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Engineering Department

Simulating Multipath Characteristics Using Site Specific Propagation Model

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George Liang

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Presentation Outline

- Motivation
- Description of the Vertical Plane Launch Method
- Compare path loss simulations with measurements
    - For Rosslyn
    - For Munich
- Delay and Angle Spread Simulation in Munich
- Complementary work
    - Parallel Processing

Motivation

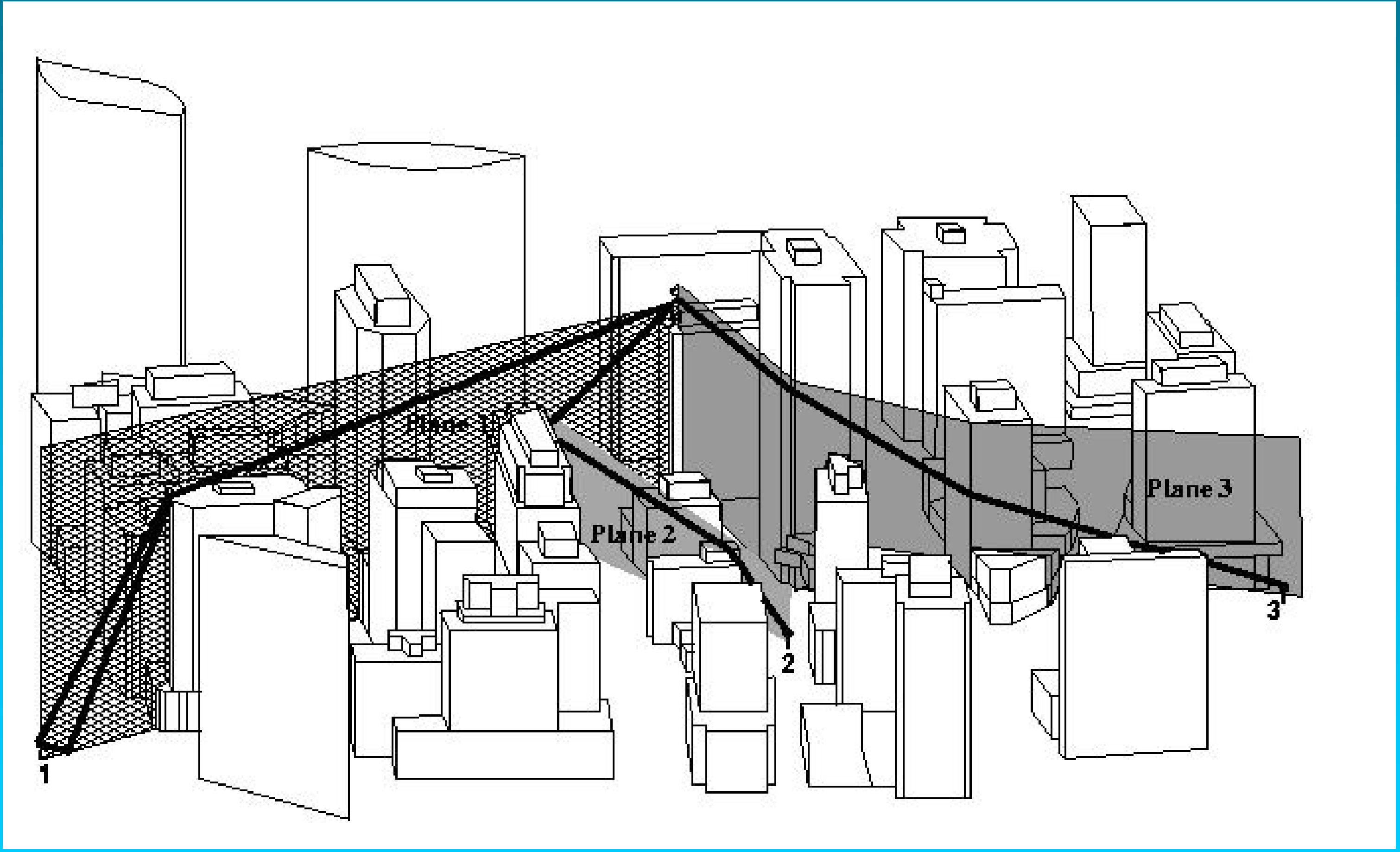
Simulate the multipath channel characteristics using deterministic physics based models and the actual shape and location of the buildings in some region

Applications:

- Communication simulator for selecting system parameters and evaluating performance
- Provide statistical channel parameter (Monte Carlo simulations) for evaluating radio systems
- Generate installation design rules for base station placement
- Radio location solution (i.e. E911)

Brief Explanation of the Vertical Plane Launch Method

Vertical Plan Launch Concept



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Description of the VPL

- *Uses Shoot-Bounce-Rays in the horizontal plane*
- *The ray trajectory in elevation is calculated deterministically*
- *Reflections are modeled with the Fresnel reflection coefficient for dielectric half space*
- *Edge Diffraction at a vertical edge are modeled with GTD/UTD coefficient modified for a dielectric wedge.*
  - *One source ray will generate a family (cone) of diffracted rays*
- *Diffraction at a horizontal edge is modeled slightly different*
  - *Still uses GTD/UTD for a dielectric wedge*
  - *Only 2 diffracted rays (will not have Keller cone of rays), in the incident and specularly reflected direction*

Description of the VPL (cont.)

Propagation paths that are considered:

- *Specular reflections from vertical building walls*
- *Single and double edge diffraction at vertical edges*
- *Multiple forward diffraction at horizontal edges, one backward diffraction*
- *Rough surface diffuse scattering can be specified for any building wall*
- *Limited number of transmitted paths into/out of a buildings using general characteristics of the building's floor plan and interior material properties*
- *Combinations of all of the above propagation paths*

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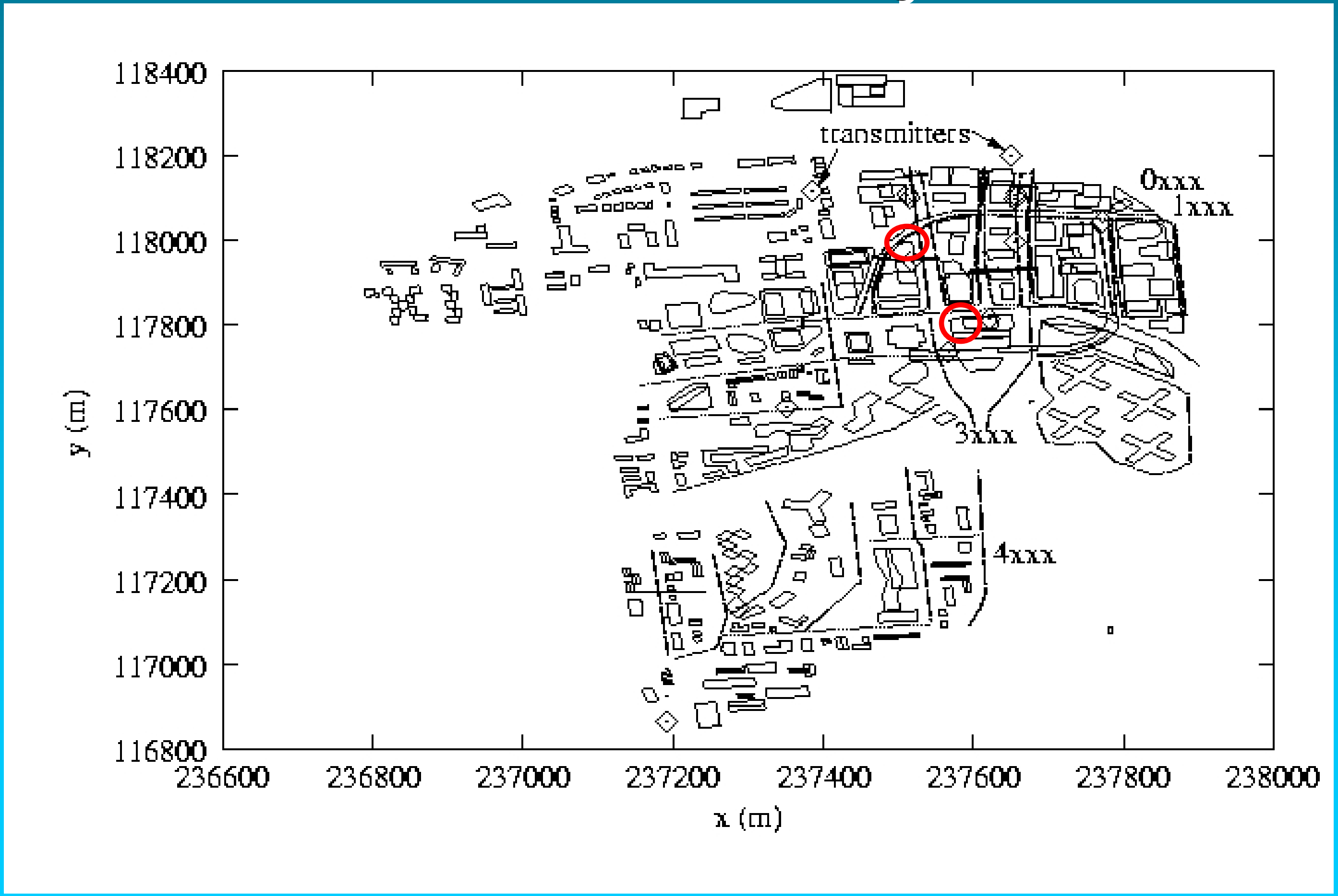
Comparison with Measurements in Rosslyn, Virginia

Transmitter Location and Measurement Routes in Rosslyn



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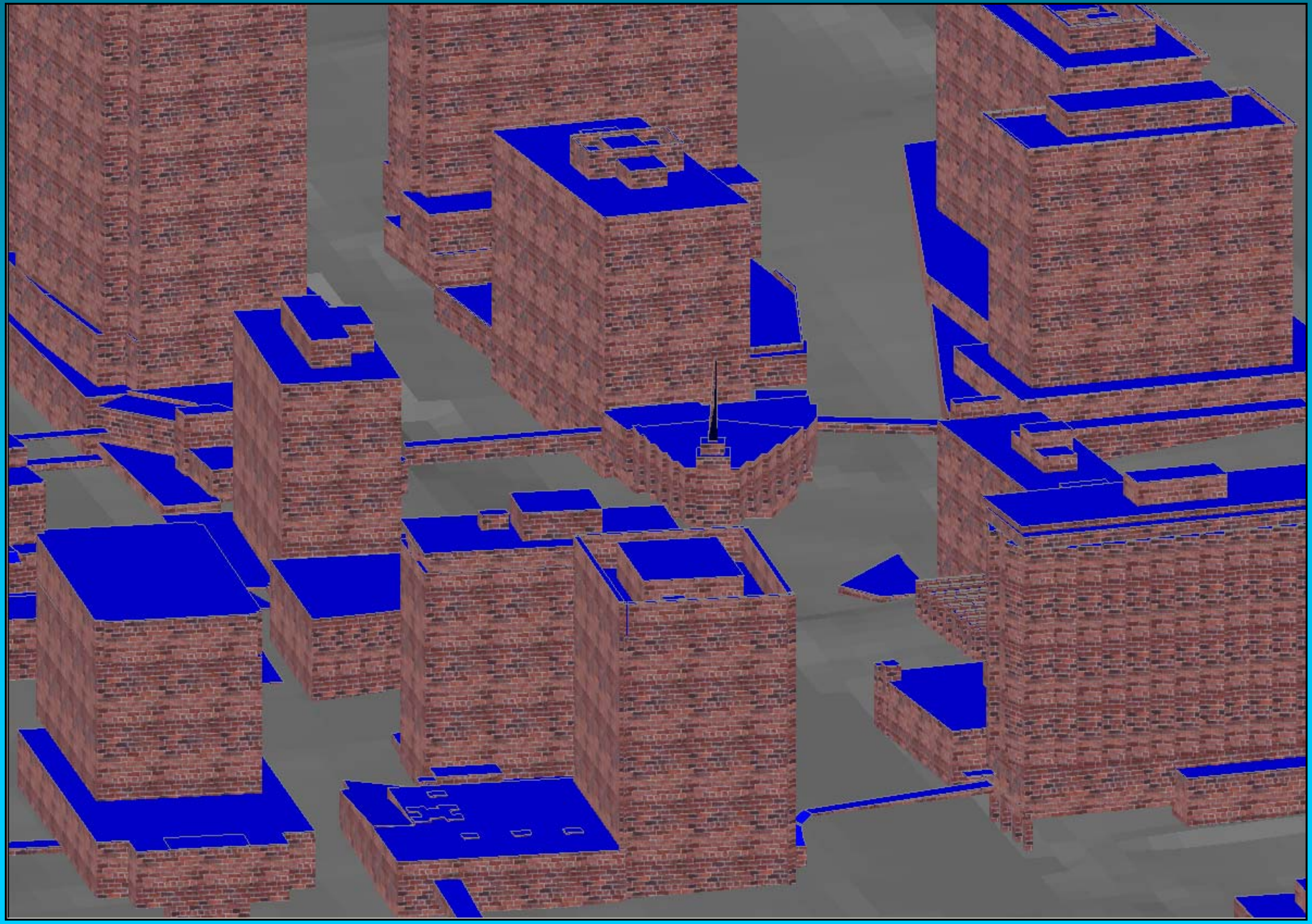
Building Characteristics of Rosslyn

Another View of Buildings in Rosslyn

Virtual Rendering of Rosslyn



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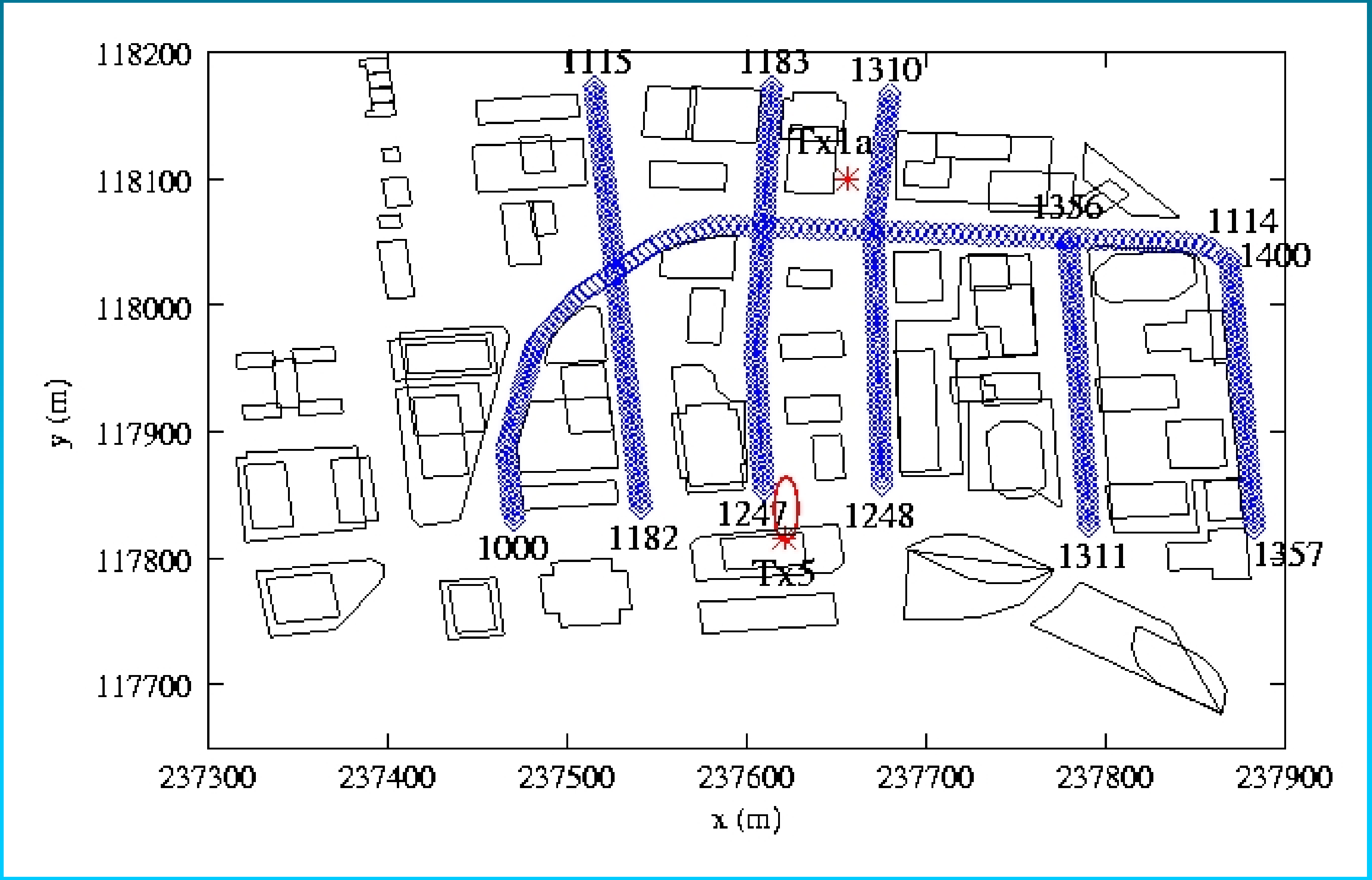
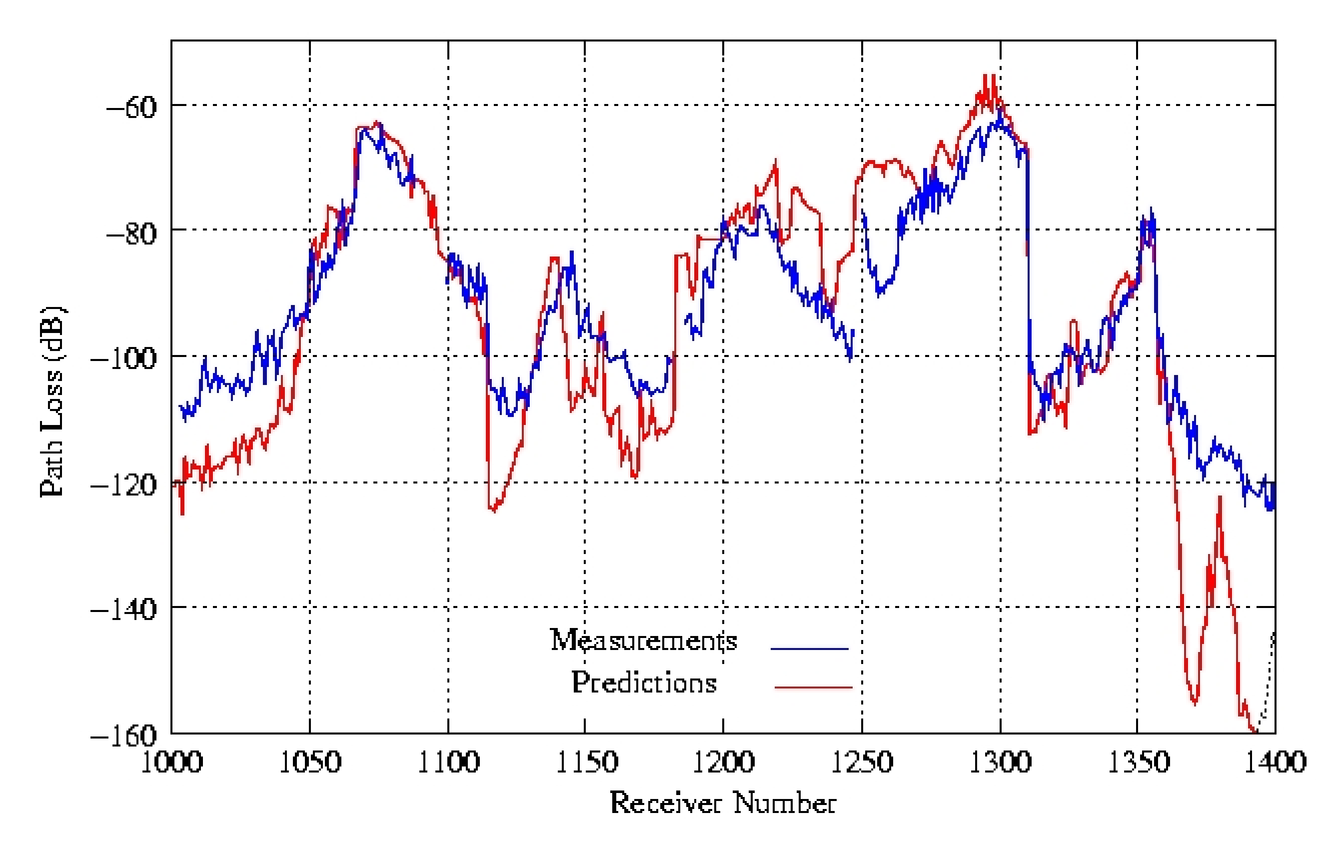
Transmitters and Receivers in Core Rosslyn



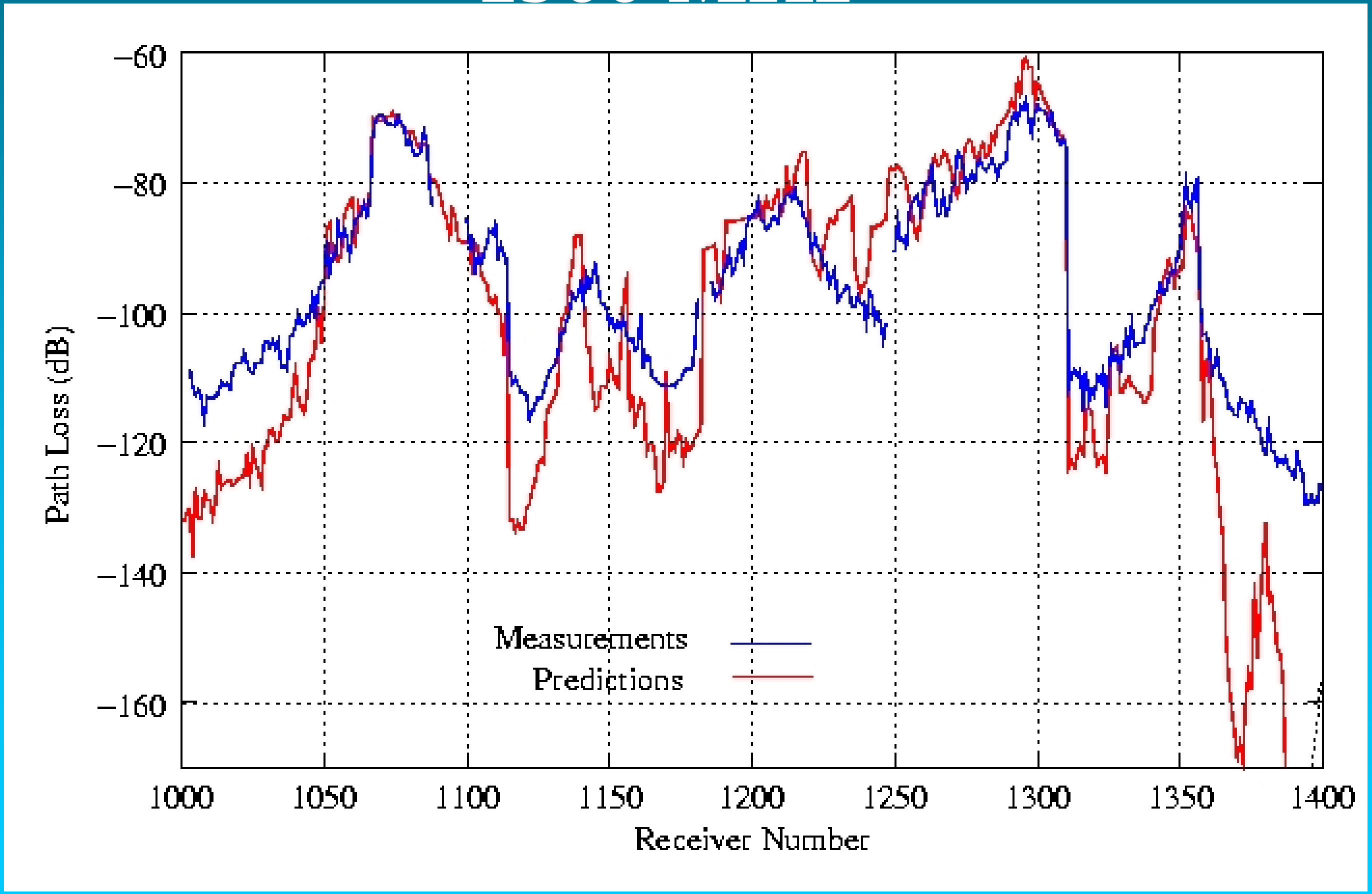
Comparison with Measurements for Tx 1a at 900 MHz



All Receivers $\eta = -3.26dB$ $\sigma = 12.25dB$

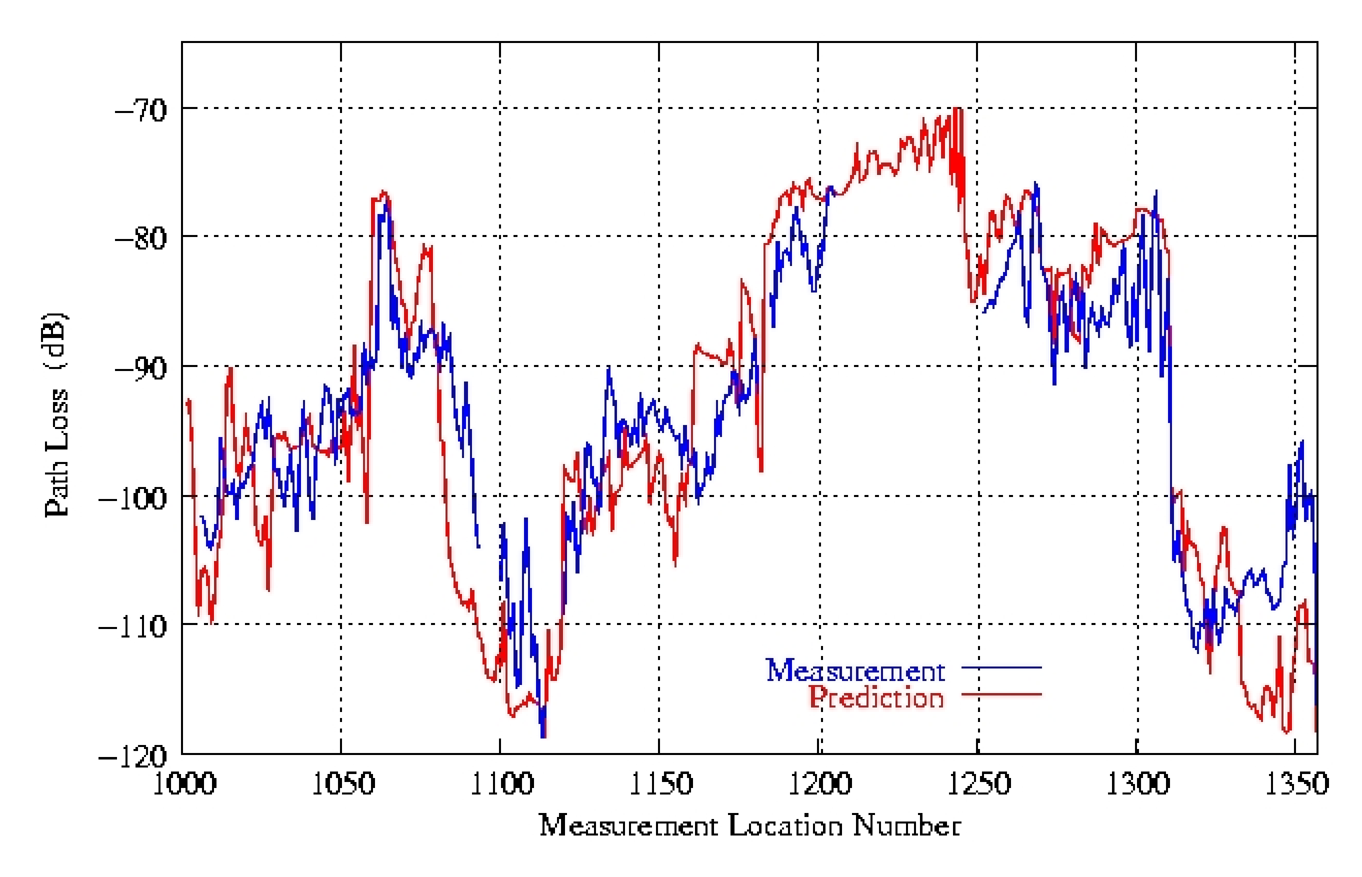
Without Rx 1357-1400 $\eta = -0.48$ $\sigma = 8.92$

Comparison with Measurements for Tx 1a at 1900 MHz



All Receivers	$\eta = -6.65dB$	$\sigma = 13.70dB$
Without Rx 1357-1400	$\eta = -3.23$	$\sigma = 8.86$

Comparison with Measurements for Rooftop Antenna in Rosslyn



All Receivers	$\eta = -1.76dB$	$\sigma = 7..97dB$
Without Rx 1357-1400	$\eta = -0.22$	$\sigma = 6.39$

Composite Error Statistics for Rosslyn

Street Level			η (dB)	σ (dB)	η (dB)	σ (dB)
1A	1XXX		-0.48	8.92	-3.23	8.86
1B	0XXX		6.93	8.50	5.53	8.57
2B	0XXX		5.58	8.67	5.39	9.75
3A	0XXX		7.82	7.60	7.87	9.19
3B	0XXX		10.17	7.81	9.07	9.40
4A	0XXX		7.30	7.23	7.59	8.50
4B	0XXX		9.01	6.23	8.75	6.69
8	1XXX		2.22	6.43	5.72	8.03
9	1XXX		2.03	7.38	0.37	9.88
10	1XXX		3.34	7.72	1.62	8.24
10	3XXX		-2.11	8.75	-2.68	9.29
10	4XXX		1.14	9.58	3.06	12.50
11	3XXX		0.12	8.43	-1.54	9.50
11	4XXX		-1.95	9.09	-0.78	11.29
12	3XXX		1.22	7.21	-6.72	8.29
12	4XXX		4.14	8.64	-0.85	9.68
Rooftop						
5N	1XXX		-0.22	6.39	-4.32	6.79
6E	1XXX		0.79	4.90	-4.21	5.61
6SE	1XXX		-0.50	5.33	-2.28	7.23
6NE	1XXX		-0.50	5.61	-7.67	8.14
All Transmitters			2.80	8.88	1.03	10.28

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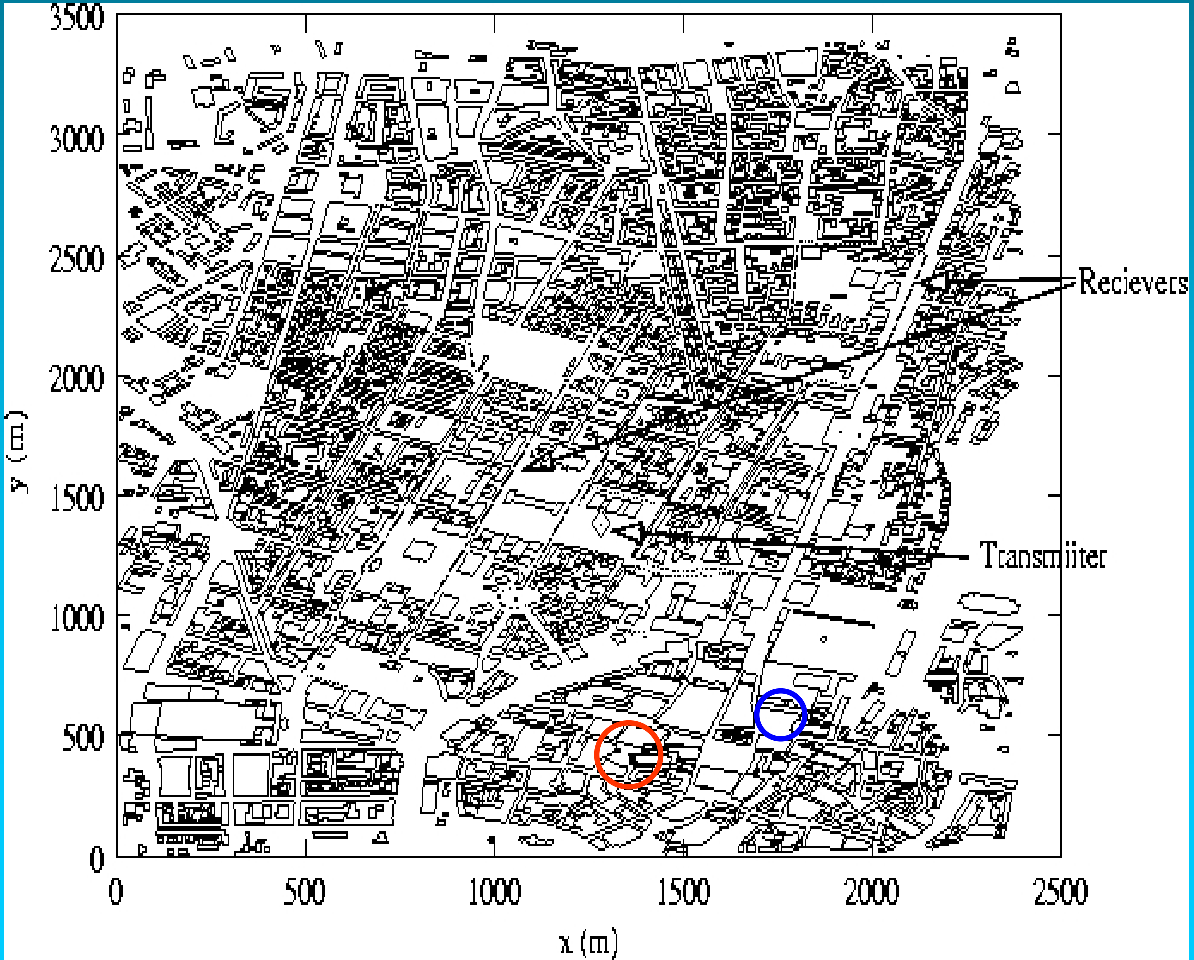
Comparison with Measurements in Munich, Germany

Transmitter Location and Measurement Routes in Munich



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Bird's Eye View of Munich

Street Level View of Munich

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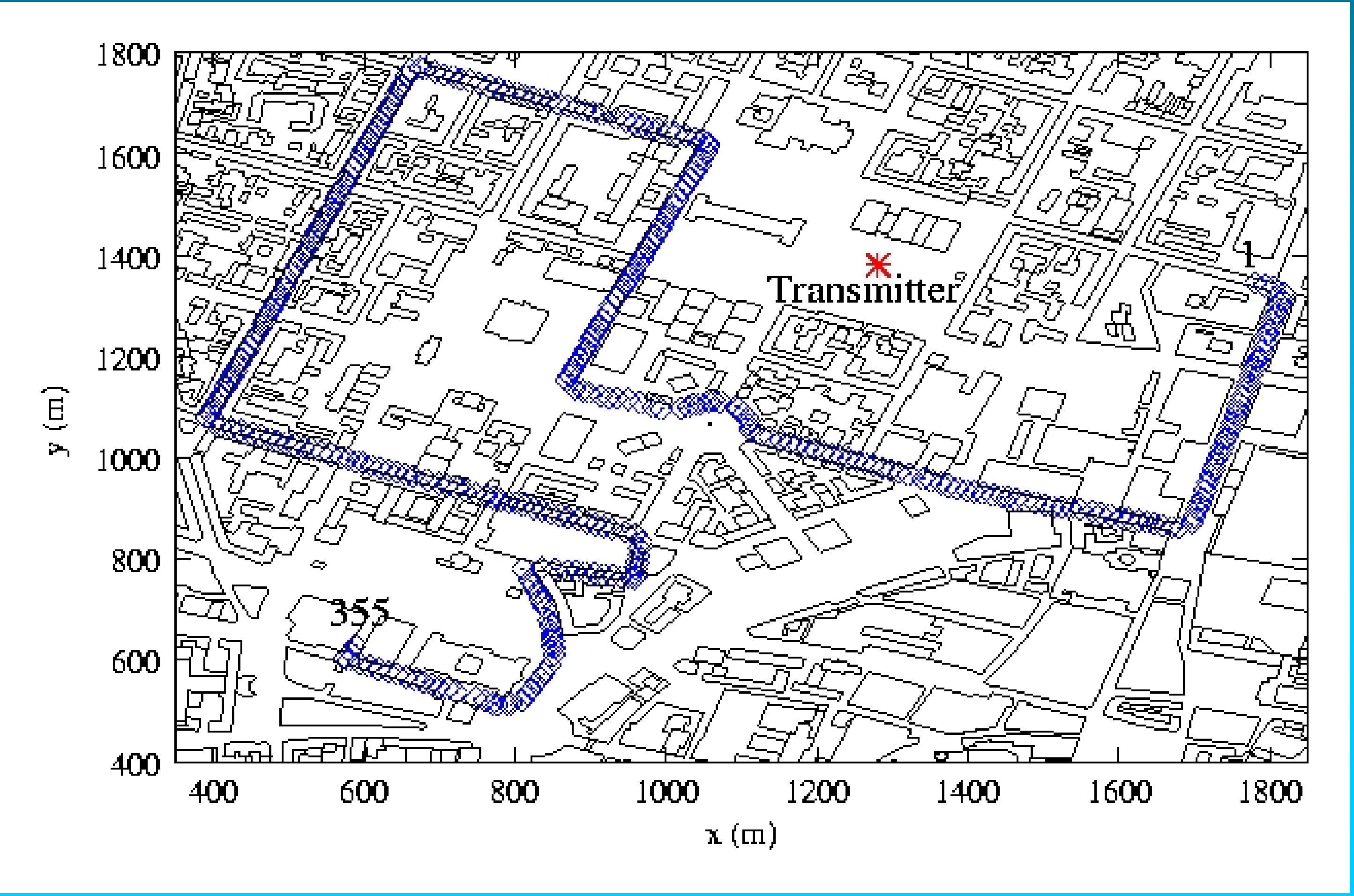
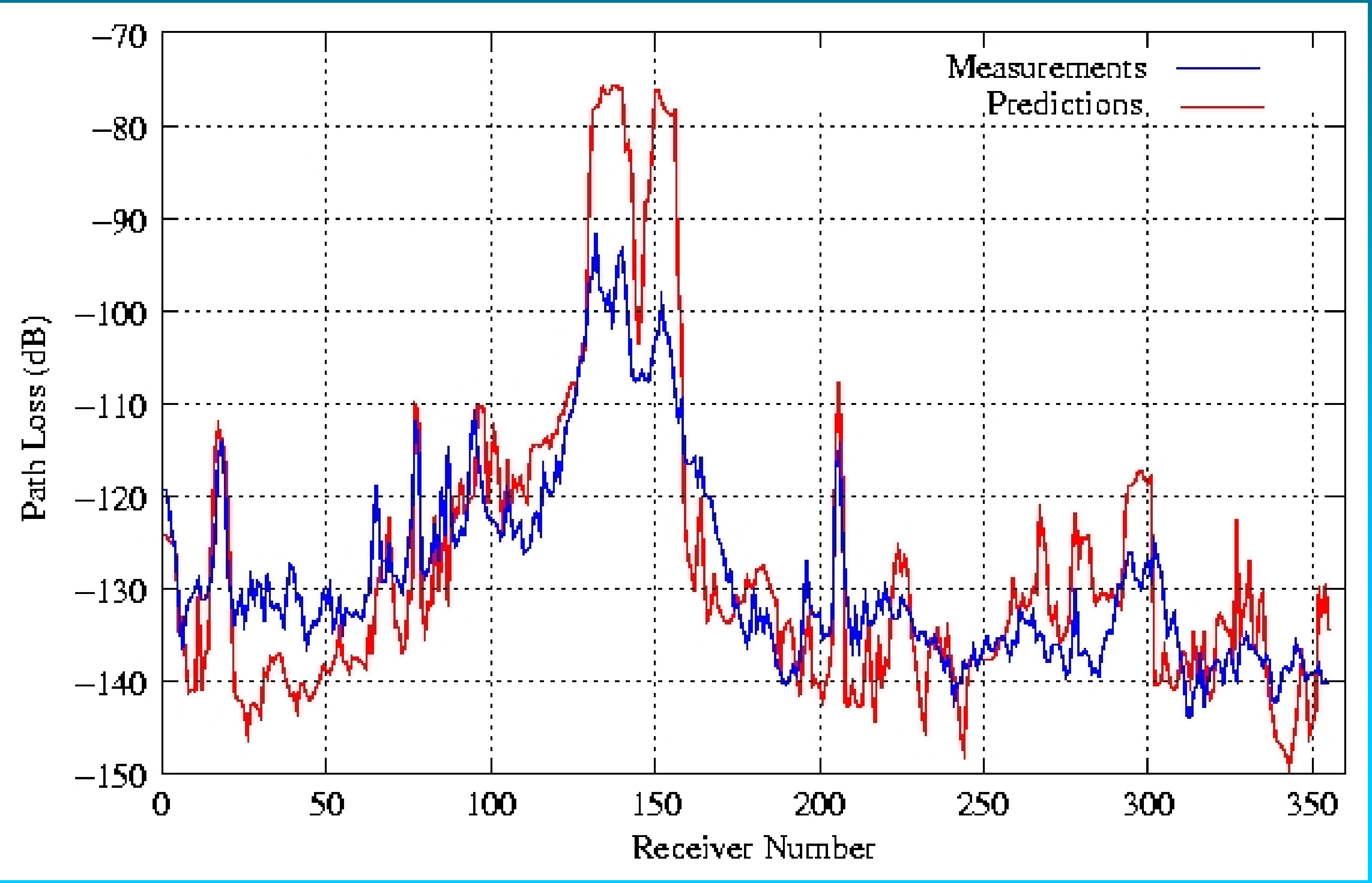
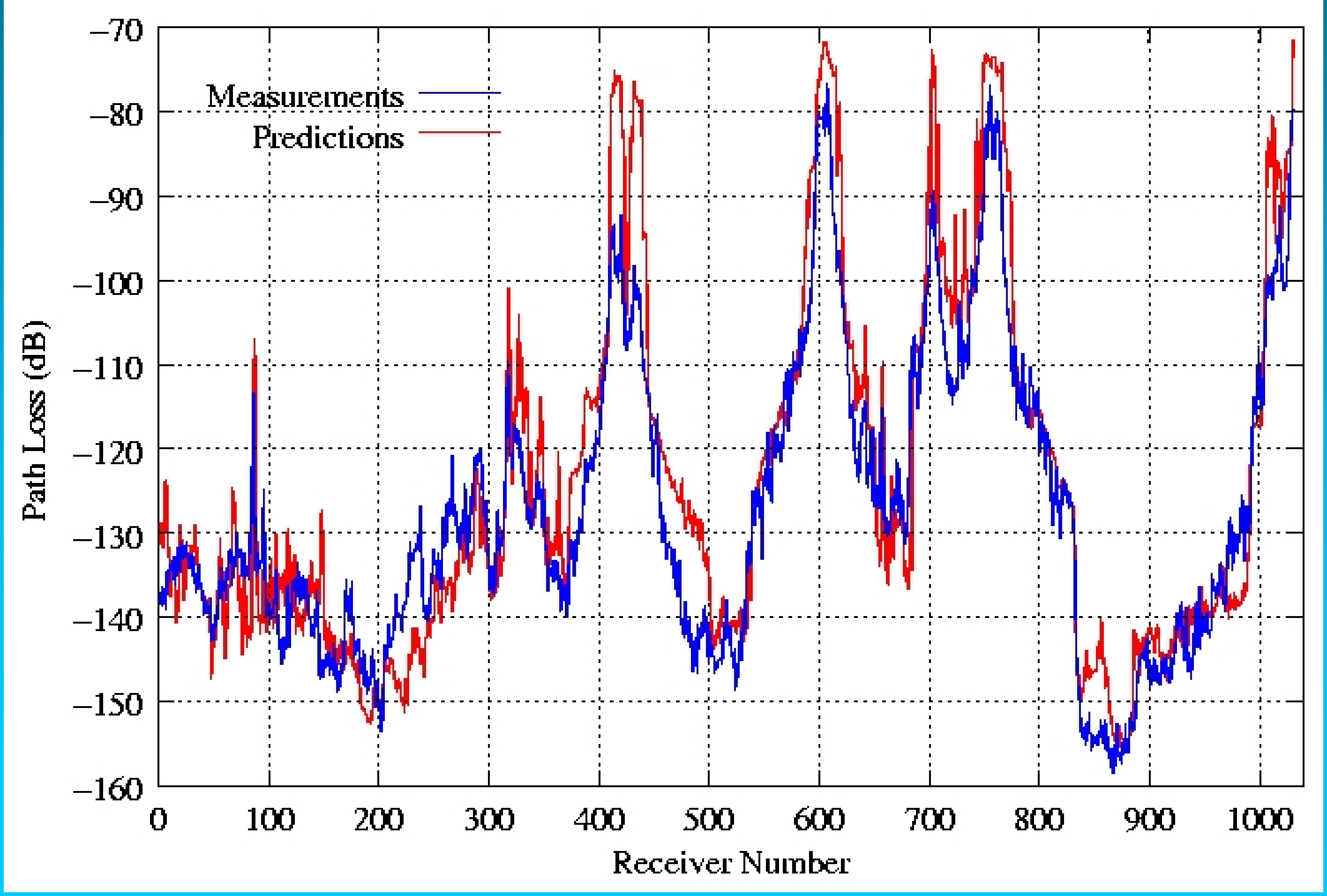
Detail View of Transmitter and Receiver Locations for Route 1



Comparison with Measurements on Route 1



Comparison with Measurements for Route 2



Error Statistics for Munich

	Average Error (dB)	Std Deviation (dB)
Route 0	2.28	6.70
Route 1	0.80	8.56
Route 2	2.88	7.29

Time Delay
and
Angle Spread

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RMS Time Delay and Angle Spread

RMS Delay Spread

$$DS^{(j)} = \sqrt{\frac{\sum_m |A_m^{(j)}|^2 (\tau_m^{(j)} - \overline{\tau^{(j)}})^2}{\sum_m |A_m^{(j)}|^2}}$$

RMS Angle Spread

$$AS^{(j)} = \frac{180}{\pi} \sqrt{\frac{\sum_m | A_m^{(j)} |^2 | \underline{v}_m^{(j)} - \overline{\underline{v}^{(j)}} |^2}{\sum_m | A_m^{(j)} |^2}}$$

$DS = T\sqrt{R}y$

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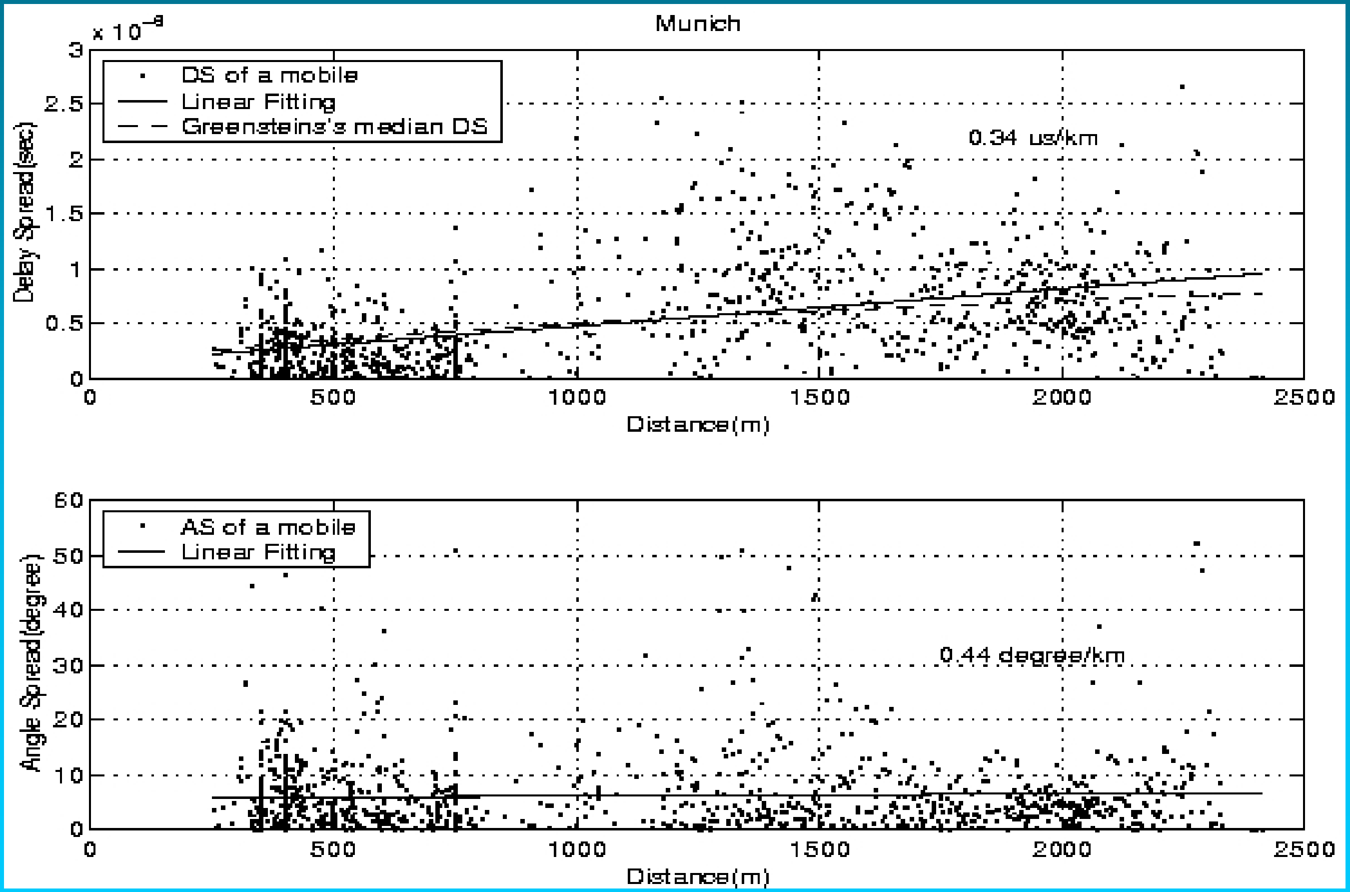
Time Delay and Angle Spread for Munich



Greenstein's statistical model $DS = T\sqrt{R}y,\ \mathrm{T} = 0.5\mu s,\ \ \mathrm{y} = 1$

Propagation Simulation with Parallel Processing

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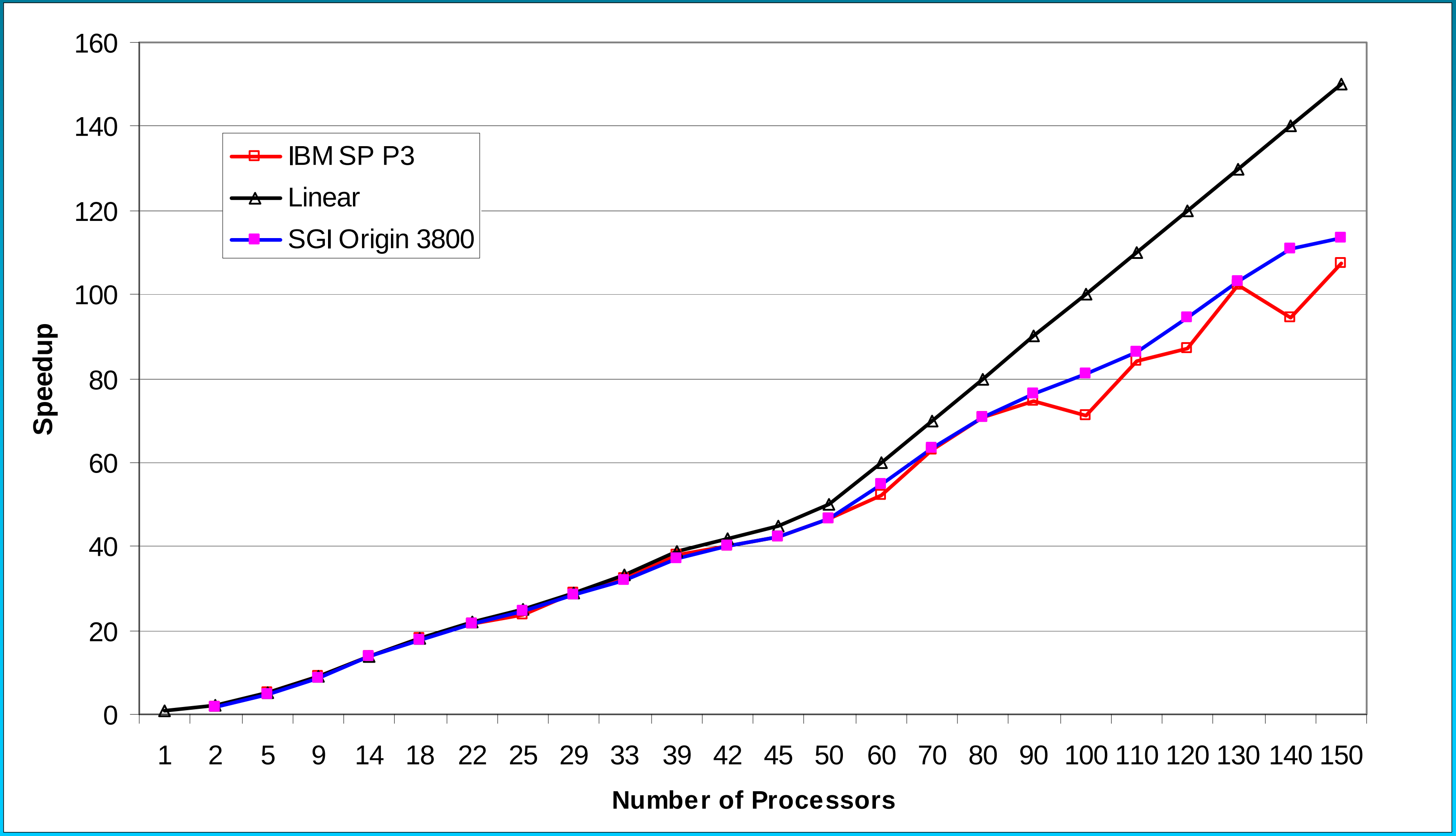
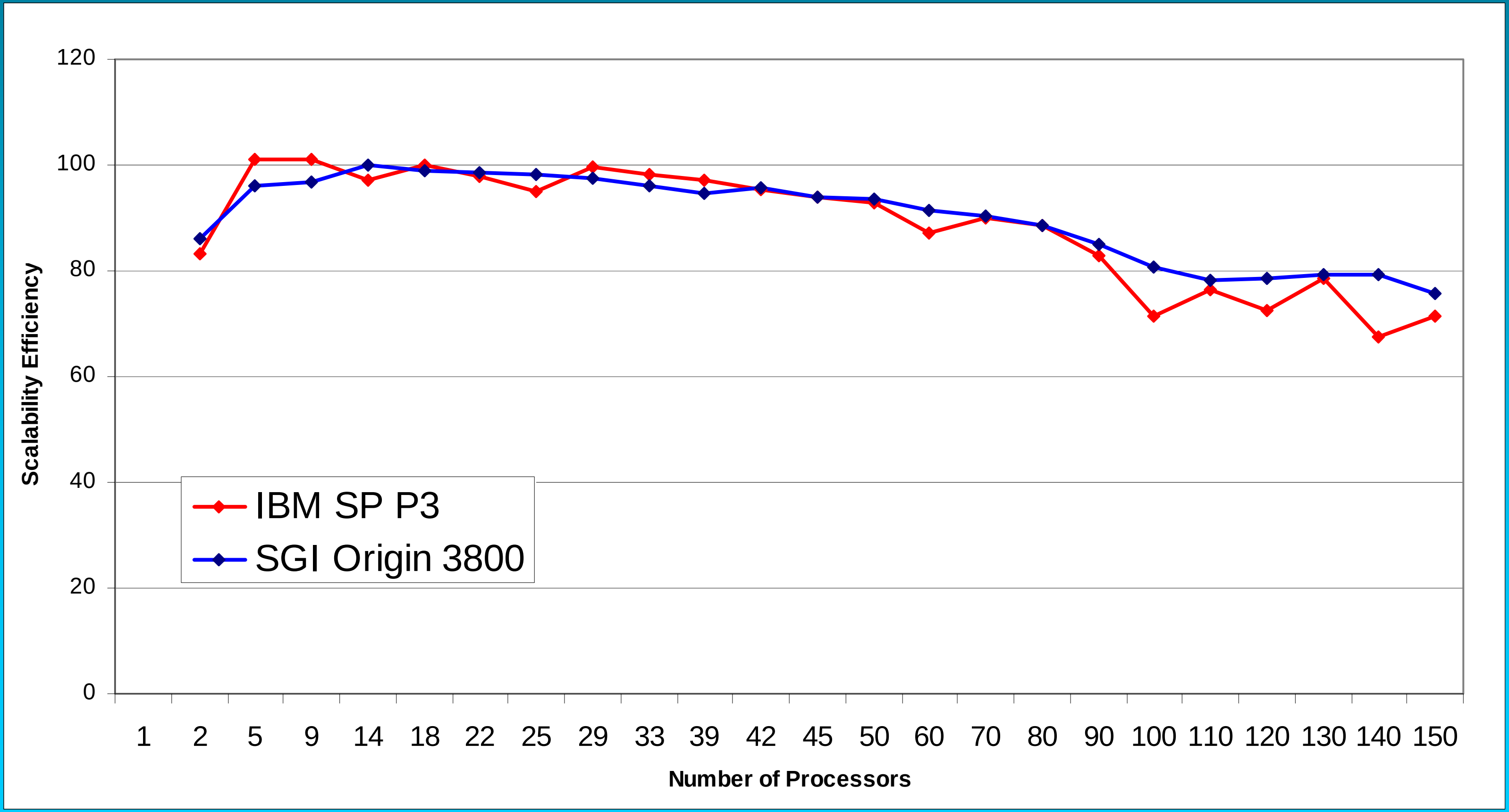
Speedup due to Parallel Processing



Scalability of Parallel Processing



Conclusions

• Deterministic ray based can provide accurate path loss prediction at UHF and microwave frequencies

- at different frequencies
- at different building environments

• Site specific propagation models might be able to accurately model the impulse response and angle of arrival characteristics

"Embrace the multipath"