measurements is described. Outdoor car and pedestrian measurements results are presented and compared with simulation in section III while in section IV indoor measurements and simulations are discussed. Finally, conclusions on the suitability of the different predictions models for WiMAX urban environments are reported in section V.

II. MEASUREMENT EQUIPMENT AND CAMPAIGN

As mentioned, different sets of dual-polarized measurements were taken [2], in an outdoor scenario in the city of Bologna and in an indoor scenario at the Villa Griffone Laboratory located in Pontecchio Marconi, which is about 15 Km from the city centre.



Fig. 1 Base station placement for outdoor urban measurements

In the outdoor scenario the WiMAX antenna was installed in a balcony of a residential building approximately 10 m above street level (see Fig. 1), while in the indoor scenario it was located both inside and outside the building.

The installed WiMAX equipment is an Alvarion BreezeMAX 3000 μ BS (micro-Base Station) shown in Fig. 2. The duplexing frequency range is 3499.5-3553.5 MHz and 3550-3600 MHz for downlink (DL), and 3399.5-3453.5 MHz, and 3450-3500 MHz for uplink (UL) [7]. The ODU (outdoor data unit) was operating at 3551.75 MHz (DL) and 3451.75 MHz (UL), the maximum transmitter power is 28dBm and the omnidirectional antenna gain is 8 dBi.

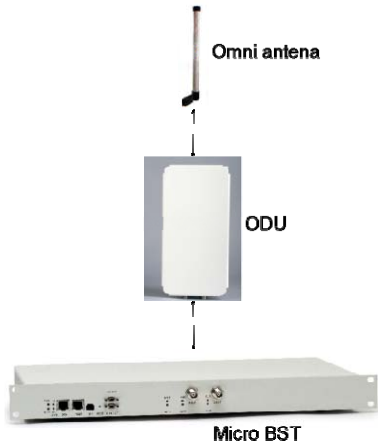


Fig. 2 Alvarion BreezeMAX 3000 equipment

In the first scenario receiver measurements were performed in streets (outdoor measurements) at different speeds (pedestrian and vehicular) while in the second scenario (Villa Griffone) measurements were taken only inside the building (indoor measurements).

Measurements were taken with both a Customer Premises Equipment (labelled CPE) and a spectrum analyser (labelled SA). The BreezeMAX CPE Si (Self-installable) is an indoor device and has six built in antenna elements with 9dBi gain and an optional 12 dBi external antenna (used for car measurements).

III. OUTDOOR RESULTS

Two kinds of outdoor measurements were taken: one with the mobile terminal (CPE) mounted on a car and one with the terminal put on a movable trolley (“pedestrian” measurements in the following).

The outdoor transmitted power is 28 dBm and the CPE was equipped with the 12 dBi omnidirectional external antenna. For measurements taken by car, the mobile antenna was placed on the windscreen on the passenger side.

Outdoor measurement routes are shown in Fig. 3: RCx denotes car routes while RPx are pedestrian routes. The urban area comprises residential buildings of about 20 m height, a shopping centre (on the lower left part of the picture) and some tree-lined streets.

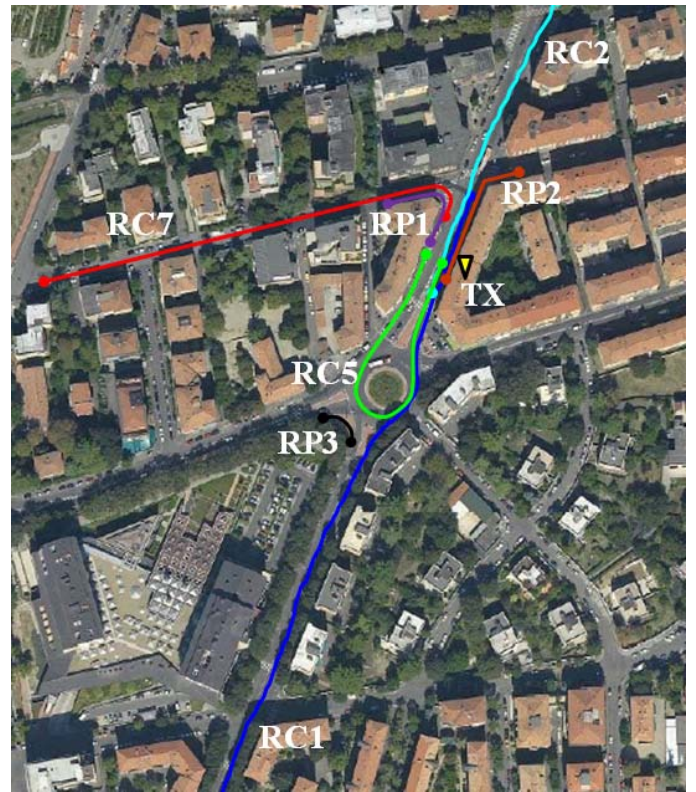


Fig. 3 Base station placement for outdoor urban measurements

A. Car measurements

We show here some results for two measurement paths, namely RC1 (Fig. 4) and RC5 (Fig. 5) comparing them with ray tracing results. In this case, the ray-tracing tool considers diffractions, reflections and scattering [5], while transmission through walls is not supported in this software version.

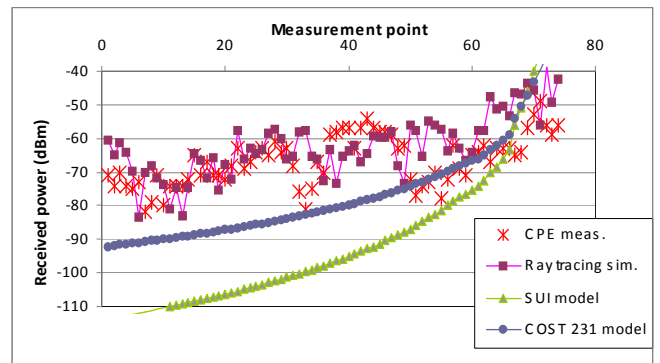


Fig. 4 Outdoor car measurement (route RC1)

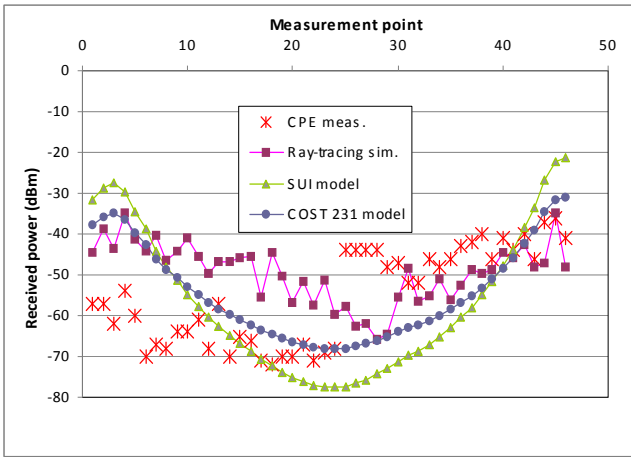


Fig. 5 Outdoor car measurement (route RC5)

From the above figures it is patent that statistical models like SUI and COST 231 are not suitable for predictions in this environment.

We also observe that, while for route RC1 the agreement between RT simulations and measurements is satisfactory, we notice remarkable errors in the first part of route RC5, which tend to disappear rather suddenly around half-way.

An explanation to this phenomenon can be found by looking at the map: in this route, the car drives in a roundabout and comes back towards the base station. So the difference between the two parts of the route can be accounted for, recalling that the CPE antenna was mounted on the windscreen: when the vehicle is driving away from the base station, it shields the antenna.

This phenomenon is was confirmed also by measurements taken along with route RC2, which was driven twice, once for each direction. Its results, which cannot be shown here due to space constraints, confirm a substantial difference between the two directions.

This behaviour will be object of further studies, that will be carried out to evaluate the effect of the vehicle structure and of the relative position of the antenna with respect to the transmitter on the received power. Similar studies for other frequency bands are already available in literature (see e.g. [8]).

B. Pedestrian measurements

We show here results for two pedestrian routes, RP1 (Fig. 6) and RP2 (Fig. 7). For route 6, we conducted measurements also with a spectrum analyser (SA). A screen capture of the SA measurements is shown in Fig. 8.

Agreement between measurements and ray-tracing simulations is generally good, apart from in one section of route RP1, after having turned the street corner, where the ray-tracing tool under-estimates received power. This might be explained by considering that the ground floor of the building on the corner hosts a shop with large glass windows, do in this case the transmission through the building could be not negligible. Further investigations are planned for this case.

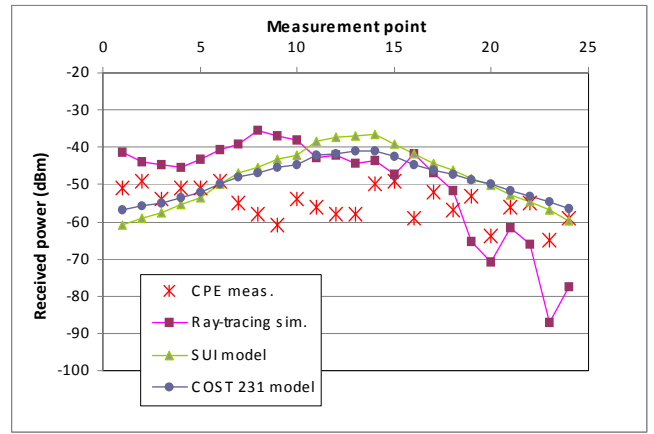


Fig. 6 Outdoor pedestrian measurement (route RP1)

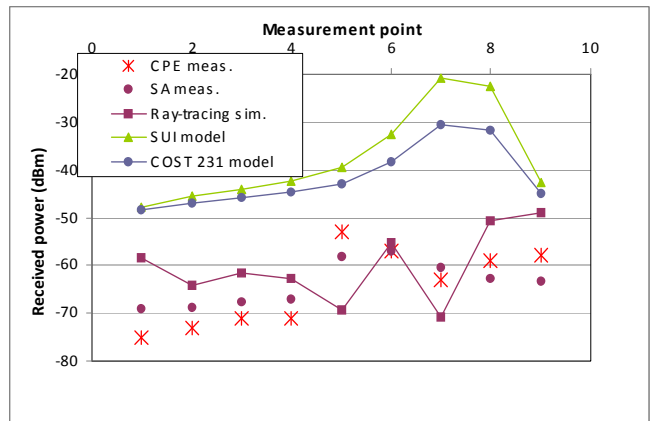


Fig. 7 Outdoor pedestrian measurement (route RP2)

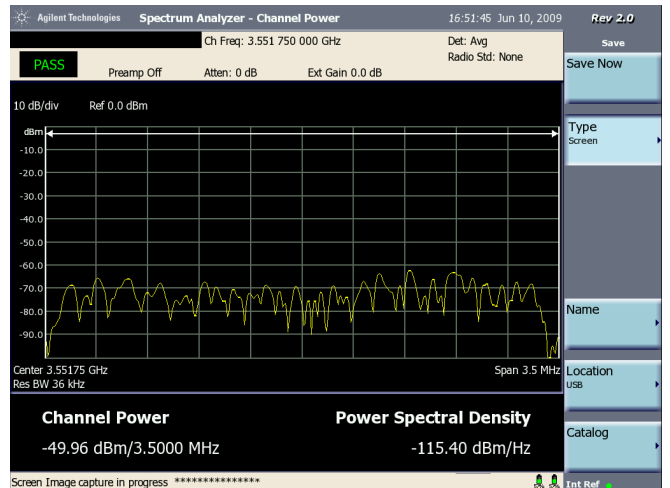


Fig. 8 Screen capture of the spectrum analyser measurements

Finally, also in this case it is clear that statistical models provide only a coarse estimate of received power.

TABLE I summarises the main statistical parameters for the various models.

TABLE I
STATISTICAL ANALYSIS OF OUTDOOR RESULTS
(μ = MEAN ERROR (dB), σ = ERROR STANDARD DEVIATION (dB))

Route	Ray-tracing		COST 231		SUI	
	μ	σ	μ	σ	μ	σ
RC1	4.23	8.83	9.69	12.66	23.23	19.71
RC2	0.17	11.33	7.44	12.77	19.20	19.70
RC5	-5.82	14.50	-0.84	14.01	1.53	18.24
RC5L*	7.23	7.33	9.54	9.93	12.11	15.53
RC1,2,5L	-0.95	10.31	8.92	12.27	20.13	19.39
RP1	-5.29	12.28	-6.44	7.08	-6.91	9.26
RP2	-4.19	10.19	-22.79	7.35	-26.87	8.98
RP3	2.75	7.65	16.09	4.05	28.64	4.21
RP1,2,3	-3.48	11.30	-5.63	14.27	-4.35	20.11

* comprises only locations from 25 to 47

In the table we present results for individual routes as well as for the overall car and pedestrian measurements sets. We also show results for the complete RC5 route and for its second part only (RC5L), that confirm the different results for the two parts of the path.

The table confirms that ray tracing is more suitable to predict field strength than statistical models, particularly when considering the error standard deviation. However this superior accuracy is achieved at the price of a higher computation time (about 10 minutes on a standard PC for each outdoor route).

IV. INDOOR RESULTS

Another measurement campaign was performed in the laboratory situated in Villa Griffone, near Bologna. In this case, the Tx power was set at the minimum, i.e. 13 dBm.

Here we present some results obtained at the first floor of the laboratory. The measurement scenario is depicted in Fig. 9: the Rx first moves towards the BS and then turns around into a side corridor.

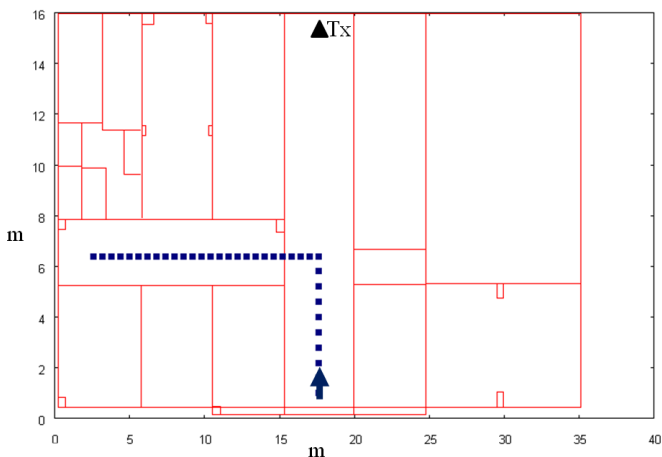


Fig. 9 Indoor measurement path

Fig. 10 shows the measurement results along with ray-tracing simulations. For this environment, we performed measurements both with the CPE and with a Spectrum Analyser (SA).

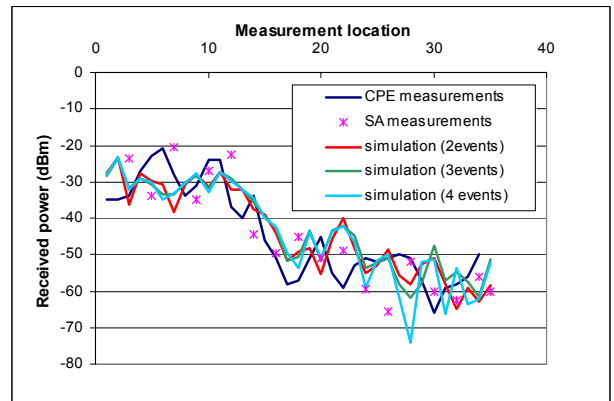


Fig. 10 Indoor measurements and ray-tracing simulations

We see that, as expected, received power drops (by about 20 dB) when the Rx turns and enters the NLOS region. We also observe that no substantial improvements are achieved by increasing the number of events (diffractions, reflections and transmissions) considered by the ray-tracing tool.

A statistical analysis of differences between the ray-tracing tool and the measurements is shown in TABLE II, for the case of two events (as we have seen, only minor improvements would be found considering more events).

TABLE II
STATISTICAL ANALYSIS OF INDOOR RESULTS

Measurement equipment	CPE	SA
Mean error (dB)	0.86	-0.24
Error standard deviation (dB)	7.74	8.90

V. CONCLUSIONS

In this paper we have presented some measurements of WiMAX propagation at 3.5 GHz in different environments (outdoor microcells in urban area and indoor picocells in a laboratory building). Measurements were compared with publicly available statistical models and with a proprietary ray-tracing tool.

Results show that the ray-tracing provides a satisfactory agreement with the measurements, provided that the environment is modelled with sufficient accuracy.

On the other hand, statistical models prove themselves unsuitable to a detailed prediction and they can be used only as preliminary evaluation tools.

Further investigation is required in order to study important issues such as the outdoor to indoor penetration and the effect of the car structure and position in case of car-mounted equipment.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

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