Virtual Drive Verification Base Station - Car

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Measurement Setup – Transmitter

Measurement system: RUSK-ATM channel sounder (MEDAV)

RF frequency: \( f_c = 2 \text{ GHz} \)
bandwidth: \( B = 120 \text{ MHz} \)
transmit power: \( P_{Tx} = 33 \text{ dBm} \)
Measurement Setup – Receiver

receiver sensitivity

$P_{Rx\text{min}} = -88 \text{ dBm}$

receive antenna
view from $Rx_2$

digital unit
RF receiver
Ray-Tracing Example (Durlacher Tor, KA)
3D Vector Data Modeled Environment

arbitrary 3D geometries composed of planar polygons

University

receiver

transmitter

buildings

Durlacher Allee
Measurement Scenarios – City of Karlsruhe

- $h_{Rx} = 40$ m
- $h_{Tx} = 2.1$ m
- $\nu \approx 7.3$ km/h

≈ 35,000 snapshots
Result of Laminar Propagation Simulation

- x in m
- y in m
- $P_0$ in dB

transmitter
Time Dependent Simulation of Wave Propagation

- base station
- mobile station
- route

T4
Comparison Measurement / Simulation T1

\[ s(t) = m(t) \cdot r(t) \]

- **m(t):** long-term fading
  - absolute values
- **r(t):** short-term fading
  - statistical parameters
Long-term Fading (without vegetation)
Comparing Long-term Fading (with vegetation)

- mean error: $\mu = 1.27$ dB
- standard deviation: $\sigma = 2.85$ dB
Short-term Fading Properties

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

![Graph showing short-term fading properties with time in seconds on the x-axis and short term fading amplitude in dB on the y-axis.](image)
Short-term Fading

Cumulative Distribution Function (CDF)

- mean difference: \( \Delta = 20.7\% \ (\approx 4.3\ dB) \)
- max. difference: \( \Delta_{\text{max}} = 200\% \ (\approx 14.2\ dB) \)
- \( K \)-factor: \( K \approx 1.3\ dB \)
Short-term Fading

Level Crossing Rate (LCR)

-30 -25 -20 -15 -10 -5 0 5 10
short-term fading amplitude in dB

Average Fade Duration (AFD)

-30 -25 -20 -15 -10 -5 0 5 10 -30
short-term fading amplitude in dB

LCR in 1/s

0.01 0.1 1 10

simulation
measurement

AFD in s

0.01 0.1 1 10 100 1000

simulation
measurement
Doppler Shift versus Path Propagation
Mean Doppler shift \( \mu_{f_D} \):
- Measurement: -3.7 Hz
- Simulation: -3.1 Hz

Mean Doppler spread \( \sigma_{f_D} \):
- Measurement: 19.8 Hz
- Simulation: 18.8 Hz
Urban and Rural Passing Doppler

Motorway roof - roof

Urban roof - roof

Distance $d$ in m

Doppler shift in Hz

Time in s

$P_r$ in dB

Distance $d$ in m

$P_r$ in dB
Doppler Considerations

Motorway roof - roof

Doppler shift in Hz

Time in s

P_0 in dB

Motorway roof - roof
To reduce the influence of side-lobes the time-variant channel impulse response is filtered with a Hamming window (\(B = 120\text{MHz}\), side-lobe level = -43dB).
Time Variant Power Delay Profile

mean delay spread
\[ \overline{\sigma}_\tau = 163.9 \text{ ns} \]

measurement

mean delay spread
\[ \overline{\sigma}_\tau = 164.9 \text{ ns} \]
simulation
Spatial Channel Properties

MISO measurements

- RF frequency: 5.2 GHz
- bandwidth: 120 MHz
- transmit power: 33 dBm
- transmit antenna: $\lambda/4$ monopol
- receiver antenna: linear 8-element array (patches)
Angular Power Spectrum

measurement

mean angular spread
\[ \overline{\sigma}_{\psi_{T,VV}} = 6.76^\circ \]

norm. receive power in dB

simulation

mean angular spread
\[ \overline{\sigma}_{\psi_{T,VV}} = 5.72^\circ \]
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.