Concept and results of the lab measurements and of the field trial with DRM+ in VHF band III

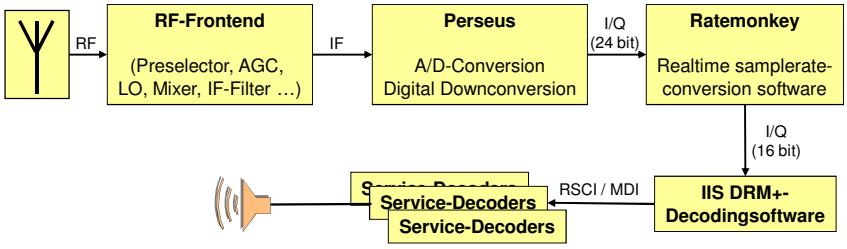
Outline:

1. *Selected elements of the DAB/DRM+ TX/RX chains*
2. *DRM+ mobile reception performance*
3. *Protection ratios DRM+/DAB*
4. *Field trials DRM+/DAB*
5. *Closing the loop: Planning parameters (preliminary)*

Martin Köhler, Joachim Lehnert, Felix Schad, Andreas Steil

► *DRM+ Prototype RXs: General architecture & overall parameters*

Rx-Name	Rx1	Rx2
RF-Frontend manufacturer	Maxim	Unkown
Frequency bands	VHF-II, VHF-III, L-Band	VHF-III, L-Band
IF-Frequency [kHz]	2.048	38.912
IF-Filter-Bandwidth [kHz]	133	1527
Sensitivity, 4/16-QAM [dBm]	-112 / -106	-117 / -112
Shoulder / dB (@-40 dBm)	36	37
Noise Figure [dB]	8.3	3.3
Near Carrier Phase Noise [dBc/Hz]	< -80	< -70



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Selected elements of the DAB/DRM+ TX/RX chains

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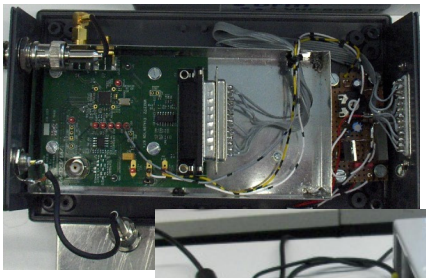
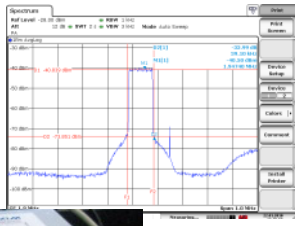
► *DRM+ Prototype Rx1: Some impressions ...*





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Selected elements of the DAB/DRM+ TX/RX chains

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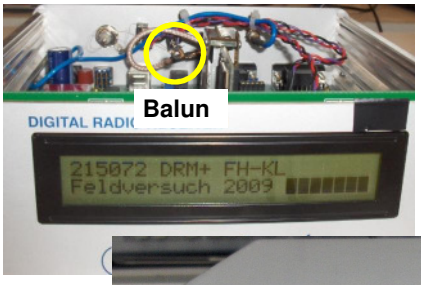
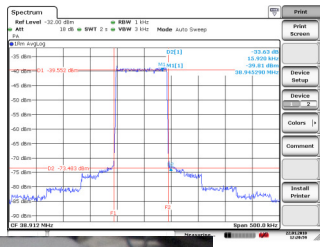
► *DRM+ Prototype Rx2 : Some impressions ...*





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Selected elements of the DAB/DRM+ TX/RX chains

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► *DAB/DAB+ RX*

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Selected elements of the DAB/DRM+ TX/RX chains

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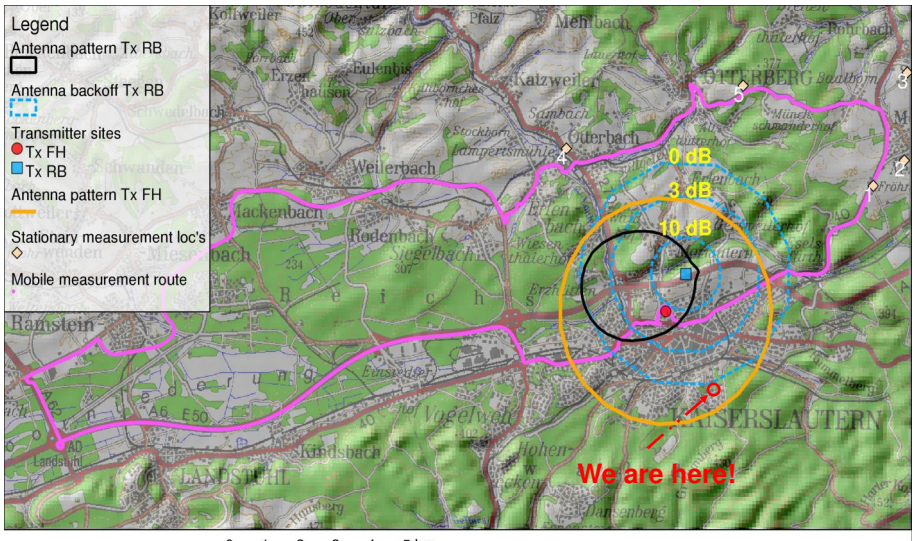
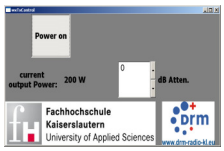
► *TX sites*

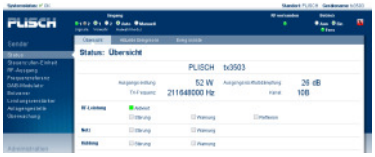


Fachhochschule Kaiserslautern | University of Applied Sciences — Selected elements of the DAB/DRM+ TX/RX chains — LMK

► *TX characteristics*

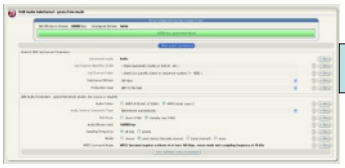
Tx name & location	„Am Kaiserberg“ (Tx FH) FH Kaiserslautern 07E 46 49 / 49N 27 10 [PD] 260 m asl, antenna: 30 m agl		„Am Rotenberg“ (Tx RB) KL-Rotenberg 07E 46 19 / 49N 27 39 [PD] 260 m asl, antenna: 50 m agl
System	DRM+, MSC: 4- or 16-QAM		DAB, DAB+
Frequency	211.648 MHz (10B)		211.648 MHz (10B)
Max. Power	90 W (ERP) Jan. to April	180 W (ERP) since May	135…300 W (ERP)
Antenna	Omni		5-elem. Yagi 6 dBi
Polarisation	vertical		vertical
Content	Audio (AAC+), sync. PRBS		Audio: Musicam (DAB), AAC+ (DAB+)
Equipment	Plisch ULE-Series		R&S SLA8000, Plisch TDA 3503





Fachhochschule Kaiserslautern | University of Applied Sciences — Selected elements of the DAB/DRM+ TX/RX chains — LMK

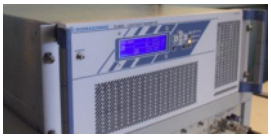
► *Transmitter KL-Rotenberg, DAB (Tx RB)*



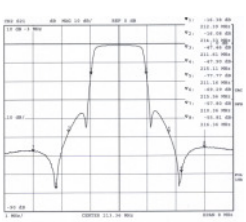
LAN — IIS DAB/DAB+-Content-Server R5 — WAN

ETI

LAN



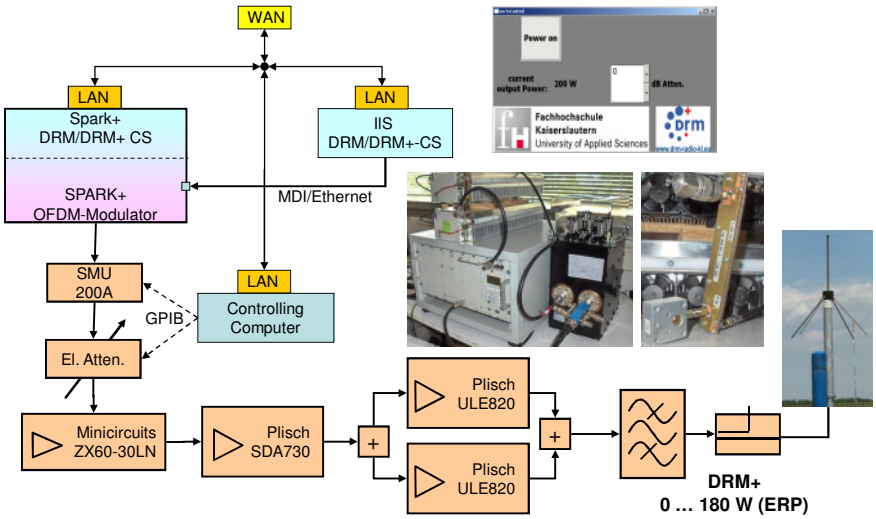
DAB-Transmitter
R&S SLA8000 < May 2010
Plisch TDA3503S >= May 2010



DAB-Maskfilter; Spinner; Ch. 10B

DAB / DAB+
135 … 300 (ERP)

► *Transmitter KL-Kaiserberg, DRM+ (Tx FH)*



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Martin Köhler, Joachim Lehnert, Felix Schad and Andreas Steil

Mobile reception with DRM+ in VHF band III ?

Q: Why should mobile reception in VHF band III be a problem?

A: Since the received signal is subjected to a Doppler shift!

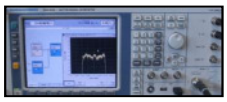
$$f_D = \frac{v}{c_0} \cdot f_0 \cdot \cos(\alpha) \quad \overset{!}{<<} \quad \Delta f$$

f_D	Doppler frequency
v	speed
c_0	speed of light
f_0	carrier frequency
α	angle of incidence
Δf	OFDM subcarrier spacing

Assuming a speed of 200 km/h, we have (roughly)

	DRM+		DAB
	VHF band II	VHF band III	VHF band III
Δf [Hz]	444	444	1000
$f_{D,max}$ [Hz]	20	42	42
$f_{D,max} / \Delta f$	0.045	**0.082**	0.042

► *Setup to assess the mobile performance by lab measurements*



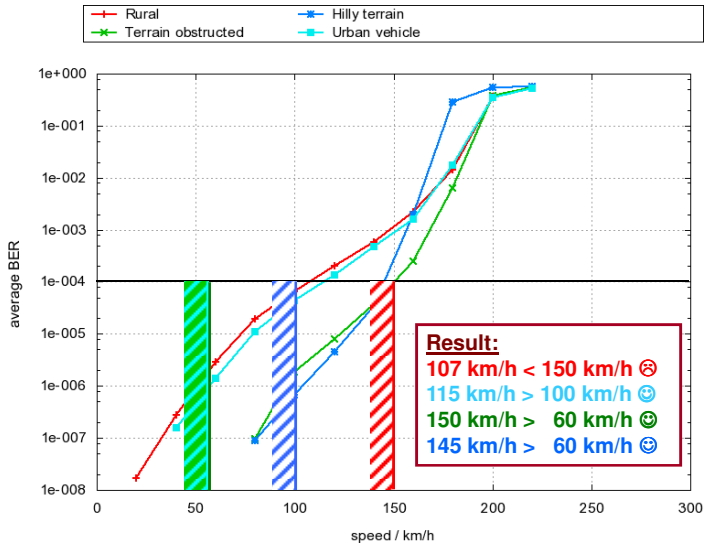
Types of measurements:

(1) **with ETSI fading profile, without AWGN** → v_{max} @ {BER = 10^{-4}}

(2) **without ETSI fading profile, with AWGN** → S/N_{AWGN} @ {BER = 10^{-4}}

(3) **with ETSI fading profile, with AWGN** → S/N_{Profil} @ {BER = 10^{-4}}

► *Example: Measurement result of type (1): v_{max}*



- RX 1
- 16 QAM
- f_0 = 230 MHz
- 1.7 10^9 Bit

► *Measurement results of type (1): v_{max}*

ETSI profile	$v_{Profile}$ [km/h]	v_{max} [km/h] RX 1		v_{max} [km/h] RX 2	
		4 QAM	16 QAM	4 QAM	16 QAM
Urban	60	169	115	157	129
Rural	150	168	**107**	161	**125**
Hilly terrain	100	165	145	162	146
Terrain obstructed	60	174	150	173	153

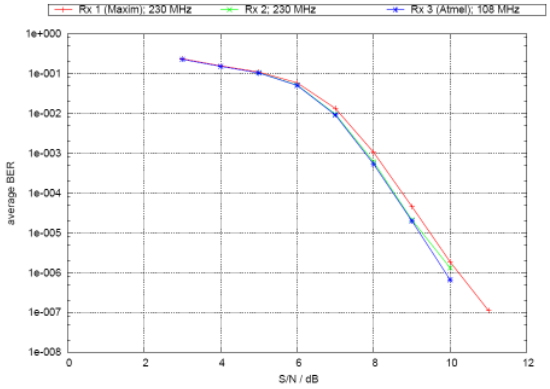
Does this mean, that the ETSI-profiles can not be met by DRM+?

No, since the

- ***AGCs of the RF frontends used***
  - ***expect a DAB signal (larger bandwidth!)***
  - ***have no software parts controlling the A/D conversion***
- ***decoder software (channel estimation, ...) could further be optimzed***

For more details: Visit the project homepage

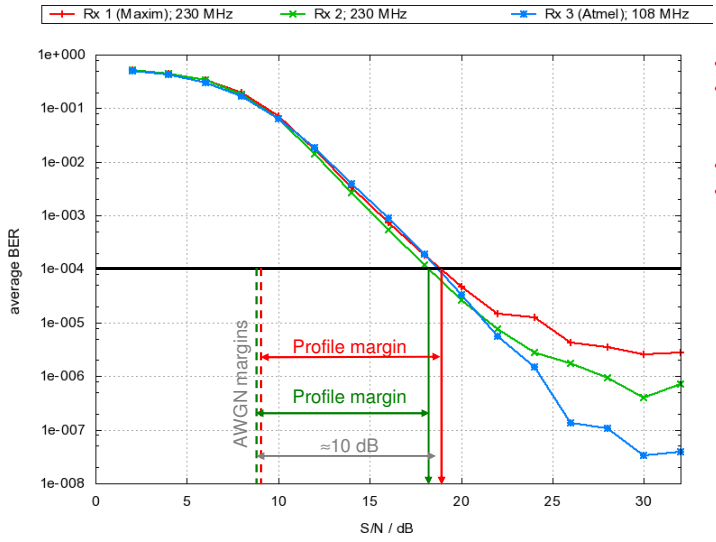
► *Measurement results of type (2): S/N_{AWGN}*



- 16 QAM
- f_0 = 230, 230, 108 MHz
- 10^9 Bit
- Input Level > -45 dBm

S/N_{AWGN} [dB]	RX 1 (230 MHz)	RX 2 (230 MHz)
4 QAM	3.3	3.3
16 QAM	8.7	8.5

► *Example: Measurement result of type (3): S/N_{Profil} for 16 QAM, urban vehicle*

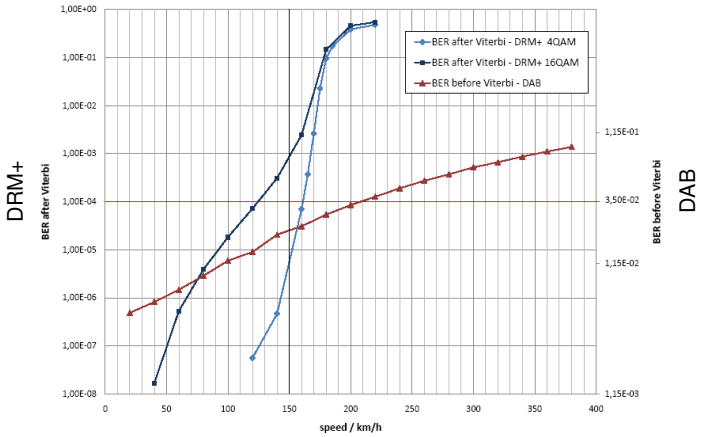


- 16 QAM
- f_0 = 230, 230, 108 MHz
- v_{Profil} = 60 km/h
- 1.7 10^9 Bit

► ***Measurement results of type (3): S/N_{Profil}***

S/N_{Profil} [dB] {margin [dB]}			RX 1 (230 MHz)		RX 2 (230 MHz)	
ETSI profile	Urban vehicle	60 km/h	12.5	{9.2}	13.9	{10.6}
			18.8	{10.1}	18.3	{9.8}
	Urban pedestrian	2 km/h	23.0	{19.7}	23.9	{20.6}
			28.0	{19.3}	27.5	{19.0}
	Rural	150 km/h	14.9	{11.6}	16.6	{13.3}
			---	---	---	---
	Hilly terrain	100 km/h	12.0	{8.7}	12.0	{8.6}
			18.4	{9.7}	17.6	{9.1}
	Terrain obstructed	60 km/h	12.0	{8.8}	12.0	{8.6}
			17.2	{8.4}	16.9	{8.4}

► ***Complement: A comparison with DAB mobile reception performance***



v_{max} [km/h] RX 2	DRM+		DAB
ETSI profile	4 QAM	16 QAM	
Rural	161	**125**	209

► *Mobile reception of DRM+ in VHF band III: Summary*

✓ **DRM+ passes all ETSI profiles except for the `rural profile`**
All measurements were based on

- **the upper fringe of VHF band III**
  → **Using a frequency < 230 MHz relieves this profile constraint even with the prototype RXs used!**
- **prototype receivers (intended for the use with DAB).**
  → **Need to optimize RF frontends, esp. AGC, for DRM+**
- **The VHF band II Rx prototype operated at 230/108 $f_{D,max}$ did comply with the `rural profile`**

→ **DRM+ could comply with the ETSI profiles tested**

? **The hardware channel simulation did not support SFN**
→ **SFN performance is not yet clarified**
→ **There *might* be constraints, this is an open issue**

For more details: Visit the project homepage

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Compatibility issues DAB/DRM+ in VHF band III ?

Q: Could DAB/DAB+ and DRM+ technically co-exist in VHF band III ?

A: Well, this depends on the protecion ratios (PRs).
Once these are established,
- *a qualified answer can be given*
- *Model network planning exercises can be done*

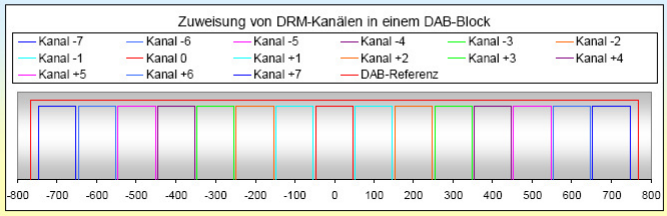
Our approach:

1. *Lab measurement of PRs:*
   - *DRM+ → DAB*
   - *DAB → DRM+*
2. *Verification of PRs with field measurements:*
   - *Stationary measurements (10 m antenna hight agl)*
   - *Mobile measurements (2m antenna hight agl)*

► *Channel definitions: Dr. Kühn's proposal*

DRM-Übertragung im VHF-Bereich

Vorschlag: Zuweisung von DRM-Kanälen in einem DAB-Referenzblock

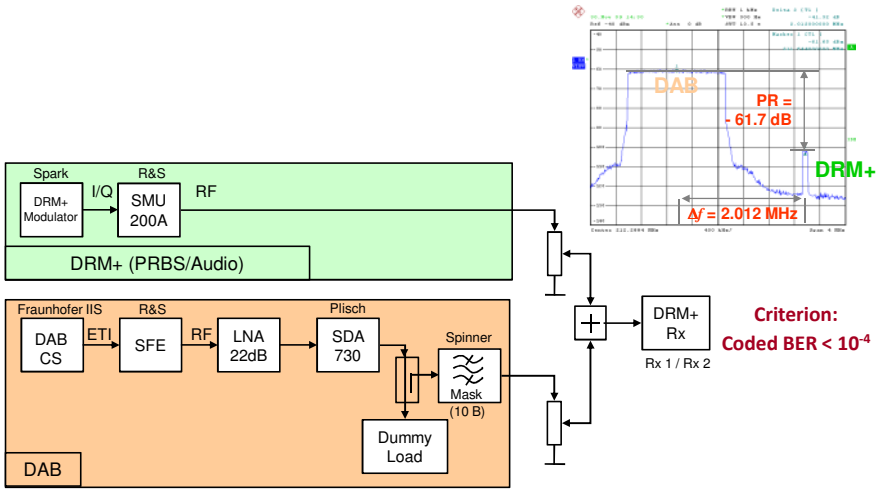


Zuweisung der DRM-Kanäle in den fiktiven DAB-Blöcken

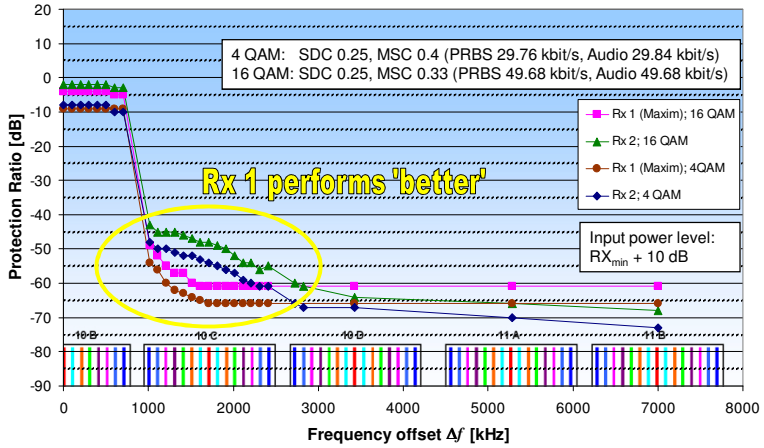
- Jedem DAB-Block werden 15 DRM-Kanäle symmetrisch zugeordnet
- Der Mittenfrequenz f_0 des DRM-Bezugskanal entspricht $f_{center\ DAB}$
- Die Mittenfrequenzen der Kanäle –7 ... –1 und +1 ... +7
  ergeben sich zu $f_{n0} = f_0 \pm n*100$ kHz
- DRM-Kanalabstand 5,8 kHz
- Randabstand zur DAB-Blockgrenze 21 kHz

MOBILE BROADCAST CONSULT DRM im VHF (v0-1) Dr.-Ing. Manfred Kühn Seite 10

► *Measurement setup: PR DAB → DRM+*

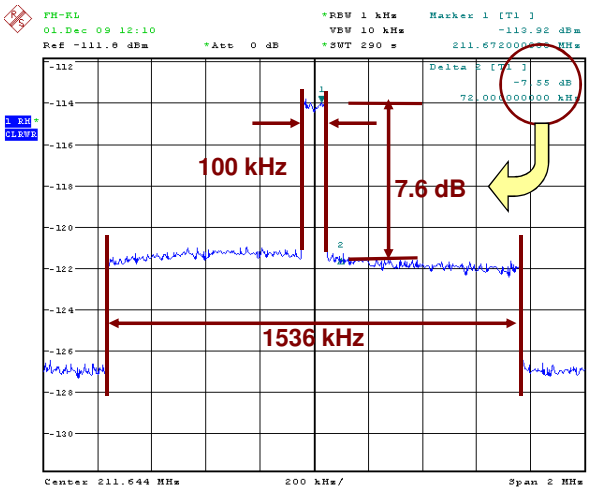


► *Result: PR DAB → DRM+*



PRs for DAB → DRM+:
- **Co-Channel: Difference 4/16 QAM ≈ 5 dB (cf. AWGN-performance!)**
- **Adjacent channel: PR < - 60 dB (Rx 1)**
- **Similar performance with RX_{min} +10/20 dB input power level / DAB TX**

► *Uhps ... panic on board ... negative PRs???*



Let's shift the dBs …

$$\left.\frac{C}{I}\right|_{100\,\mathrm{kHz}} = 7.6\,\mathrm{dB}$$

$$I|_{100\,\mathrm{kHz}} = C - 7.6\,\mathrm{dB}$$

$$I|_{1536\,\mathrm{kHz}} = I|_{100\,\mathrm{kHz}} + \underbrace{10\log_{10}\left(\frac{1536}{100}\right)}_{11.9\,\mathrm{dB}}$$

$$= C - 7.6\,\mathrm{dB} + 11.9\,\mathrm{dB}$$

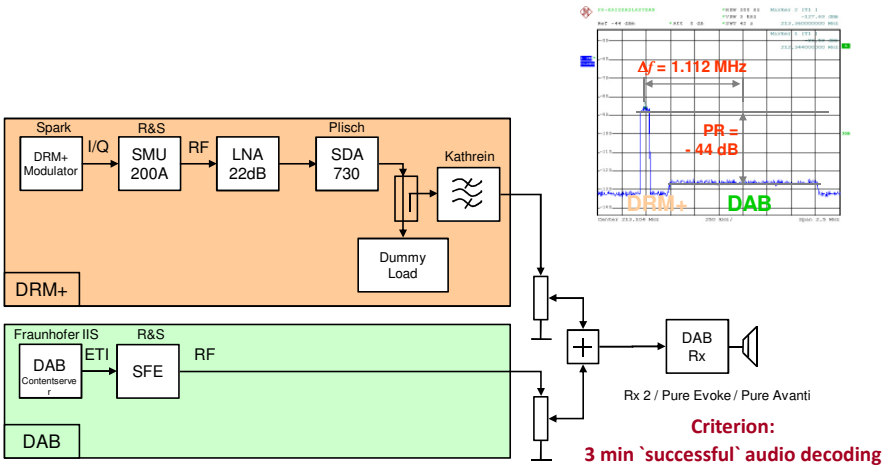
$$= C + 4.3\,\mathrm{dB}$$

$$\mathrm{PR}|_{\mathrm{dB}} = C - I|_{1536\,\mathrm{kHz}} = -4.3\,\mathrm{dB}$$

Theory

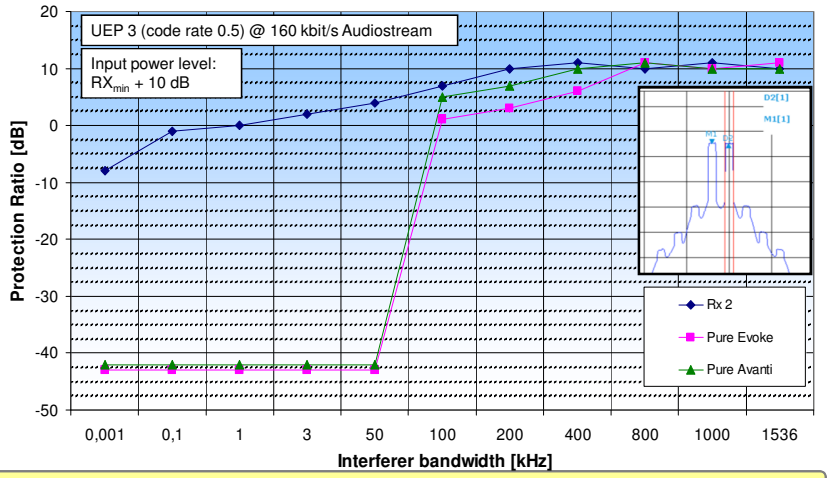
Measured: ≈ - 5 dB

► *Measurement setup: PR DRM+ → DAB*



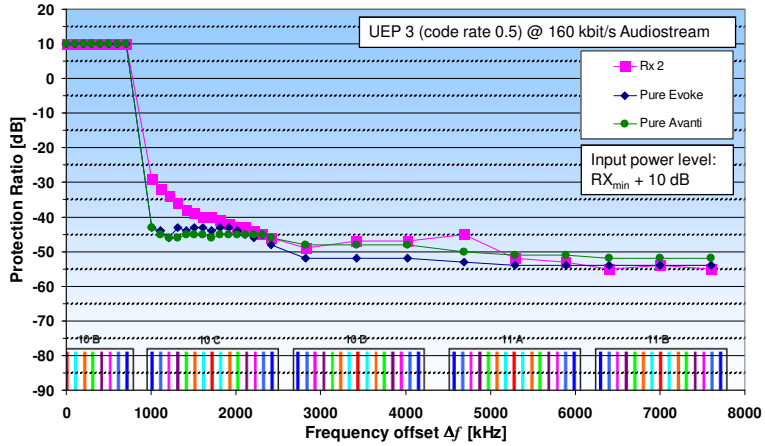
Criterion:
3 min `successful` audio decoding

► *Example: PR DRM+ → DAB (Cochannel, multiple DRM+ interferer)*



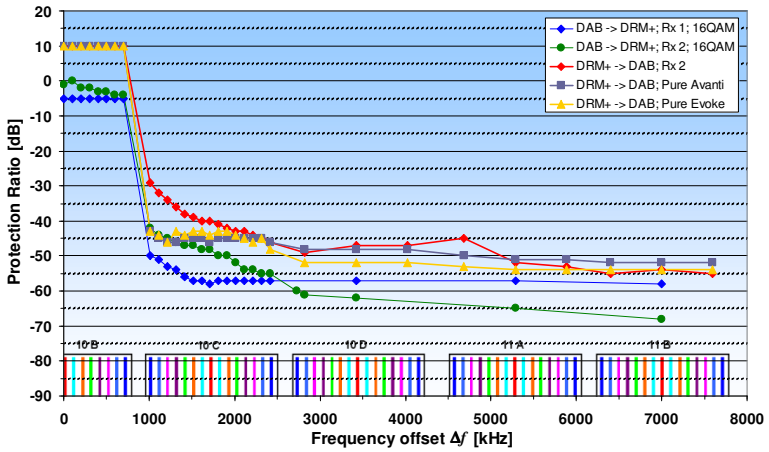
PRs for DRM+ → DAB
• Co-Channel: ≈ 7 … 10 dB (1 … 15 DRM+ interferer)

► *Result: PR DRM+ → DAB*



PRs for DRM+ → DAB
• No influence of DRM+ modulation (4/16 QAM)
• Co-Channel: ≈ 7 … 10 dB; adjacent Channels < -40 dB

► *Comparision of PRs (DRM+ 16QAM; DAB)*



PRs (esp. in Co-Channel!) are quite different due to different
- **bandwidth (→ definition of PR)**
- **error protection schemes and audio coding schemes**

► *Lab measurements of PRs: Summary*

✓ **DAB channel spacing:**
- **Co-Channel:**
  - **DRM+ → DAB:**
    - **≈ 7 ... 10 dB (1 ... multiple DRM+ interferer)**
  - **DAB → DRM+:**
    - **≈ - 9 / -7 dB (4 QAM - Rx1 / Rx2)**
    - **≈ -4 / -2 dB (16 QAM - Rx1 / Rx2)**
- **Adjacent channel case: `uncritical`, i.e. < - 40 dB**

✓ **DRM+ channel spacing:**
- **Co-Channel:**
  - **DRM+ → DRM+:**
    - **≈ 5 dB (4 QAM)**
    - **≈ 11 dB (16 QAM)**

DRM+ and DAB/DAB+ could coexist in VHF band III

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► *Transmitter setup (reprise ☺)*

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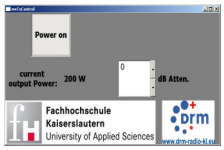
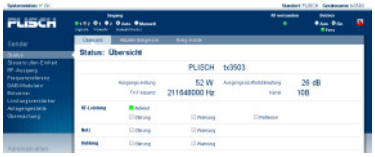
Max. Power	90 W (ERP) Jan. to April	180 W (ERP) since May	135…300 W (ERP)
Antenna	Omni		5-elem. Yagi 6 dBi
Polarisation	vertical		vertical
Content	Audio (AAC+), sync. PRBS		Audio: Musicam (DAB), AAC+ (DAB+)
Equipment	Plisch ULE-Series		R&S SLA8000, Plisch TDA 3503





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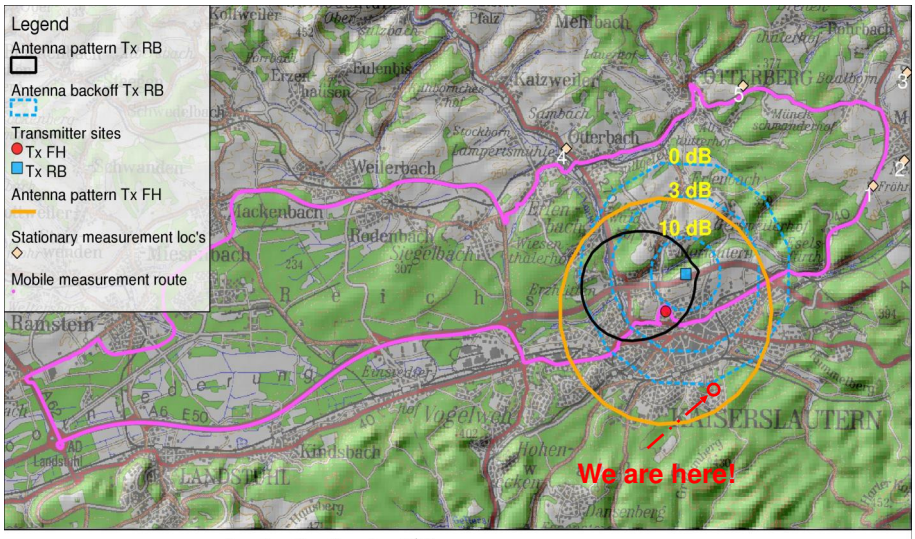
► *The scenario (reprise ☺)*



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► *Stationary measurements: Setup*

VHF-Directional antenna
10m agl.
k = 8.9 dB

Frontend

Perseus
- A/D-Conversion
- Digital Downconversion

Spectrum Analyzer
R&S FSP30
- Channel power measurement

Laptop
- UMTS-Connector for Transmitter Control
- DRM-Decoder
- Decoder Monitoring (BER, Audio)

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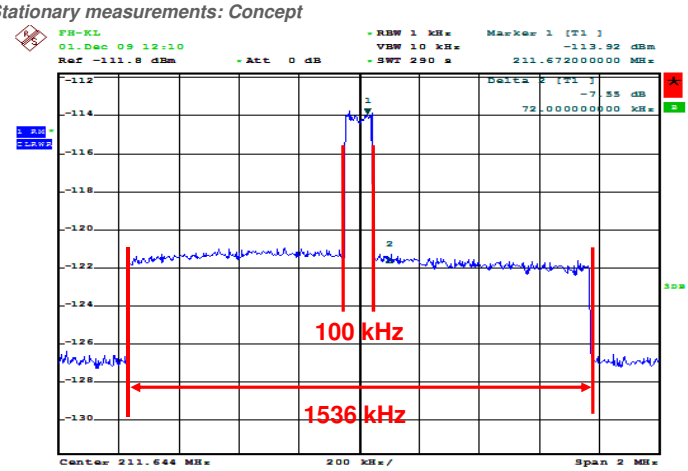
► *Stationary measurements: Concept*



- **Measure** DRM+ / DAB signal power within respective bandwidths (separate measurement; turn on/off the Tx's before…)
- **Decrease** DRM+-Tx-Power until mean BER ~ 10^{-4}
- **Calculate** $PR_{field} = P_{DAB} - (P_{DRM+} - \text{Tx Attenuation})$

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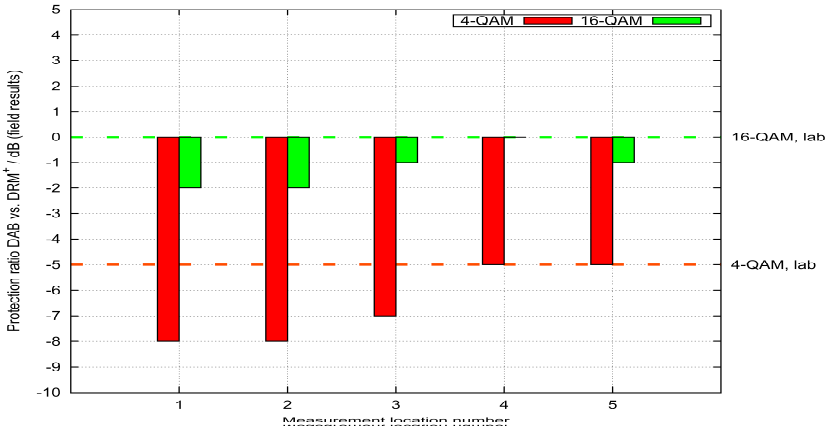
► *Stationary measurements: PR Results*



- Field results tend to confirm laboratory results → Influence of non-flat channel ...
- Measurement uncertainity ≈ ± 1dB, esp. critical in 4-QAM-Mode due to the steep gradient of mean BER vs. S/N
- Measured PR difference (4-/16-QAM) similar at each location

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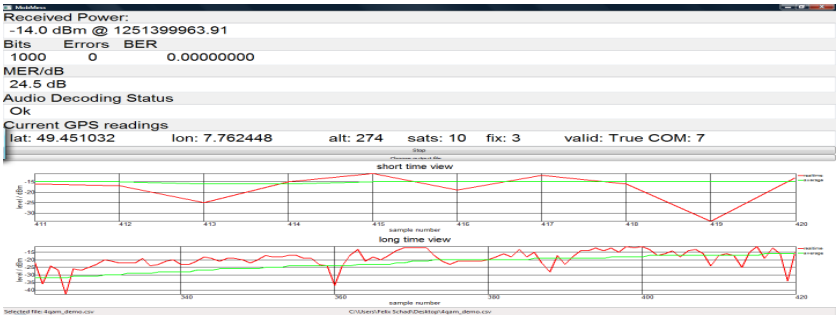
► *Mobile measurements: Monitoring software*



- Realtime-monitoring of
  - location, time, ...
  - RF-Power, BER, MER, … (DRM+)
  - RF-Power, audio status, Rx-Sync., CRC-Frame-Errors, … (DAB)
- RF-Power sampled in equal intervals at 0.8λ (~ 1.14m)
- Sub-(consumer) GPS-Resolution achieved by equalizing via the known measurement distance
- Vector-data output to various GIS-tools for analysis

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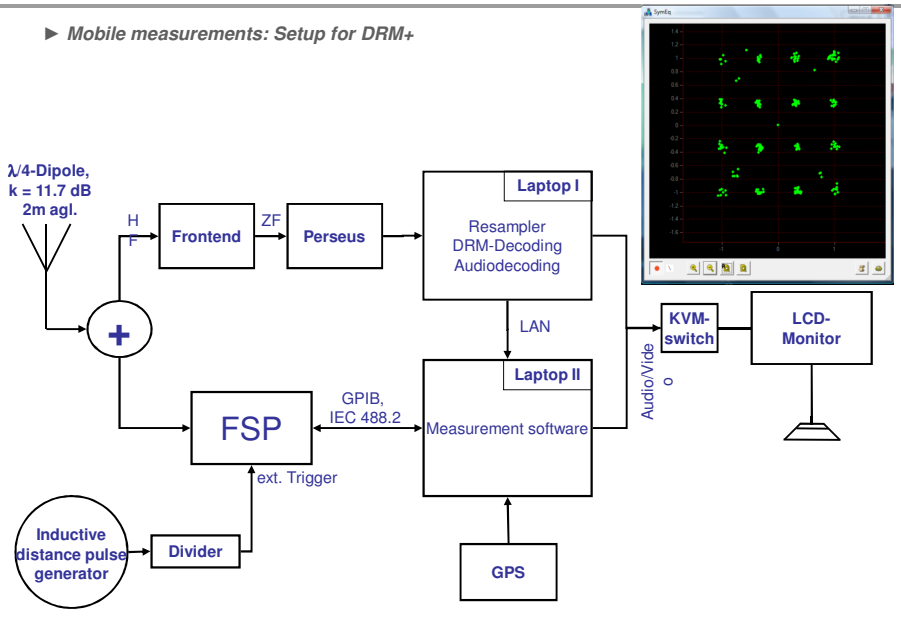
► *Mobile measurements: Setup for DRM+*



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Field trials DRM+/DAB

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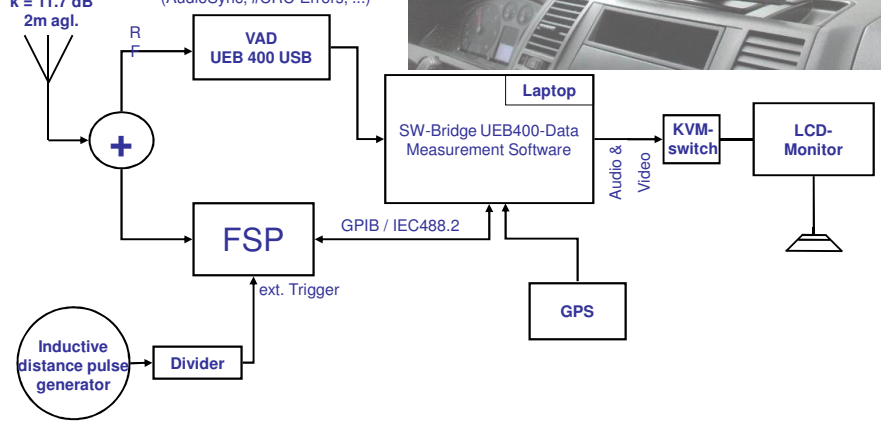
► *Mobile measurements: Setup for DAB*



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Field trials DRM+/DAB

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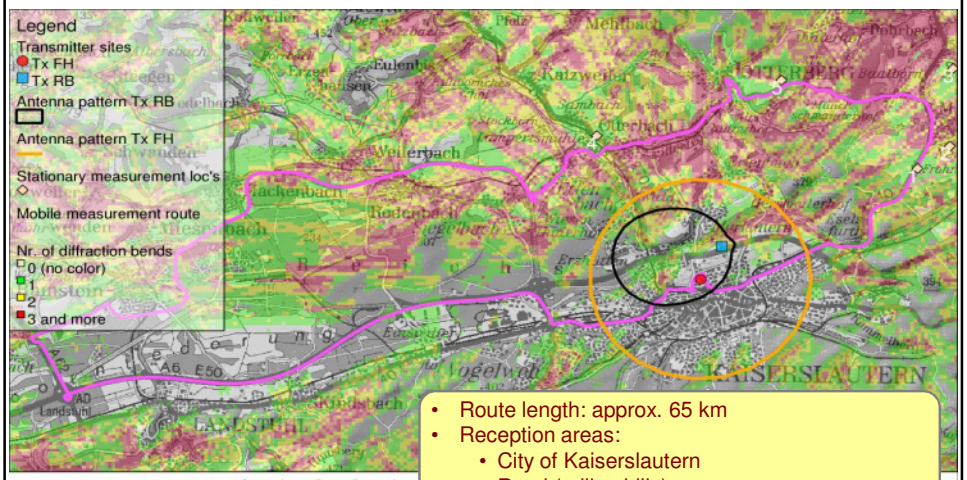
► *Mobile measurements: A topographic look around (LOS-Conditions)*



- Route length: approx. 65 km
- Reception areas:
  - City of Kaiserslautern
  - Rural (rolling hills)
  - Motorway (max. speed: 120 km/h)
  - Light industrial and residential zones
- LOS-Rating based on DEM only (i.e. no buildings)

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Field trials DRM+/DAB

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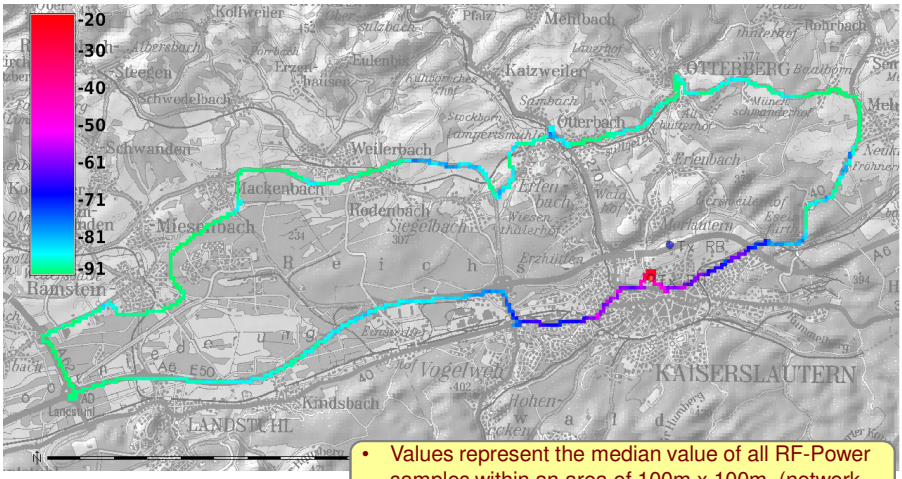
► *Mobile measurements: Received power [dBm] of Tx FH@180W ERP*



- Values represent the median value of all RF-Power samples within an area of 100m x 100m (network planning!)
- Sensitivity (min value: -93 dBm) limited by spectrum analyzer; no measurement receiver available ☹

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Field trials DRM+/DAB

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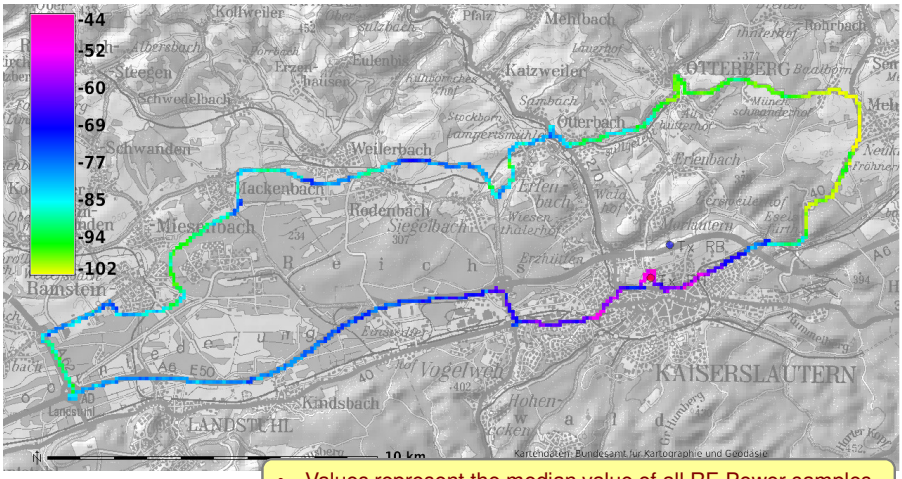
► *Mobile measurements: Received power [dBm] of Tx RB@135W ERP*



- Values represent the median value of all RF-Power samples within an area of 100m x 100m
- Same color-scale as before
- Higher sensitivity due to usage of VAD-Rx (slower)

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Field trials DRM+/DAB

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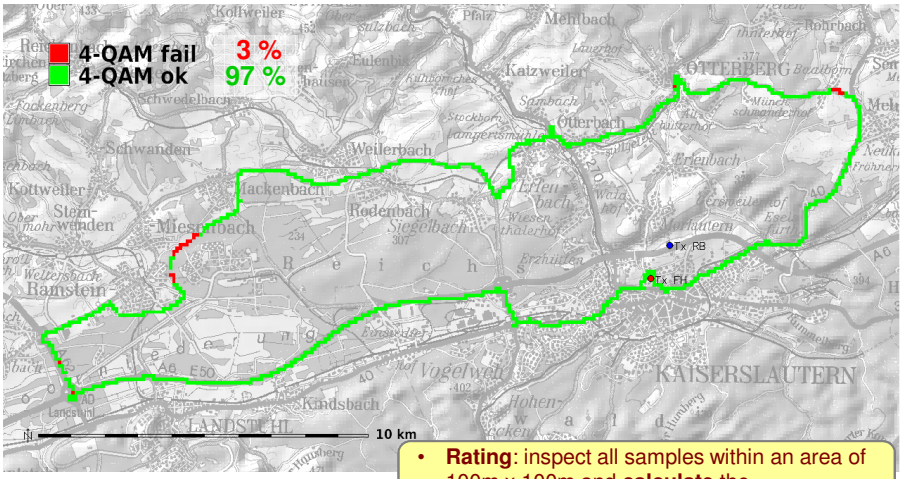
► *Mobile measurements: Coverage for DRM+, 180W ERP*



- **Rating**: inspect all samples within an area of 100m x 100m and **calculate** the (instantenous-) BER's 75%-percentile q
- q <= 10^{-4} → **Green**
- **Green**: Implies succesful audio-decoding!

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Field trials DRM+/DAB

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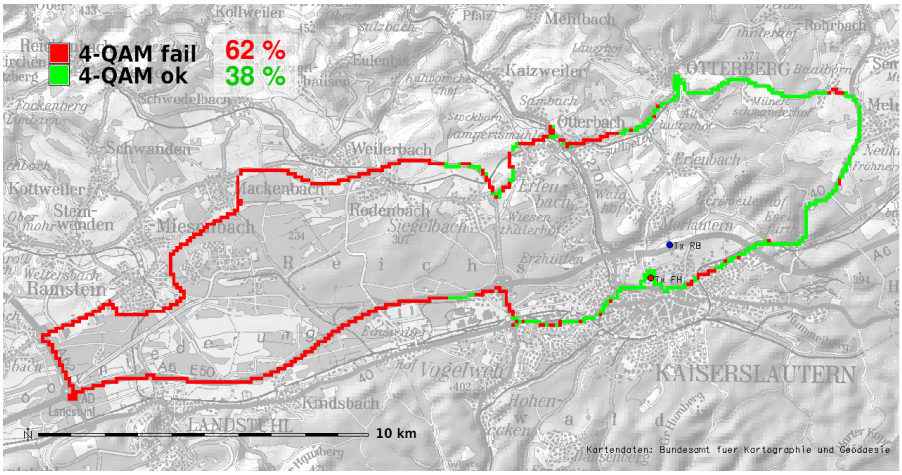
► *Mobile measurements: Coverage for DRM+, 180W ERP interfered by DAB, 135W ERP*



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Field trials DRM+/DAB

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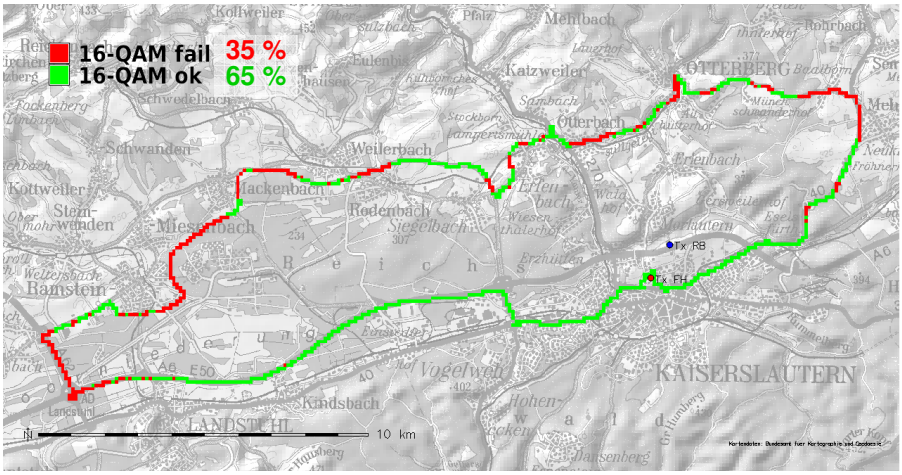
► *Mobile measurements: Coverage for DRM+ (180W ERP)*



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Field trials DRM+/DAB

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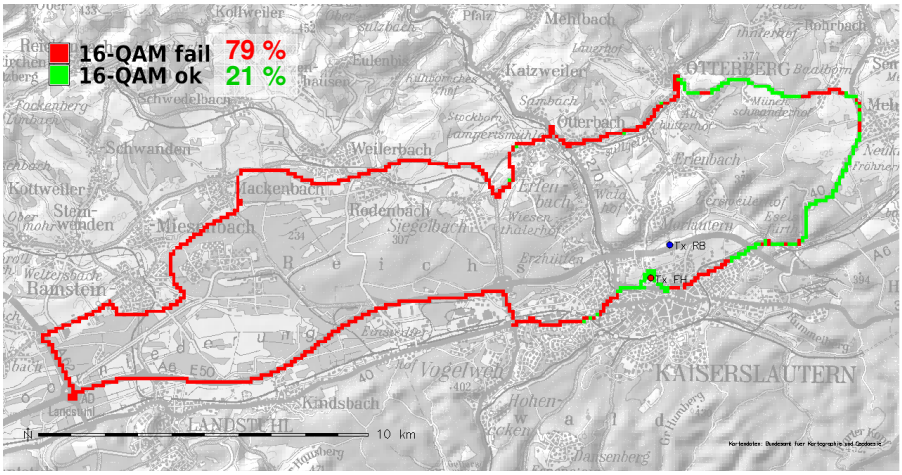
► *Mobile measurements: Coverage for DRM+ (180W ERP) interfered by DAB(135W ERP)*



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Field trials DRM+/DAB

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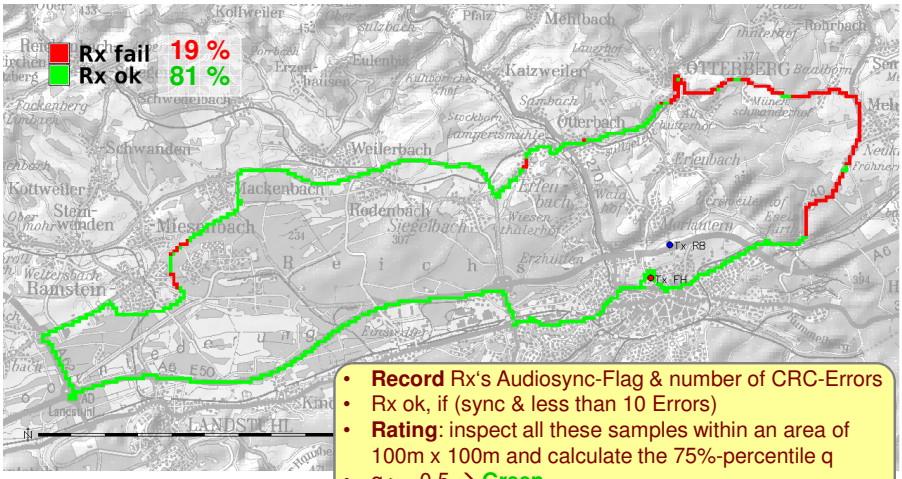
► *Mobile measurements: Coverage for DAB (135W ERP)*



- **Record** Rx's Audiosync-Flag & number of CRC-Errors
- Rx ok, if (sync & less than 10 Errors)
- **Rating**: inspect all these samples within an area of 100m x 100m and calculate the 75%-percentile q
- q >= 0.5 → **Green**
- Rating matches the listener's **subjective perception**
- **Note**: less than 2% more ‚red pixels' when inspecting the 90%-Percentile

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Field trials DRM+/DAB

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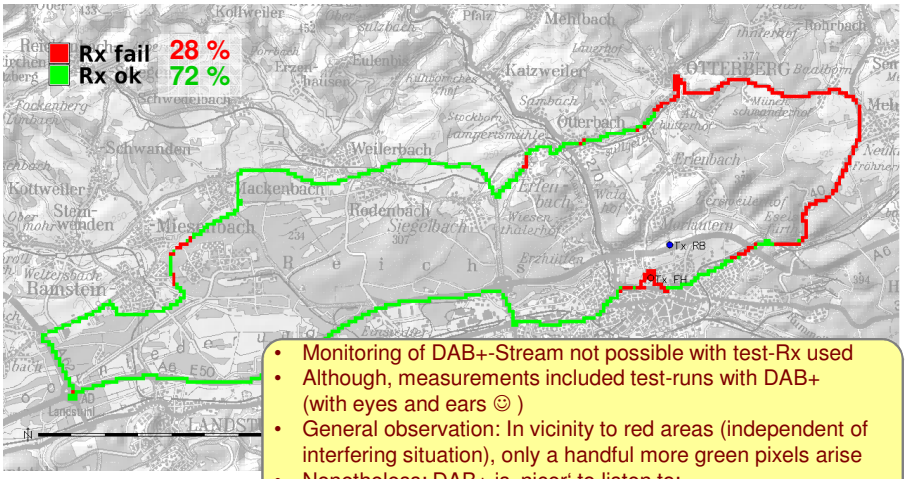
► *Mobile measurements: Coverage for DAB (135W ERP) interfered by DRM+ (90W ERP)*



- Monitoring of DAB+-Stream not possible with test-Rx used
- Although, measurements included test-runs with DAB+ (with eyes and ears ☺)
- General observation: In vicinity to red areas (independent of interfering situation), only a handful more green pixels arise
- Nonetheless: DAB+ is ‚nicer' to listen to:
  - higher quality & error tolerance
  - No more gargling sounds, hard muting of the audio stream in case of bad reception

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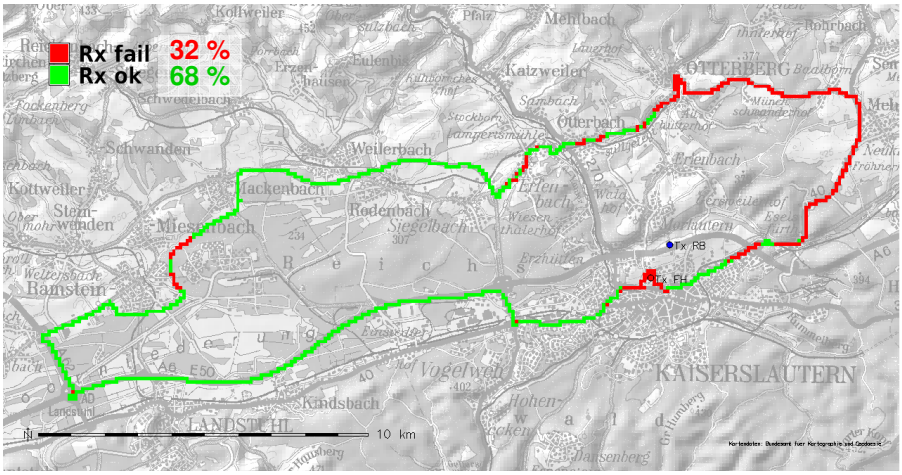
► *Mobile measurements: Coverage for DAB (135W ERP) interfered with 2 DRM+-Blocks (90W ERP)*



Only very small differences as compared to 1 DRM+ interfering block observed…

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► *Field measurements: Summary*

✓ **PR lab measurements (DRM+/DAB)**
- **Validated by stationary measurements in 10m height**
- **Notes:**
  - Channel not `flat` → Slight PR difference to lab
  - Adjacent channel measurements not possible (limited dynamics)

✓ **Mobile reception along measurement route**
- **Simulations confirmed**
- **DRM+ mobile reception as compared to DAB/DAB+ ok within coverage area!**
- ***Subjective* audio quality comparable to DAB+, in any case superior to DAB (*muting* instead of *tweeting*)**

DRM+ DAB DAB+

DRM+ and DAB/DAB+ could coexist in VHF band III

For more details: Visit the project homepage

Concept and results of the lab measurements and of the field trial with DRM+ in VHF band III

Outline:

1. *Selected elements of the DAB/DRM+ TX/RX chains*
2. *DRM+ mobile reception performance*
3. *Protection ratios DRM+/DAB*
4. *Field trials DRM+/DAB*
5. *Closing the loop: Planning parameters (preliminary)*

Martin Köhler, Joachim Lehnert, Felix Schad and Andreas Steil

Planning parameters for DRM+ in VHF band III ?

Q: What are the planning parameters for DRM+ in VHF band III?

A: This is a quite difficult question:

- *Close to DAB/DAB+ planning parameters and paradigms*
- *Definition of reasonable margins to ensure correct decoding*
- *Definition of RX scenarios, RX types, ...*

A lot of work ...

- *Reflection of measurement results back into the planning world in progress (like it or not ☺), to come soon (11th WSDB)*
- *Here: First, first analyses ...*
  - *Data mining & number crunching*
  - *Cross checking to validate data*

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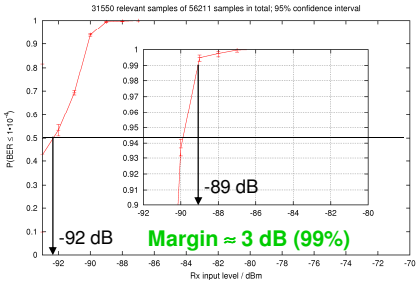
► *Example: Margins for mobile reception (useful signal) out of the mobile recordings*

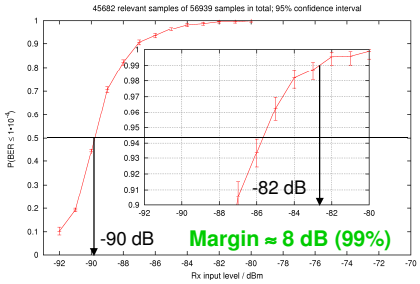
Coverage validation by , e.g., determining the RX margin from 50% (median) to XX %

Example:

4 QAM



16 QAM



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► *Example: Margins for mobile reception (useful signal) out of the mobile recordings*

Algorithm (symbolic code):

```
FORALL vector data points IN RXLEVEL DO {
    IF (RXLEVEL > RX_50 + MARGIN_XX ) THEN
        RF_XX = True; ELSE RF_XX = False;
}
FORALL vector data points IN RF_XX DO {
    RF_XX_RASTER = RasterizeToPixel(RF_XX,1x1);
} % Only 1 value per pixel
AUDIO_Prediction = RESAMPLE(RF_XX_RASTER,100x100, value = XX%);

FORALL vector data points IN BER DO {
    BER_RASTER = RasterizeToPixel(BER,1x1);
} % Only 1 value per pixel
AUDIO_Measured = RESAMPLE(BER_XX_RASTER,100x100, value = 75%); %Subjectivly OK

COMPARE(AUDIO_Prediction, AUDIO_Measured);
```

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Planning parameters (peliminary)

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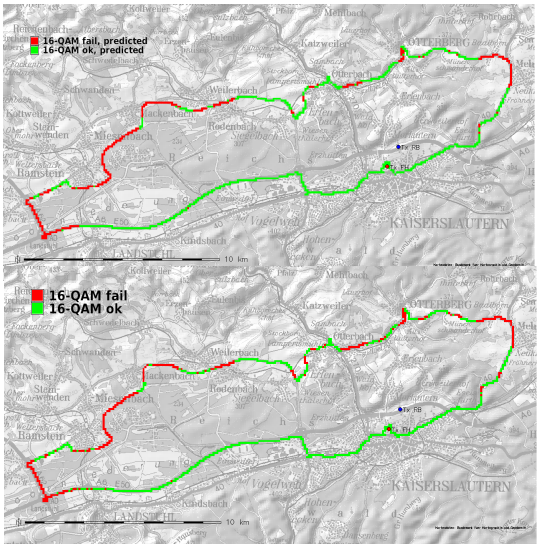
► *Example: Comparison of measured and predicted coverage acc. to algorithm*



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Planning parameters (peliminary)

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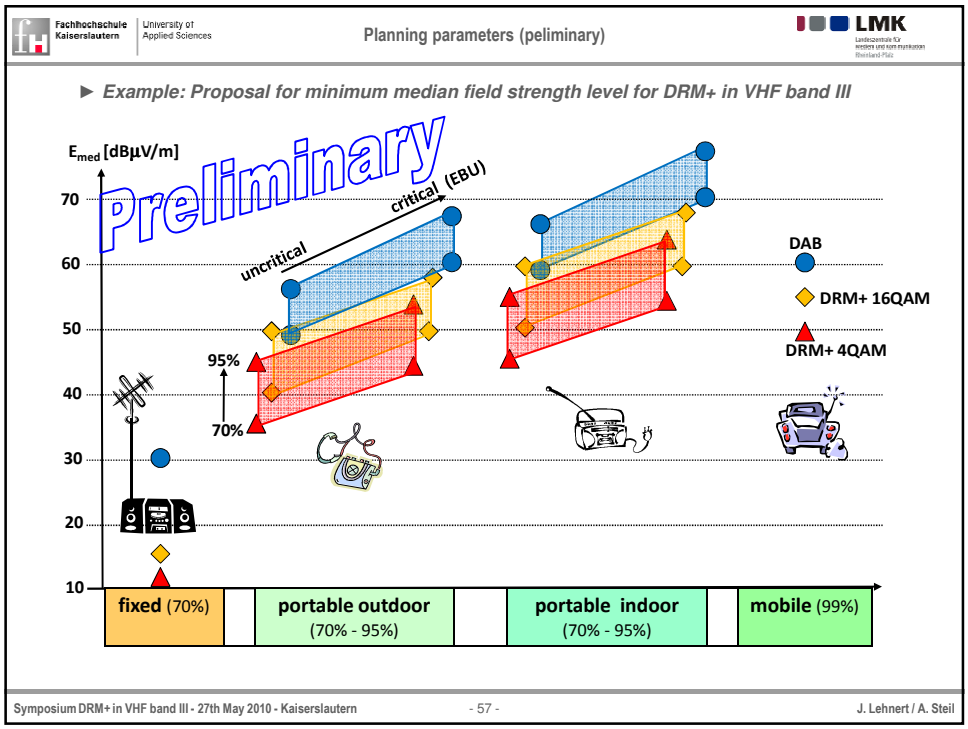
► *Example: Proposal for receiving scenarios*

Preliminary

type of reception	fixed	portable indoor		portable outdoor		mobile
receiver type						
channel profile / reception area	AWGN +3dB	suburban	urban	suburban	urban	terrain obstructed
reception situation		uncritical	critical (EBU)	uncritical	critical (EBU)	
antenna values	D +7dBD	ND -2.2 dBD	ND -13 dBD	ND -2.2 dBD	ND -13 dBD	ND -2.2 dBD
antenna height	10 m	1.5 m				
feeder loss	2 dB	0 dB				0.4 dB
building penetration loss	0 dB	9 dB (σ=3 dB)		0 dB		
location probability	70 %			95 %		99 %
man made noise	2 dB					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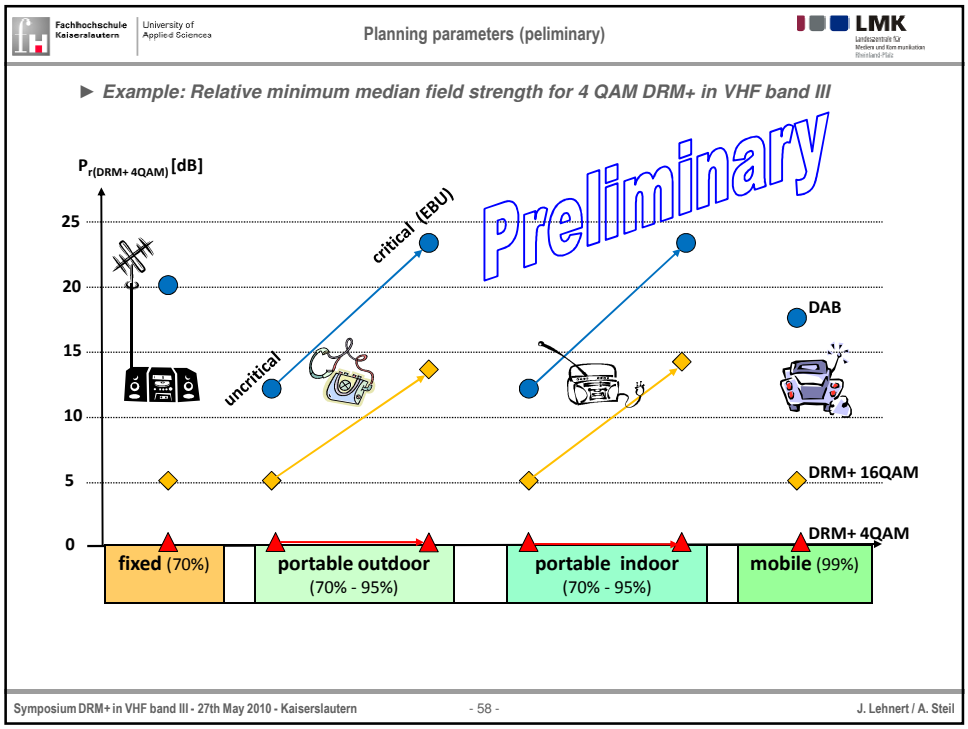
Planning parameters (peliminary)
LMK
► Example: Proposal for minimum median field strength level for DRM+ in VHF band III
Preliminary
E_med [dBµV/m]
70
60
50
40
30
20
10
critical (EBU)
uncritical
95%
70%
DAB
DRM+ 16QAM
DRM+ 4QAM
fixed (70%)
portable outdoor (70% - 95%)
portable indoor (70% - 95%)
mobile (99%)
Symposium DRM+ in VHF band III - 27th May 2010 - Kaiserslautern
- 57 -
J. Lehnert / A. Steil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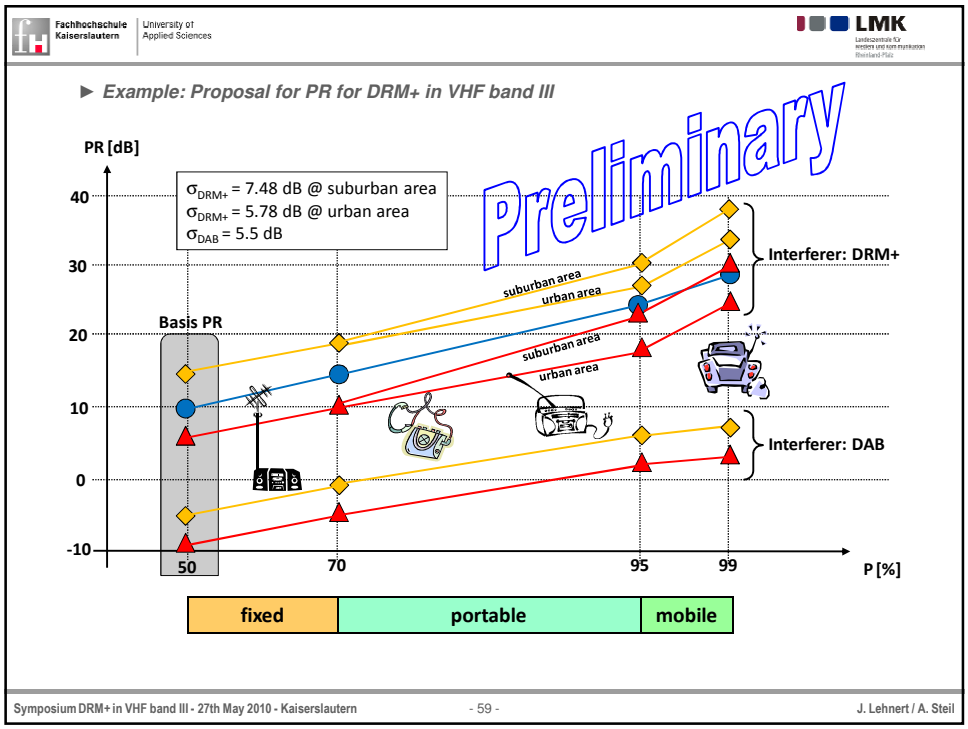
Planning parameters (peliminary)
LMK
► Example: Relative minimum median field strength for 4 QAM DRM+ in VHF band III
Preliminary
P_r(DRM+ 4QAM) [dB]
25
20
15
10
5
0
critical (EBU)
uncritical
DAB
DRM+ 16QAM
DRM+ 4QAM
fixed (70%)
portable outdoor (70% - 95%)
portable indoor (70% - 95%)
mobile (99%)
Symposium DRM+ in VHF band III - 27th May 2010 - Kaiserslautern
- 58 -
J. Lehnert / A. Steil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LMK
► Example: Proposal for PR for DRM+ in VHF band III
PR [dB]
σDRM+ = 7.48 dB @ suburban area
σDRM+ = 5.78 dB @ urban area
σDAB = 5.5 dB
Preliminary
40
30
20
10
0
-10
Basis PR
suburban area
urban area
suburban area
urban area
Interferer: DRM+
Interferer: DAB
50
70
95
99
P [%]
fixed
portable
mobile
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- 59 -
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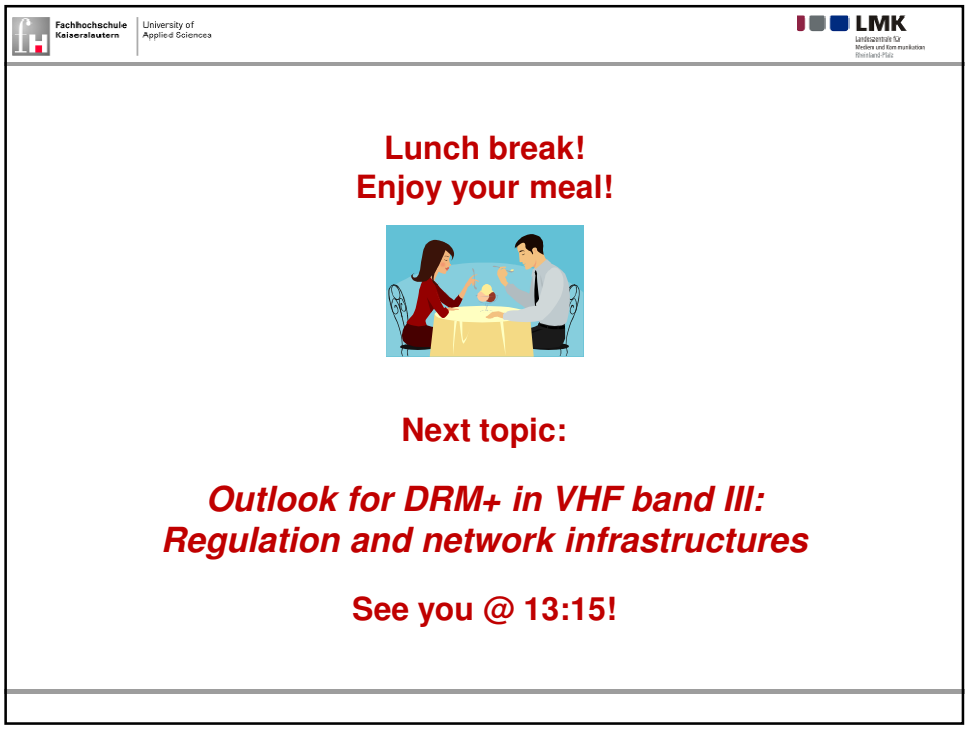
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LMK
Lunch break!
Enjoy your meal!
Next topic:
Outlook for DRM+ in VHF band III:
Regulation and network infrastructures
See you @ 13:15!