ITS-G5 Train-to-Car Measurements in Urban Environments: Path Loss and Shadow Fading Analysis

Paul Unterhuber and Stephan Sand
German Aerospace Center (DLR)

Three exemplarily scenarios for urban railway environments are presented. All measurements have been conducted with Cohda MK5 wireless modems as presented in [1].

For all scenarios, a log-distance path loss model (1) was fitted to the measurement data. The path loss exponent n and the standard deviation σ (2) are estimated.

$$PL_{(d)} = PL_{(d_0)} + 10nlog_{10}\left(\frac{d}{d_0}\right) + \chi_\sigma \quad (1)$$

$$\chi_\sigma \sim \aleph(0, \sigma^2) \quad (2)$$

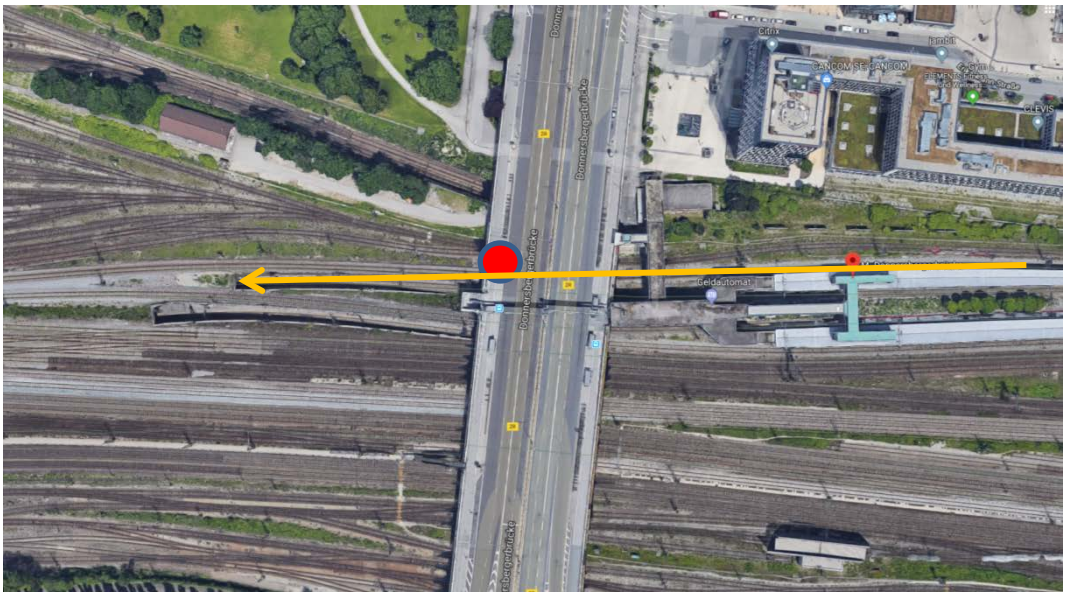
As a reference, the free space path loss

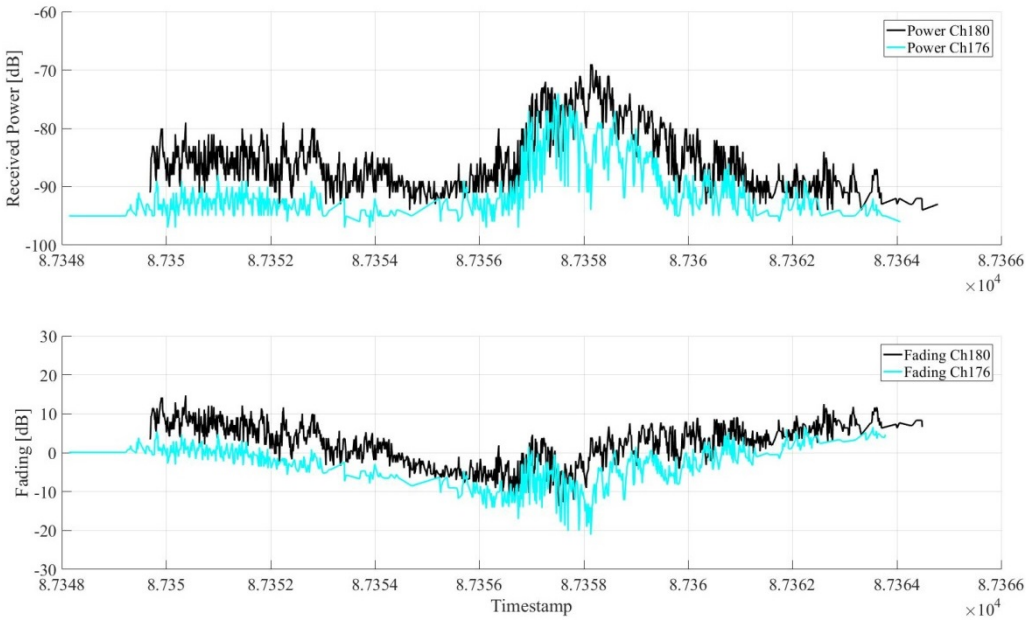
$$FSPL_{(d)} = 20log_{10}\left(\frac{4\pi df}{c}\right) \quad (3)$$

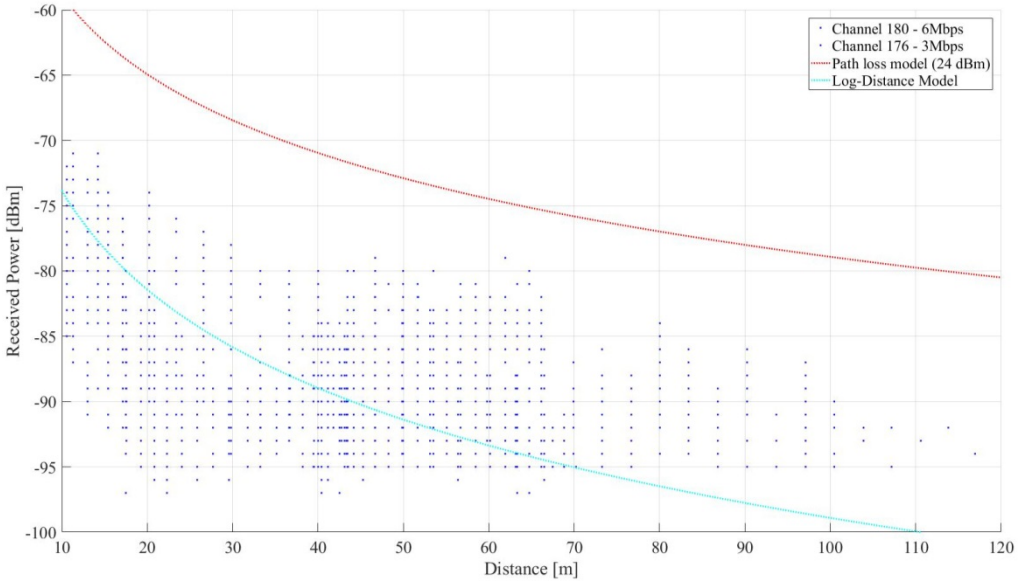
is plotted as well in all figures.

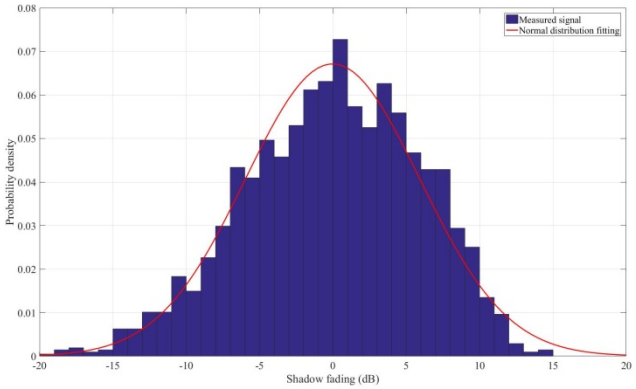
Static measurement on a cross bridge:

The car was parked on top of the bridge marked with the red dot. The train was driving with a velocity of 40-60 km/h. The train was approaching from the Station to the right and was driving in direction of the orange arrow under the bridge inside the tunnel.



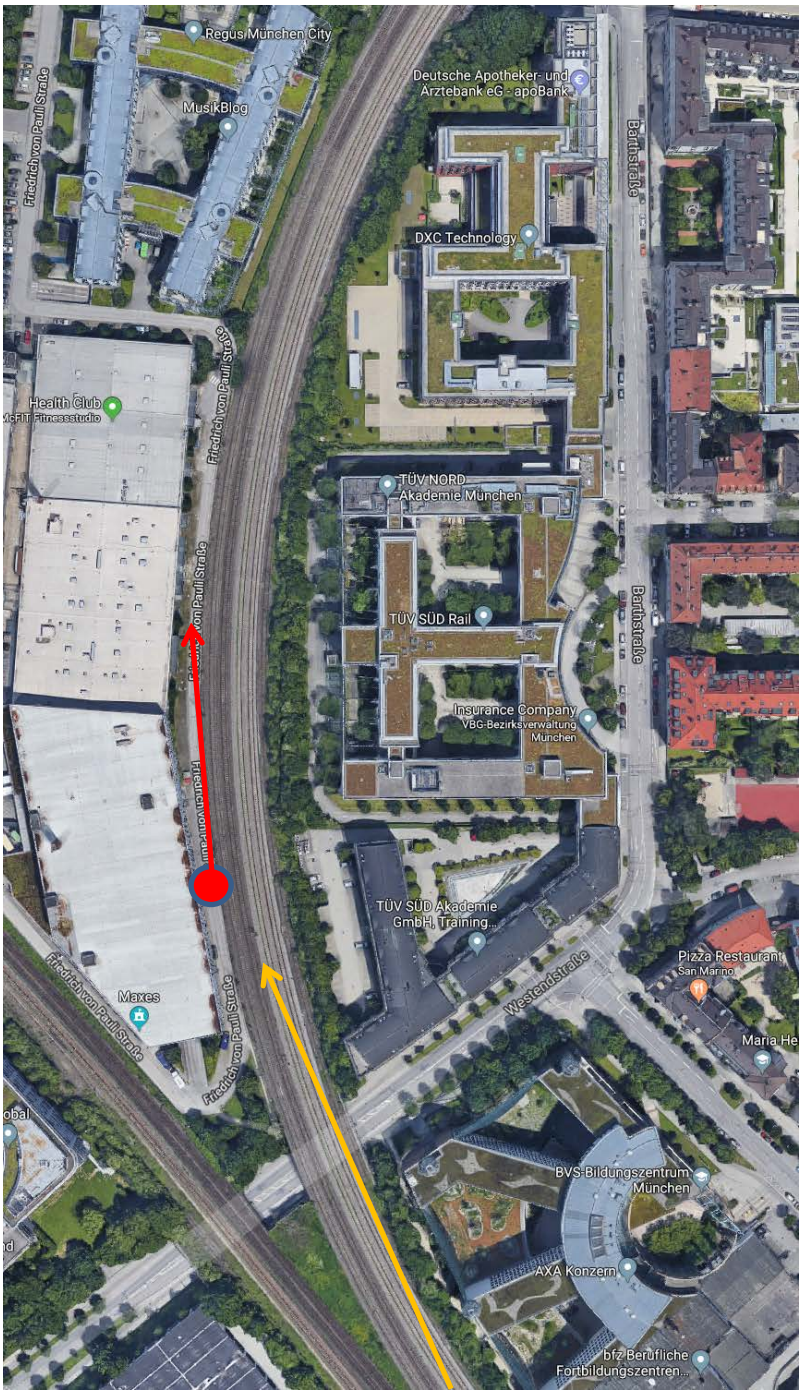

Power Ch180
Power Ch176
Received Power [dB]
-60
-70
-80
-90
-100
8.7348
8.735
8.7352
8.7354
8.7356
8.7358
8.736
8.7362
8.7364
8.7366
×10^4
Fading Ch180
Fading Ch176
Fading [dB]
30
20
10
0
-10
-20
-30
Timestamp

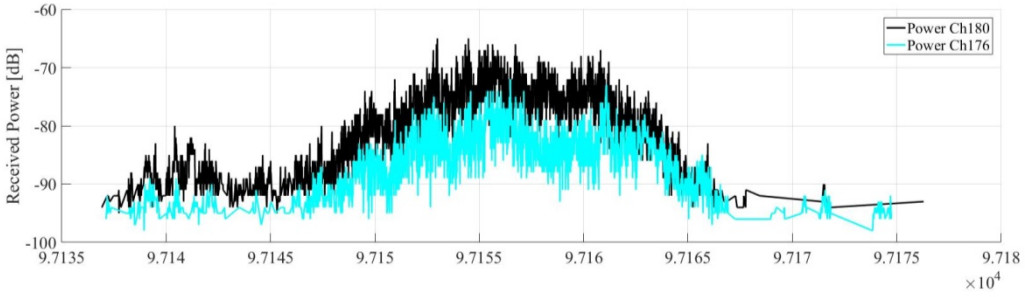


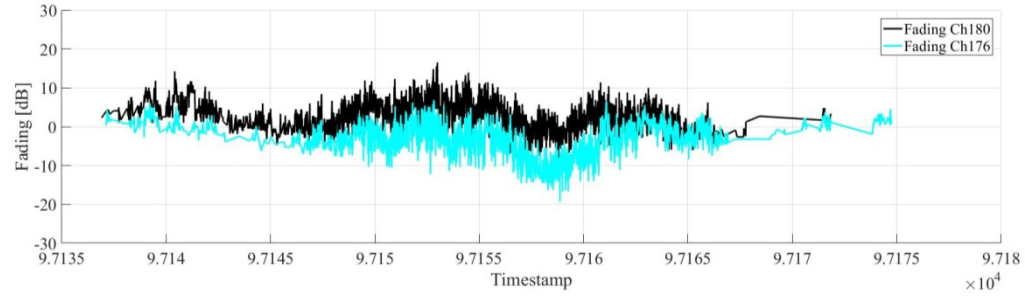


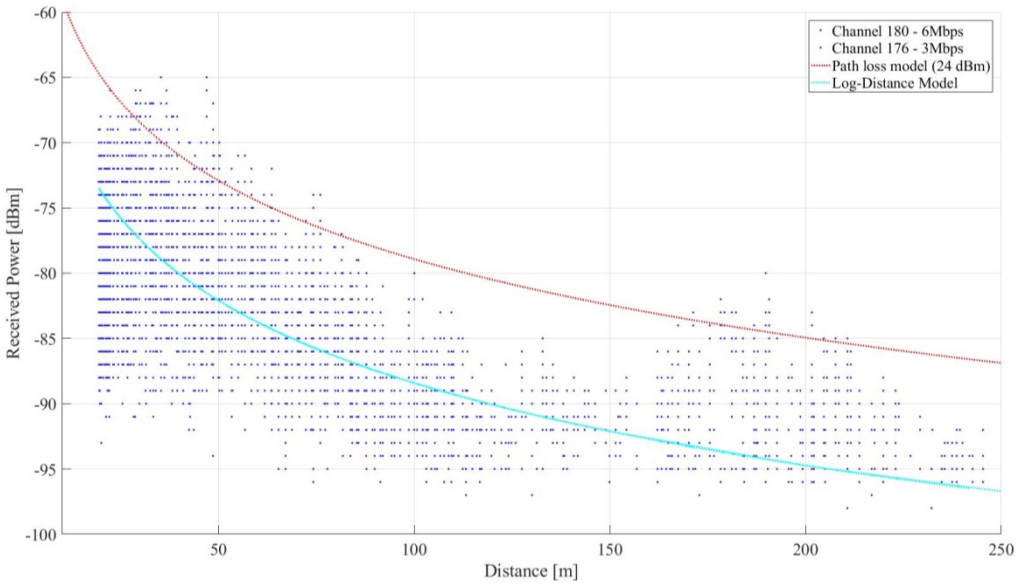
Dynamic measurement:

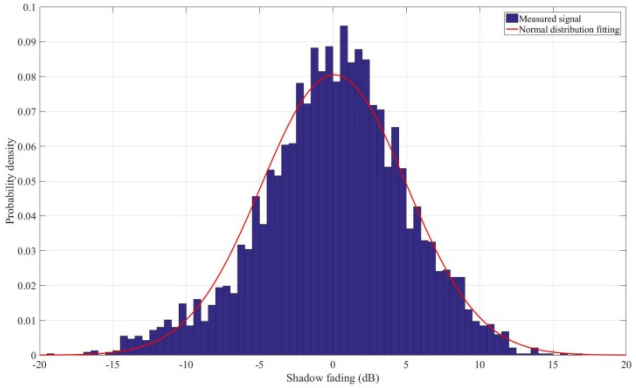
The train (orange) and the car (red) were driving next to each other for 150 m between several large buildings. Catenary masts and little trees were blocking the LOS from time to time. The train was driving with a velocity of 65 km/h and the car with 40 km/h.


Regus München City
MusikBlog
Friedrich-von-Pauli-Straße
Deutsche Apotheker- und Ärztebank eG - apoBank
Barthstraße
DXC Technology
Health Club
TÜV NORD Akademie München
TÜV SÜD Rail
Insurance Company
VBG-Bezirksverwaltung München
TÜV SÜD Akademie GmbH, Training...
Westendstraße
Pizza Restaurant
San Marino
Maxes
BVS-Bildungszentrum München
AXA Konzern
bfz Berufliche Fortbildungszentren...


Power Ch180
Power Ch176
Received Power [dB]
-60
-70
-80
-90
-100
9.7135
9.714
9.7145
9.715
9.7155
9.716
9.7165
9.717
9.7175
9.718
×10^4

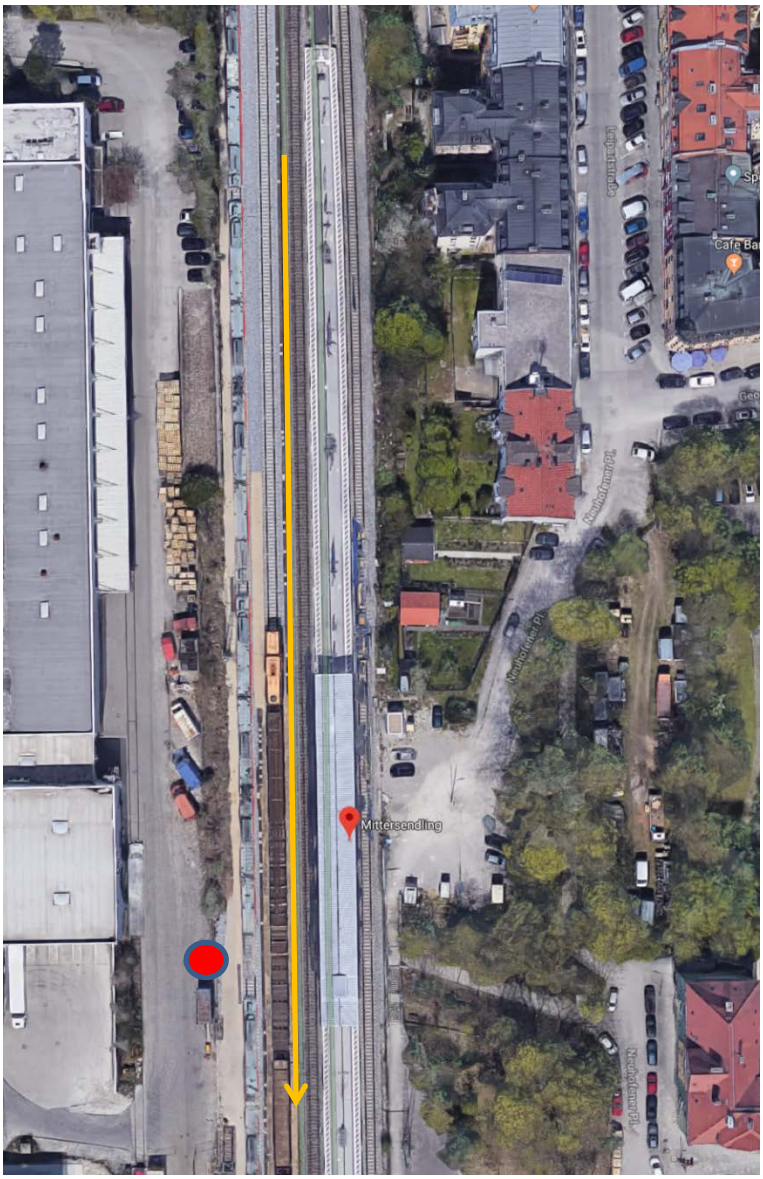

Fading Ch180
Fading Ch176
Fading [dB]
30
20
10
0
-10
-20
-30
9.7135
9.714
9.7145
9.715
9.7155
9.716
9.7165
9.717
9.7175
9.718
Timestamp
×10^4

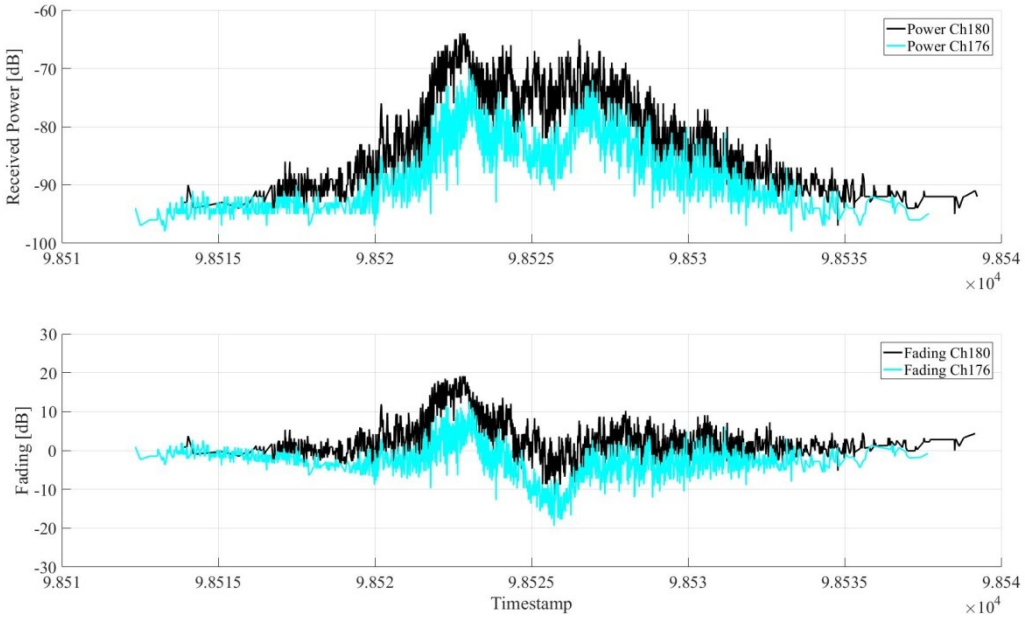

Channel 180 - 6Mbps
Channel 176 - 3Mbps
Path loss model (24 dBm)
Log-Distance Model
Received Power [dBm]
-60
-65
-70
-75
-80
-85
-90
-95
-100
50
100
150
200
250
Distance [m]

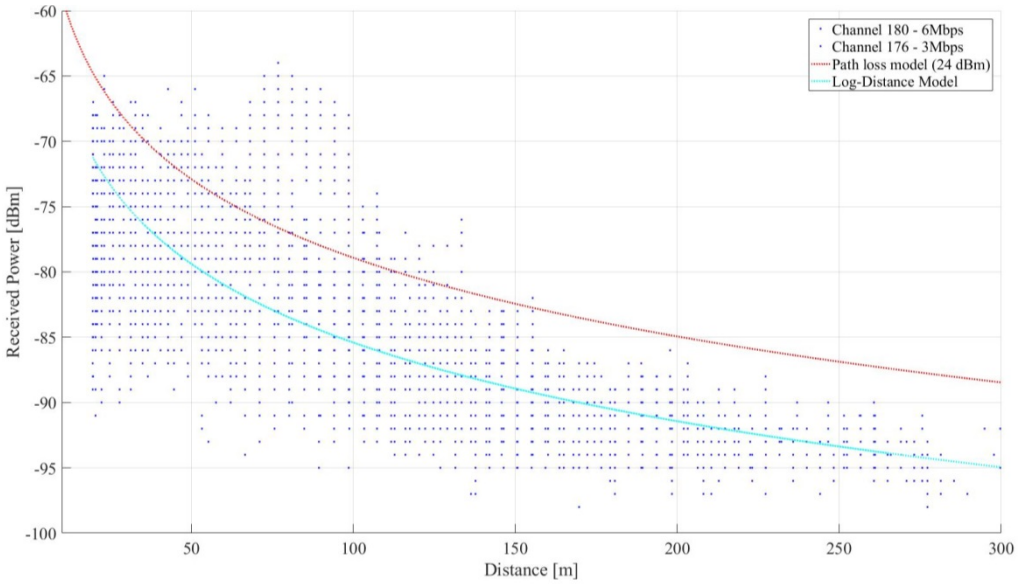

Measured signal
Normal distribution fitting
Probability density
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-20
-15
-10
-5
0
5
10
15
20
Shadow fading (dB)

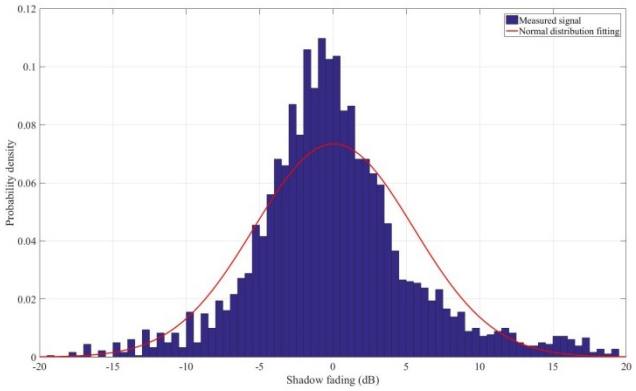
Static next to the track

The car was parked next to the railway track on the other side of the station marked with the red dot. The train (orange arrow) was driving with 85 km/h and passed by the car. In comparison to the satellite image, no trains or other obstacles were in between the car and the train.




Power Ch180
Power Ch176
Received Power [dB]
-60
-70
-80
-90
-100
9.851
9.8515
9.852
9.8525
9.853
9.8535
9.854
×10^4
Fading Ch180
Fading Ch176
Fading [dB]
30
20
10
0
-10
-20
-30
Timestamp





Summary

All values are summarized in Table 1.

Table 1: Summary of the model parameters

Scenario	Environment	Manoeuvre	Packets received	P_{tx} [dBm]	EIRP [dBm]	P_0 [dB]	d_0 [m]	n	σ
static	urban bridge	Car parks on top of a cross bridge	3077	24	8,95	57,9	1	2,5	5,94
dynamic	urban	Train overtakes car	4740	24	8,95	55,4	1	2,1	4,95
static	urban	Car parks next to the railway track	3610	24	8,95	54,4	1	2	5,43

Literature

[1] Paul Unterhuber, Andreas Lehner, and Fabian de Ponte Müller, „Measurement and Analysis of ITS-G5 in Railway Environments," 10TH International workshop on communication technologies for Vehicles, San Sebastian, 2016, RTJTFIR(18)000008