Digital Broadcasting 7th Workshop
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Session 1: Digital Radio Mondiale DRM

Technical feasibility study and field trial concept for DRM-based digital radio in the VHF-FM radio band

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Motivation

- *Initiative Digital Radio* (IDR) of the German Federal Government - Recommendations related to FM radio:

Oct. 2000 **Report on Digital Broadcasting in Germany**

- Phase out analogue radio between 2010 and 2015
- After it: Substitude FM with T-DAB

Sept. 2005 **Report of the joint working group „Digital Radio“**

- The previous political aim to substitude FM with T-DAB in VHF band II will certainly not be reached
- It‘s still the right way to substitude FM with a digital radio system in the long term

? Which digital system can be used to substitude FM-radio ?

Cooperation

Federal State authority of Rhineland-Palatine for Media and Communication
Landeszentrale für Medien und Kommunikation (LMK) Rheinland-Pfalz

member of

Technical Committee of the German Federal State authorities
TKLM = *Technische Kommission der Landesmedienanstalten*

Reflection: Is it possible to design a grid-conforming digital radio system in the VHF-FM band to substitute FM-radio?
(as DRM for AM-radio and DVB-T for TV)?
Then: Definition of the basic requirement for the digital system in the VHF-FM-radio-band

studies, measurements, radio-design, field-trial

University of Applied Sciences in Kaiserslautern
- Signal theory
- Mobile radio
- RF-design

Technical University in Kaiserslautern
- Signal theory
- Equalization and estimation
- Channel coding

Presentation outline

Part I: Feasibility study about a grid-conforming OFDM-system in VHF band II (87.5-108 MHz)

Part II: Concept for a simple, but complete prototype transmission chain

Part III: Planned field trial & measurements

Part I: Technical feasibility study

► *Basic requirements & technical setpoints for the investigation*

Basic requirements

- Use of state-of-the art transmissions principles of DRM **standard**
- **Coverage** and **structures** similar to VHF-FM system, accounting for
  - **Mobility**, up to 300 km/h
  - Portable **receiver characteristics**
  - Full **indoor receiption**
  - **Grid-conforming**
- **CD-like** audio quality and PAD
- SFN capability
- Switching over on a single VHF-FM frequency possible (**smooth transition**)

Technical setpoints

System bandwidth	100 kHz
Modulation Scheme	OFDM
Subcarrier modulation	4-,16-,64-QAM
Coded BER	10^{-4}
Channel model	Urban Area
Channel coding	Conv., R = ½
SFN TX-distances	60 km

Part I: Technical feasibility study

► *Main results (I)*

	Modulation scheme		
	4-QAM	16-QAM	64-QAM
Bandwidth	100 kHz		
Subcarrier spacing	375 Hz	750 Hz	1500 Hz
# of subcarriers	266	132	66
Maximum speed	300 km/h		200 km/h
QAM symbol duration	2.667 ms	1.333 ms	0.667 ms
Guard intervall	166.667 µs		
Duration of OFDM symbol	2.833 ms	1.5 ms	0.833 ms
# of pilots/OFDM symbol	11		
Gross data rate	187.7 kbit/s	352.0 kbit/s	475.2 kbit/s
Net data rate	93.5 kbit/s	175.5 kbit/s	237.5 kbit/s
Audio data rate	79.5 kbit/s	149.1 kbit/s	201.8 kbit/s

Part I: Technical feasibility study

► *Main results (II)*

RX_{min}: {**Minimum received power**}@{receiver input}
E_{plan} : **Planning field strength**, used for RF-planning

receiving situation / receiver type		fixed	portable		mobile@v_{max}
			outdoor	indoor	
FM (Stereo)	E_{plan}	54 dBµV/m	73 dBµV/m	80 dBµV/m	77 dBµV/m
4-QAM	RX_{min}	-102 dBmW			-99 dBmW
	E_{plan}	10 dBµV/m	35 dBµV/m	42 dBµV/m	42 dBµV/m
16-QAM	RX_{min}	-92 dBmW			-84 dBmW
	E_{plan}	20 dBµV/m	45 dBµV/m	52 dBµV/m	57 dBµV/m
64-QAM	RX_{min}	-84 dBmW			-80 dBmW
	E_{plan}	28 dBµV/m	53 dBµV/m	60 dBµV/m	61 dBµV/m
T-DAB	E_{plan}	35 dBµV/m	56 dBµV/m	59 dBµV/m	60 dBµV/m

Part I: Technical feasibility study

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► *Conclusion*

➔ The designed OFDM-system in band II fulfilles the requirements

➔ But there‘s a new problem related to the stereo-decoder in FM radios

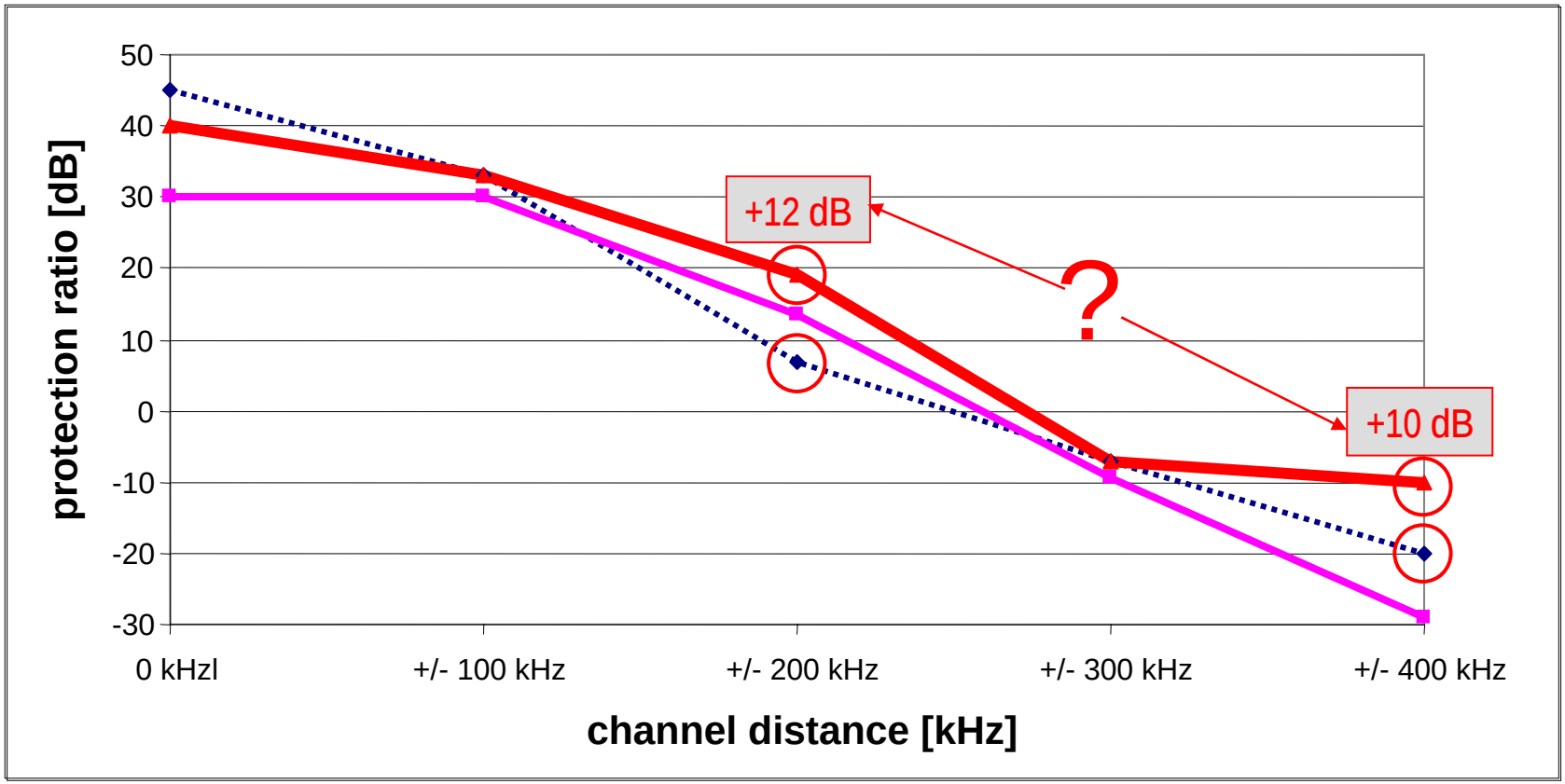
- Off-air-measurements and simulations show that the OFDM-system might affect the stereo decoding of FM radios in a wide spectrum range
- Therefore a higher level of protection may be necessary
- More studies about this effect have to be made in the near future in laboratory and in field trails

➔ An evaluation is mandatory to answer the questions:

- Is this a knock-out-criteria for DRM+ in the FM-radio-band?
- Is this problem really relevant in existing, interfering limited FM-networks with field strengths >70 dBμV/m in the coverage areas and compressed modulation?
- Are there any other problems, like bad interference (e.g. with aeronautical communication sites like it is with DAB in band III)?

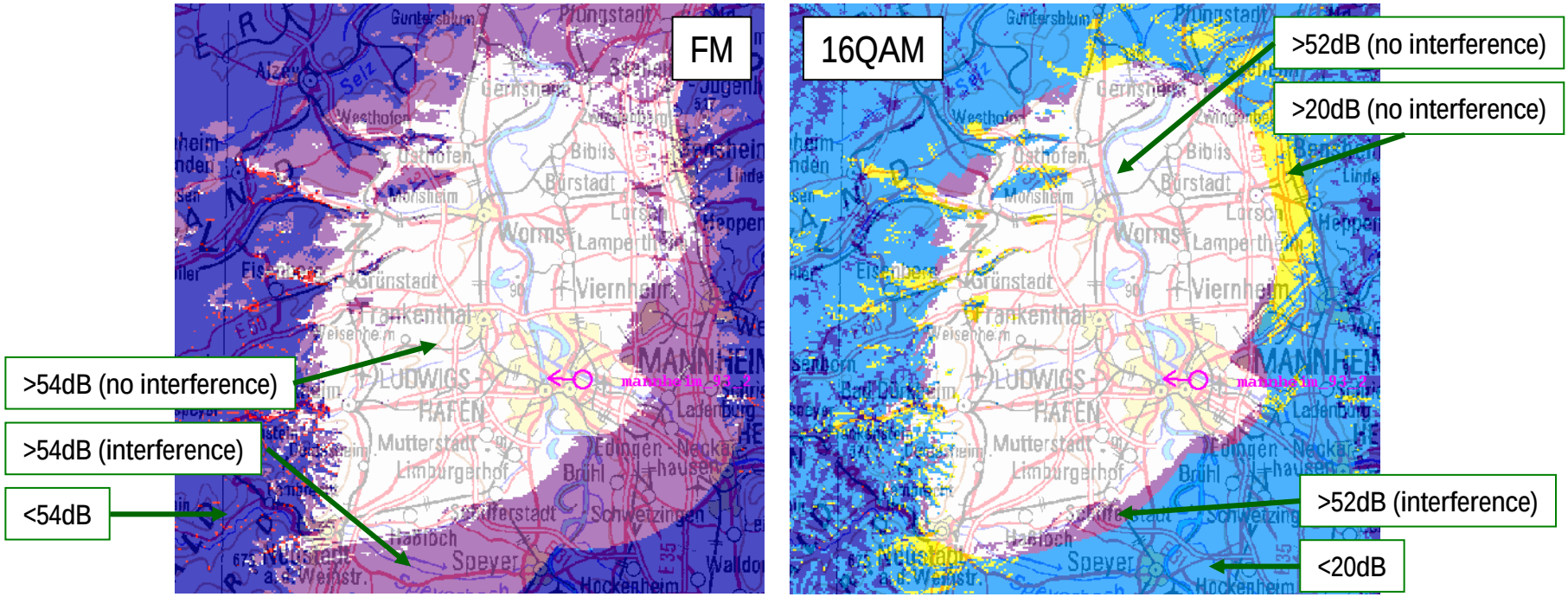
Part I: Technical feasibility study

► *Intersystem compatibility issues – protection ratios*



Part I: Technical feasibility study

► *Analogue vs. digital coverage (example)*



Transmitter	Mannheim, 93.2 MHz, ND	
Modulation	FM (Rockland Radio)	16QAM
ERP	30 dBW	18 dBW (12 dB reduced)
consideration of the 20 strongest interfering FM-transmitters	CCIR protection ratio (FM-FM)	protection ratios: 16QAM->FM „red“ and FM>16QAM „study“: No FM stations are affected!!!

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Part II: Prototype transmission chain

► *Example: Parameter-Setup for 16 QAM, 15 AAC / TF*

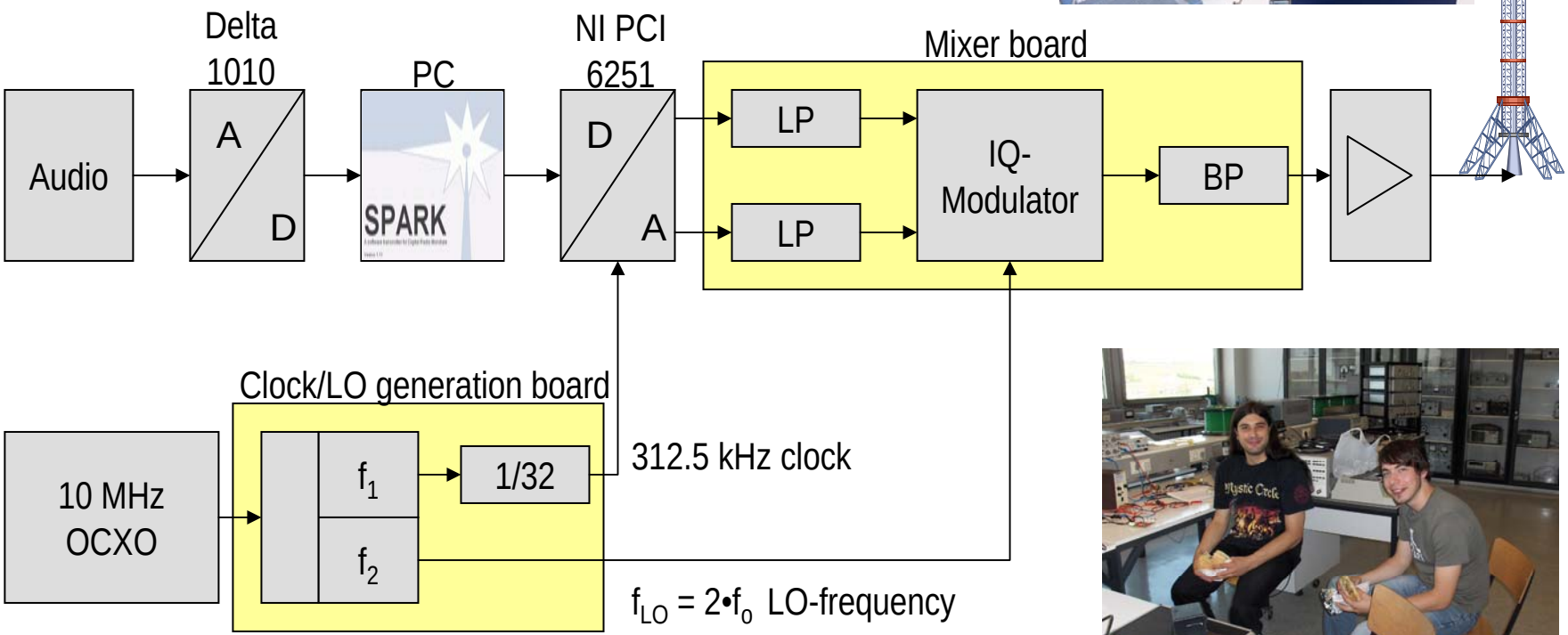
	Timebase
Input sample rate	48 kHz
# samples / AAC frame	960
→ Duration of AAC frame	20 ms
# AAC frames / AAC superframe	10
→ Duration of transmission frame	200 ms
	OFDM & TSF parameter
Duration of OFDM symbol	1.333 ms
→ # OFDM symbols / TSF	150
# cells / symbol	111
Lower carrier index	-55
→ Upper carrier index	55
→ Carrier spacing	857.14 kHz
→ Unguarded OFDM signal bandwidth	95.142 kHz
Duration of guard intervall	0.166 ms
→ Duration of unguarded OFDM symbol	1.166 ms
# transmission frames / TSF	2
→ Duration of TSF	400 ms
→ # OFDM symbol / TSF	300
DC carries data	No

	Pilot scattering
Periodicity frequency- / time-domain	10 / 10
→ Pilot cells / TF	606
	SDC configuration
# OFDM symbols / SDC	4
→ # cells / SDC	419
SDC code rate	0.5
SDC bits / cell	4
→ # SDC bytes	104.75
	FAC configuration
# cells / FAC	65
FAC code rate	0.5
FAC bits / cell	4
→ FAC bits	130
	MSC configuration
→ # cells / MSC / TSF	31239
MSC code rate	0.5
MSC bits / cell	4
→ MSC bytes / TSF	7809.75
→ MSC net data rate	156 kbit/s

For details see paper

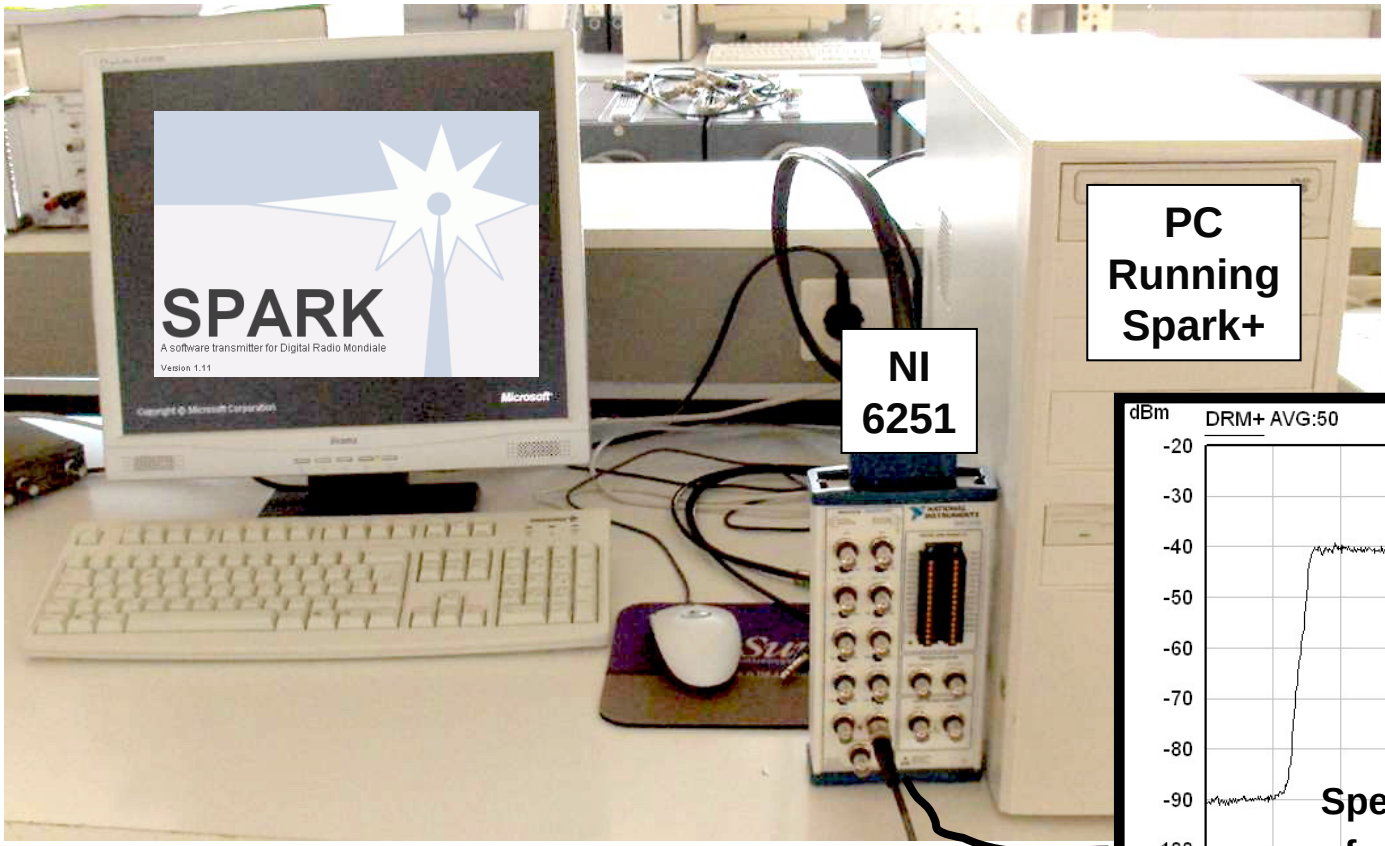
Part II: Prototype transmission chain

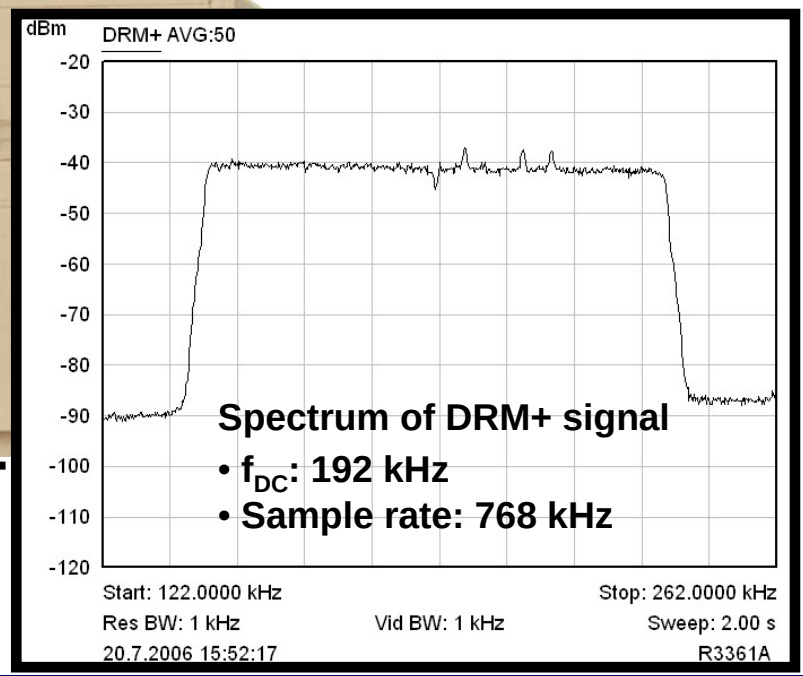
► *Transmitter concept*



Part II: Prototype transmission chain

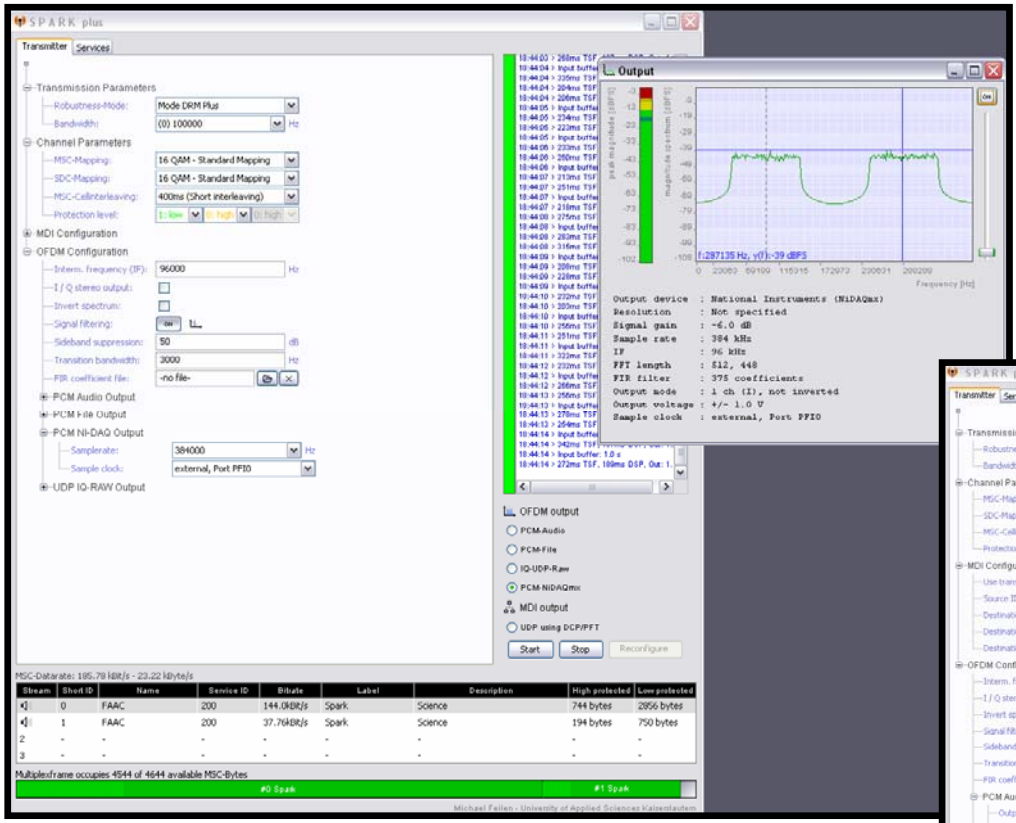
► *Transmitter: A/D-conversion; Spark+; D/A-conversion*

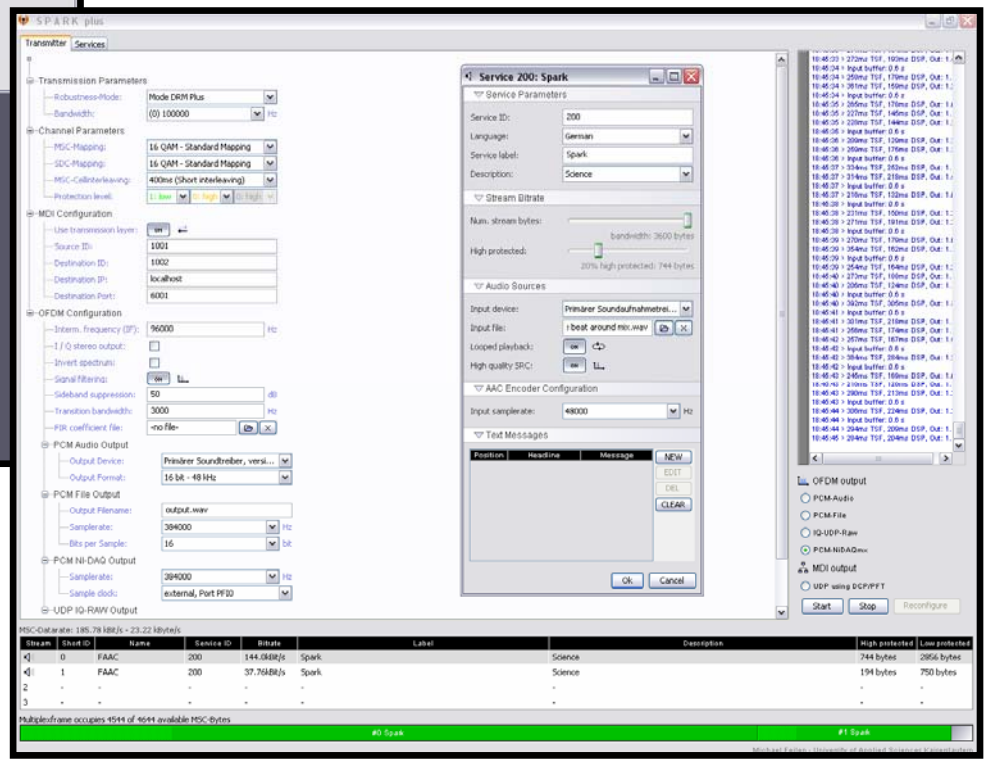




Part II: Prototype transmission chain

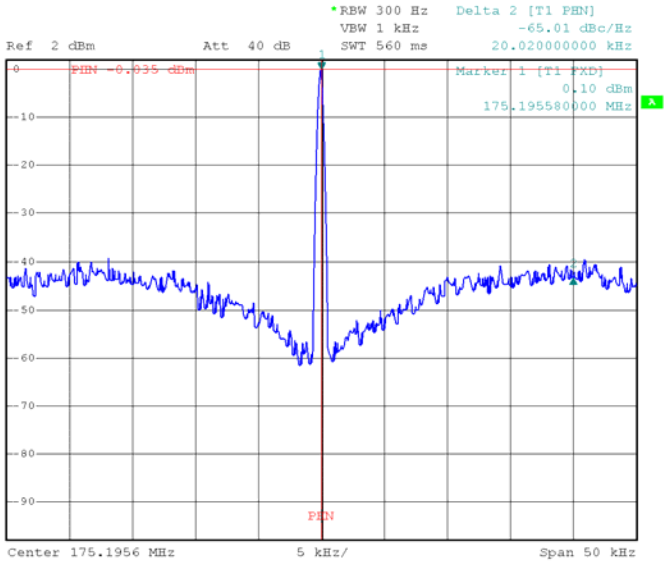
► *Transmitter: Spark+ screenshots*



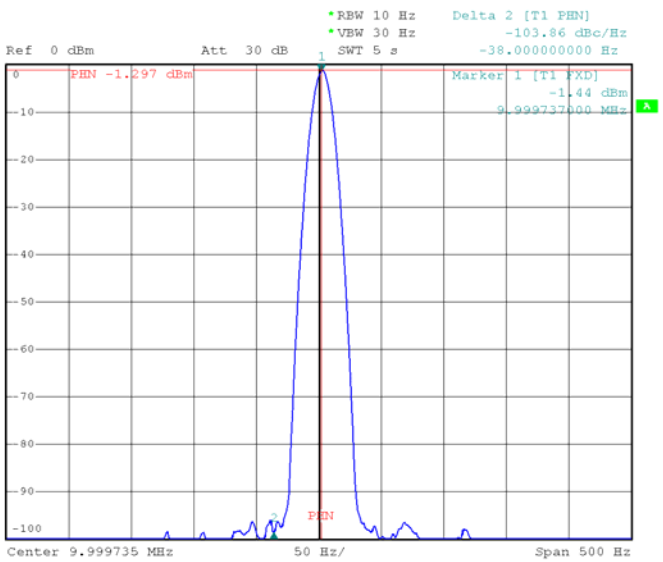


Part II: Prototype transmission chain

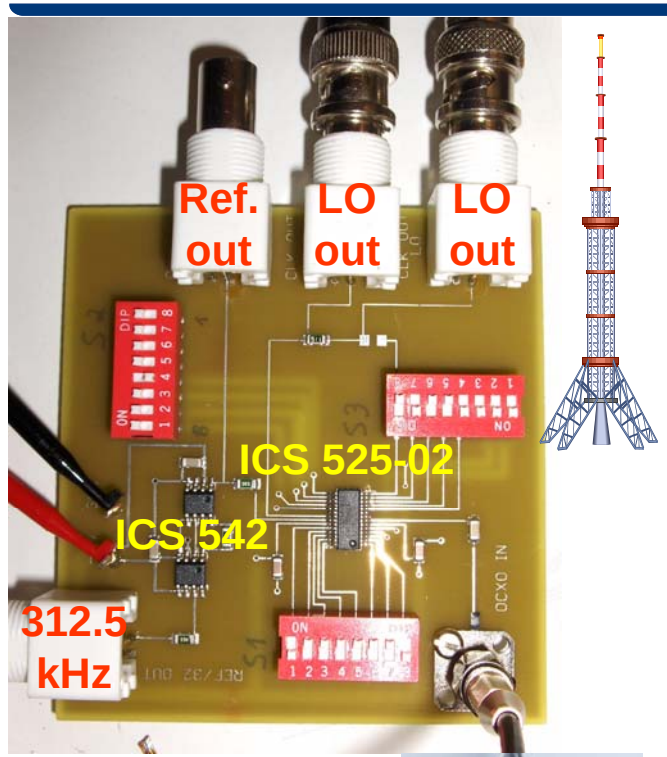
► *Transmitter: Clock/LO generation*



{LO out}@{175.2 MHz}
- **PN: {–65 dBc/Hz}@{20 kHz}**
- **Span: 50 kHz**

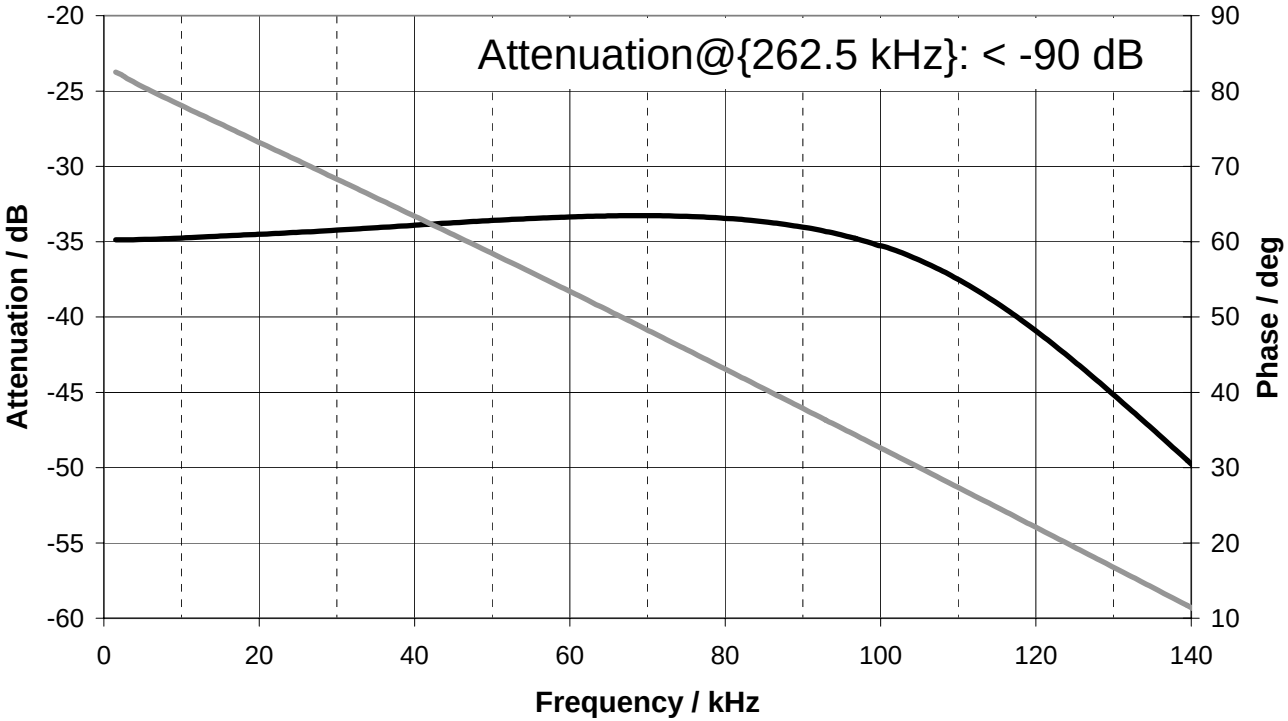


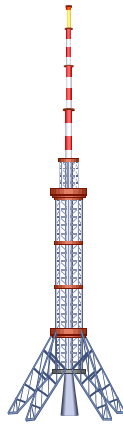
10 MHz Reference
- **PN: {–104 dBc/Hz}@{38 Hz}**
- **Span 500 Hz**

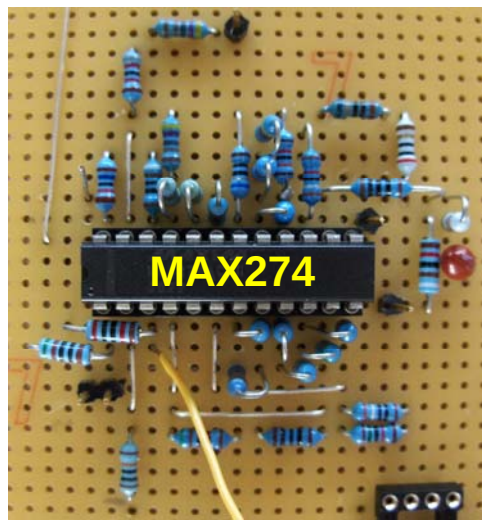


Part II: Prototype transmission chain

► *Transmitter: Anti-aliasing LP-filter*





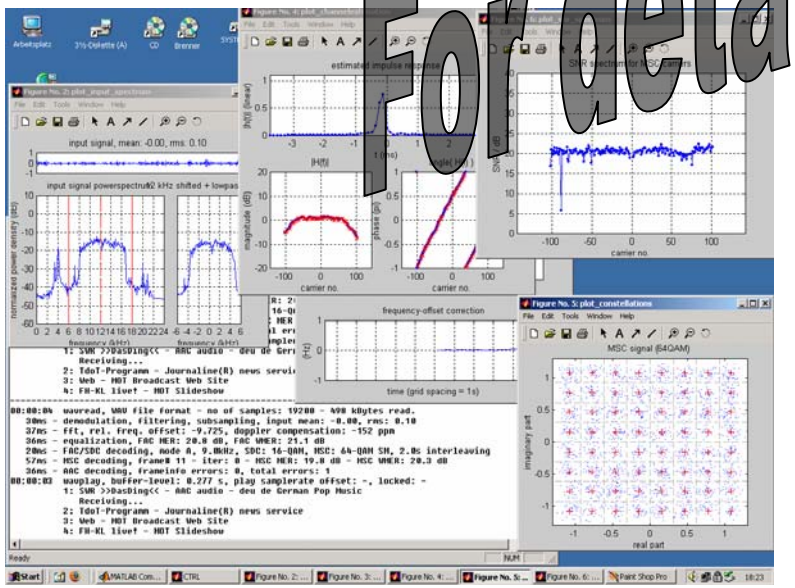


Part II: Prototype transmission chain

► *Receiver (I): DIORAMA – DRM receiver using MATLAB*

➔ DIORAMA

- Real-time radio including text message, Journaline(R), web page broadcasting
- Online display of input spectrum, synchronization, channel estimation, constellations, SNR per carrier ...



➔ I/O, Acquisition and Tracking

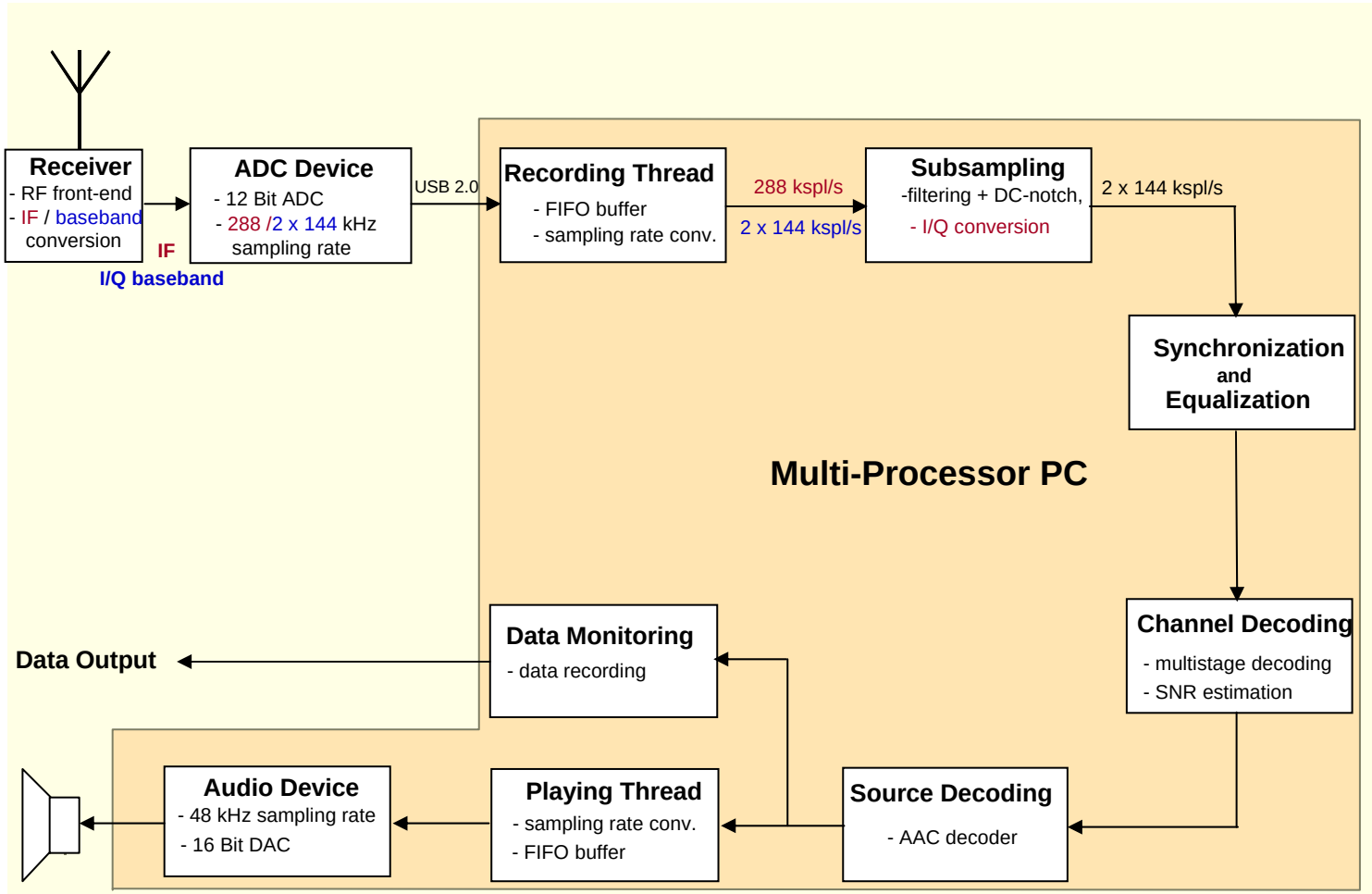
- Polyphase dynamic I/O sampling rate conversion
- *f* / *t* synch. (coarse) & sampling rate offset by guard interval correlation
- Channel estimation and equalization using 2D-Wiener filter (pre-computed coefficients)
- *f* synch. (fine) by actual received pilots and Wiener interpolated passed pilots
- *t* synch. (fine) and guard interval removal based on estimated impulse response

➔ Channel Decoding

- Iterative multi-stage decoding using estimated SNR
- SNR estimation based on channel transfer function, decoded data and equalized OFDM cells

Part II: Prototype transmission chain

► Receiver (II): DIORAMA-based receiver for DRM+



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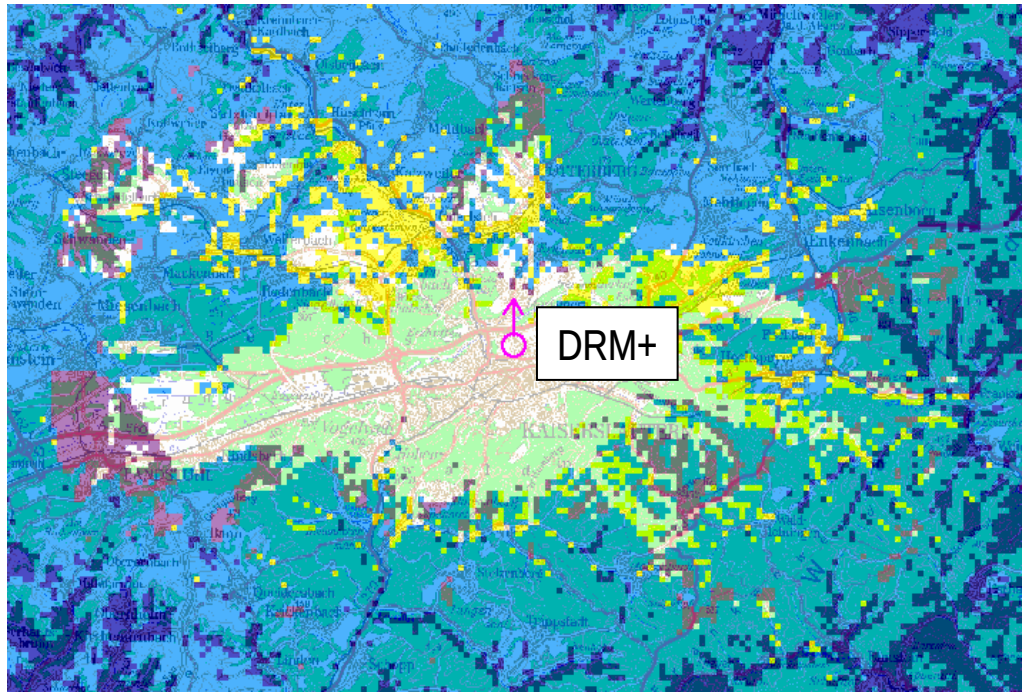
► *DRM+ field trial in K-Town*



Transmitter:

- 87.6 MHz, 100W (analogue), ND
- Location: campus of FH Kaiserslautern
- Coverage: whole city of Kaiserslautern & motorway (A6)

Measurements:

- Digital reception (quality / probability in house and by car)
- Interference between FM and DRM+
- Different receiver concepts (Technical University of Kaiserslautern)

Part III: Planned field trial & measurements

► *Future work*

I. Finish transmitter & receiver (offline/real time processing)
II. Lab measurements
    - Intersystem compatibility
    - Protection ratios
    - RDS performance
    - …
III. Field trial & field measurements

- Implement parameter settings of DRM Consortium

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Thank you for your attention!