Leaving the dead-end street:
New ways for the digitisation of the VHF-FM sound broadcasting with DRM+

Part II
First results on compatibility planning of DRM+ and HD-Radio™ in the VHF band

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INTRODUCTION

DRM+ is a digital radio broadcasting system, based on the open DRM-System standard [1], which allows for 'digitising' the European's FM stations broadcasting in the 87.5 … 108 MHz frequency range. The proprietary US American system HD-Radio™ [2] - promoted as potential candidate for digitising this frequency band - is currently tested in Europe.

The technical challenge for the migration period from analogue to digital radio broadcasting is the deployment of *new* digital TX stations into the actually congested VHF FM band.

This report presents and discusses exemplary first compatibility and coverage predictions with ten dominant VHF FM TX sites in and around the German city of Kaiserslautern assuming that one out of these TX sites is virtually converted from FM to either DRM+ or HD-Radio™, respectively. The objective of this planning exercise is to derive technical conditions which allow insertion of digital TX stations into the European VHF FM band relying on the legal radio regulations and coordination procedures.

METHODOLOGY

Frequency planning

For frequency analysis, the frequency and network planning software „FRANSY" [3] was used. Based on TX site databases, terrain databases, and wave propagation models, the coverage of a broadcasting system and its interference impact on other stations can be calculated. A specialised version of „FRANSY" compiled for the German State Media Authority of Rhineland-Palatinate (Landeszentrale für Medien und Kommunikation - LMK) allows to include DRM+ and HD-Radio™ in the analyses.

Protection ratios

The protection ratios shown in **Fig. 1** provide the basis for the calculations:

- *DRM+ into FM and HD-Radio™ into FM, respectively.* These curves are based (a) on the results of laboratory measurements conducted by the University of Applied Sciences of Kaiserslautern and the German Federal Network Agency "Bundesnetzagentur - BNetzA" in the 2007 [4], and, (b) on findings from the field trials with DRM+ (Kaiserslautern, from 01/03/2008 to 31/05/2008) and HD-Radio™ (Heidelberg, from 01/12/2007 to 29/02/2008), respectively[1],
- *FM into DRM+* (4-QAM and 16-QAM) as a result of latest studies [5],
- *FM into FM* according to the protection ratio values of ITU-R BS.412-9 [6].

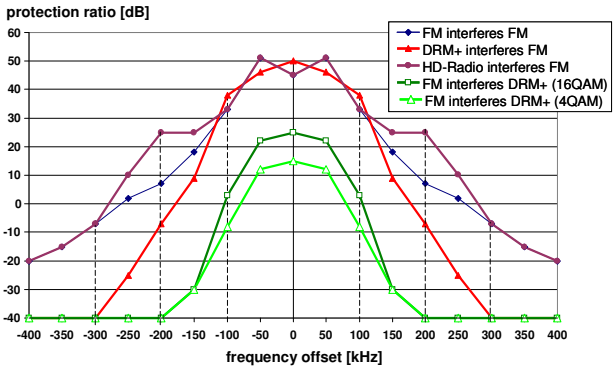

Fig. 1. Protection ratios for FM / DRM+ / HD-Radio™

Inspecting the protection rations in **Fig. 1** leads to the following conclusions relative to the (mutual) interference potential of the systems under consideration:

- *DRM+ into FM*: DRM+ produces more interference in the co-channel as well as in 100 kHz adjacent channel (each 5 dB more), but substantially less interference starting from the 200 kHz adjacent channel,
- *FM into DRM+*: DRM+ is interfered essentially less in the co-channel as well as in 100 kHz adjacent channel (from 19 dB on) and, starting from the 200 kHz adjacent channel, there is no more interference. 4QAM is less interfered than 16QAM,
- *HD-Radio™ into FM*: HD-Radio™ produces more interference in the 200 kHz adjacent channel (18 dB more) as well as in the 150 kHz und 250 kHz adjacent channel, too. Otherwise, it shows the same interference potential as FM into DRM+.

[1] The protection ratios used in this paper are based on latest studies and, therefore, marginally differ from those presented in the DRM+ symposium in May 2008 in Kaiserslautern [4].

Selection of VHF FM TXs

A selection of ten VHF FM TX sites with different classes of effective radiated powers (ERP) situated in and around the German city of Kaiserslautern has been analyzed, cf. **Tab. 1**.

Tab. 1. Analysed VHF FM TXs

TX No.	TX name	Program	Frequency	ERP (FM)
1	Donnersberg	SWR 1	99.1 MHz	60 kW
2	Donnersberg	SWR 2	92.0 MHz	60 kW
3	Donnersberg	SWR 3	101.1 MHz	60 kW
4	Donnersberg	SWR 4 RP	105.6 MHz	60 kW
5	Bornberg	RPR 1	103.1 MHz	25 kW
6	Bornberg	BigFM	107.6 MHz	25 kW
7	KL-Vogelweh	AFN	100.2 MHz	7 kW
8	KL-Dansenberg	Antenne KL	96.9 MHz	0.5 kW
9	KL-Dansenberg	DLF	105.1 MHz	0.2 kW
10	KL-Dansenberg	DR Kultur	98.1 MHz	0.16 kW

CONVERSION ANALYSIS

Method of analyses and calculations

First, for each TX, an *interference analysis* outputs FM stations potentially compromised by the conversion of the TX site under investigation from FM to DRM+ and HD-Radio™ Hybrid Mode, respectively.

Then, for each TX, a *compatibility analysis* identifies the constraints for conversion to either DRM+ or HD-Radio™, respectively, based on the so called 'Administrative proceeding of potentially concernment' of the German BNetzA [7].

Finally, for each TX, a *coverage analysis* for FM operation and DRM+ operation completes the planning exercise. HD-Radio™ was not considered[2].

Interference and compatibility analysis for DRM+- and HD-Radio™

The ERP constraints of the converted TXs arising from the interference analysis are summarised in the sequel. These constraints coming from the analysis are defined via the maximum radial sectoral indention of the antenna pattern (in 10° steps). Assuming that the antenna remains unchanged, this indention (i.e. antenna pattern constraint) is translated into reducing the ERP by the same amount (i.e. an ERP constraint), cf. **Tab. 2**.

The results obtained for the *conversion from FM to DRM+* suggest the following:

- In general, reducing the ERP by about 5 dB is sufficient to protect the existing FM networks, i.e. an FM TX can be replaced by a DRM+ TX by lowering the ERP by 5 dB.

The results obtained for the *HD-Radio™ Hybrid Mode* suggest the following: Converting

- a low power TX (by far less than 1 kW) is sporadically possible without any power reduction, but, in other cases, only possible with ERP reductions up to 17 dB, and, thus, with loss of existing FM coverage,
- a mid power and high power TX is only possible with ERP reductions up to 17 dB due to the high interference in the 200 kHz adjacent channel, leading to loss of existing FM coverage,
- is not possible above 107.5 MHz due to increasing interference into aeronautical radio navigation located on the frequency range above 108 MHz.

Tab. 2. Conversion power constraints from FM to either DRM+ or HD-Radio™

	Conversion to DRM+		HD-Radio™ Hybrid Mode	
TX No.	Power constraint	ERP (DRM+)	Power constraint	ERP (FM)[1)]
1	4.7 dB	20.3 kW	16.7 dB	1.3 kW
2	4.7 dB	20.8 kW	16.6 dB	1.3 kW
3	4.6 dB	20.8 kW	16.8 dB	1.3 kW
4	4.6 dB	20.8 kW	17.2 dB	1.1 kW
5	4.7 dB	8.5 kW	16.5 dB	0.6 kW
6	4.7 dB	8.5 kW	Conversion is not possible due to interferences into aeronautical radio navigation	
7	3.9 dB	2.9 kW	7.7 dB	1.2 kW
8	2.6 dB	0.27 kW	16.6 dB	0.01 kW
9	2.5 dB	0.11 kW	0 dB	0.2 kW
10	4.3 dB	0.06 kW	0 dB	0.16 kW
[1)] ERP of the HD-Radio™ signal is 20 dB less				

Coverage analysis for DRM+

The coverage analyses have been carried out based on the assumption that the compatibility of a DRM+ TX is established by reducing ERP by 5 dB to protect the existing FM stations.

Taking the 20 strongest interferers into account, the coverage prediction for DRM+ and FM as shown in **Fig. 2** is obtained.

The coverage analyses done suggest that the

- coverage of a DRM+ TX is better than the coverage of the former FM TX, in spite of the power reduction of 5 dB. This effect stems from the low protection ratio for FM into DRM+, yielding a low value of the usable field strength, and, therefore, a low interference impact,
- coverage reserve within the coverage area of a DRM+ TX is higher than those of the former FM TX,
- coverage area of a DRM+ TX using 4-QAM is larger as compared to 16-QAM.

[2] Protection ratios FM into HD-Radio™ were not available.

As an example of coverage analysis the result of TX no. 8 (Kaiserslautern-Dansenberg, 96.9 MHz) is shown, cf. **Fig. 2**. The TX's ERP was reduced from ERP_{FM} = 0.5 kW to ERP_{DRM+} = 0.17 kW (i.e. 5 dB)

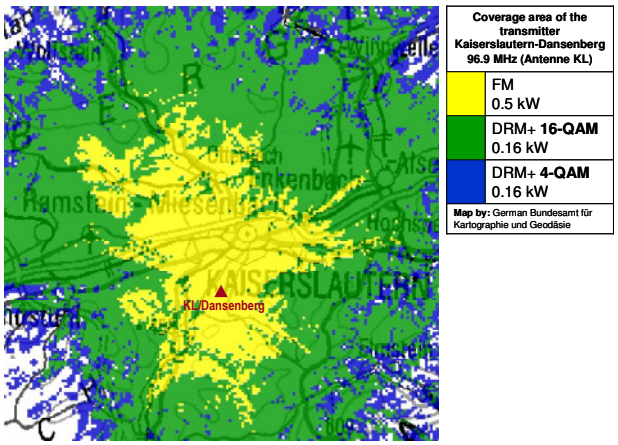

Fig. 2. Coverage area of the FM-TX 96.9 MHz in Kaiserslautern before and after conversion to DRM+

ANALYSIS OF DRM+ HYBRID MODE

Description

The previous analyses assume that a DRM+ TX *replaces* an existing FM TX, but no FM broadcaster would do this in the early stage of the VHF FM band digitisation!

Simulcast broadcasting with FM and DRM+ service in the same service area would be an acceptable approach for broadcasters - and it's feasible. A DRM+ TX can be 'inserted' in a suitable frequency gap somewhere in the VHF FM band in addition to the FM TX. Due to economic reasoning, broadcasting the FM and the DRM+ signal over the same TX and the same antenna should be aimed for. This simulcast broadcasting system is denoted as *DRM+ Hybrid Mode* in what follows.

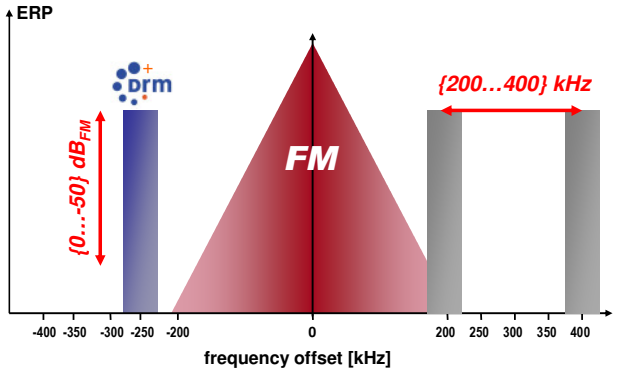

Fig. 3. DRM+ Hybrid Mode

The DRM+ Hybrid Mode could have the following parameters, cf. **Fig. 3**:

- The frequency offset between the DRM+ signal and the FM signal ranges from ±200 kHz to ±400 kHz in 50 kHz steps, and is chosen such that the interference impact of the DRM+ into other FM station's coverage areas is minimised.
- The FM TX power remains unchanged.
- The DRM+ TX power is lowered (relative to the FM power) until the two conditions are met:
  - simulcast FM coverage just gets free of simulcast DRM+ interference, and
  - the coverage area of the other FM stations is not compromised
- 4-QAM modulation for DRM+ is used to achieve the same coverage area as with FM to compensate for the significant DRM+ power reduction.

Interference and coverage analysis

The previous analyses show how a 'DRM+ Hybrid Mode' TX can be planned being compatible to the existing FM environment, assuming that the simulcast DRM+ TX interference independently from the simulcast FM TX[3]. As a consequence, the simulcast FM power remains unchanged, and the simulcast DRM+ power can be chosen according the constraints. It is noteworthy that in HD-Radio™, this flexibility is not given since the simulcast FM and simulcast OFDM power level's difference is fixed to -20 dBc, implying that a constraint on power affects both FM and OFDM, or, in other words, FM and OFDM power levels can not be adjusted separately as in the proposed 'DRM+ Hybrid Mode'.

In order to determine the required power reductions, in a first approach, the simulcast DRM+ TXs were virtually planned with the same ERP as the already existing (simulcast) FM TX. Then, the best frequency distance with minimum interference impact on other FM stations could be found out, cf. **Tab. 3**.

Tab. 3. Power reductions for DRM+ using the DRM+ Hybrid Mode

	Minimum interference impact of DRM+ using the DRM+ Hybrid Mode		
TX No.	**Frequency Offset of DRM+ to FM**	**Power Constraint (P_{FM} = 0 dBr)**	**ERP (DRM+)**
1	-250 kHz	40.3 dB	5.6 W
2	-300 kHz	43.4 dB	2.7 W
3	250 kHz	40.1 dB	5.9 W
4	350 kHz	45.1 dB	1.8 W
5	-250 kHz	40.3 dB	5.6 W
6	-250 kHz	36.2 dB	6.0 W
7	250 kHz	12.8 dB	375 W
8	200 kHz	15.9 dB	4.1 W
9	250 kHz	3.2 dB	96 W
10	200 kHz	15.9 dB	4.1 W

The results obtained for the DRM+ Hybrid Mode propose that

- the interferences - and hence the determined power reductions - of the DRM+ Hybrid signal are similar to a HD-Radio™ Hybrid signal, and the ERP values are in the lower watt range,

[3] This is approach neglects the fact that the signals involved (FM and DRM+ in hybrid mode) are correlated since they originate from the same TX location.

- in some cases, a quite high DRM+ signal power can be reached,
- the required power reduction is obviously not as high for low power TXs as for high power TXs,
- the DRM+ coverage is still greater as the FM coverage if the DRM+ power reduction is higher than 20 dB (which is a similar power difference as for a HD-Radio™ Hybrid signal), but, with a power reduction of 40 dB or more, the DRM+ coverage is smaller than the FM coverage, cf. **Fig. 4**.

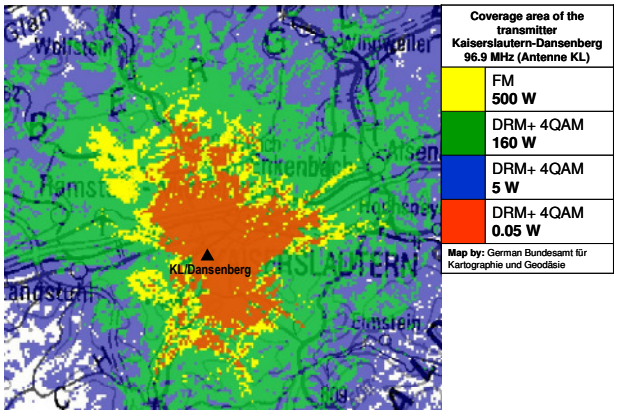

Fig. 4. Coverage of DRM+ Hybrid Mode

SUMMARY – OUT OF THE DEAD-END STREET?

The analyses presented here show that the introduction of a new 'digital' TX into the existing VHF FM environment involves high or even insurmountable barriers:

- HD-Radio™ can only be planned with loss of existing FM coverage,
- DRM+ can only be planned with high coverage if the existing FM TX is replaced,
- DRM+ Hybrid Mode gives leeway (and hope) for local or regional coverage areas, but this mode is currently not more than just an idea.

The above statements result from the fact that planning is done in line with the old, but still legal ITU planning recommendations applicable for FM systems. It is well known that a FM station can be received far beyond it's 'nominal' coverage area, predicted using the ITU recommendations, because:

- the ITU planning recommendations are based on protection ratios which had been set in the 1970s for planning FM stations and which were fixed with FM receivers of that time [8] – indeed, today's radios are more selective in the adjacent channels,
- the determination of the protection ratios are defined via the drop of the un-interfered psophometrically weighted audio SNR of 56 dB to an interfered SNR of 50 dB [9]. Today, this value is typically never reached since, on the hand, audio compression reduces audio dynamics (OptiMod), and, on the other hand, most of today's FM RX do not reach this SNR. Furthermore, even those receivers which have this high audio dynamics can not reach this value in real reception conditions due to interference limitations,
- the reduction of the psophometrically weighted audio SNR by 6 dB to 50 dB does no longer go along with a subjective audio quality reduction.

For these reasons, the planned coverage area ('planned world') of a FM station and the area, where this station can be received ('real world'), significantly differ. The real world is by far bigger than the planned world. To correct this discrepancy and to facilitate the introduction of new digital TX stations into the FM band, the ITU planning recommendations need to be modified in such a way that today's real world is reflected properly – also taking into account mobile and portable reception -, i.e. that planned and real world no longer diverge. In particular, the audio criterion to define the interference between two stations has to be altered:

- An audio SNR of 40 dB (often used today, e.g. in the Netherlands) reduces interference by 10 dB. This reduction holds for to the interference of OFDM into FM, too, thus giving more room for planning new digital stations into the VHF FM band.
- The compatibility criterion should refer to perceptible audible distortion and not to a degradation of audio SNR. Therefore, using e.g. SINAD (Signal, Noise And Distortion) [10] as criterion could be appropriate.

REFERENCES

[1] ETSI ES 201 980: Digital Radio Mondiale (DRM) - System Specification

[2] http://www.fcc.gov/mb/audio/digital

[3] http://www.irt.de/de/produkte/programverbreitung/fransy.html

[4] http://www.drm-radio-kl.eu

[5] Interim report of a diploma thesis of the Technical University Kaiserslautern to be published until October 2008 under http://www.drm-radio-kl.eu

[6] ITU-R BS.412-9: Planning standards for terrestrial FM sound broadcasting at VHF

[7] http://www.bundesnetzagentur.de/media/archive/958.pdf

[8] ITU-R BS.704: Characteristics of FM Sound Broadcasting Reference Receivers for Planning Purposes

[9] ITU-R BS.641: Determination of Radio-Frequency Protection Ratios for Frequency-Modulated Sound Broadcasting

[10] http://www.radio-electronics.com/info/receivers/sensitivity/sinad.php