**Motivation for the DRM+ field trial in VHF band III in Kaiserslautern**

- **Objective:** Investigations on compatibility between FM and DRM+  
- **Objective:** Determination of DRM+ coverage for fixed and mobile reception

**Positive technical results:**
- DRM+ transmitters could be coordinated (compatible with existing FM networks)  
- DRM+ transmitters show a better coverage than FM transmitters (equal ERP) especially in the service area, for mobile and portable reception  
- DRM+ is frequency economic since SFN is possible

**Negative regulatory results:**
- Available frequencies are not foreseeable for a long time in VHF band II  
- Potential restrictions of aeronautical services block the deployment as long as ITU-Recs for compatibility with digital systems in VHF band II are missing  
- Multinational coordination procedures in Europe are missing

The - somewhat sad – conclusion is obvious:
- Deploying DRM+ in FM VHF band II in Europe is impossible (mid/long term).
Considerations of the deployment of DRM+ in VHF band III

Is there another fitting broadcasting service band for DRM+ in Europe with a chance of a quicker deployment as in FM VHF band II?

**VHF Band I (47-68 MHz)**
- Not a digital broadcasting services band of RRC-06
- Other services operate in VHF band I
- Extensive network infrastructures, lack of clarity of the RX design (RF frontend, reception antennas)
- Propagation conditions are problematic; no frequency co-ordination agreements
- VHF band I is currently included in the DRM+ ETSI standard

**VHF Band III (174-230 MHz)**
- Allocated to the digital sound broadcasting service in RRC-06
- Huge amount of available frequencies without affecting the use of DAB
- Digital radios for VHF band III are in the market for DAB reception.
- Coordination regulations of RRC-06 are applicable for DRM+
- VHF band III is NOT currently included in the DRM+ ETSI standard – it’s not a technical motivated border, more a fictive border to protect the DAB frontyard

😊 not feasible 😊

😊 fitting candidate 😊

MOTIVATION for deploying DRM+ in VHF band III:
- Acceleration of the digitalization of the sound broadcasting with DRM+ in addition to DAB+ in VHF band III, especially for local and regional sound broadcasters (DAB is uneconomical)

First: Clarifications on the technical level:
- Is DRM+ applicable with its system parameters in frequencies up to 230 MHz for mobile reception due to the OFDM subcarrier spacing?
- Is DRM+ compatible to existing DAB networks?
- Is DRM+, with its coverage and network infrastructure, an alternative or even better solution to DAB/DAB+ for local and regional sound broadcasters?
- Can DAB+ radios be updated for DRM+ reception with low cost (antenna and RF frontend work in the same frequency band, audio decoding is the same, signal processing is similar)?
Investigations of DRM+ in VHF band III (174 – 230 MHz)

To clarify the questions regarding coverage and system parameters for a good mobile reception: Laboratory measurements and field trials in Kaiserslautern were performed

Objectives (same as in the FM VHF band II investigations):
- Investigations of compatibility between DAB/DAB+ and DRM+
- Determination of DRM+ coverage for fixed and mobile reception at high speed

Approach:
1.: Laboratory measurements with channel simulations
2.: Field trial under real conditions
3.: Proposals of planning parameters

So here we go: Outline

DRM+, a perfect complement to DAB/DAB+ in VHF band III
- Technical results, planning aspects, and regulatory work -

I. Selected elements of the DAB/DRM+ TX/RX chains
II. Lab measurements
III. Field trials
IV. Proposal for planning parameters
V. Outlook
Selected elements of the DAB/DRM+ TX/RX chains

### DRM+ Prototype RXs: General architecture & overall parameters

<table>
<thead>
<tr>
<th>Rx-Name</th>
<th>Rx1</th>
<th>Rx2</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF-Frontend manufacturer</td>
<td>Maxim</td>
<td>Unknown</td>
</tr>
<tr>
<td>Frequency bands</td>
<td>VHF-II, VHF-III, L-Band</td>
<td>VHF-III, L-Band</td>
</tr>
<tr>
<td>IF-Frequency [kHz]</td>
<td>2,048</td>
<td>38,912</td>
</tr>
<tr>
<td>IF-Filter-Bandwidth [kHz]</td>
<td>133</td>
<td>1527</td>
</tr>
<tr>
<td>Sensitivity, 4/16-QAM [dBm]</td>
<td>-112 / -106</td>
<td>-117 / -112</td>
</tr>
<tr>
<td>Shoulder / dB (@-40 dBm)</td>
<td>36</td>
<td>37</td>
</tr>
<tr>
<td>Noise Figure [dB]</td>
<td>8.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Near Carrier Phase Noise [dBc/Hz]</td>
<td>&lt; -80</td>
<td>&lt; -70</td>
</tr>
</tbody>
</table>

### DRM+ Prototype Rx1: Some impressions ...

![Image of DRM+ Prototype Rx1 setup]

- **RF-Frontend**: (Preselector, AGC, LO, Mixer, IF-Filter ...)
- **IF**: 
- **Perseus**: A/D-Conversion, Digital Downconversion
- **Ratemonkey**: Realtime samplerate-conversion software
- **Service-Decoders**: 
- **IIS DRM+ Decoding software**: 

---

© FH Kaiserslautern / Landeszentrale für Medien und Kommunikation
Selected elements of the DAB/DRM+ TX/RX chains

► DRM+ Prototype Rx2: Some impressions ...

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

TX sites

Legend

- Tx FH
- Tx RB
- Stationary measurement locs
- Mobile measurement route

Map data: Bundesamt für Kartographie und Geodäsie

TX characteristics

<table>
<thead>
<tr>
<th>Tx name &amp; location</th>
<th>„Am Kaiserberg“ (Tx FH) FH Kaiserslautern</th>
<th>„Am Rotenberg“ (Tx RB) KL-Rotenberg</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>DRM+, MSC: 4- or 16-QAM</td>
<td>DAB, DAB+</td>
</tr>
<tr>
<td>Frequency</td>
<td>211.648 MHz (10B)</td>
<td>211.648 MHz (10B)</td>
</tr>
<tr>
<td>Max. Power</td>
<td>90 W (ERP) Jan. to April</td>
<td>135…300 W (ERP) since May</td>
</tr>
<tr>
<td>Antenna</td>
<td>Omni</td>
<td>5-elem. Yagi 6 dBi</td>
</tr>
<tr>
<td>Polarisation</td>
<td>vertical</td>
<td>vertical</td>
</tr>
<tr>
<td>Content</td>
<td>Audio (AAC+), sync. PRBS</td>
<td>Audio: Musicam (DAB), AAC+ (DAB+)</td>
</tr>
<tr>
<td>Equipment</td>
<td>Plisch ULE-Series</td>
<td>R&amp;S SLA8000, Plisch TDA 3503</td>
</tr>
</tbody>
</table>

TX sites (stationary/remote)

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

© FH Kaiserslautern / Landeszentrale für Medien und Kommunikation
Selected elements of the DAB/DRM+ TX/RX chains

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

- **LAN**
- **WAN**
- **IIS DAB/DRM+ Content-Server R5**
- **DAB-Transmitter R&S SLA8000 < May 2010**
- **Pilsch TDA3903S >= May 2010**
- **DAB / DAB+ 135 ... 300 (ERP)**
- **DAB Maskfilter: Spinner; Ch. 10B**

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

- **LAN**
- **WAN**
- **IIS DRM/DRM+ CS**
- **SPARK+ OFDM Modulator**
- **MDI/Ethernet**
- **LAN**
- **Controlling Computer**
- **Minicircuits ZA60-30LN**
- **PLisch ULE820**
- **Plisch ULE820**
- **DRM+ 0 ... 180 W (ERP)**
So here we go: Outline

DRM+, a perfect complement to DAB/DAB+ in VHF band III
- Technical results, planning aspects, and regulatory work -

I. Selected elements of the DAB/DRM+ TX/RX chains
II. Lab measurements
III. Field trials
IV. Proposal for planning parameters
V. Outlook

Part II: Lab measurements

1. DRM+ mobile reception performance
2. Protection ratios DRM+/DAB
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!

\[ f_D = \frac{v}{c_0} \cdot f_0 \cdot \cos(\alpha) \ll \Delta f \]

Doppler frequency
\( f_0 \)
speed
\( c_0 \)
speed of light
\( f_0 \)
carrier frequency
\( \alpha \)
angle of incidence
\( \Delta f \)
OFDM subcarrier spacing

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

<table>
<thead>
<tr>
<th></th>
<th>DRM+</th>
<th>DAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta f ) [Hz]</td>
<td>444</td>
<td>444</td>
</tr>
<tr>
<td>( f_{D,\text{max}} ) [Hz]</td>
<td>20</td>
<td>42</td>
</tr>
<tr>
<td>( f_{D,\text{max}} / \Delta f )</td>
<td>0.045</td>
<td>0.082</td>
</tr>
</tbody>
</table>

Setup to assess the mobile performance by lab measurements

- Decoding
- Simulation Control
- BER measurement
- BER < 10^{-4}
- Audio Failure

Types of measurements:
1. with ETSI fading profile, without AWGN  \( \Rightarrow \gamma_{\text{max}} \) (BER = 10^{-4})
2. without ETSI fading profile, with AWGN  \( \Rightarrow S/N_{\text{AWGN}} \) (BER = 10^{-4})
3. with ETSI fading profile, with AWGN  \( \Rightarrow S/N_{\text{Prob}} \) (BER = 10^{-4})
Example: Measurement result of type (1): \( v_{\text{max}} \)

- Rural
- Hilly terrain
- Terrain obstructed
- Urban vehicle

\[
V_{\text{max}} = \int (\text{BER}) \cdot \text{RX 1} \\
\cdot 16 \text{ QAM} \\
\cdot f_0 = 230 \text{ MHz} \\
\cdot 1.7 \times 10^4 \text{ Bit}
\]

Result:
- 107 km/h < 150 km/h ☺
- 115 km/h > 100 km/h ☺
- 150 km/h > 60 km/h ☺
- 145 km/h > 60 km/h ☺

Example: Measurement result of type (1): \( v_{\text{max}} \)

<table>
<thead>
<tr>
<th>ETSI profile</th>
<th>Profile [km/h]</th>
<th>( v_{\text{max}} ) [km/h] RX 1</th>
<th>( v_{\text{max}} ) [km/h] RX 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>60</td>
<td>4 QAM: 169, 115</td>
<td>4 QAM: 157, 129</td>
</tr>
<tr>
<td>Rural</td>
<td>150</td>
<td>16 QAM: 168, 107</td>
<td>16 QAM: 161, 125</td>
</tr>
<tr>
<td>Hilly terrain</td>
<td>100</td>
<td>4 QAM: 165, 145</td>
<td>4 QAM: 162, 146</td>
</tr>
<tr>
<td>Terrain obstructed</td>
<td>60</td>
<td>16 QAM: 174, 150</td>
<td>16 QAM: 173, 153</td>
</tr>
</tbody>
</table>

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 optimized

For more details: Visit the project homepage ☺
**Measurement results of type (2): S/N_{AWGN}**

- **16 QAM**
  - $f_0 = 230, 230, 108$ MHz
  - 10² Bit
  - Input Level > -45 dBm

<table>
<thead>
<tr>
<th>S/N_{AWGN} [dB]</th>
<th>RX 1 (230 MHz)</th>
<th>RX 2 (230 MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 QAM</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>16 QAM</td>
<td>8.7</td>
<td>8.5</td>
</tr>
</tbody>
</table>

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

- **16 QAM**
  - $f_0 = 230, 230, 108$ MHz
  - $F_{Profile} = 60$ km/h
  - 1.7 10² Bit
### DRM+ mobile reception performance

#### Measurement results of type (3): $\text{SNR}_\text{profil}$

<table>
<thead>
<tr>
<th>DRM+ channel model</th>
<th>velocity</th>
<th>$\text{Rx}_1$ (230MHz)</th>
<th>$\text{Rx}_2$ (230MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel 7 (AWGN)</td>
<td>0 km/h</td>
<td>3.29 dB</td>
<td>3.32 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.75 dB</td>
<td>8.50 dB</td>
</tr>
<tr>
<td>Channel 8 (Urban)</td>
<td>60 km/h</td>
<td>12.50 dB</td>
<td>13.89 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18.84 dB</td>
<td>18.26 dB</td>
</tr>
<tr>
<td>Channel 8 (Urban)</td>
<td>2 km/h</td>
<td>23.01 dB</td>
<td>23.94 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28.07 dB</td>
<td>27.50 dB</td>
</tr>
<tr>
<td>Channel 9 (Rural)</td>
<td>120 km/h</td>
<td>14.86 dB</td>
<td>16.63 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BER $&gt; 10^4$</td>
<td>BER $&gt; 10^4$</td>
</tr>
<tr>
<td>Channel 10 (Terrain obstructed)</td>
<td>60 km/h</td>
<td>12.04 dB</td>
<td>11.96 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17.18 dB</td>
<td>16.90 dB</td>
</tr>
<tr>
<td>Channel 11 (Hilly terrain)</td>
<td>100 km/h</td>
<td>11.97 dB</td>
<td>11.96 dB</td>
</tr>
</tbody>
</table>

#### DRMs 4QAM

- Rural 161

#### DRMs 16QAM

- Rural 125

#### Complement: A comparison with DAB mobile reception performance

<table>
<thead>
<tr>
<th>$v_\text{max}$ [km/h]</th>
<th>RX 2</th>
<th>DRM+</th>
<th>DAB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ETSI profile</td>
<td>4 QAM</td>
<td>16 QAM</td>
</tr>
<tr>
<td></td>
<td>Rural</td>
<td>161</td>
<td>125</td>
</tr>
</tbody>
</table>
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_{T1,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

Part I: Lab measurements

1. DRM+ mobile reception performance
2. Protection ratios DRM+/DAB
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 protection 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+ interfered with by DAB
   - DAB interfered with by DRM+

2. **Verification of PRs with field measurements:**
   - Stationary measurements (10 m antenna height agl)
   - Mobile measurements (2m antenna height agl)

---

**Channel definitions: Dr. Kühn’s proposal**

<table>
<thead>
<tr>
<th>DRM-Übertragung im VHF-Bereich</th>
<th>Vorschlag: Zuweisung von DRM-Kanälen in einem DAB-Referenzblock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zuweisung von DRM-Kanälen in einem DAB-Block</td>
<td>Kanal 1</td>
</tr>
<tr>
<td>Kanal 6</td>
<td>Kanal 7</td>
</tr>
</tbody>
</table>

Zuweisung der DRM-Kanäle in den fiktiven DAB-Blöcken
- Jedem DAB-Block werden 15 DRM-Kanäle symmetrisch zugeordnet
- Der Mittenfrequenz $f_0$ des DRM-Bezugskanals entspricht $f_{\text{Mittel}}$ des DAB
- Die Mittenfrequenzen der Kanäle $f_{\text{Kanal}} = f_0 \pm n \cdot 100$ kHz
- ergeben sich zu $f_{\text{Kanal}} = f_0 \pm n \cdot 100$ kHz
- DRM-Kanalabstand 6,8 kHz
- Randabstand zur DAB-Blockgrenze 21 kHz
**Measurement setup: PR of DRM+ interfered with by DAB**

- **Lab measurements of protection ratios (PR)**

**Criterion:**
Coded BER $< 10^{-4}$

**Result: PR of DRM+ interfered with by DAB**

- **PRs for DAB → DRM+:**
  - Co-Channel: Difference 4/16 QAM = 5 dB (ct. AWGN-performance!)
  - Adjacent channel: PR $< -60$ dB (Rx 1)
  - Similar performance with $R_X\text{min} +10/20$ dB input power level / DAB TX
Lab measurements of protection ratios (PR)

- **Uups ... panic on board ... negative PRs??**

Let's shift the dBs ...

\[
\begin{align*}
C_{100\text{kHz}} &= 7.6 \text{ dB} \\
C_{001\text{kHz}} &= C - 7.6 \text{ dB} \\
C_{036\text{kHz}} &= C - 10 \log_{10} \left( \frac{1536}{100} \right) \\
&= C - 7.6 \text{ dB} + 11.9 \text{ dB} \\
&= C + 4.3 \text{ dB} \\
\text{PR}_{\text{DB}} &= C - C_{036\text{kHz}} \\
&= 4.3 \text{ dB}
\end{align*}
\]

Measured: -5 dB

Lab measurements of protection ratios (PR)

- **Measurement setup: PR of DAB interfered with by DRM+**

Criterion:

- 3 min "successful" audio decoding
Example: PR of DAB interfered with by DRM+ (Cochannel, multiple DRM+ interferer)

- Co-Channel: ≈ 7 ... 10 dB (1 ... 15 DRM+ interferer)

Result: PR of DAB interfered with by DRM+

- 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 protection ratios (PR)

Lab measurements of protection ratios (PR): Summary

 ✓ DAB channel spacing:
   • Co-Channel:
     • PR of DAB interfered with by DRM+:
       • ≈ 7 ... 10 dB (1 ... multiple DRM+ interferer)
     • PR of DRM+ interfered with by DAB:
       • ≈ -7 dB (4 QAM)
       • ≈ -2 dB (16 QAM)
     • Adjacent channel case: ’uncritical’, i.e. < - 40 dB

 ✓ DRM+ channel spacing:
   • Co-Channel:
     • DRM+ interfered with by DRM+:
       • ≈ 4 dB (4 QAM)
       • ≈ 10 dB (16 QAM)

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

For more details: Visit the project homepage

© FH Kaiserslautern / Landeszentrale für Medien und Kommunikation 18
So here we go: Outline

DRM+, a perfect complement to DAB/DAB+ in VHF band III
- Technical results, planning aspects, and regulatory work -

I. Selected elements of the DAB/DRM+ TX/RX chains
II. Lab measurements
III. Field trials
IV. Proposal for planning parameters
V. Outlook

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

Field trials DRM+/DAB

Transmitter setup (reprise)

<table>
<thead>
<tr>
<th>Tx name &amp; location</th>
<th>&quot;Am Kaiserberg&quot; (Tx FH) FH Kaiserslautern</th>
<th>&quot;Am Rotenberg&quot; (Tx RB) KL-Rotenberg</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>DRM+, MSC: 4- or 16-QAM</td>
<td>DAB, DAB+</td>
</tr>
<tr>
<td>Frequency</td>
<td>211.648 MHz (10B)</td>
<td>211.648 MHz (10B)</td>
</tr>
<tr>
<td>Max. Power</td>
<td>90 W (ERP) Jan. to April</td>
<td>180 W (ERP) since May</td>
</tr>
<tr>
<td></td>
<td>135...300 W (ERP)</td>
<td></td>
</tr>
<tr>
<td>Antenna</td>
<td>Omni</td>
<td>5-elem. Yagi 6 dBi</td>
</tr>
<tr>
<td>Polarisation</td>
<td>vertical</td>
<td>vertical</td>
</tr>
<tr>
<td>Content</td>
<td>Audio (AAC+), sync. PRBS</td>
<td>Audio: Musicam (DAB), AAC+ (DAB+)</td>
</tr>
<tr>
<td>Equipment</td>
<td>Plisch ULE-Series</td>
<td>R&amp;S SLA8000, Plisch TDA 3503</td>
</tr>
</tbody>
</table>
The scenario (reprise ☺)

Stationary measurements: Setup

- VHF-Directional antenna
  - 10m agl
  - $k = 8.9 \text{ dB}$

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)
Field trials DRM+/DAB

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 $\approx 10^{-4}$
- **Calculate** $P_{R\text{DAB}} - P_{D\text{RM}} - (P_{D\text{RM}} - \text{Tx Attenuation})$

Stationary measurements: PR Results

- Field results tend to confirm laboratory results $\rightarrow$ Influence of non-flat channel ...
- Measurement uncertainty $\pm 1$dB, 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
Mobile measurements: Monitoring software

- Real-time 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 0.8A (~ 1.14m)
  - Sub-consumer GPS-Resolution achieved by equalizing via the known measurement distance
  - Vector-data output to various GIS-tools for analysis

Mobile measurements: Setup for DRM+

- 1/4-Dipole, k = 11.7 dB
  - 2m a.g.l.
- Frontend
- Perseus
- Resampler DRM Decoding
- Audiodecoding
- Laptop I
- Laptop II
- GPB, IEC 488.2
- Measurement software
- GPS
- LCD-Monitor
- KVM-switch
- Inductive distance pulse generator
- Ext. Trigger
- Divider
- Audio/Video
• 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)
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.

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)
Field trials DRM+/DAB

11th Workshop Digital Broadcasting 2010, Erlangen

- Mobile measurements: Coverage for DRM+, 180W ERP
  - Green
    - Rating: inspect all samples within an area of 100m x 100m and calculate the (instantaneous-) BER’s 75%-percentile q
    - $q \leq 10^{-4} \rightarrow$ Green
    - Green: Implies successful audio-decoding!

- Mobile measurements: Coverage for DRM+, 180W ERP interfered by DAB, 135W ERP
  - Green
    - 62%
    - 38%

© FH Kaiserslautern / Landeszentrale für Medien und Kommunikation
Mobile measurements: Coverage for DRM+ (180W ERP)

- 16-QAM fail: 35%
- 16-QAM ok: 65%

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

- 16-QAM fail: 79%
- 16-QAM ok: 21%
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

Field trials DRM+/DAB

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

Field measurements: Coverage for DAB (135W ERP) interfered with 2 DRM+ Blocks (90W ERP)

Field trials DRM+/DAB

Ok

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

For more details: Visit the project homepage

11th Workshop Digital Broadcasting 2010, Erlangen

J. Lehnert / A. Steil
So here we go: Outline

DRM+, a perfect complement to DAB/DAB+ in VHF band III
- Technical results, planning aspects, and regulatory work -

I. Selected elements of the DAB/DRM+ TX/RX chains
II. Lab measurements
III. Field trials
IV. Proposal for planning parameters
V. Outlook

Planning parameters for DRM+ in VHF band III

<table>
<thead>
<tr>
<th>type of reception</th>
<th>handheld (RRC-06)</th>
<th>portable (RRC-06)</th>
<th>(EBU)</th>
<th>handheld (RRC-06)</th>
</tr>
</thead>
<tbody>
<tr>
<td>reception situation</td>
<td>D +4dB</td>
<td>ND -2.2 dB</td>
<td>ND -19 dB</td>
<td>ND -2.2 dB</td>
</tr>
<tr>
<td>receiver type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>antenna pattern / gain</td>
<td>D +4dB</td>
<td>ND -2.2 dB</td>
<td>ND -19 dB</td>
<td>ND -2.2 dB</td>
</tr>
<tr>
<td>location probability</td>
<td>70 %</td>
<td>95 %</td>
<td>99 %</td>
<td></td>
</tr>
<tr>
<td>antenna height</td>
<td>10 m</td>
<td>1.5 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>feeder loss</td>
<td>1.4 dB</td>
<td>0 dB</td>
<td>0.28 dB</td>
<td></td>
</tr>
<tr>
<td>building penetration loss</td>
<td>0 dB</td>
<td>9 dB (at 5.5 m)</td>
<td>0 dB</td>
<td></td>
</tr>
</tbody>
</table>
### Proposal for minimum receiver input power level for DRM+ VHF band III

<table>
<thead>
<tr>
<th>type of reception</th>
<th>handheld</th>
<th>portable receiver</th>
<th>portable, indoor</th>
<th>vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver noise figure (F) [dB]</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Bandwidth (B) [kHz]</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Receiver noise input power level [dBW]</td>
<td>-147</td>
<td>-147</td>
<td>-147</td>
<td>-147</td>
</tr>
<tr>
<td>ETSI DRM channel model +3dB implementation margin</td>
<td>7 - AWGN</td>
<td>8 - urban</td>
<td>11 - hilly terrain</td>
<td></td>
</tr>
<tr>
<td>Representative minimum C/N level [dB]</td>
<td>4QAM 4.3</td>
<td>10.3</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16QAM 10.9</td>
<td>18.4</td>
<td>15.8</td>
<td></td>
</tr>
</tbody>
</table>

These values are taken from ETSI ES 201 980. Out from the lab measurements of the FH Kaiserslautern the values are:
- 13.1 dB /13.5 dB (4QAM/16QAM) for channel 8 – urban
- 12.0 dB / 18.0 dB (4QAM/16QAM) for channel 11 – hilly terrain

### Proposal for median field strength levels for DRM+ in VHF band III

<table>
<thead>
<tr>
<th>type of reception</th>
<th>handheld (RRC-06)</th>
<th>portable receiver (RRC-06)</th>
<th>portable, indoor (RRC-06)</th>
<th>vehicle (RRC-06)</th>
</tr>
</thead>
<tbody>
<tr>
<td>feeder loss [dB]</td>
<td>1.4</td>
<td>0</td>
<td>0</td>
<td>0.28</td>
</tr>
<tr>
<td>effective antenna aperture [dB]</td>
<td>4.7 dB</td>
<td>-1.5 dB</td>
<td>-18.3 dB</td>
<td>-1.5 dB</td>
</tr>
<tr>
<td>minimum field strength level @ receiving antenna [dBµV/m]</td>
<td>4QAM 3.4</td>
<td>16.6</td>
<td>27.4</td>
<td>24.7</td>
</tr>
<tr>
<td></td>
<td>16QAM 10.0</td>
<td>24.7</td>
<td>35.5</td>
<td>24.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Correction factors for reception modes [dB]</th>
<th>handheld</th>
<th>portable</th>
<th>indoor</th>
<th>vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>min. MEDIAN field strength level @ receiving location [dBµV/m]</td>
<td>4QAM 9.3</td>
<td>42.9</td>
<td>56.9</td>
<td>69.5</td>
</tr>
<tr>
<td></td>
<td>16QAM 15.9</td>
<td>51.0</td>
<td>65.0</td>
<td>77.6</td>
</tr>
</tbody>
</table>
Proposal for minimum median field strength level for DRM+ in VHF band III

Planning parameters for DRM+ in VHF band III

Proposal for protection ratios for DRM+ in VHF band III (co-channel)

values given for suburban area
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

Remark: On base of ITU-Rec. P.1546 the margin for DRM+ in VHF band III for 99% location probability are given by: \( C_1(99\%) = 17.4 \text{ dB} \) for suburban areas

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_RASTER,100x100, value = 75%); %Subjectively OK
  COMPARE(AUDIO_Prediction, AUDIO_Measured);
```
So here we go: Outline

DRM+, a perfect complement to DAB/DAB+ in VHF band III
- Technical results, planning aspects, and regulatory work -

I. Selected elements of the DAB/DRM+ TX/RX chains
II. Lab measurements
III. Field trials
IV. Proposal for planning parameters
V. Outlook

Outlook
If there is a strong will to push DRM+ into the market [?]
what has to be done as from now?

• A lot of lobby work
  (nationwide, DRM-Consortium, WorldDMB, ETSI, ITU, EU)

• A lot of technical work
  (SFN-tests, high-power-tests, development of network infrastructures and market fitting receivers, frequency and network analyses)

• A lot of standardization work
  (proposals for system and planning parameters for ECC, ETSI, ITU)

• A lot of marketing work
  (public information, convincing the market partners, esp. the broadcasters and the „users“, development of interesting radio programmes and services)

• A lot of regulatory work
  (offering easy legal conditions and support for network operators and broadcasters)
Outlook

Preconditions to reach this objective:

- a lot of communication and networking is needed in the next years
- and last but not least: a common action plan [for Europe] is needed to digitize the whole sound broadcasting together with the DAB family and the DRM family
Motto: „We are Family”

We will keep in touch with DRM+!

- Frequency plannings and analyses
- Proposals for planning parameters
- Support of further essential SFN field trials (by request)
- Cooperation in the process of standardization and regulation matters for DRM+ in the VHF bands
- Publication of results and proposals

DRM+, a perfect complement to DAB/DAB+ in VHF band III

- Technical results, planning aspects, and regulatory work -

Thank you for your attention …

… further information on www.DRM-Radio-KL.eu