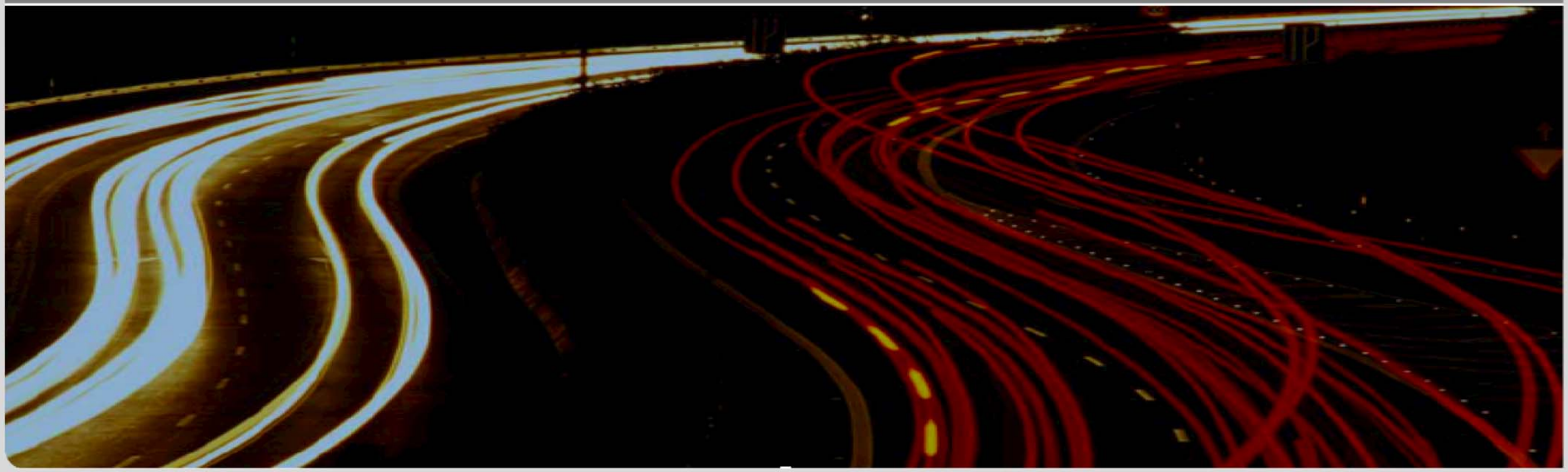
Karlsruhe Institute of Technology

Virtual Drive Verification Base Station - Car

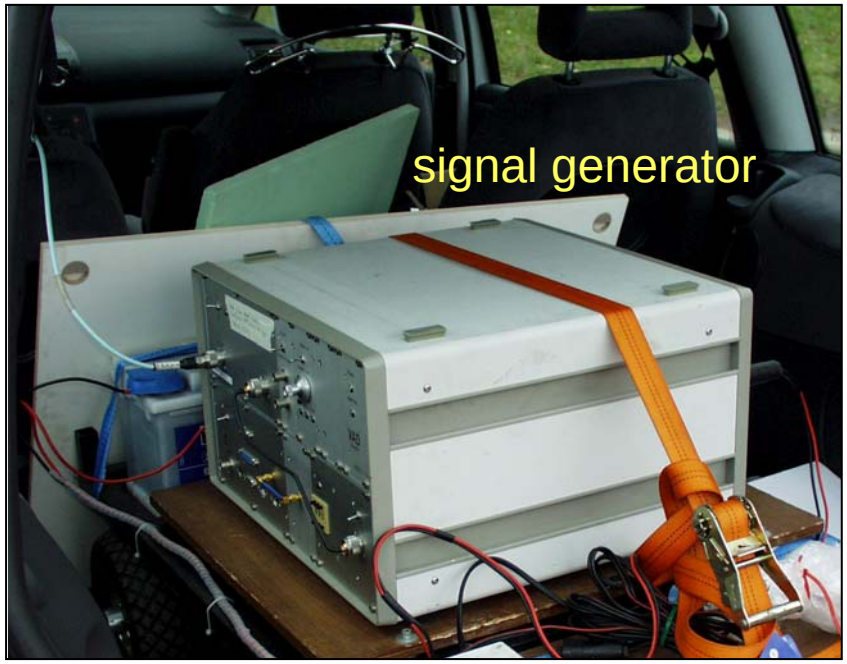
Prof. Dr.-Ing. Dr. h.c. Dr.-Ing. E.h. mult. Werner Wiesbeck

Institut für Hochfrequenztechnik und Elektronik



Measurement Setup – Transmitter

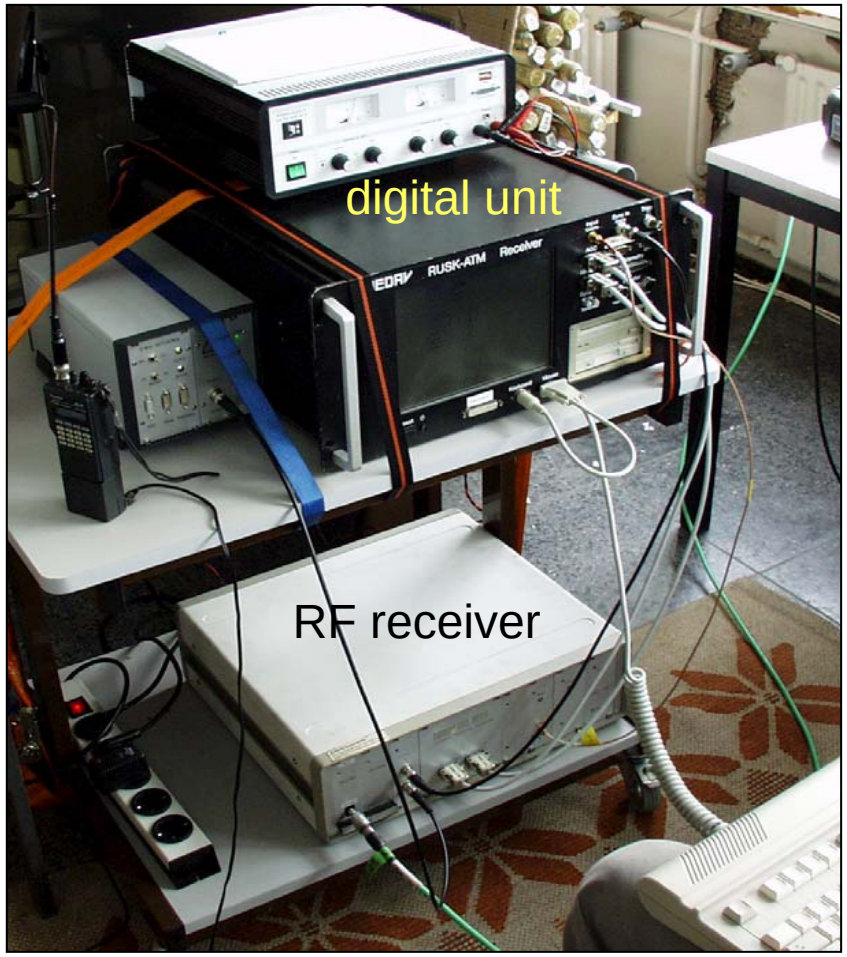
Measurement system: RUSK-ATM channel sounder (MEDAV)



RF frequency:	f_c = 2 GHz
bandwidth:	B = 120 MHz
transmit power:	P_{Tx} = 33 dBm

Institut für Hochfrequenztechnik
und Elektronik

Measurement Setup – Receiver

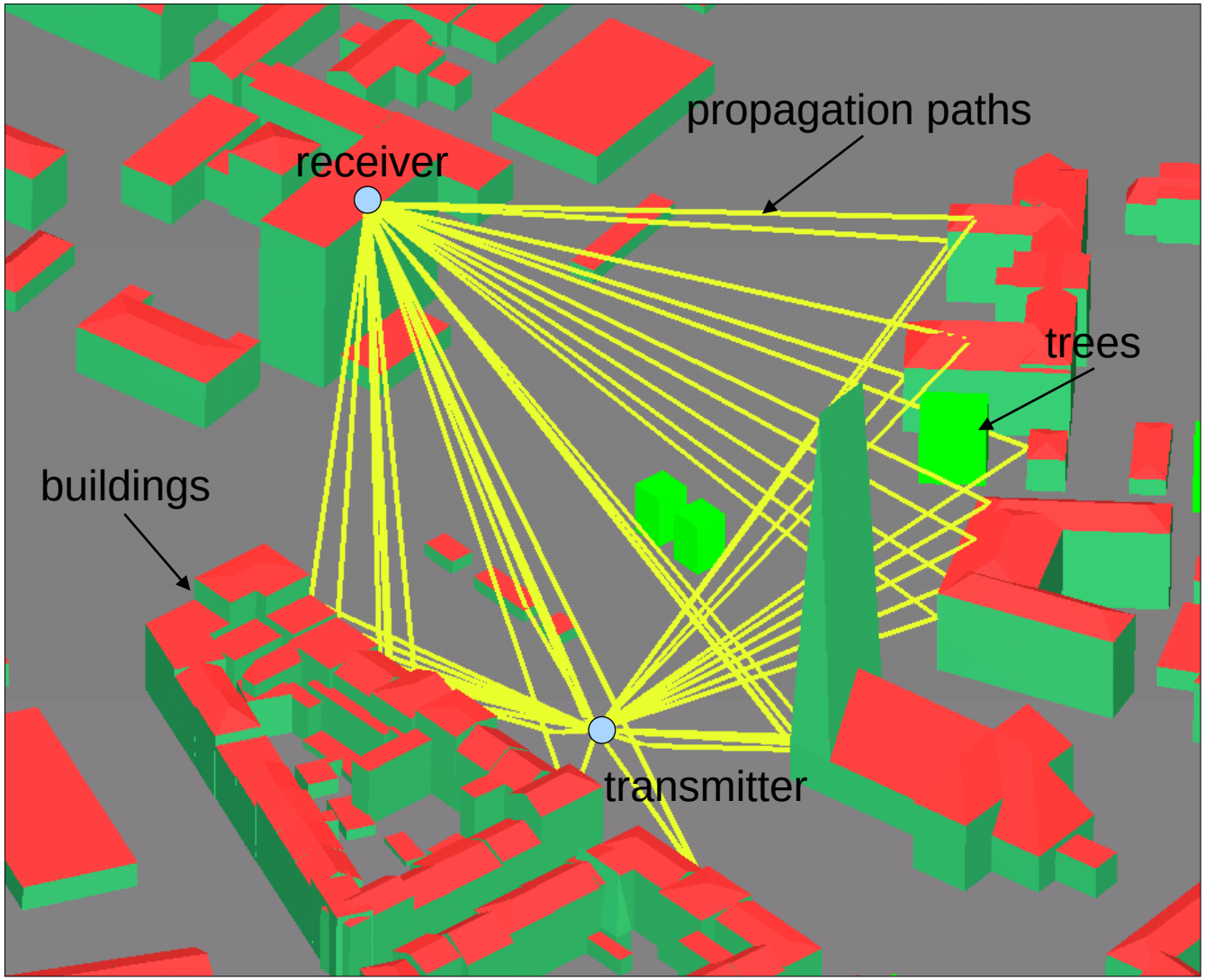


receiver sensitivity

P_{Rxmin} = -88 dBm

Institut für Hochfrequenztechnik
und Elektronik

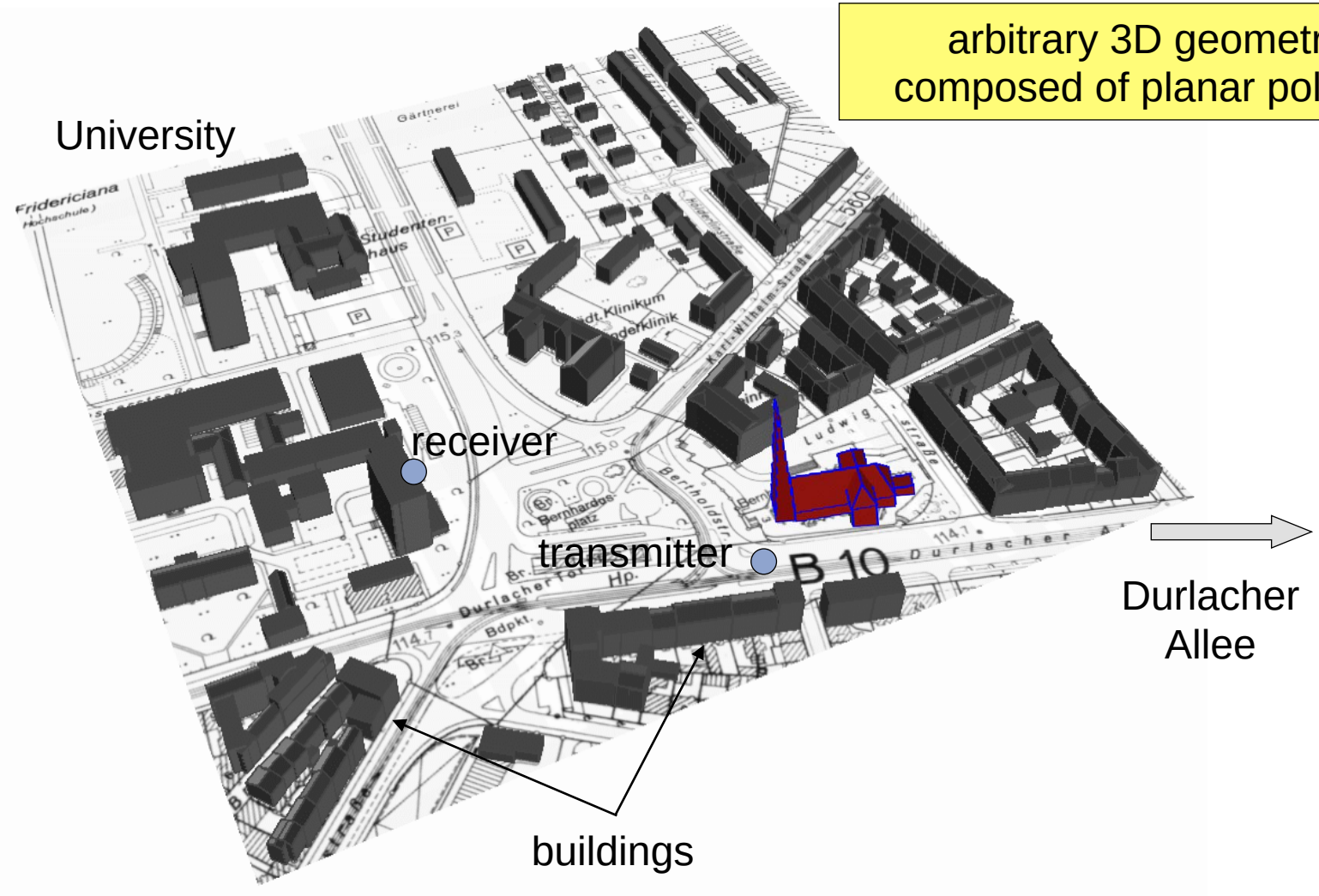
Ray-Tracing Example (Durlacher Tor, KA)



Institut für Hochfrequenztechnik
und Elektronik

3D Vector Data Modeled Environment

arbitrary 3D geometries
composed of planar polygons

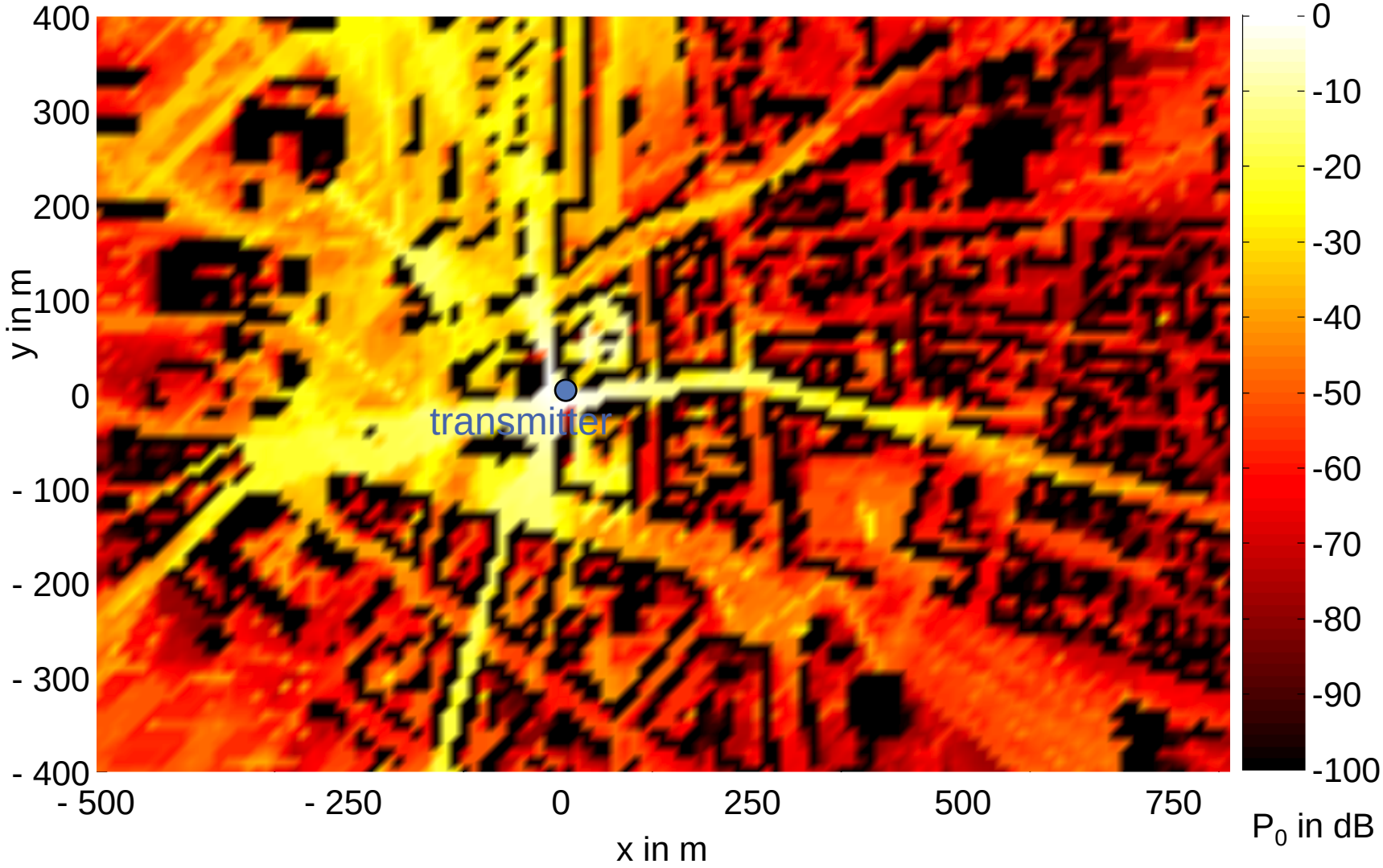


Measurement Scenarios – City of Karlsruhe

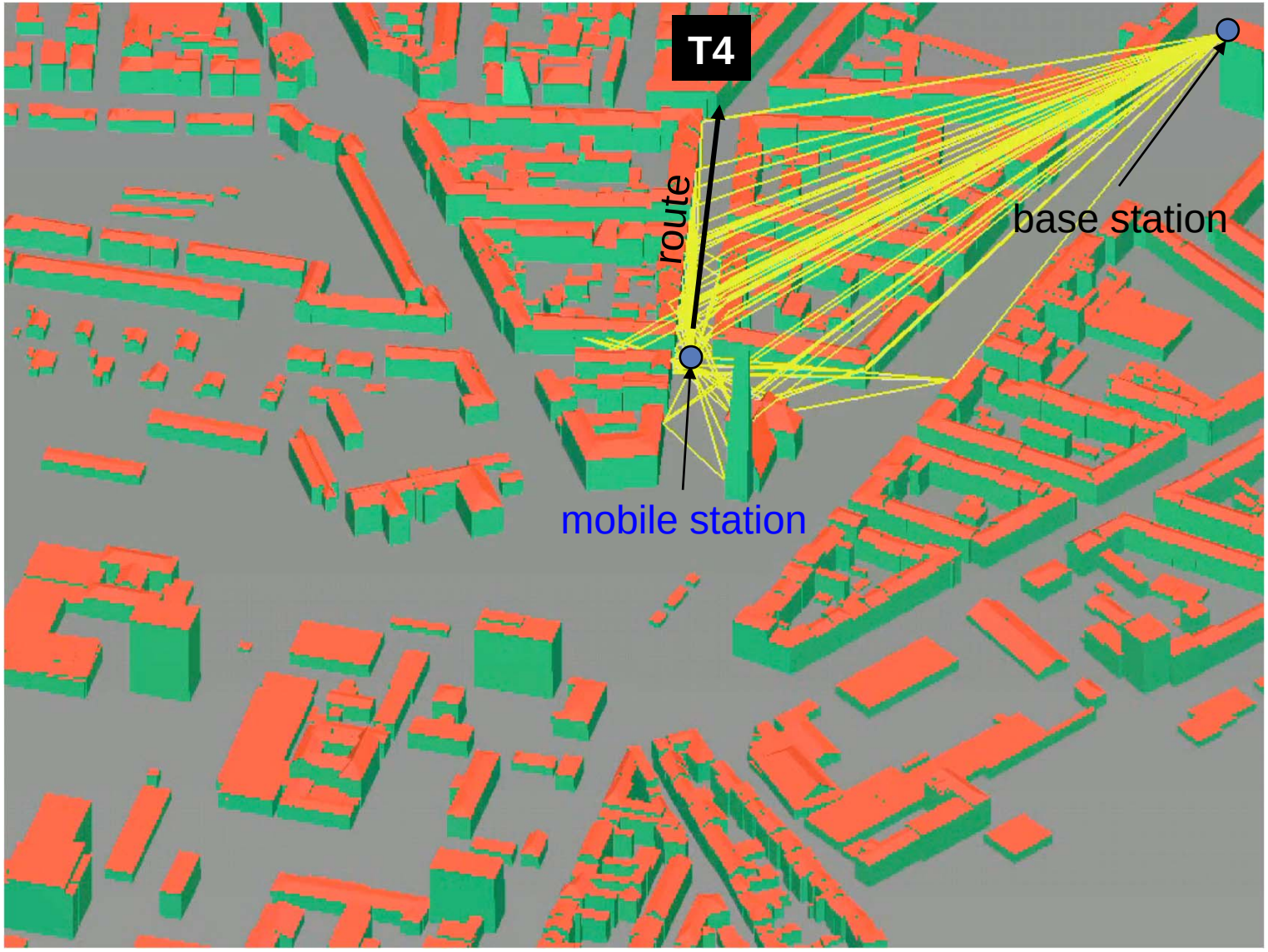
- h_{Rx} = 40 m
- h_{Tx} = 2.1 m
- v ≈ 7.3 km/h

≈ 35.000 snapshots

Result of Laminar Propagation Simulation



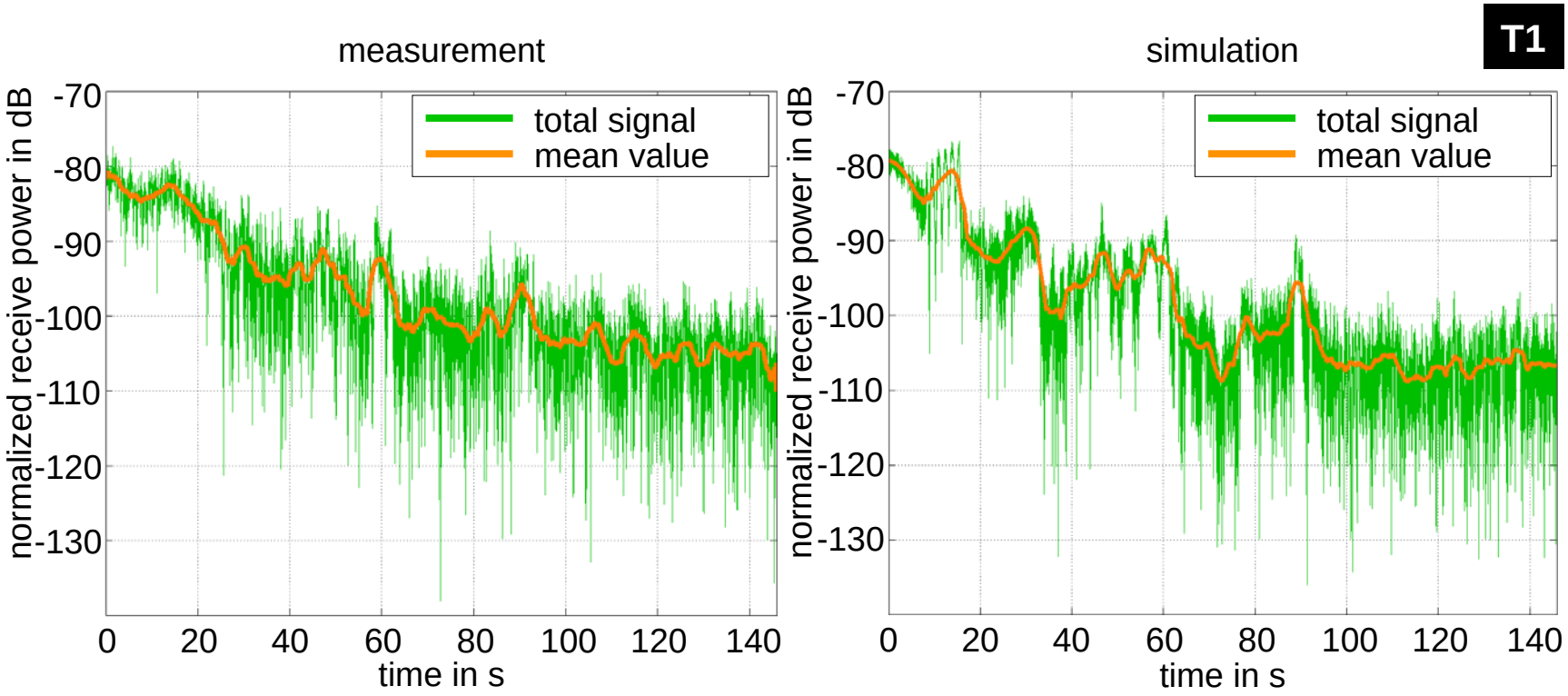
Time Dependent Simulation of Wave Propagation



Institut für Hochfrequenztechnik
und Elektronik

Simulated Wave Propagation in Karl-Wilhelm-Street

Comparison Measurement / Simulation T1



$$s(t) = m(t) \bullet r(t)$$

m(t): long-term fading

- absolute values

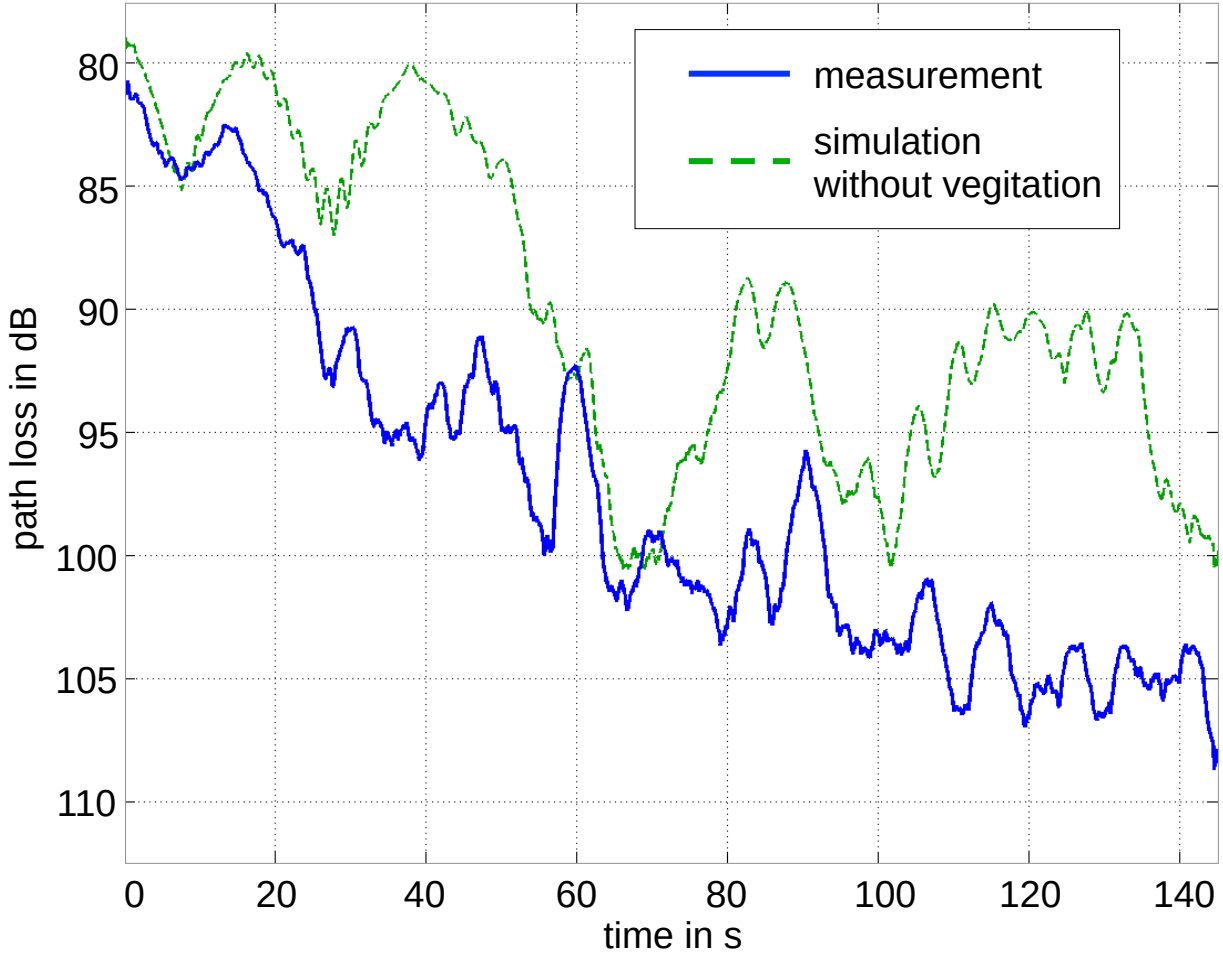
r(t): short-term fading

- statistical parameters

Institut für Hochfrequenztechnik
und Elektronik

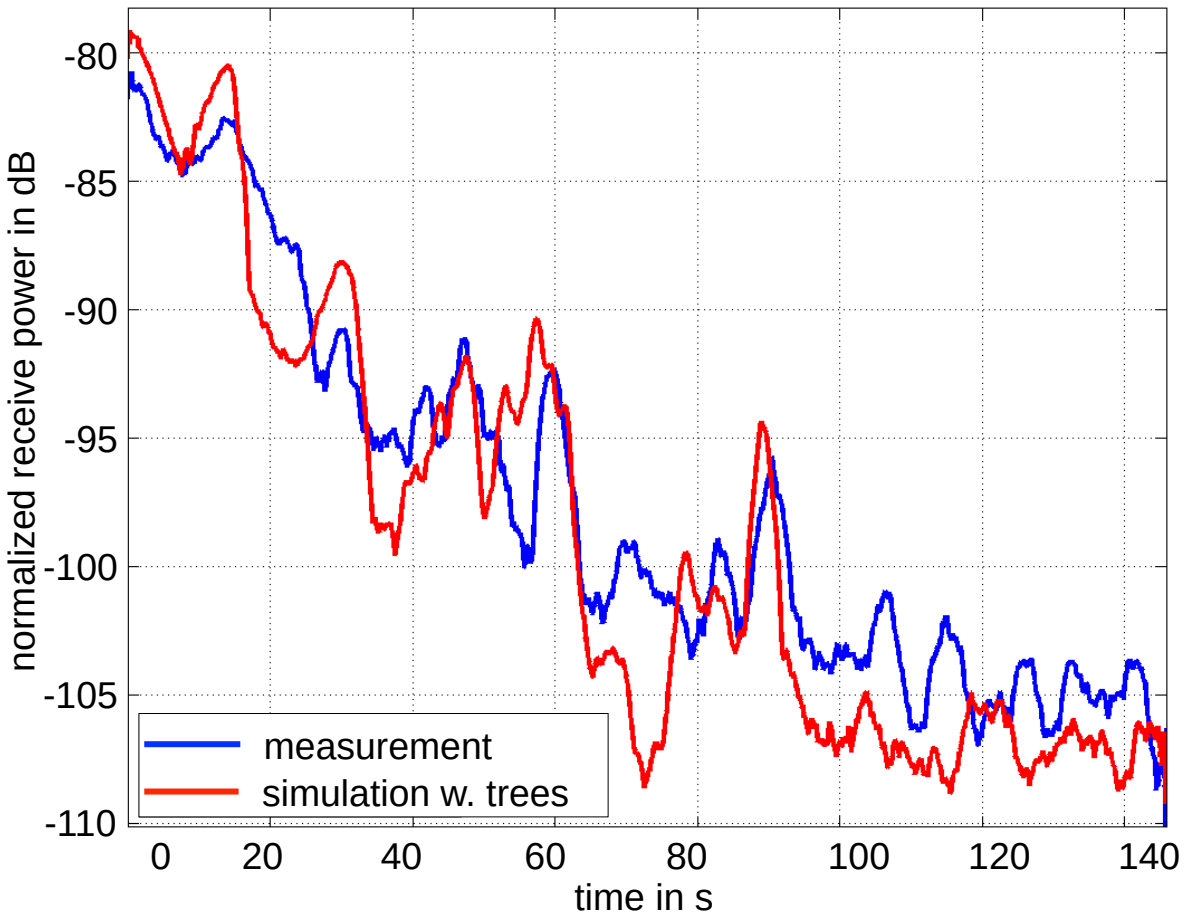
Long-term Fading (without vegetation)

T1



Comparing Long-term Fading (with vegetation)

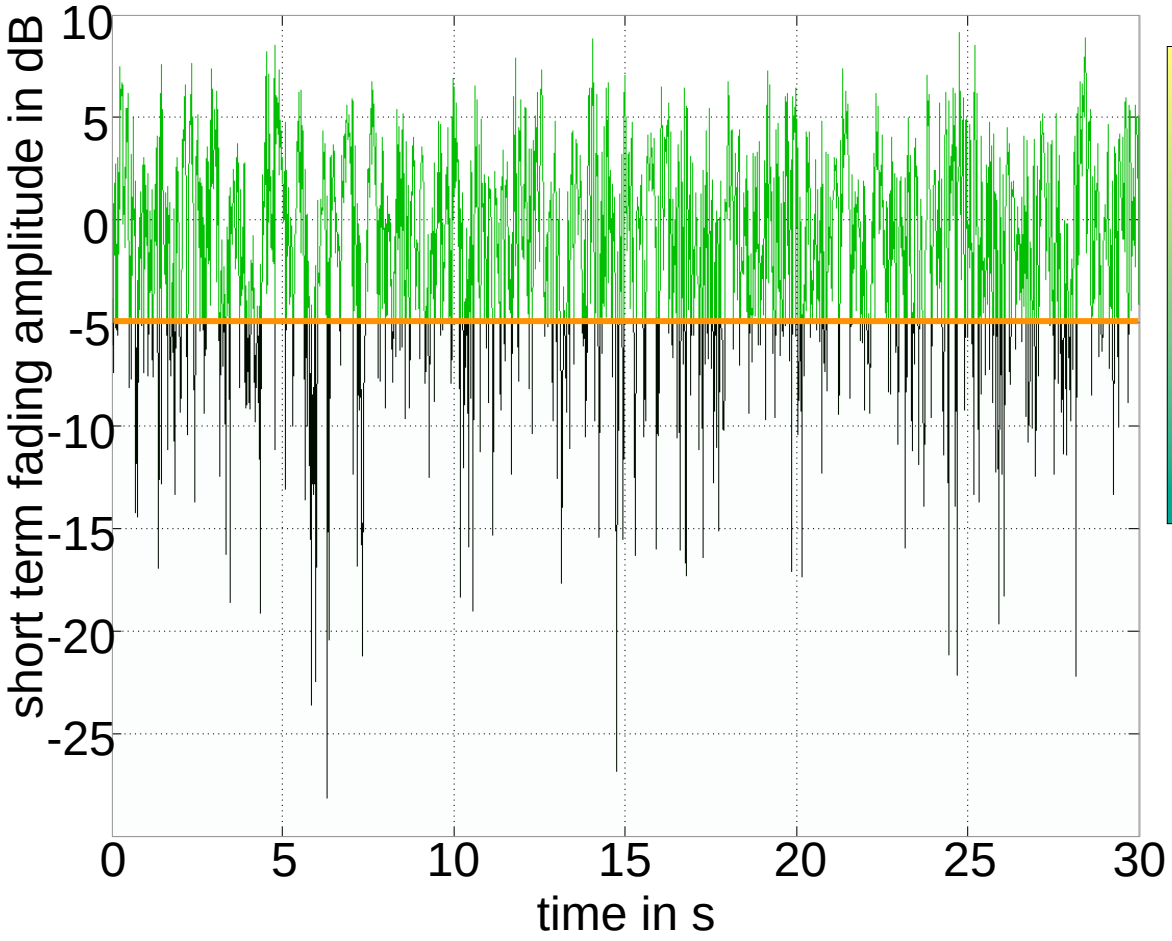
T1



mean error: μ = 1.27 dB standard deviation: σ = 2.85 dB

Short-term Fading Properties

T1

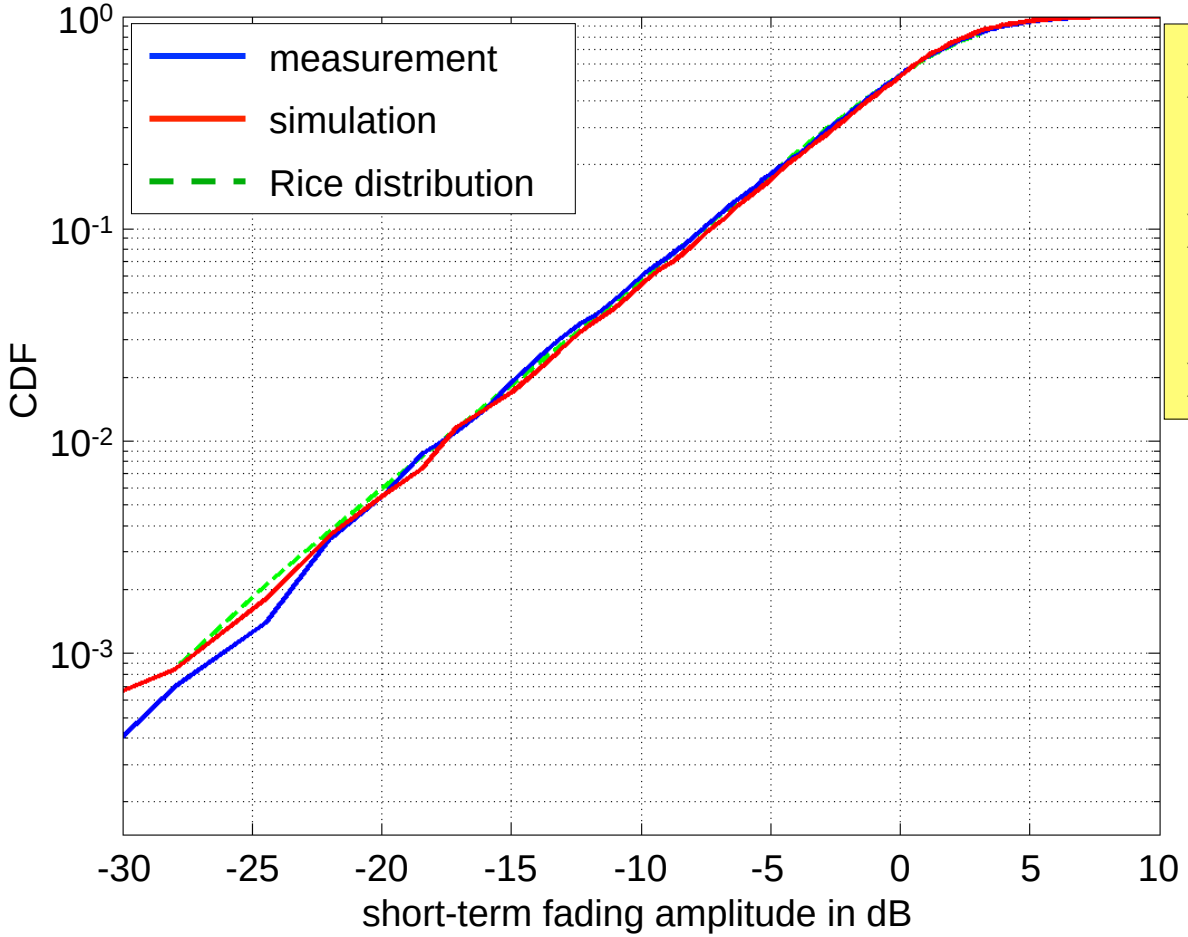


- CDF:
  Cumulative Distribution Function
- LCR:
  Level Crossing Rate
- AFD:
  Average Fade Duration

Short-term Fading

T1

Cumulative Distribution Function (CDF)

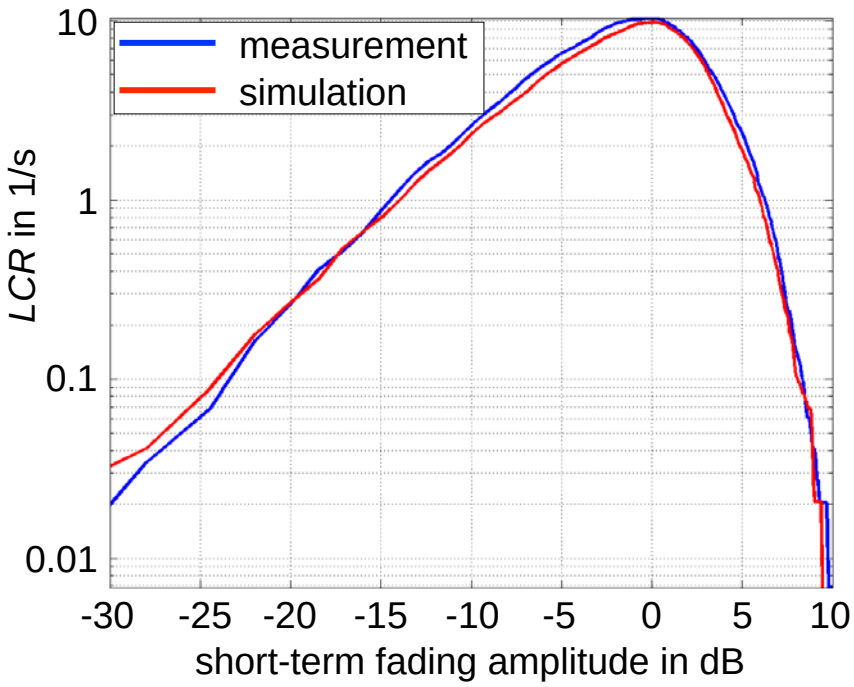


- mean difference:
  Δ = 20,7 % (≅4.3 dB)
- max. difference:
  Δ_{max} = 200 % (≅14.2 dB)
- *K* - factor: $K \approx$ 1.3 dB

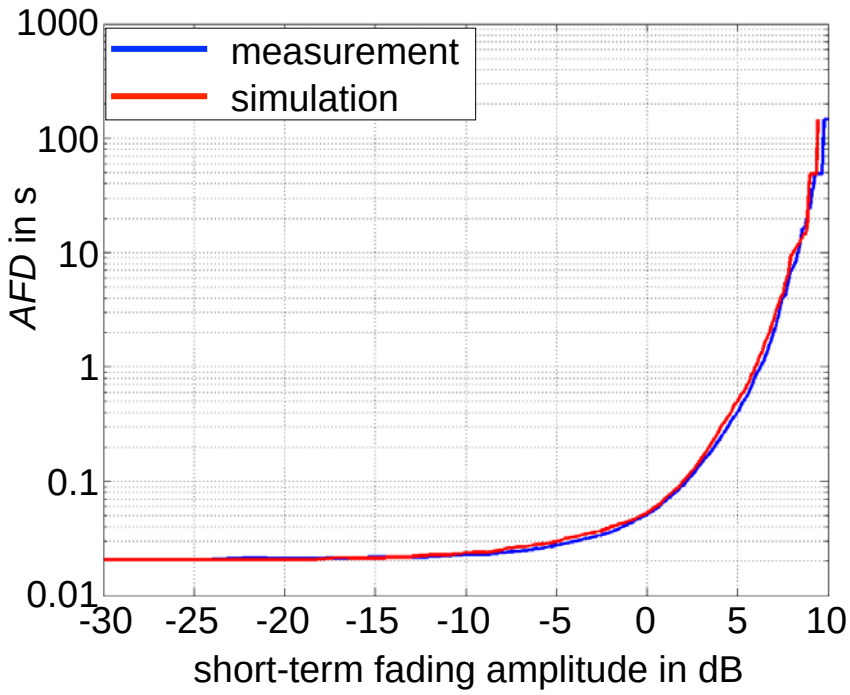
Short-term Fading

T1

Level Crossing Rate (LCR)

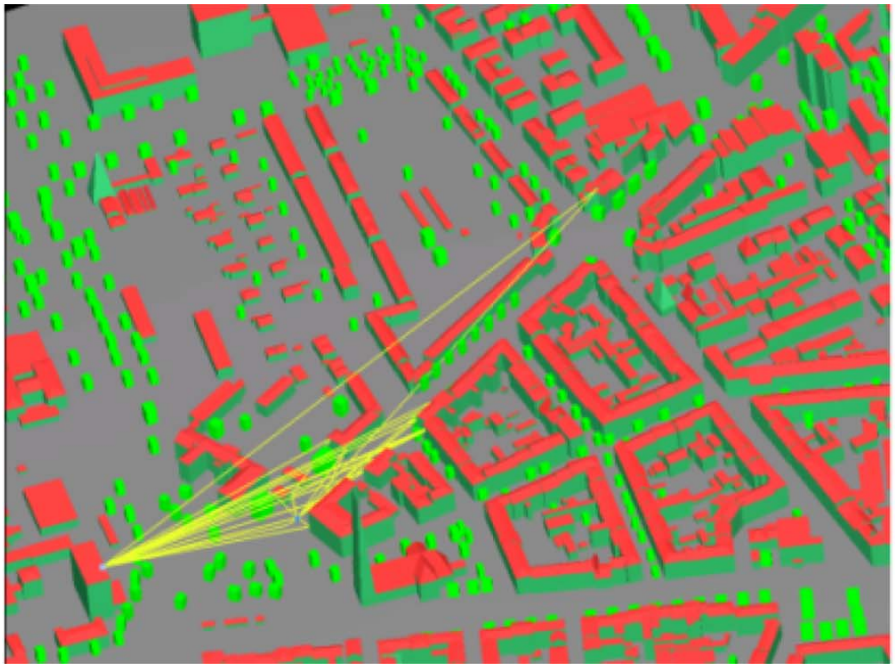


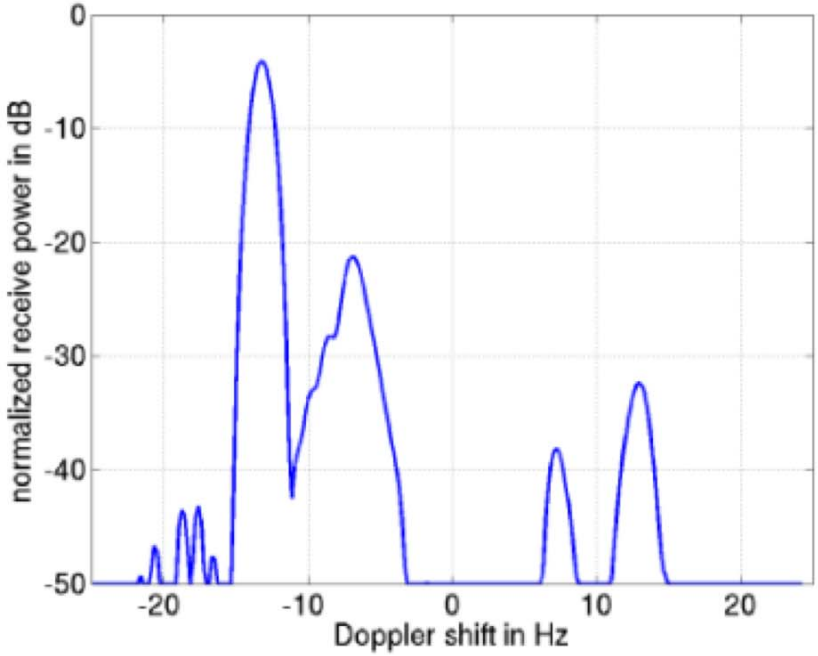
Average Fade Duration (AFD)



Doppler Shift versus Path Propagation

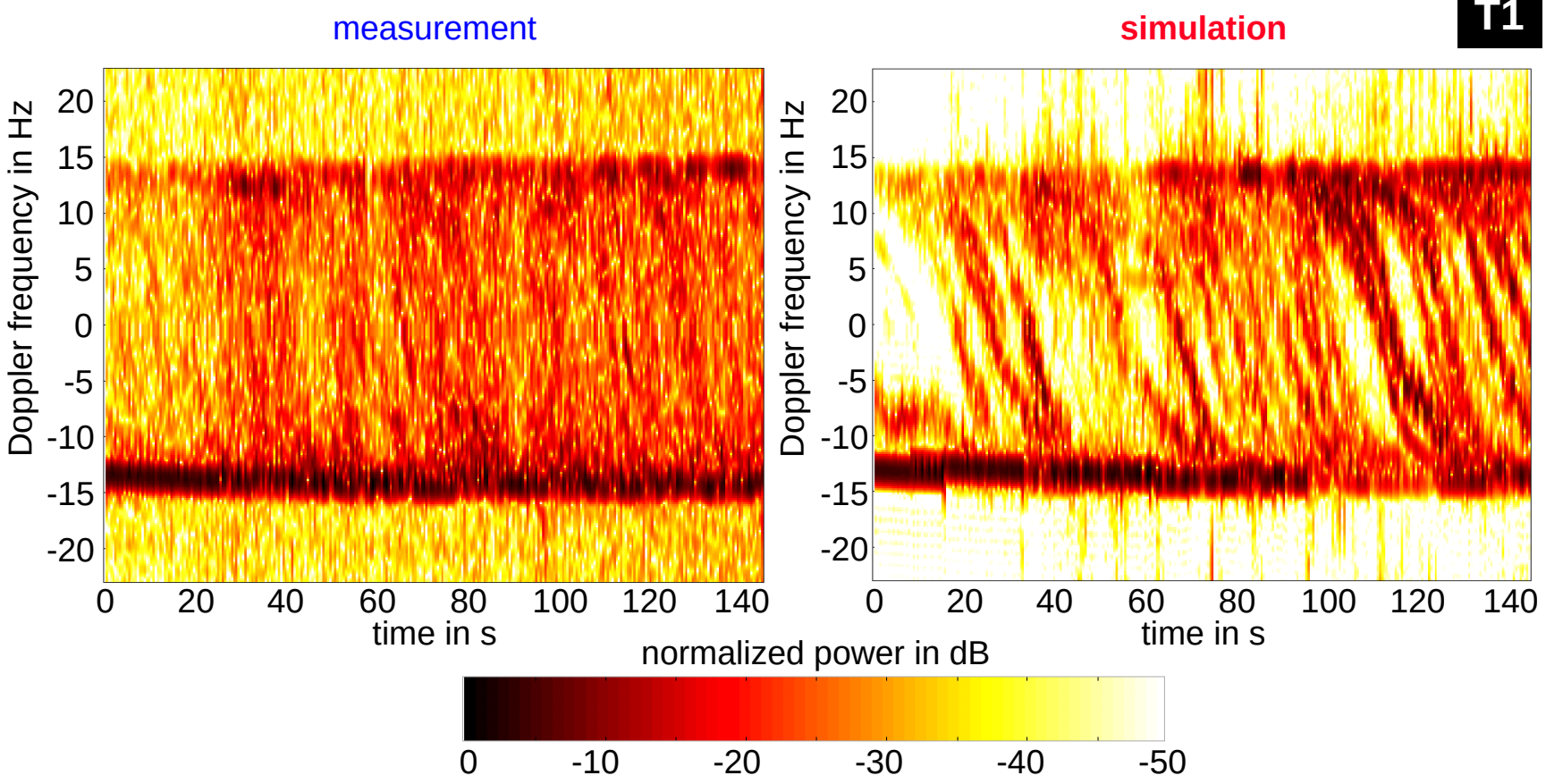
T1





Doppler Spectrum

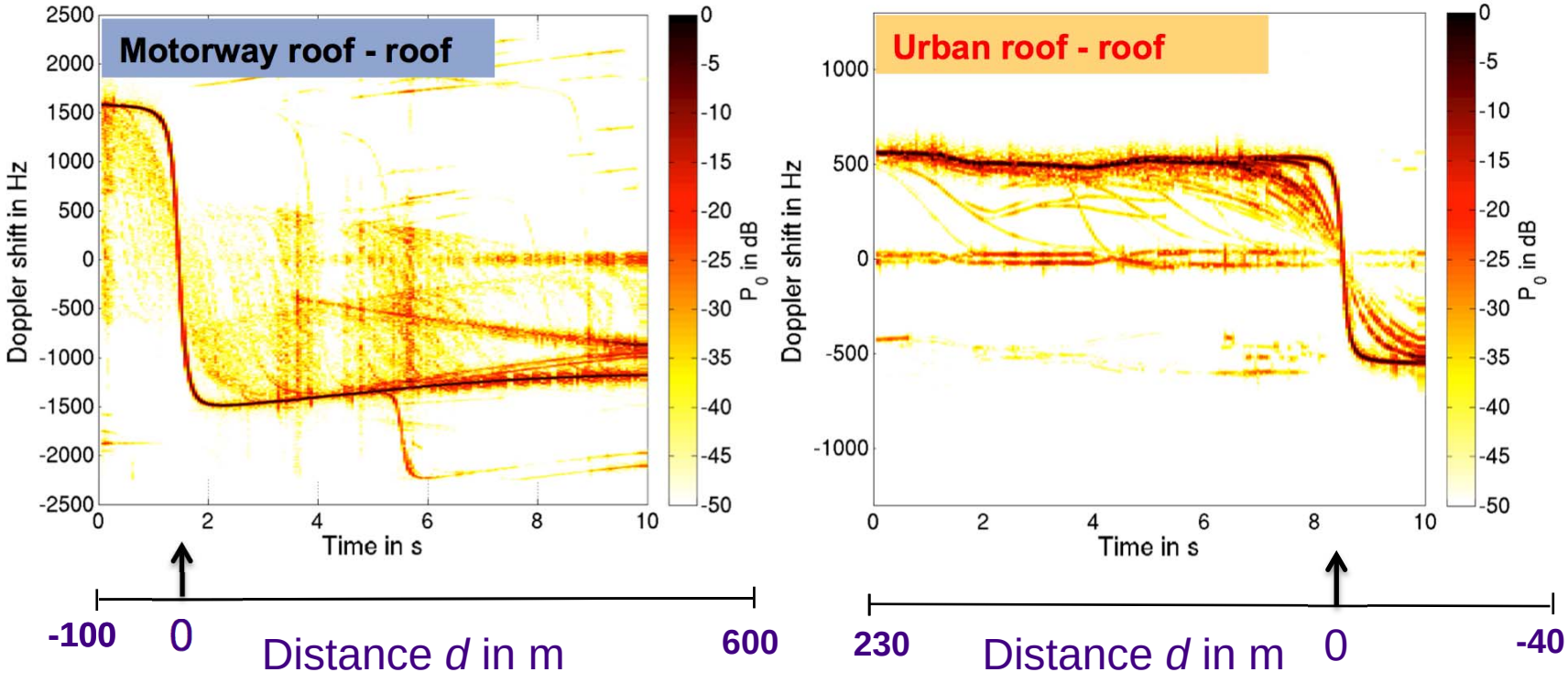
T1

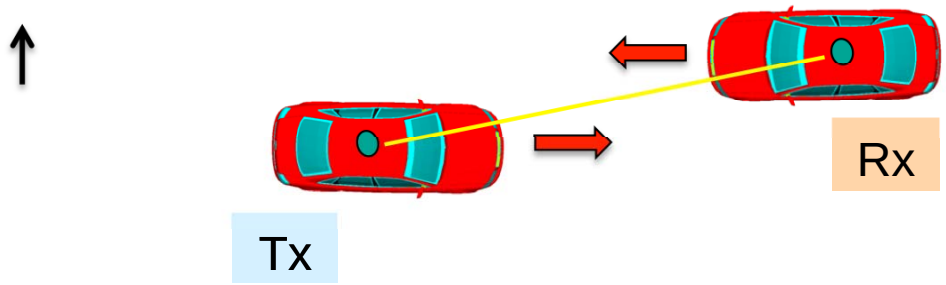


Mean Doppler shift	$\overline{\mu}_{f_D}$	measurement = - 3.7 Hz	simulation = -3.1 Hz
Mean Doppler spread	$\overline{\sigma}_{f_D}$	measurement = 19.8 Hz	simulation = 18.8 Hz

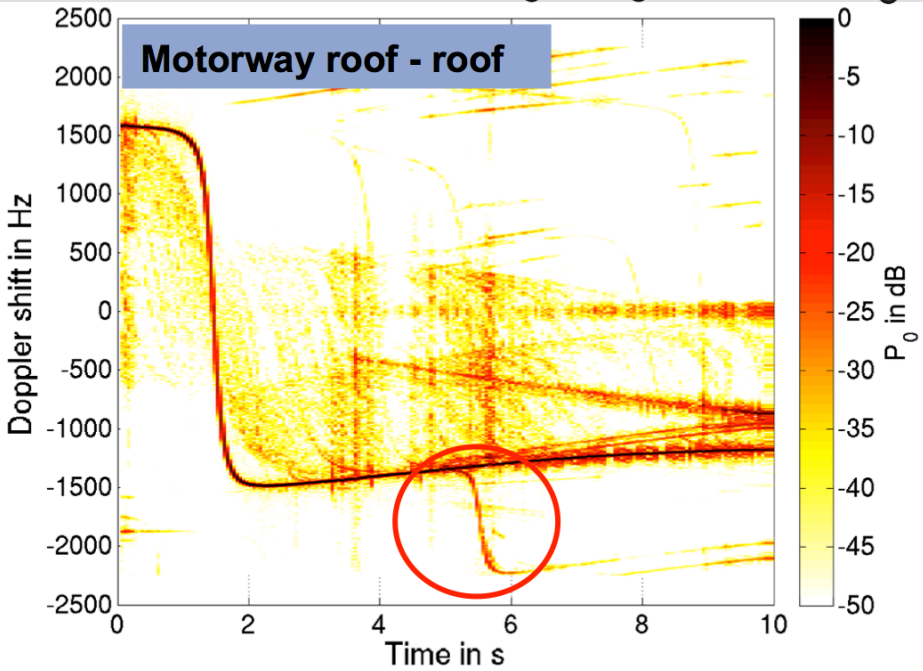
Institut für Hochfrequenztechnik
und Elektronik

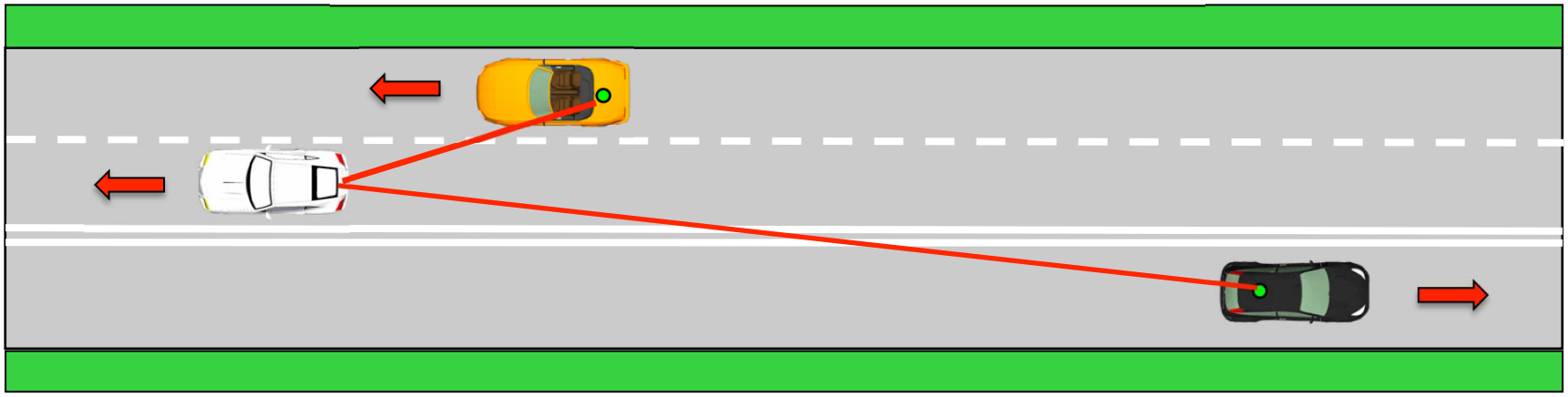
Urban and Rural Passing Doppler





Doppler Considerations

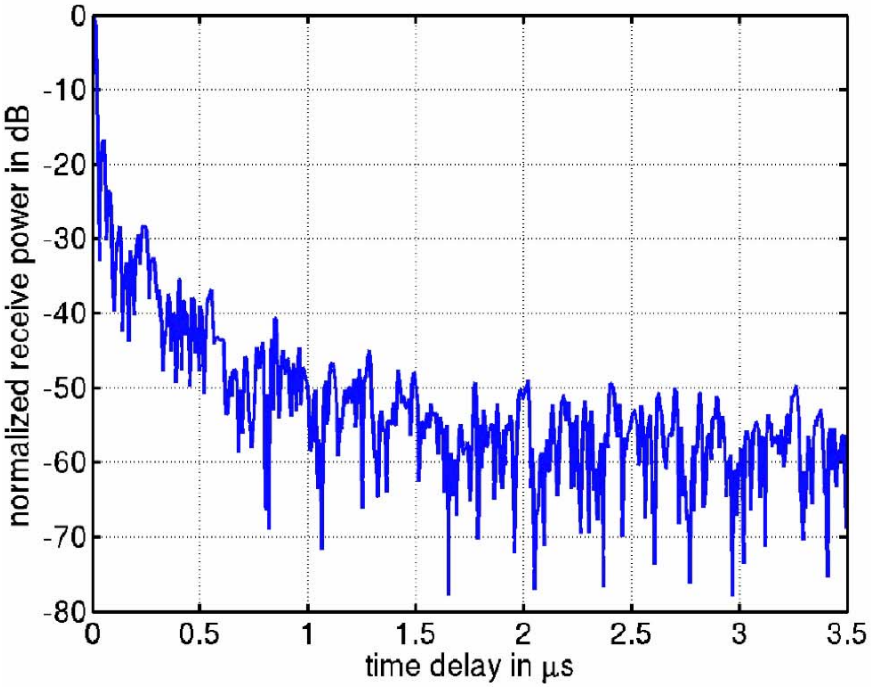




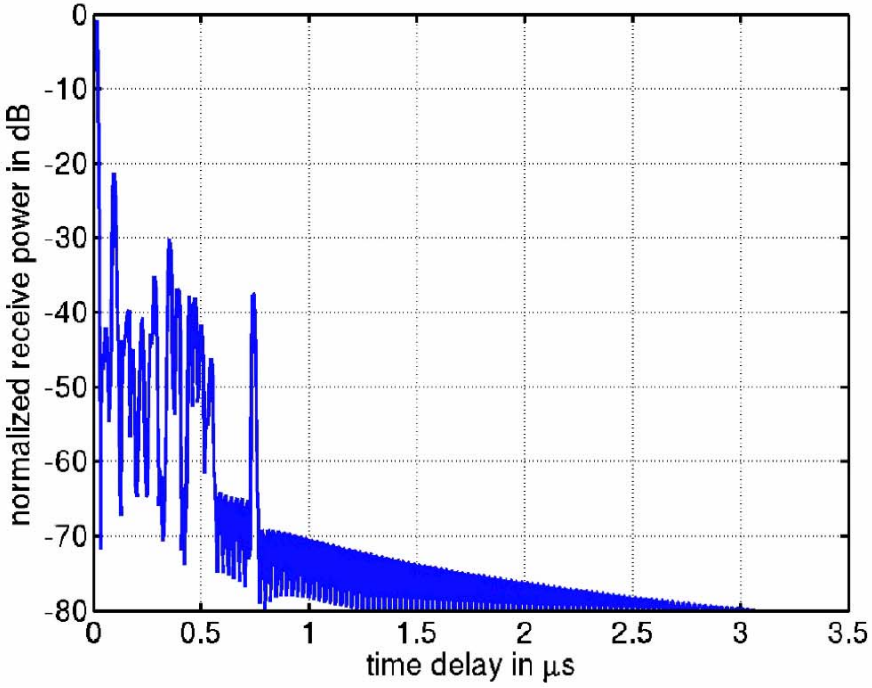
Power Delay Profile versus Time

T1

measurement

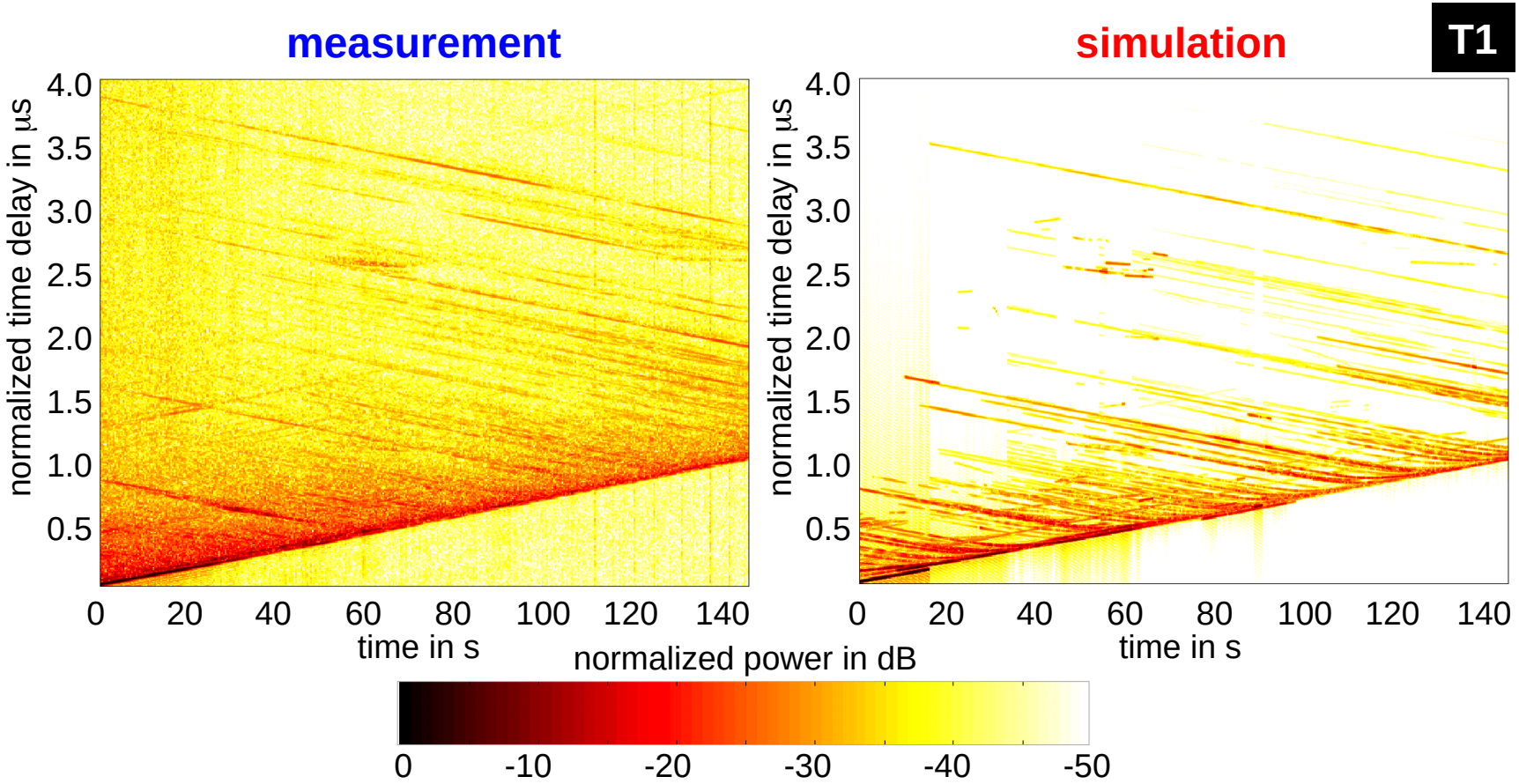


simulation



To reduce the influence of side-lobes the time-variant channel impulse response is filtered with a Hamming window (*B* = 120MHz, side-lobe level = -43dB).

Time Variant Power Delay Profile



mean delay spread

$\overline{\sigma}_\tau = 163.9$ ns

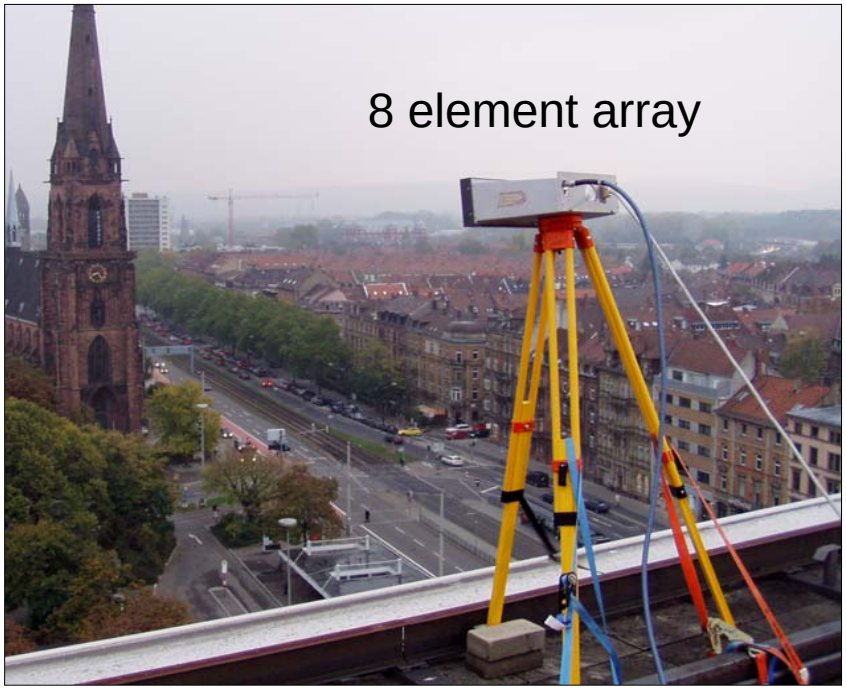
mean delay spread

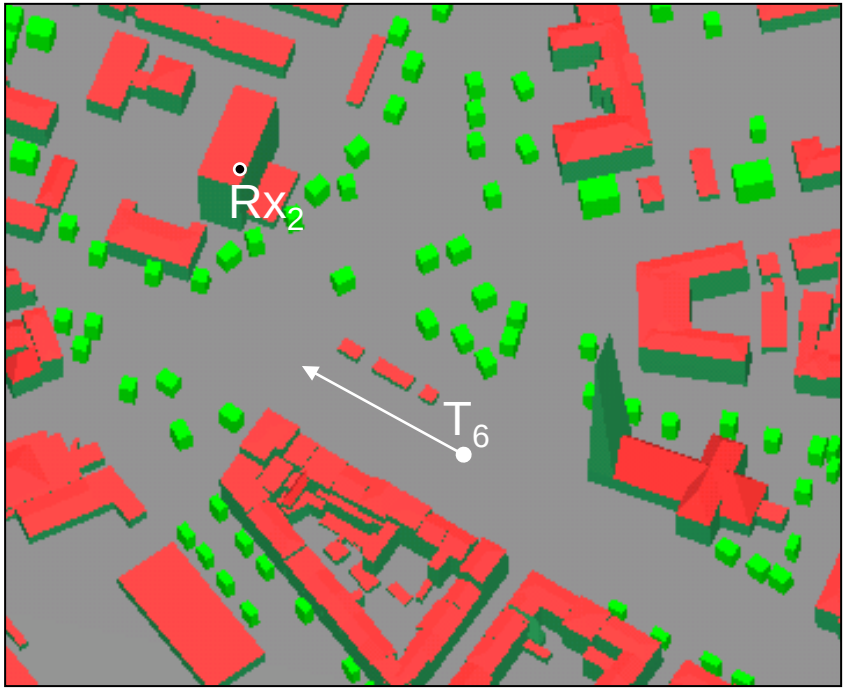
$\overline{\sigma}_\tau = 164.9$ ns

Spatial Channel Properties

MISO measurements

T6





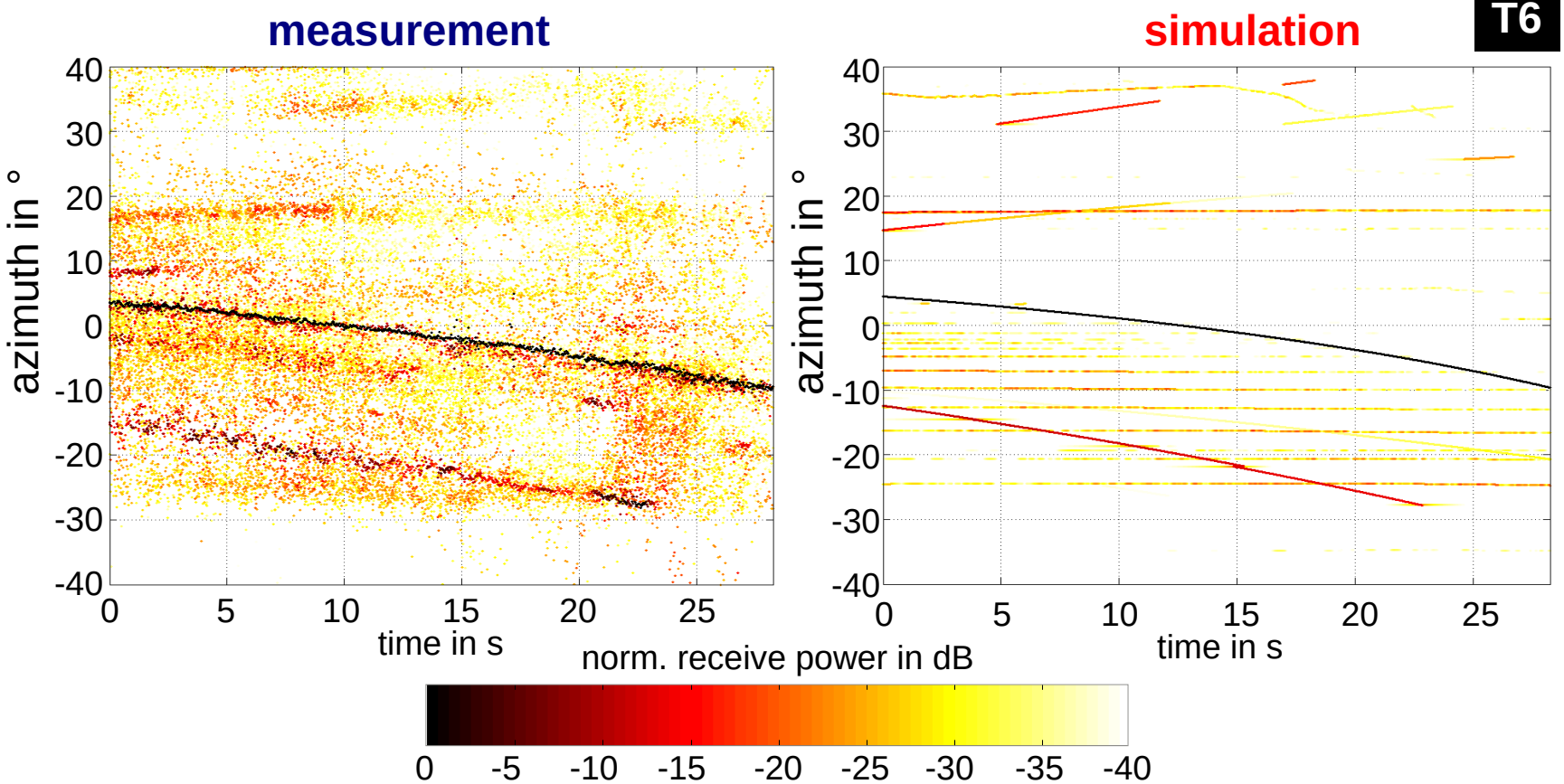
- RF frequency: 5.2 GHz
- bandwidth: 120 MHz
- transmit power: 33 dBm

- transmit antenna: $\lambda/4$ monopol
- receiver antenna:
  linear 8-element array (patches)

Institut für Hochfrequenztechnik
und Elektronik

Angular Power Spectrum

T6



mean angular spread

$\overline{\sigma}_{\psi_{T,VV}} = 6.76\,°$

mean angular spread

$\overline{\sigma}_{\psi_{T,VV}} = 5.72\,°$

Institut für Hochfrequenztechnik
und Elektronik

Conclusion

On the basis of the 3D channel model it is possible:

- **to characterize the propagation channel in urban environments with high accuracy**
- **to extract parameter sets for the specification of future communications systems**

The model can be directly used for performance evaluation of smart antenna systems.