Preliminary report : DRM+ measurements in band II

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1 Introduction

DRM+ is an enhancement of the existing DRM (Digital Radio Mondial) standard up to band III. It has been approved in the ETSI DRM standard [1] in 2009. To analyse system performance, a field trial was carried out within the scope of the pilot project "Digital radio broadcast for local area with the system DRM", which is carried out between the Niedersächsische Landesmedienanstalt (NLM) and the Institute of Communications Technology of the University of Hanover. The measurements were made in the city of Hanover, Germany and its sourroundings in winter/spring 2009/10.

This report contains a description of the DRM+ system parameters, the system setup and equipment that was used in the trial and the measuring results that were optained in the measuring campaign.

2 DRM+ System parameter

The DRM+ system parameter are shown in the following table:

System parameter	
Modulation	OFDM
Data rate	40 - 186 kbps
Subcarrier modulation	4-/16-QAM
Signalbandwith	96 kHz
Subcarrierspread	444.444 Hz
Number of subcarriers	213
Symbol duration	2.25 ms
Guard interval duration	0.25 ms
Frame length	100 ms
Number of programs	1-4

2.1 Encoding

In DRM Mode E with 4-QAM the MSC (Main Service Channel), which contains the user data, has the following protection levels with the corresponding code rates and bit rates:

MSC: 4-QAM		
Protection level	**Code rate**	**Bit rate [kbit/s]**
0	0.25	37.3
1	0.33	49.8
2	0.4	59.7
3	0.5	74.6

In DRM Mode E with 16-QAM the MSC uses multilevel coding and has the following protection levels with the corresponding overall code rates and bit rates:

MSC: 16-QAM		
Protection level	**Code rate**	**Bit rate [kbit/s]**
0	0.33	99.5
1	0.41	122.6
2	0.5	149.3
3	0.62	186.6

The SDC (Service Description Channel), which contains signaling data, is modulated with 4-QAM uses the following code rates:

SDC: 16-QAM
Code Rate
0.5
0.25

The FAC (Fast Access Channel) uses a fix code rate of R = 0.25.

2.2 Interleaving

In order to improve the robustness of the bitstream to channel errors, bit interleaving is carried out over one frame (100 ms) and convolutional cell interleaving over 6 frames (600 ms).

2.3 Mobile reception

DRM+ has a subcarrier spacing of 444.444 Hz. A rule of thump is that a dopller spread of 10 % of the subcarrier spacing is ok. At carrier frequencies around $f_0 = 100$ MHz this makes a receiver velocity of $v = \frac{44.444\ Hz \cdot c}{f_0} \cdot 3.6 = 479.99$ km/h. Where $c = 3 \cdot 10^8$ m/s is the speed of light.

The cell interleaver over 600 ms only works properly for receiver velocities $v \gg 10$ km/h. Therefore in frequency flat fading channels with slow receiver velocities transmitter delay diversity could enhance system performance. This will be evaluated in Hanover in further measurements.

3 System setup

The transmitter was located at the University of Hanover, the transmitting antenna was mounted on the roof of the University building (Appelstr.9A, 30167 Hannover, GPS: lat: 52.388, long: 9.712) at a high of 70 m above ground. Transmitting power is licenced up to 30 W ERP at a frequency of 95.2 MHz.

Tests were made with one very roboust 4-QAM modulation and one 16-QAM modulation with hight data rates. The details can be found in the following tables:

MSC: 4-QAM		
Protection level	**Code rate**	**Bit rate [kbit/s]**
1	0.33	49.8

MSC: 16-QAM		
Protection level	**Code rate**	**Bit rate [kbit/s]**
2	0.5	149.3

For SDC the more robust mode was choosen:

SDC: 16-QAM
Code Rate
0.25

For this encodings simulation results of the required SNR values are available in the DRM ETSI standard [1] in Annex A.

3.1 Equipment

Figure 1: Transmitting antenna for vertical polarised transmission

The following equipment was used for the measurements:

- Fraunhofer Contentserver
- RFmondial Modulator
- Nautel Exciter/Amplifier NVE
- Transmit antenna: Kathrein K 52 40 1, 4- Element Yagi directional antenna (direction: 120 °), measurements were conducted with horizontal (antenna array) and vertical polarisation (see details in annex A) , figure 1 shows the vertically mounted antenna
- Receive antenna: Kathrein K 51 16 4 / BN 510 351, Monopole, an antennafactor of = 10 dB was measured, the antenna was mounted on the roof of a van at a hight of around 2 m
- HF-Frontend: Rhode & Schwarz ESVB Measuring receiver, 10.7 MHz IF
- Field strength measurements: ESVB, BW: 300 kHz
- A/D converter Perseus
- RFmondial Software Receiver

3.2 Transmission content

The transmission consisted in both modes in an AAC encoded stereo audio stream and a synchronous pseudo random bit sequence (prbs) which was used for the calculation of the bit error rate (BER) (see [2] for details).

3.3 Measurement parameters

The following parameters were recorded and analysed during the measurements:

- Field strength (measured with Rhode & Schwarz ESVB Measuring receiver, BW: 300 kHz, RMS) triggered via GPIB every 16th frame (1.6 sec)
- GPS coordinates
- Bit error rate

- Signal to noise ratio (calculated via the time correlation/syncronisation, see [3])
- Receiver status information (status of audio decoding, shows if one or more audio frames are corrupted within one DRM multiplex frame, see [2])

4 Measurements

4.1 Measuring locations

Measurements were conducted at two places in the city of Hanover and on one radial route in the direction of the main beam as shown in figure 2.

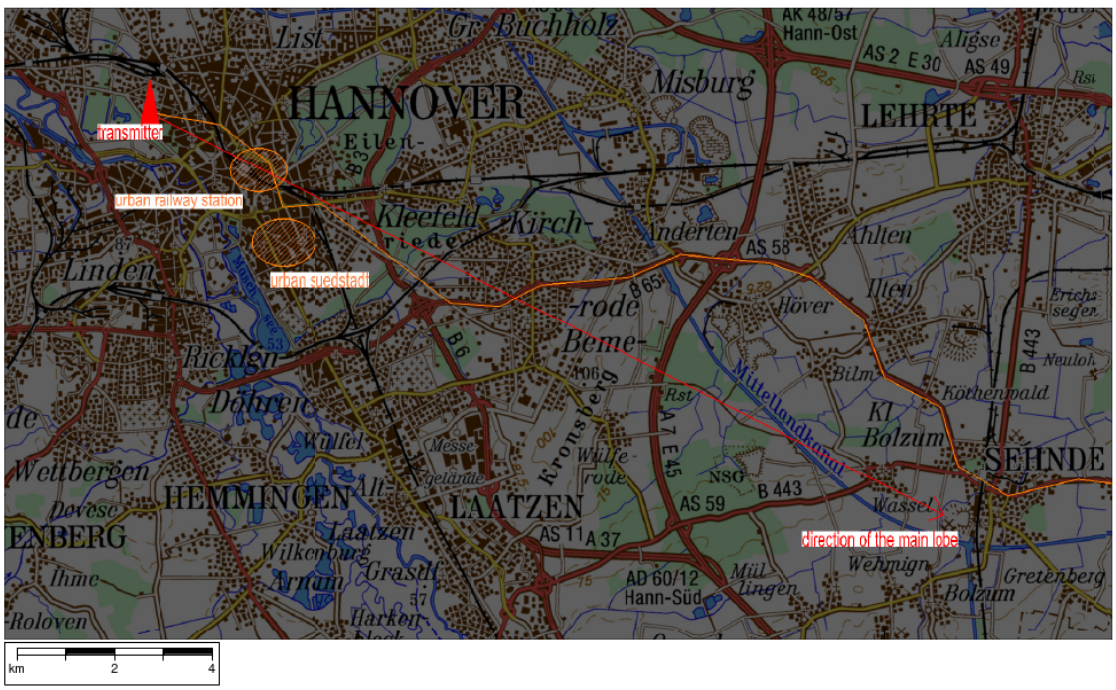


Figure 2: Measuring locations and routes (mapsource: Bundesamt für Kartographie und Geodäsie)

4.2 Measurements in urban environments

The first measurements were conducted with horizontal antenna polarization. As the receiving antenna is vertically mounted on the roof of a car, the antenna was rotated to vertical polarization and the measurement results were compared. The different antenna patterns has to be taken into account, but as the location behind the railway station lies in the main beam and the location in the Suedstadt at an angle of around 12° there should be no big difference.

The measurements of the horizontal polarized transmission were conducted the 19.01.2010. There was some snow and a lot of ice on the ground. The vertically polarized measurements were conducted the 3.3.2010. There was sometimes sun, mostly overcast and little snow on the ground.

4.2.1 Measurements behind the railway station

In the streets behind the main station of Hanover a kind of dense urban environment with high buildings and small streets can be found (see figure 3). The average distance to the transmitter is around 2.5 km. Measurements were made in 16-QAM Mode (Coderate 0.5).

Figure 3: Pictures of the environment behind the railway station

Figure 4 shows the field strength distribution for the horizontal an vertical polarized transmission. For horizontal transmission the variability of the fieldstrength is between 30 and above 50 $dB\mu V/m$, for vertical transmission it is mostly above 40 $dB\mu V/m$.

(a) Horizontal polarization

(b) Vertical polarization

Figure 4: Field strength in an "dense" urban environment (mapsource: Bundesamt für Kartographie und Geodäsie)

Figure 5 shows a plot of the receiver status information (rsta) which describes whether all audio frames are ok (green) or one or more audioframes are corrupted (red). As there is enough fildstrength, reception was mostly without errors with both polarizations.

In figure 6 a comparision of the field strength, the SNR, the BER and the RSTA (0: all audioframes ok, 1 one or more audio frames corrupted) for the horizontal polarized transmission is plotted over the frames (one frame corresponds to 100 ms). Figure 7 shows the same for the vertical polarized

(a) Horizontal polarization (b) Vertical polarization

Figure 5: Measurement of the audio data in the urban environment (mapsource: Bundesamt für Kartographie und Geodäsie)

transmission.

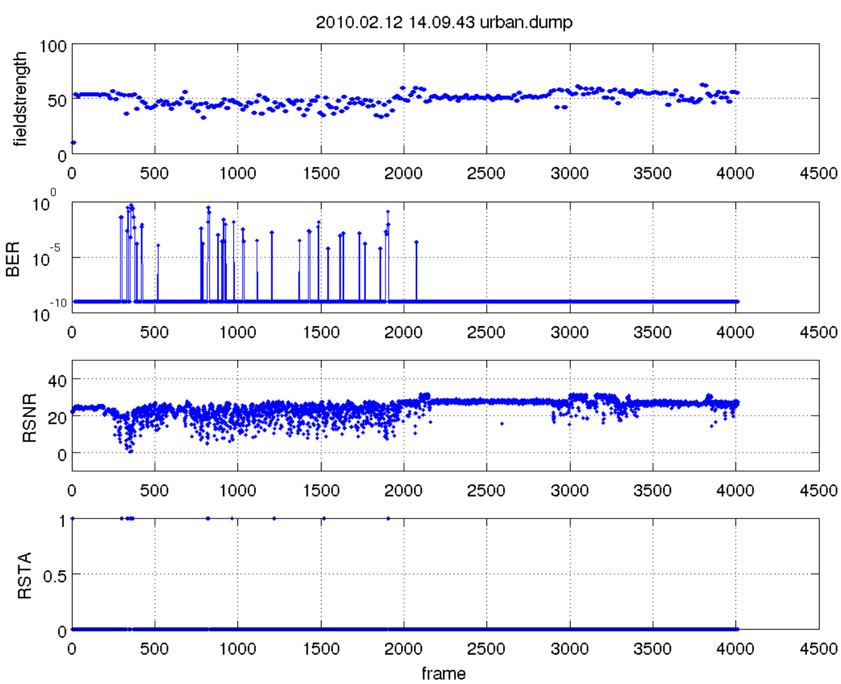


Figure 6: Measurement results in a "dense" urban environment with horizontally polarized transmission

Here the field strength difference is more obvious. In horizontal transmission the fieldstrength is mostly around 50 $dB\mu V/m$, for vertical transmission it is up to 70 $dB\mu V/m$. With horizontal polarization the bit error rate is higher at some places and there are some corrupted audio frames whereas with vertical polarization there are almost no errors. The calculated SNR is variating much

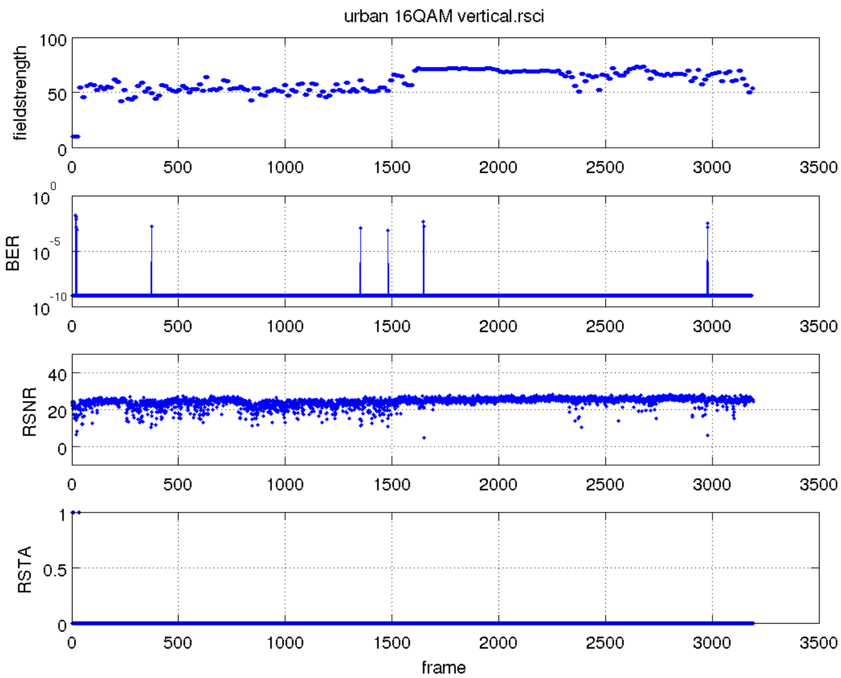


Figure 7: Measurement results in a "dense" urban environment with vertically polarized transmission

more in horizontal polarization, the maximum value of around 28 dB is caused by calculation.

4.2.2 Measurements in the "Suedstadt"

Further measurements were conducted in the Suedstadt of Hanover, an urban residential district with most buildings with around 5-6 floors. The average distance to the transmitter here is 4 km.

Figure 8 shows the field strength distribution for the horizontal an vertical polarized transmission. For horizontal transmission the variability of the fieldstrength is between 30 and 50 $dB\mu V/m$, for vertical transmission it is mostly above 40 $dB\mu V/m$.

Figure 9 shows a plot of the receiver status information (rsta). Here a difference for vertical and horizontal polarization can be seen.

As also shown in figure 10 and 11 with fieldstrengthes above 46 $dB\mu V/m$ reception is possible without errors in the urban environment. The corresponding calculated SNR is around 18 dB.

(a) Horizontal polarization (b) Vertical polarization

Figure 8: Field strength in the Suedstadt (mapsource: Bundesamt für Kartographie und Geodäsie)

(a) Horizontal polarization (b) Vertical polarization

Figure 9: Measurement of the audio data in the Suedstadt (mapsource: Bundesamt für Kartographie und Geodäsie)

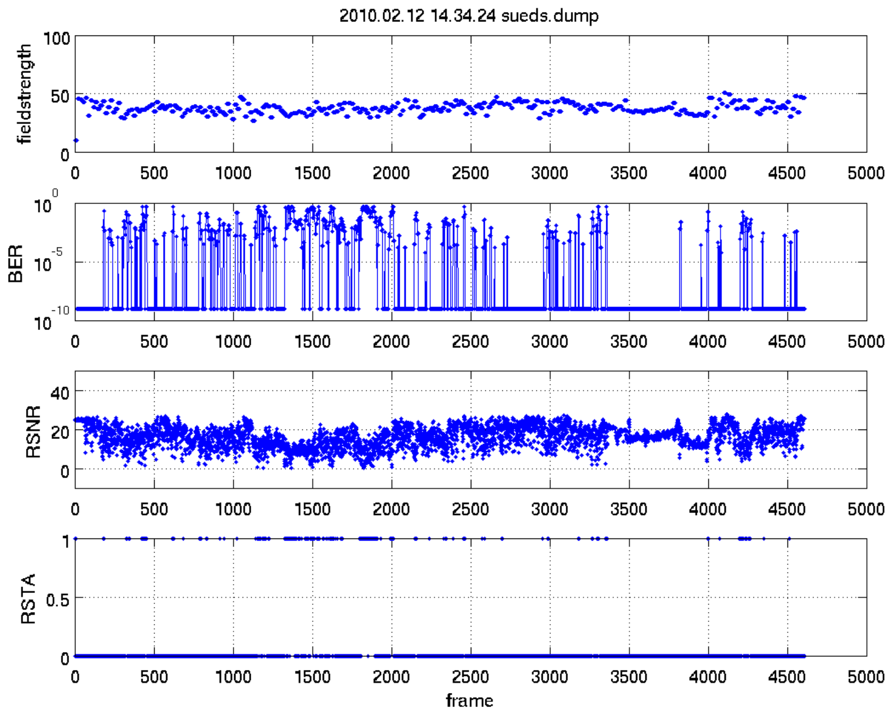


Figure 10: Measurement results in the Suedstadt with horizontally polarized antenna

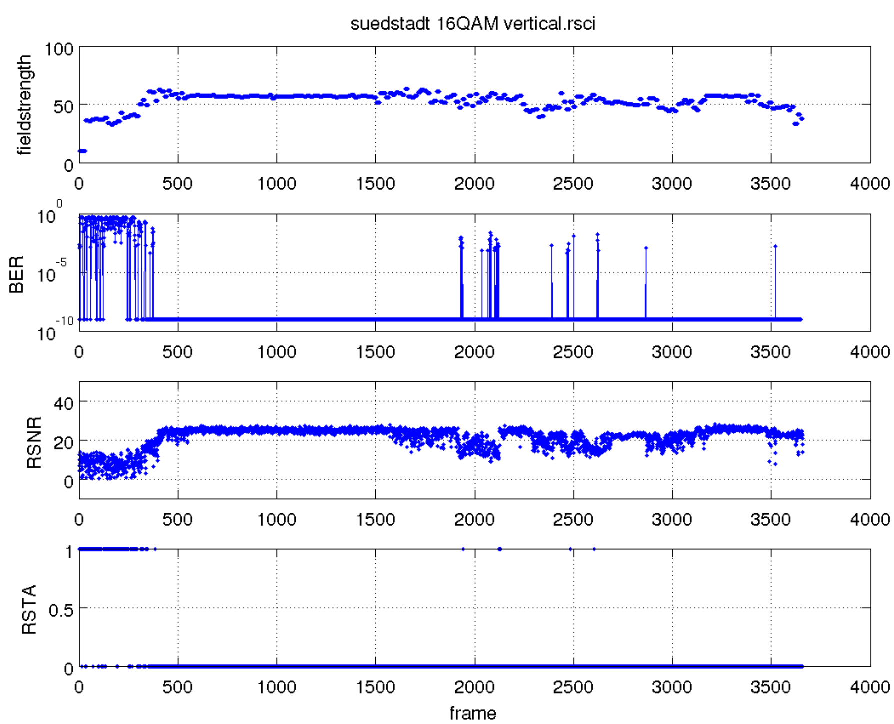


Figure 11: Measurement results in the Suedstadt with vertically polarized antenna

4.3 Measurement of the coverage limit

As vertical polarization worked much better, further tests were made vertically polarized. Measurements of the coverage limit were made in the main beam of the transmitting antenna with 16- and 4-QAM modulation. The measuring day was also the 3.3.2010.

The route was chosen on the B65, a rural road lying mostly in the main beam of the transmission. The measurement was continued until audio quality became bad.

4.3.1 Measurements with 4-QAM

Figure 12 shows the fieldsstrength measured on the route.

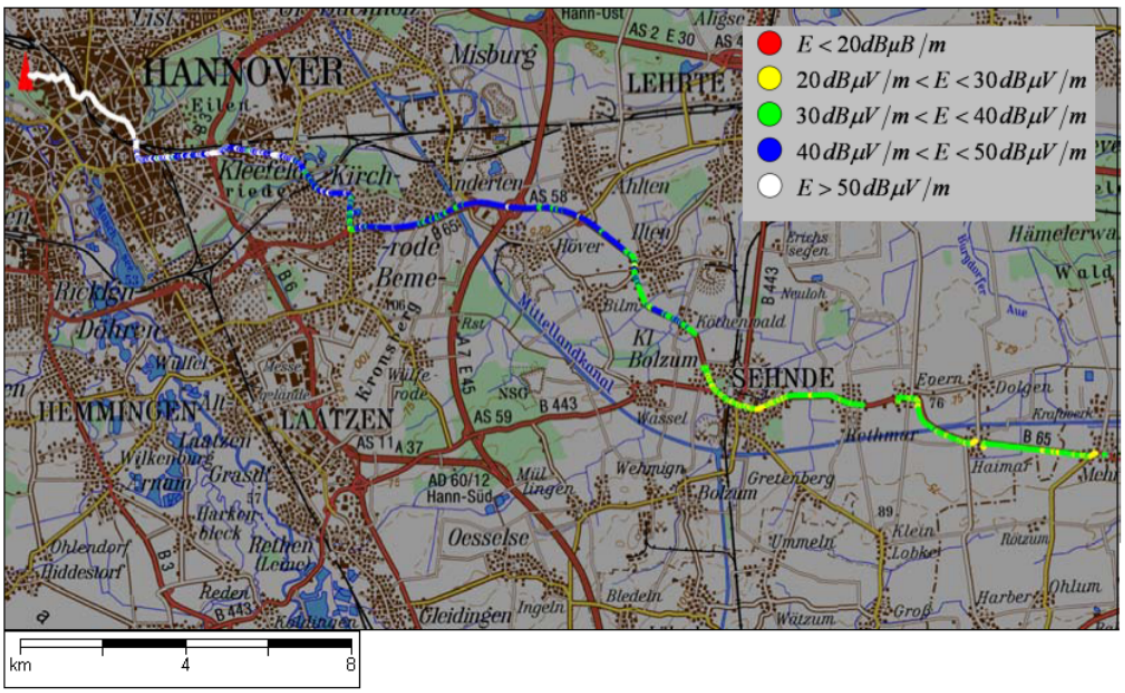


Figure 12: Fieldstrength measurment of the coverage limit 4 QAM Mode (Coderate: 0.33) (mapsource: Bundesamt für Kartographie und Geodäsie)

Figure 13 shows the audio status measured on the route. Here it can be seen that with more distance to the transmitter, passing the villages, the audiostate becomes errornous, whereas passing the countryside with almost no obstacles (the countryside in Hannover is quite flat) receiving quality is still ok.

Figure 14 shows the reception parameter over the frames in the direction away from the transmitter. On the radial route reception was possible down to a fieldstrength of around 30 $dB\mu V/m$ with an SNR of around 10 dB.

We stopped the measurement at a distance of around 30 km from the transmitter, were audio quality became too bad even in the free countryside.

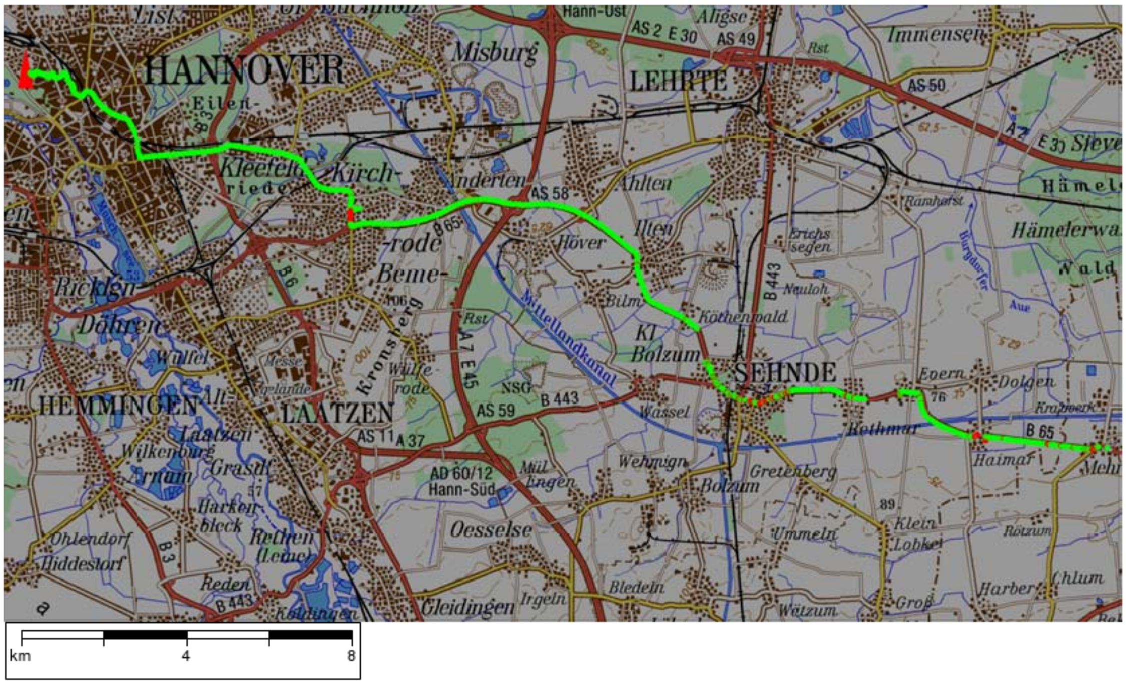


Figure 13: Measurment of the coverage limit in 4 QAM Mode (Coderate: 0.33), green: audioframes ok, red: one or more audioframes corrupted (mapsource: Bundesamt für Kartographie und Geodäsie)

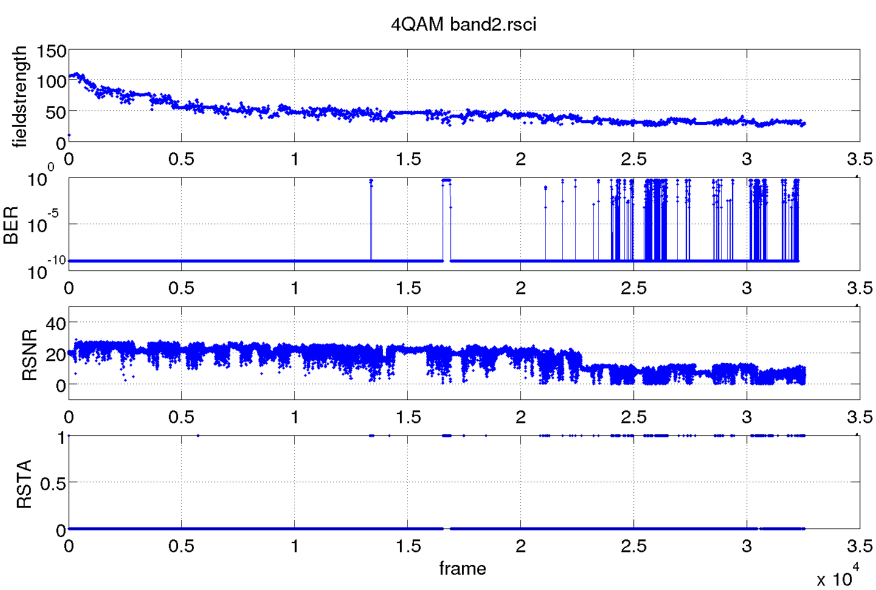


Figure 14: Reception parameter on the B65 with 30 W ERP and 4 QAM Mode (Coderate: 0.33) (mapsource: Bundesamt für Kartographie und Geodäsie)

4.3.2 Measurements with 16-QAM

On the way back the 16-QAM mode was measured. Figure 15 shows the fieldstrength measured then. A reason that there is some less fieldstrength measured on the way back is probably an asymmetrical behaviour of the receiving antenna mounted on the car, as 4-QAM and 16-QAM should not make differences in the fieldstrength. There were also measurements in 16-QAM Mode driving on some parts of the route to the other direction, here fieldstrength was the same as at the corresponding locations in 4-QAM mode.

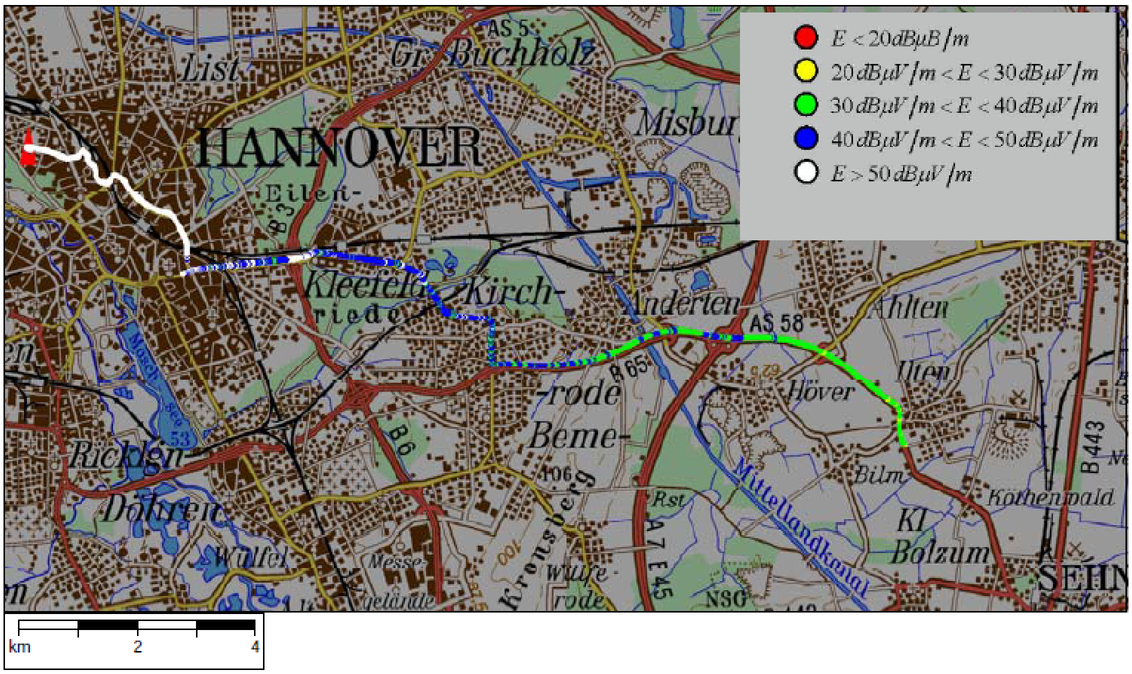


Figure 15: Fieldstrength measurment of the coverage limit 16 QAM Mode (Coderate: 0.5) (map-source: Bundesamt für Kartographie und Geodäsie)

Figure 16 shows a plot of the receiver status information (rsta). The measurement was stopped at a distance of around 15 km from the transmitter.

In figure 17 the fieldstrength is ploted in comparision to the signal to noise ratio (SNR), the bit error rate (BER) and the audio status (rsta) over the frames. It shows that the reception was ok down to a fieldstrength of around 46 $dB\mu V/m$ at an calculated SNR of around 18 dB.

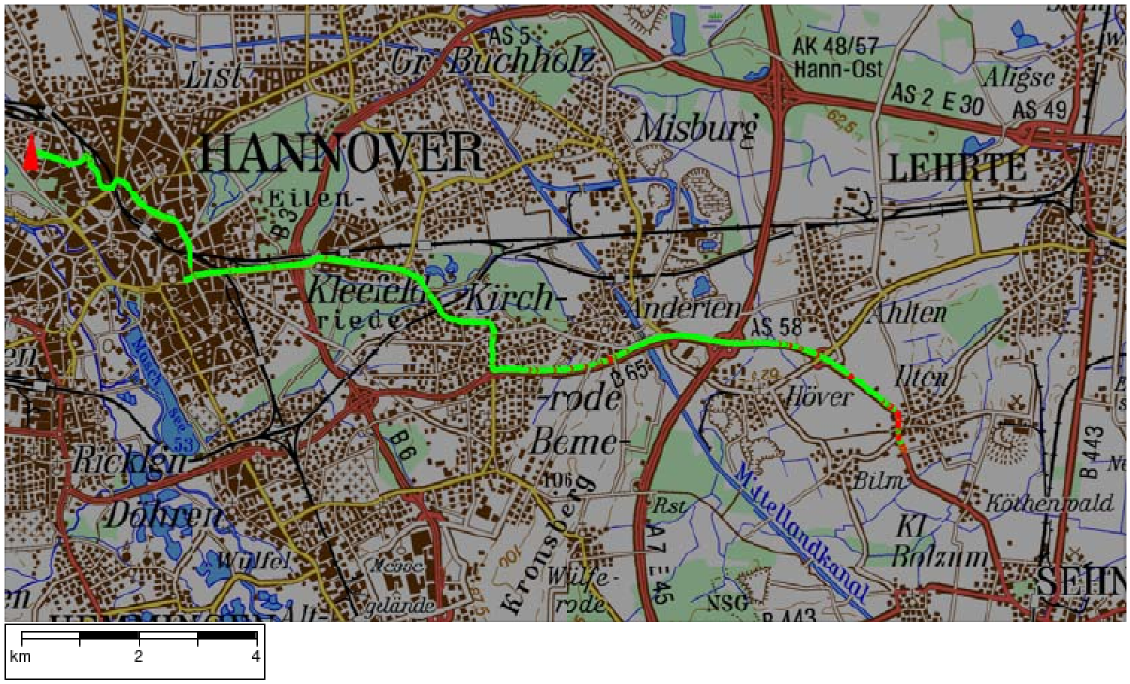


Figure 16: Measurment of the coverage limit in 16 QAM Mode (Coderate: 0.5), green: audioframes ok, red: one or more audioframes corrupted (mapsource: Bundesamt für Kartographie und Geodäsie)

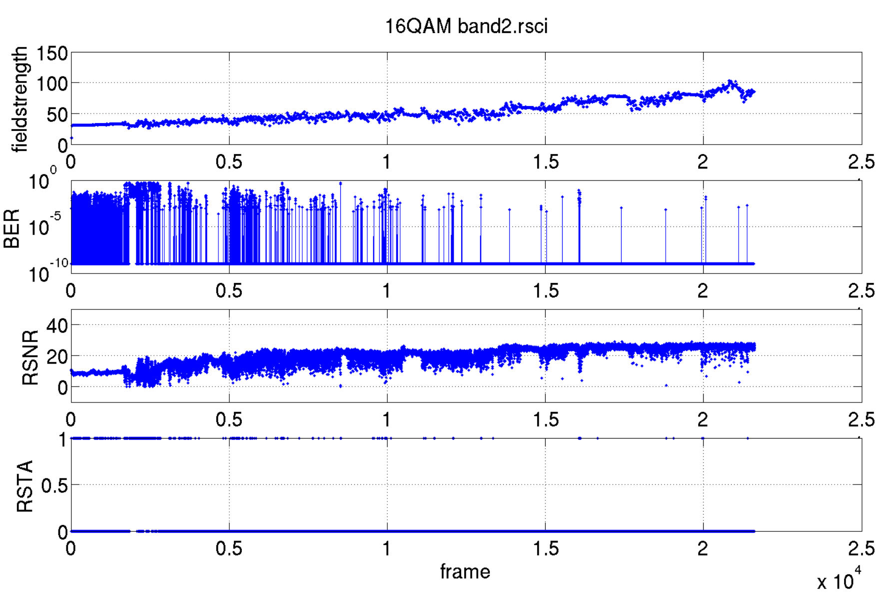


Figure 17: Reception parameter on the B65 with 30 W ERP and 16 QAM Mode (Coderate: 0.5) (mapsource: Bundesamt für Kartographie und Geodäsie)

5 Conclusion

Tests were made at a frequency of 95.2 MHz in urban surroundings and on a radial route passing through the city of Hanover and rural environments in the main beam of the transmission. Measurements of the fieldstrength, the bit error rate, the calculated signal to noise ratio and the audio status show that in 4-QAM mode with a coderate of 0.33 reception with good audio quality was possible down to a fieldstrength of around 30 $dB\mu V/m$ and a calculated SNR of 10 dB. In the 16-QAM mode reception was possible down to 46 $dB\mu V/m$ at an SNR of around 18 dB. As comparision, a FM stereo signal needs according to [4] a fieldstrength of 66 $dB\mu V/m$ in urban environment at a hight of 10 m (+ 10 dB at a height of 1.5 m). The required SNR values are a bit higher than in the simulation results in [1] (7.3 dB for 4-QAM with an urban channel model at 60 km/h and 15.4 for 16-QAM). However the simulations were made with optimal channel estimation and implementation losses are not considered.

With an ERP of 30 W reception dropped out in the countryside at a distance of around 30 km in 4-QAM mode and at around 15 km in the 16-QAM mode.

Thanks to the NLM, RFmondial, Nautel, the Bundesnetzargentur, Fraunhofer IIS and the DRM Consortium and many others for their support and good advices.

References

[1] ETSI. *ES 201 980, Digital Radio Mondiale (DRM), System Specification.* 2009.

[2] ETSI. *TS 102 349, Digital Radio Mondiale (DRM), Receiver Status and Control Interface (RSCI).* 2009.

[3] K. Ramasubramanian and K. Baum. *An OFDM timing recovery scheme with inherent delay-spread estimation.* IEEE Global Telecommunications Conference, 2001.

[4] ITU. *ITU-R BS.412-9, Planning Standards for terrestrial FM sound broadcasting at VHF.* 1995.

A The transmit antenna

The transmit antenna is mounted horizontaly on the roof of the university building in the Appelstr. 9A in Hanover. Direction is to an azimuth of 120 °. For horizontal polarization an antenna array of two Yagi antennas as shown in figure 18 was used. For Vertical polarization a single Yagi antenna as shown in figure 1 was used.

On the next page, the data sheed including the antenna pattern and gain can be found.

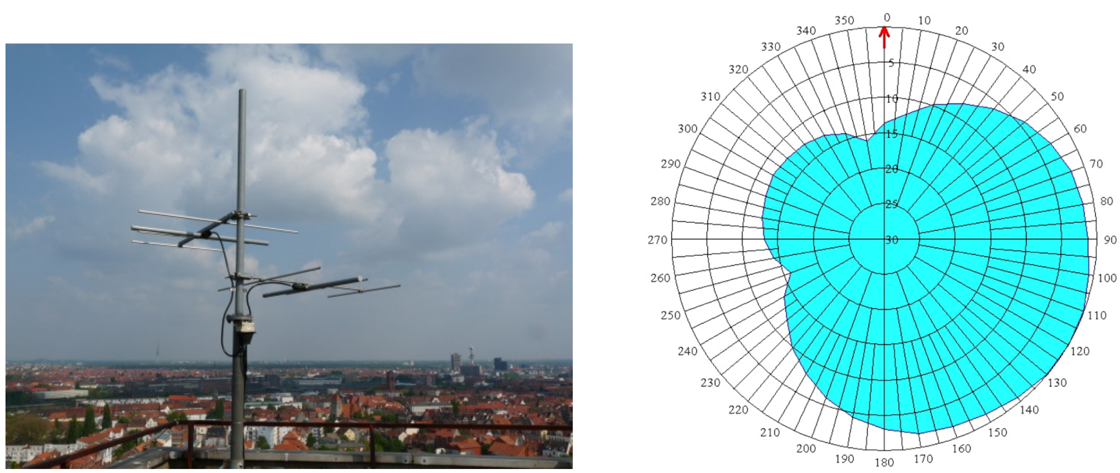


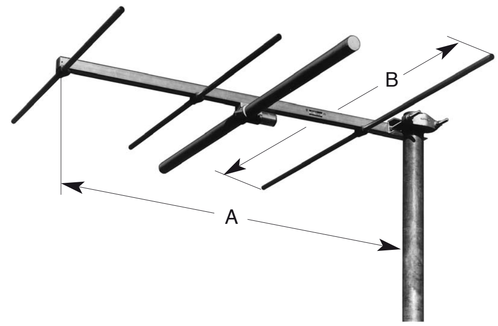
Figure 18: Transmitting antenna array and pattern for horizontal polarised transmission

K 52 40 1. .
Directional Antenna
87.5 – 108 MHz

KATHREIN
Antennen · Electronic

- 4 element broadband Yagi antenna.
- Component for low power transmitting antennas.

Type No. Order No.	**K 52 40 17** 600 263
Input	7-16 female
Frequency range	87.5 – 108 MHz
VSWR	s < 1.3
Gain (ref. λ/2 dipole)	5.5 dB at mid-band
Impedance	50 Ω
Polarization	Horizontal or vertical
Max. power	500 W (at 40 °C ambient temperature)
Weight	13.5 kg
Wind load (at 160 km/h)	
Horizontally polarized	frontal / lateral: 215 N / 160 N
Vertically polarized	frontal / lateral: 215 N / 340 N
Max. wind velocity	225 km/h
Packing size	160 x 160 x 1900 mm



A = 1400 mm
B = 1700 mm

Material: Supporting pipe: Hot-dip galvanized steel. Director pipe and reflector: Weather-proof aluminum. Radiator in fiberglass radome.

Mounting: To pipes of 60 – 115 mm diameter by means of mounting clamps, supplied.

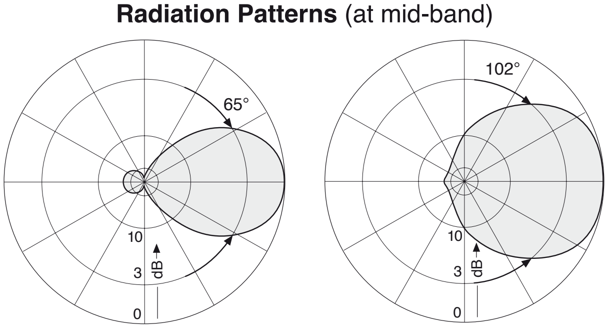
Grounding: Via mounting parts.

Combinations: The antenna is especially suitable as a component in arrays to achieve various radiation patterns.

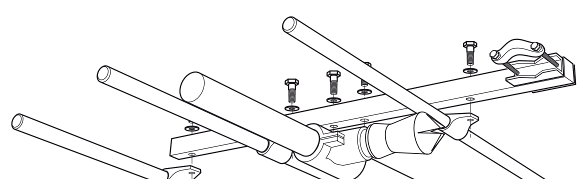
Special features: The antenna is shipped dismounted.

New: **The design has been improved to allow use of both polarizations.**

Radiation Patterns (at mid-band)



in E-plane   in H-plane



Assembly

936.059/c Subject to alteration.

Internet: http://www.kathrein.de

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