



Planning Parameters related to DRM Mode E (‘DRM+’)

in VHF Band II (87.5 – 108 MHz)



A proposal
based on investigations and field trials
in Kaiserslautern (Germany)

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1 SCOPE / INTRODUCTION

This document describes system, transmitter and receiver parameters for DRM mode E [ETSI-DRM], referred to as 'DRM+' in the sequel, to define a suitable framework for calculating all DRM+ radio network planning parameters. The work presented here exploits the findings on and the outcomes of the DRM+ related work done by the State Media Authority of Rhineland-Palatinate (Landeszentrale für Medien und Kommunikation (LMK) Rheinland-Pfalz) (Germany) and the University of Applied Science of Kaiserslautern (Germany) in the years 2005-2009 [FHKL] (<http://drm-radio-kl.eu>) and reflects these against the background of radio network planning for DRM+ in VHF band II (87.5 – 108 MHz). On this note, the publication of this document completes an important milestone the authors set themselves in the context of investigating DRM+ in VHF band II.

The present document intends to offer a - hopefully complete, coherent and self-consistent - starting point for both the discussion and the definition of all DRM+ related radio network planning issues and paradigms in terms of numbers, figures, margins, etc. Besides covering state-of-the art reception modes, portable scenarios are further differentiated into critical and non-critical modes as a novelty.

Last but not least, as an outlook on future work in 2010, this document will be extended by the authors to cover DRM+ in VHF band III.

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2 DRM+ SYSTEM PARAMETERS

2.1 Modes and code rates

2.1.1 SDC modes

DRM+ defines the SDC code rates summarized in Tab. 1. Unfortunately, the different SDC-modes for 16-QAM are not mentioned in [ETSI-DRM], but they are supported by the Fraunhofer IIS content server and other applications.

Tab. 1. SDC code rates

MSC-Mode 11 (4-QAM)		MSC-Mode 00 (16-QAM)	
SDC-Mode	Code rate R	SDC-Mode	Code rate R
0	0.5	0	0.5
1	0.25	1	0.25

2.1.2 MSC modes

DRM+ defines the

MSC modes 00: 16-QAM, no hierarchical
 11: 4-QAM, no hierarchical

with code rates given in Tab. 2.

Tab. 2. MSC code rates

Protection level	Code rate for MSC mode 11: 4-QAM		Code rate combinations for MSC mode 00: 16-QAM			
	R_{all}	R_0	R_{all}	R_0	R_1	$R_{Y_{icm}}$
0	0.25	1/4	0.33	1/6	1/2	6
1	0.33	1/3	0.41	1/4	4/7	28
2	0.4	2/5	0.5	1/3	2/3	3
3	0.5	1/2	0.62	1/2	3/4	4

2.1.3 Modes and code rates for investigations and evaluations

Some of the parameters derived later on in this document depend on the characteristics of the transmitted DRM+ signal. To limit the amount of calculations, two representative parameters settings were chosen as a basis for investigations and evaluations: One setting providing a high data rate and a low protection, the other setting providing a low data rate and a high protection.

These two representative parameter settings, which are used throughout this document (and used by the FH Kaiserslautern for all measurements), are displayed in the following Tab. 3:

Tab. 3. MSC code rates used throughout this document

MSC mode	11 - 4-QAM	00 - 16-QAM
MSC protection level	2	0
MSC code rate	0.4	0.33
SDC mode	1	1
SDC code rate	0.25	0.25
Bit rate approx.	58.2 kbps	97.0 kbps

2.2 Propagation-related OFDM parameters

The propagation-related OFDM parameters of DRM+ are given in Tab. 4.

Tab. 4. OFDM parameters

Elementary time period T	83 1/3 μ s
Duration of useful (orthogonal) part $T_u=27\cdot T$	2.25 ms
Duration of guard interval $T_g=3\cdot T$	0.25 ms
Duration of symbol $T_s = T_u + T_g$	2.5 ms
T_g/T_u	1/9
Duration of transmission frame T_f	100 ms
Number of symbols per frame N_s	40
Channel bandwidth	100 kHz
Carrier spacing $1/T_u$	444 4/9 Hz
Carrier numbers	$K_{min} = -106; K_{max} = 106$
Unused carriers	none

2.3 Frequency bands

The DRM system is designed to be used at any frequency below 174 MHz, with variable channelization constraints and propagation conditions throughout these bands [ETSI-DRM].

This document covers DRM+ in VHF band II, i.e. the frequency range 87.5 - 108 MHz.

2.4 Transmission signal spectrum

Important key parameters of the DRM+ signal prior to high power amplification are given in Fig. 1 and Fig. 2.

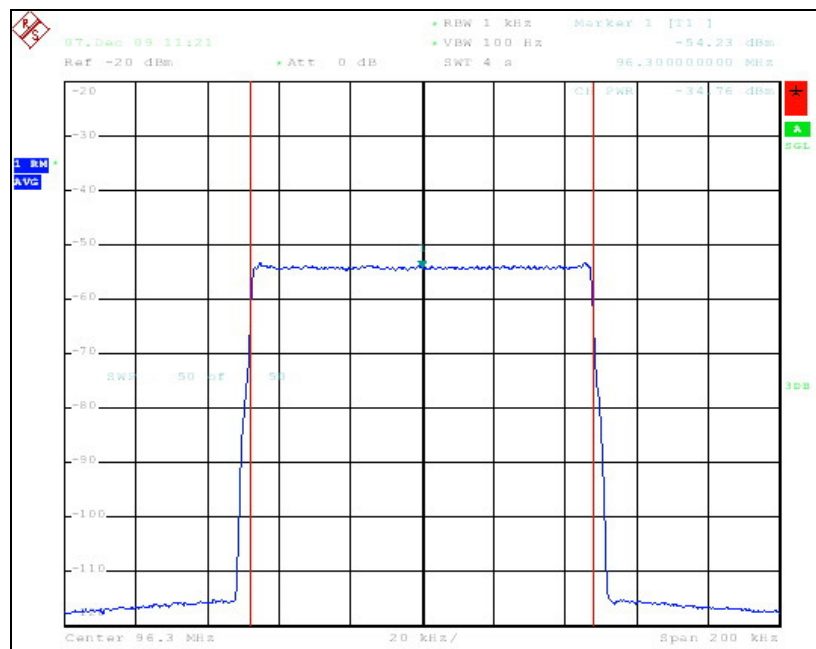


Fig. 1. Measured typical DRM+ OFDM signal in VHF band II (prior to high power amplification)

The DRM+ signal shown in Fig. 1 has a bandwidth of approximately 100 kHz, and its shoulder distance is roughly 60 dB. Note that the spectrum after high power amplification should comply with the out-of-band spectrum mask proposed in section 2.5.

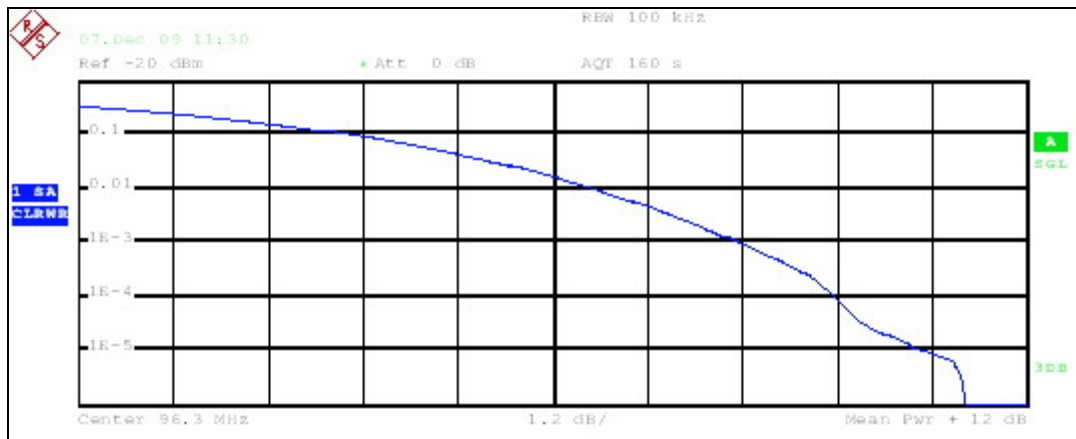


Fig. 2. Baseband crest factor of the DRM+ OFDM signal in VHF band II (prior to high power amplification)

Fig. 2 shows a typical measured complementary cumulative density function (CCDF) representing the DRM+ base band amplitude statistics. From this CCDF, the following figures were derived:

Mean:	-34.06 dBm	10%	3.65 dB
Peak:	-22.76 dBm	1%	6.60 dB
Crest:	11.30 dB	0.1%	8.42 dB
		0.01%	9.60 dB

2.5 Out-of-band spectrum mask

The power density spectrum at the transmitter output is important to determine the adjacent channel interference.

An out-of-band spectrum mask for DRM+ as minimum transmitter requirement is proposed in Tab. 5. The vertices of the symmetric out-of-band spectrum mask for FM transmitters are given in [ETSI-FM]. An out-of-band spectrum mask for DRM+ fitting into the FM mask is proposed, cf. Tab. 5 and Fig. 3. Note that the out-of-band spectrum masks are defined for a resolution bandwidth (RBW) of 1 kHz.

Tab. 5 Out-of-band spectrum masks for FM and DRM+ in VHF band II

Spectrum mask (100 kHz channel) / relative level for FM		Spectrum mask (100 kHz channel) / relative level for DRM+	
Frequency offset [kHz]	Level [dBr]/[1 kHz]	Frequency offset [kHz]	Level [dBr]/[1 kHz]
0	0	0	-20
± 50	0	± 50	-20
± 100	0	± 60	-50
± 200	-80	± 200	-80
± 300	-85	± 300	-85
± 400	-85	± 400	-85

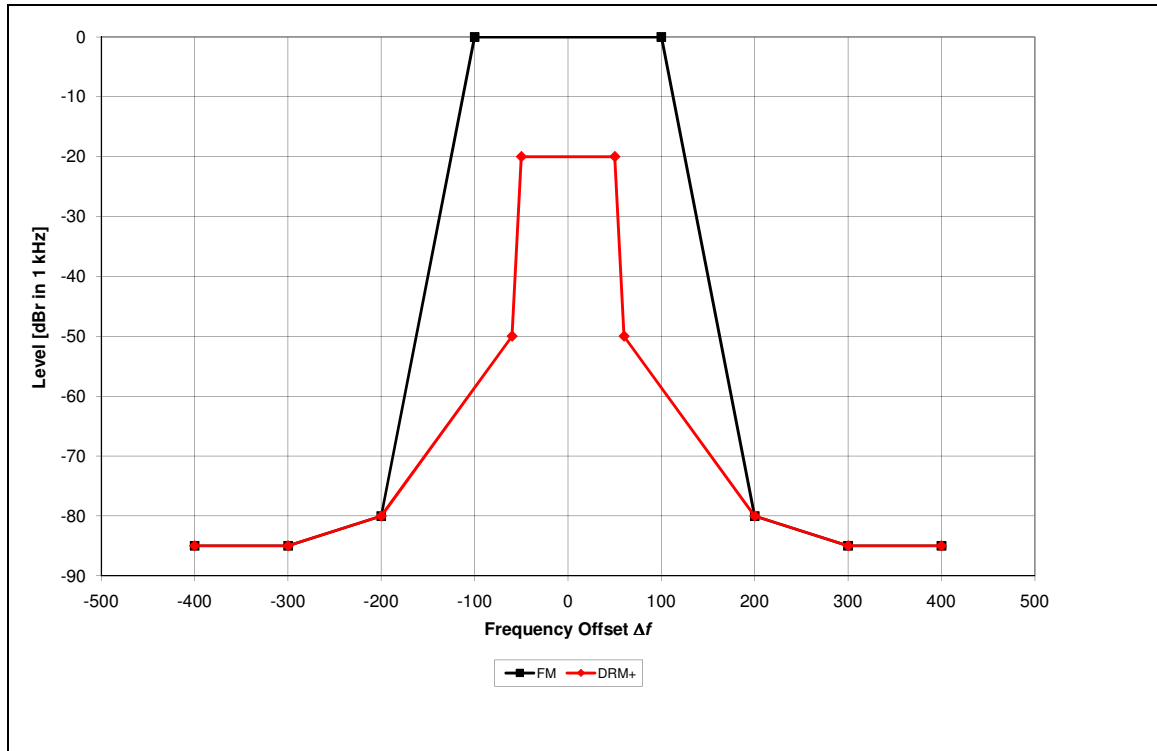


Fig. 3. Out-of-band spectrum masks: FM (black) acc. to [ETSI-FM] and DRM+ (red) (proposed)

2.6 SFN operating capability

The maximum echo delay can be calculated from

$$D_{\text{echo(max)}} [\text{km}] = T_g \cdot c_0 \quad \text{with } c_0 = 300 \cdot 10^3 [\text{km/s}], T_g [\text{s}]$$

Since the length T_g of the DRM+ guard interval is 0.25 ms, cf. Tab. 4, the maximum echo delay, and, therefore, the maximum transmitter distance, yields 75 km.

3 DRM+ RECEIVER PARAMETERS

A DRM+ receiver is intended to receive and decode programs transmitted according to the DRM system specification Mode E (DRM+) [ETSI-DRM].

3.1 General characteristics

3.1.1 Receiver parameters

The parameters relevant for determining the required minimum field strength levels are

- Noise figure F [dB]: Overall noise figure, measured from the antenna input to the (I/Q) base band DRM+ decoder input (including down conversion and A/D conversion).
- Bandwidth B [kHz]: The DRM+ signal bandwidth.
- Effective antenna aperture A_a [dBm²]
- Minimum carrier-to-noise ratio $(C/N)_{min}$ at the DRM+ decoder input.

3.1.2 Decoder parameters

After the channel decoding process an average coded Bit Error Rate (BER) of $1 \cdot 10^{-4}$ is used as service quality criterion.

Since the coded BER is related to (C/N) , thus, (C/N) serves to link receiver performance and service quality.

3.2 (C/N) values

3.2.1 Channel models

Radio wave propagation in VHF bands is characterized by diffraction, scattering and reflection of the electromagnetic waves on their way between the transmitter and the receiver. Typically the waves arrive at different times and different angles at the receiver (multipath propagation) resulting in more or less strong frequency-selective fading (dependent on system bandwidth). In addition movements of the receiver or surrounding objects cause a time variation of the channel characteristic (Doppler effect).

For calculation of the different reception modes the different channel models for VHF band II given in Tab. 6 have been assumed and investigated.

Tab. 6. Channel models

Channel model	Velocity
Channel 7 (AWGN)	0 km/h, no time variation
Channel 8 (Urban)	2 km/h and 60 km/h (pedestrian and vehicle speed)
Channel 9 (Rural)	150 km/h (vehicle speed on highways)
Channel 10 (Terrain obstructed)	60 km/h (vehicle speed within built-in areas)
Channel 11 (Hilly terrain)	100 km/h (vehicle speed along country roads)
Channel 12 (SFN)	150 km/h (vehicle speed on highways)

The channel models given in Tab. 7 were used for the different receiving profiles and serve as basis for further calculations of the minimum field strength level.

Tab. 7. Channel models for reception modes

Reception mode	Channel model
Fixed reception	Channel 7 (AWGN)
Portable reception	Channel 8 (Urban)
Mobile reception	Channel 9 (Rural)

3.2.2 $(C/N)_{\min}$ in ETSI ES 201 980

ETSI ES 201 980 V3.1.1 gives a required $(C/N)_{\min}$ for a transmission to achieve an average coded BER = $1 \cdot 10^{-4}$ after the channel decoder for different channel models (out of Matlab-based simulations), cf. Tab. 8.

Tab. 8. $(C/N)_{\min}$ for DRM+ in ETSI ES 201 908 with different channel models

$(C/N)_{\min}$ [dB] for Channel model	4-QAM R=0.33 (PL = 1)	16-QAM R=0.5 (PL = 2)
Channel 7 (AWGN)	1.3	7.9
Channel 8 (Urban) at 60 km/h	7.3	15.4
Channel 9 (Rural)	5.6	13.1
Channel 10 (Terrain obstructed)	5.4	12.6
Channel 11 (Hilly terrain)	5.5	12.8
Channel 12 (SFN)	5.4	12.3

3.2.3 $(C/N)_{\min}$ for DRM+ out of laboratory measurements

Tab. 9 gives the required $(C/N)_{\min}$ for a transmission to achieve an average coded BER = $1 \cdot 10^{-4}$ bit after the channel decoder for different channel models (out of lab based measurements using real-time fading simulator and a real-time *prototype* receiver).

Tab. 9. $(C/N)_{\min}$ for DRM+ out of laboratory measurements with different channel models

$(C/N)_{\min}$ [dB] for Channel model	4-QAM, R=0.4 (PL = 2)	16-QAM, R=0.33 (PL = 0)
Channel 7 (AWGN)	2.9	7.8
Channel 8 (Urban) at 60 km/h	13.0	18.7
Channel 9 (Rural)	11.4	17.7
Channel 10 (Terrain obstructed)	11.2	17.0
Channel 11 (Hilly terrain)	11.7	16.8

3.3 Receiver input level and minimum field strength level

The following equations are used to calculate different receiver input levels and the minimum receiver field strength levels.

Effective antenna aperture [RRC06]: $A_a \text{ [dBm}^2\text{]} = G_d \text{ [dBd]} + 10 \cdot \log(1.64 \cdot \lambda^2 / 4\pi)$
 with: $G_d = 0 \text{ dBd}$, $\lambda \text{ [m]}$

Receiver noise input power level: $P_n \text{ [dBmW]} = F + 30 \text{ [dB]} + 10 \log(k t_0 B)$
 with: $B = 100 \text{ [kHz]}$; $T_0 = 290 \text{ [K]}$; $k = 1.38 \cdot 10^{-23} \text{ [J/K]}$

Minimum signal input power level: $P_{\text{min}} \text{ [dBmW]} = P_n + (C/N)_{\text{min}}$
 with: $B = 100 \text{ [kHz]}$; $T_0 = 290 \text{ [K]}$; $k = 1.38 \cdot 10^{-23} \text{ [J/K]}$

Minimum field strength level
 at receiving location: $E_{\text{min}} \text{ [dB}(\mu\text{V/m)}\text{]} = P_{\text{min}} \text{ [dBmW]} - G_d \text{ [dB]} - 20 \log(\lambda) \text{ [m]} + 124,6$
 with: $G_d = 0 \text{ dBd}$

Based on the above equations, the minimum field strength level at the receiving location can be calculated for 16 QAM, cf. section 3.3.1, Tab. 10, and 4 QAM, cf. section 3.3.2, Tab. 11.

3.3.1 Minimum field strength level for 16-QAM, PL=0

Tab. 10. Minimum field strength level for 16-QAM, PL=0

Reception mode		fixed	portable	mobile
Channel model		7 (AWGN)	8 (urban)	9 (rural)
Frequency	f [MHz]	100	100	100
Receiver noise figure	F [dB]	7	7	7
Receiver noise input power	P_n [dBmW]	-117.98	-117.98	-117.98
Representative minimum C/N ratio	$(C/N)_{\text{min}}$ [dB]	7.8	18.7	17.7
Minimum receiver signal input power	P_{min} [dBmW]	-110.18	-99.28	-100.28
Effective antenna aperture (reference 0 dBd)	A_a [dBm ²]	0.70	0.70	0.70
Minimum field strength level at receiving location	E_{min} [dB(μV/m)]	4.88	15.78	14.78

3.3.2 Minimum field strength level for 4-QAM, PL=2

Tab. 11. Minimum field strength level for 4-QAM, PL=2

Reception mode		fixed	portable	mobile
Channel model		7 (AWGN)	8 (urban)	9 (rural)
Frequency	f [MHz]	100	100	100
Receiver noise figure	F [dB]	7	7	7
Receiver noise input power	P_n [dBmW]	-117.98	-117.98	-117.98
Representative minimum C/N ratio	$(C/N)_{\text{min}}$ [dB]	2.9	13.0	11.4
Minimum receiver signal input power	P_{min} [dBmW]	-115.08	-104.98	-106.58
Effective antenna aperture (reference 0 dBd)	A_a [dBm ²]	0.70	0.70	0.70
Minimum field strength level at receiving location	E_{min} [dB(μV/m)]	-0.02	10.08	8.48

4 PARAMETERS RELATED TO PROPAGATION AND FIELD-STRENGTH PREDICTION

4.1 Antenna gain

The antenna gain G_d is used in the derivation of the minimum median equivalent field strength level values. Note that G_d references to a half-wave dipole.

4.1.1 Antenna gain for fixed reception

In [ITU-599] and [RRC06] the antenna pattern for fixed reception is given for VHF band II. From these references, the antenna gain for fixed reception is assumed to be

$$G_d = 4 \text{ dBd.}$$

4.1.2 Antenna gain for portable and mobile reception

[RRC06] assumes an omnidirectional VHF antenna pattern with an antenna gain of -2.2 dBd for portable receiver planning.

On the other hand, [EBU-3317] states that different manufacturers provide information about the gain of their antennas in quite different ways. It is therefore important to distinguish between three antenna types: integrated, external (for example telescopic antennas or the cable of wired headsets) and adapted antennas. The antenna gain value for the integrated antenna is based on measurements made at the IRT (Institut für Rundfunktechnik, Germany). Since the external antenna is better matched to the wavelength, the improvement in antenna gain is assumed to be 4 dB.

Antenna gains for VHF band III (200 MHz) and for portable reception modes are given [EBU-3317] by:

Receiver integrated antenna: -17 dBd
 External antenna (Telescopic or wired headsets): -13 dBd
 Adapted antenna (for mobile reception): -2.2 dBd

Effective antenna aperture [RRC06]: $A_a [\text{dBm}^2] = G_d [\text{dBd}] + 10 \cdot \log(1.64 \cdot \lambda^2 / 4\pi)$
 with: $G_d = 0 \text{ dBd}$, $\lambda [\text{m}]$

With these effective antenna apertures the antenna gains for the different bands can be calculated. The antenna gains for portable reception modes in VHF band II are given in Tab. 12.

Tab. 12. Antenna gain for portable and mobile reception

Frequency	[MHz]	100
Effective antenna aperture	[dBm ²]	0.7
Effective antenna aperture (reference 200 MHz)	[dBm ²]	6.02
Antenna gain for receiver integrated antenna	[dBd]	-23.02
Antenna gain for external antenna (Telescopic or wired headsets)	[dBd]	-19.02
Adapted antenna (for mobile reception)	[dBd]	-2.2

Since the antenna gains vary considerably, two situations for portable reception are proposed to be used in planning and regulation:

- **non-critical portable reception** with adapted antenna: -2.2 dBd,
- **critical portable reception** with external antenna: -19.02 dBd.

4.2 Feeder-loss

The feeder-loss expresses the signal attenuation from the receiving antenna to the receiver's RF input.

The feeder-loss for fixed reception at 200 MHz is given in [RRC06] with 2 dB for 10 m cable length.

The frequency dependent cable attenuation is assumed to be equal to the attenuation at 200 MHz:

$$L_c \text{ [dB]} = 0.2 \cdot l \cdot (f/f_0)^{0.5}$$

where: $f_0 = 200 \text{ MHz}$

$l = \text{length of the antenna cable in meter}$

The feeder-loss values per meter at 100 MHz is $L_c = 0.14 \text{ dB}$.

4.3 Height loss correction factor

A correction in dB is applied to the predicted field strength levels at roof level when making a prediction for lower reception heights.

The height loss correction factor for an antenna height of 1.5 m for T-DAB at 200 MHz is given in [ITU-1660-1] as 10 dB.

The height loss correction factor for an antenna height of 1.5 m for suburban coverage is given in [RRC06] as follows:

- 12 dB at 200 MHz
- 16 dB at 500 MHz
- 18 dB at 800 MHz

Therefore, the height loss correction factor the value for suburban coverage at 100 MHz is assumed to 10 dB.

Tab. 13. Height loss correction factor

Frequency	[MHz]	100
height loss correction factor for suburban coverage	[dB]	10
height loss correction factor for urban coverage [EBU-3317]	[dB]	17

The following height loss correction factors are used for portable reception modes, cf. section 5.1.2:

- correction factor of 10 dB for suburban coverage for the **non-critical portable reception** (with adapted antenna),
- correction factor of 17 dB for urban coverage for **critical portable reception** with external antenna.

4.4 Building penetration loss

4.4.1 Mean building penetration loss

The ratio between the mean field strength inside a building at a given height above ground level and the mean field strength outside the same building at the same height above ground level expressed in decibels is the mean building penetration loss.

The mean building penetration loss in VHF band III is given in [RRC06] as 9 dB with a standard deviation of 3 dB, which is proposed to be used for band II, too, cf. Tab. 14.

Tab. 14. Building penetration loss

Frequency	[MHz]	100
Mean building penetration loss L_b	[dB]	9
Standard deviation σ_{L_b}	[dB]	3

4.5 Standard deviation

4.5.1 Standard deviation of DRM+

Values of standard deviation σ_L for digital systems having a bandwidth less than 1 MHz as well as for analogue systems are given as a function of frequency by [ITU-1546]:

$$\sigma_L \text{ [dB]} = K + 1.6 \cdot \log(f) \quad f \text{ [MHz]}$$

where: K= 2.1 for mobile systems in urban locations

K= 3.8 for mobile systems in suburban locations or amongst rolling hills

K= 5.1 for analogue broadcasting systems

The following fixed values are given:

Broadcasting, analogue at 100 MHz: 8.3 dB

Broadcasting, digital (more than 1 MHz bandwidth): 5.5 dB

The standard deviations σ_L calculated for DRM+ are given in Tab. 15.

Tab. 15. Standard deviation for DRM+

Frequency	[MHz]	100
in urban locations	[dB]	5.3
in suburban locations or amongst rolling hills	[dB]	7.0

4.5.2 Combined standard deviation

The combined location correction factor is used to convert the wanted and nuisance field strengths levels which refer to 50% of location into the value corresponding to the percentage of location needed for the wanted service [RRC06].

The combined location correction factor shall be calculated as follows:

$$CF [dB] = \mu [(\sigma_w^2 + \sigma_n^2)]^{0.5}$$

with: σ_w : standard deviation of location variation for the wanted signal [dB]
 σ_n : standard deviation of location variation for the nuisance signal [dB]
 μ : distribution factor

For DRM+ the combined location correction factors at 50% of location are calculated for urban and suburban areas, cf. Tab. 16.

Tab. 16. Combined correction factor at 50% of location

Frequency	[MHz]	100	100
Reception area		urban	suburban
DRM+ interference combined with DRM+	[dB]	7.50	9.90
DRM+ interference combined with FM	[dB]	9.85	10.86

4.6 Man-made noise

Man-made noise at 200 MHz is given in [RRC06] by 2 dB. It is proposed to use this figure in VHF band II, too, if noise limited scenarios are considered.

If interference limited scenarios are considered, man made noise is neglected, i.e. set to 0 dB.

4.7 Location variability in land-coverage prediction

4.7.1 Location correction factor (distribution factor) for location variability in land-coverage prediction

The more or less random variation of the received signal level with location due to terrain irregularities and the effect of obstacles in the near vicinity of the receiver location is modelled by a statistical distribution (typically log normal) over a specified area (typically a square with an edge length of 100 m to 200 m).

The field strength level E which will be exceeded for $q\%$ of locations for a land receiving/mobile antenna location is given by

$$E(q) [dB(\mu V/m)] = E(\text{median}) + C_i$$

$$\text{with: } C_i [dB] = Q_i(q/100) \cdot \sigma_L(f) = \mu \cdot \sigma_L$$

where: $Q_i(x) = \mu$: inverse complementary cumulative normal distribution; distribution factor μ [ITU1546].
 σ_L : standard deviation of the Gaussian distribution of the local means in the study area.

Tab. 17. Location correction factor

Percentage of receiving locations	50%	70%	90%	95%	99%
Distribution factor μ	0	0.524	1.282	1.645	2.327

5 DRM+ SERVICE PLANNING PARAMETERS

5.1 Correction values for reception modes

5.1.1 Fixed reception

Fixed reception is defined as reception where a directional receiving antenna mounted at roof level is used. It is assumed that near-optimal reception conditions (within a relatively small volume on the roof) are found when the antenna is installed. In calculating the field strength levels for fixed antenna reception, a receiving antenna height of 10 m above ground level is considered to be representative for the broadcasting service [RRC06].

For fixed reception, channel model 7 (AWGN) and suburban area is used. The overall correction factor is given in Tab. 18.

Tab. 18. Correction values for fixed reception

Frequency	f [MHz]	100
Antenna form and gain relative to half wave dipole	Yagi / G _D [dB]	4
Cable length / feeder-loss	10 m / L _c [dB]	1.41
Antenna height / Antenna height loss	10 m / L _c [dB]	0
Allowance for man-made noise	P _{mmn} [dB]	0
Building penetration loss	L _b [dB]	0
Standard deviation of building penetration loss	σ _{L_b} [dB]	0
Location correction factor	@50% [dB]	0
Overall location correction factor	C _l [dB]	0
Sum of correction factors	C_{all} [dB]	-2.59

5.1.2 Different situations of portable reception

Due to the great variability of portable reception situations with different receiver-/antenna-types and also different reception conditions, the portable reception is proposed to be differentiated in two rather opposing reception situations:

Non-critical situation: This situation gives the reception situation with good reception conditions and a receiver with an adapted antenna in a suburban area.

Critical situation: This situation gives the reception situation with bad reception conditions and a receiver with an external antenna in an urban area.

For both situations channel model 8 (urban) is proposed to be used.

5.1.3 Portable indoor reception

Portable indoor reception is defined by a portable receiver with stationary power supply and a build-in (folded)-antenna or with a plug for an external antenna. The receiver is used indoors at no less than 1.5 m above floor level in rooms with on the ground floor, or with a window in an external wall. The location of the receiver is fixed [RRC06].

The overall correction factors are given in Tab. 19.

Tab. 19. Correction values for portable indoor reception

Frequency	f [MHz]	100	100
Reception situation		non-critical	critical
Reception area		suburban	urban
Antenna form and gain relative to half wave dipole	Omni / G_D [dB]	-2.2	-19.02
Cable length / feeder-loss	0 m / L_c [dB]	0	0
Antenna height / Antenna height loss	1.5 m / L_c [dB]	10	17
Allowance for man-made noise	P_{mmn} [dB]	0	0
Building penetration loss	L_b [dB]	9	9
Standard deviation of building penetration loss	σ_{Lb} [dB]	3.00	3.00
Location correction factor	@ 70% [dB]	3.67	2.78
Overall location correction factor	C_1 [dB]	4.74	4.09
Sum of correction factors	C_{all} [dB]	25.94	49.11

5.1.4 Portable outdoor reception

Portable outdoor reception is defined as reception by a portable receiver with battery supply and an attached or built-in antenna is used outdoors at no less than 1.5 m above ground level; urban area [RRC06].

The overall correction factors are given in Tab. 20.

Tab. 20. Correction values for portable outdoor reception

Frequency	f [MHz]	100	100
Reception situation		non-critical	critical
Reception area		suburban	urban
Antenna form and gain relative to half wave dipole	Omni / G_D [dB]	-2.2	-19.02
Cable length / feeder-loss	0 m / L_c [dB]	0	0
Antenna height / Antenna height loss	1.5 m / L_c [dB]	10	17
Allowance for man-made noise	P_{mmn} [dB]	0	0
Building penetration loss	L_b [dB]	0	0
Standard deviation of building penetration loss	σ_{Lb} [dB]	0	0
Location correction factor	@ 95% [dB]	11.52	8.72
Overall location correction factor	C_1 [dB]	11.52	8.72
Sum of correction factors	C_{all} [dB]	23.72	44.74

5.1.5 Mobile reception

Mobile reception is defined as reception by a receiver in motion also at high speed with a matched antenna situated at no less than 1.5 m above ground level or floor level [RRC06].

For mobile reception, channel model 9 (rural) and rural resp. suburban area is used. The overall correction factor is given in Tab. 21.

Tab. 21. Correction values for mobile reception

Frequency	f [MHz]	100
Antenna form and gain relative to half wave dipole	Omni / G_D [dB]	-2.20
Cable length / feeder-loss	2 m / L_c [dB]	0.28
Antenna height / Antenna height loss	1.5 m / L_c [dB]	10
Allowance for man-made noise	P_{mmn} [dB]	0
Building penetration loss	L_b [dB]	0
Standard deviation of building penetration loss	σ_{Lb} [dB]	0
Location correction factor	@99% [dB]	16.29
Overall location correction factor	C_1 [dB]	16.29
Sum of correction factors	C_{all} [dB]	28.77

5.2 Minimum median field strength level

The minimum median field strength level at 10 m above ground level for 50% of time and for 50% of locations for interference limited situations is calculated for the different reception modes, cf. section 5.2.1, Tab. 22 and section 5.2.2, Tab. 23.

5.2.1 Median field strength level for 16-QAM, PL=0

Tab. 22. Median field strength level for 16-QAM, PL=0

Frequency	f [MHz]	100	100	100	100	100	100
Reception mode		fixed	portable indoor	portable indoor	portable outdoor	portable outdoor	mobile
Reception situation			non-critical	critical	non-critical	critical	
Location probability		50 %	70 %	70 %	95 %	95 %	99 %
Reception area		suburban	suburban	urban	suburban	urban	rural
Minimum field strength level at receiving location	E_{min} [dB(μ V/m)]	4.88	15.78	15.78	15.78	15.78	14.78
Sum of correction factors	C_{all} [dB]	-2.59	25.94	49.11	23.72	44.74	28.77
Minimum field strength level at receiving location	E_{med} [dB(μV/m)]	2.29	41.72	64.89	39.50	60.52	43.55

5.2.2 Median field strength level for 4-QAM, PL=2

Tab. 23. Median field strength level for 4-QAM, PL=2

Frequency	f [MHz]	100	100	100	100	100	100
Reception mode		fixed	portable indoor	portable indoor	portable outdoor	portable outdoor	mobile
Reception situation			non-critical	critical	non-critical	critical	
Location probability		50 %	70 %	70 %	95 %	95 %	99 %
Reception area		suburban	suburban	urban	suburban	urban	rural
Minimum field strength level at receiving location	E_{\min} [dB(μ V/m)]	-0.02	10.08	10.08	10.08	10.08	8.48
Sum of correction factors	C_{all} [dB]	-2.59	25.94	49.11	23.72	44.74	28.77
Minimum field strength level at receiving location	E_{med} [dB(μV/m)]	-2.61	36.02	59.19	33.80	54.82	37.25

5.3 Polarization discrimination

5.3.1 Fixed reception

It is possible to take advantage of polarization discrimination for fixed reception.

[GE84] does not take into account polarization discrimination in the planning procedure for VHF band II, except in specific cases with the agreement of affected administrations. In such cases, a value of 10 dB was used for orthogonal polarization discrimination.

Polarization discrimination shall not be taken into account in the DRM+ planning procedures.

5.3.2 Portable and mobile reception

Polarization discrimination shall not be taken into account in the planning procedures.

6 NETWORK PLANNING PARAMETERS

6.1 Position of DRM+ frequencies in band II

The DRM+ frequencies are positioned in 100 kHz distance according to the FM frequency grid. The nominal carrier frequencies are, in principle, integral multiples of 100 kHz.

6.2 Correction margin for median field strength levels in interference situations

The values of the standard deviations to be used for DRM+ depend on the scenario considered, cf. Tab. 24 and section 4.5.

Tab. 24. Correction factors for 50% of locations

Reception area		urban	suburban
DRM+ (noise limited)	[dB]	5.30	7.00
DRM+ (interfered with by DRM+)	[dB]	7.50	9.90
DRM+ (interfered with by FM)	[dB]	9.85	10.86

Therefore different correction margins of the median field strength level of DRM+ in an interference situation is needed for portable and mobile receptions, cf. Tab. 25.

Tab. 25. Correction margins of the median field strength level for DRM+ in interference situations

Reception mode	portable indoor	portable indoor	portable outdoor	portable outdoor	mobile
Reception area	suburban	urban	suburban	urban	rural
Reception situation	non-critical	critical	non-critical	critical	
Location probability	70 %	70 %	95 %	95 %	99 %
Distribution factor μ	0.524	0.524	1.645	1.645	2.327
Location correction of DRM+	3.67	2.78	11.52	8.72	16.29
Location correction of DRM+ interfered with by DRM+	5.19	3.93	16.29	12.33	23.03
Location correction of DRM+ interfered with by FM	5.69	5.16	17.86	16.20	25.26
Correction margin of the median field strength level for DRM+ interfered with by DRM+	1.52	1.15	4.77	3.61	6.75
Correction margin of the median field strength level for DRM+ interfered with by FM	2.02	3.8	6.35	7.48	8.98

6.3 Median field strength levels for DRM+ in interference situations

Using the correction margins of the median field strength level of DRM+ in an interference situation as basis the median field strength level for DRM+ in interference situations for portable and mobile receptions is calculated.

6.3.1 Median field strength levels in interference situations for 16-QAM, PL=0

Tab. 26. Median field strength levels for 16-QAM, PL=0 in interference situations

Reception mode		fixed	portable indoor	portable indoor	portable outdoor	portable outdoor	mobile
Reception area		suburban	suburban	urban	suburban	urban	rural
Reception situation			non-critical	critical	non-critical	critical	
Location probability		50 %	70 %	70 %	95 %	95 %	99 %
Minimum field strength level for DRM+ at receiving location without interferers	$E_{med\ DRM+}$ [dB(μ V/m)]	2.29	41.72	64.89	39.50	60.52	43.55
Minimum field strength level for DRM+ at receiving location interfered with by DRM+	$E_{med\ DRM+/DRM+}$ [dB(μ V/m)]	2.29	43.24	66.04	44.27	64.14	50.30
Minimum field strength level for DRM+ at receiving location interfered with by FM	$E_{med\ DRM+/FM}$ [dB(μ V/m)]	2.29	43.74	67.27	45.84	68.00	52.53

6.3.2 Median field strength levels in interference situations for 4-QAM, PL=2

Tab. 27. Median field strength levels for 4-QAM, PL=2 in interference situations

Reception mode		fixed	portable indoor	portable indoor	portable outdoor	portable outdoor	mobile
Reception area		suburban	suburban	urban	suburban	urban	rural
Reception situation			non-critical	critical	non-critical	critical	
Location probability		50 %	70 %	70 %	95 %	95 %	99 %
Minimum field strength level for DRM+ at receiving location without interferers	$E_{med\ DRM+}$ [dB(μ V/m)]	-2.61	36.02	59.19	33.80	54.82	37.25
Minimum field strength level for DRM+ at receiving location interfered with by DRM+	$E_{med\ DRM+/DRM+}$ [dB(μ V/m)]	-2.61	37.54	60.34	38.57	58.44	44.00
Minimum field strength level for DRM+ at receiving location interfered with by FM	$E_{med\ DRM+/FM}$ [dB(μ V/m)]	-2.61	38.04	61.57	40.14	62.30	46.23

6.4 FM Signal parameters (unwanted signal)

The FM signal parameters are given in [ITU-412].

6.5 Protection ratios

6.5.1 Broadcasting services in VHF band II

Tab. 28 gives the protection ratio between services in VHF band II broadcasting bands.

Tab. 28. Protection ratios between broadcasting services in VHF band II

Frequency offset	[kHz]	0	± 100	± 200	± 300	± 400
DRM+ (16-QAM, PL=0) interfered with by DRM+	[dB]	14	-6	-34	-65	-67
DRM+ (4-QAM, PL=2) interfered with by DRM+	[dB]	6	-14	-40	-72	-74
DRM+ (16-QAM, PL=0) interfered with by FM (stereo)	[dB]	18	-9	-49	-68	-69
DRM+ (16-QAM, PL=0) interfered with by FM (norm signal)	[dB]	17	-20	-65	-68	-69
DRM+ (4-QAM, PL=2) interfered with by FM (stereo)	[dB]	11	-13	-54	-76	-77
DRM+ (4-QAM, PL=2) interfered with by FM (norm signal)	[dB]	12	-26	-73	-76	-76
FM (stereo) interfered with by DRM+	[dB]	50	38	-7	-40	-40

6.5.2 Other services interfered with by DRM+

Except from FM sound broadcasting there are no other services interfered with by DRM+ in the VHF band II (87.5 – 108 MHz).

Below the VHF band II broadcasting band, land mobile services with security tasks are located. The interference potential of DRM+ into these services is not higher as the one of FM signals.

Above the VHF band II broadcasting band, aeronautical radio navigation services are located. The interference potential of DRM+ into these services is not higher as the one of FM signals.

6.6 Single frequency networks

DRM+ can be operated in single frequency network (SFN) mode.

7 RULES FOR COORDINATION

7.1 Frequency plans

7.1.1 ITU frequency plan for VHF band II (GE 84)

As an alternative, other systems having different characteristics (e.g. other pre-emphasis characteristics, digital modulation) may be used, provided that such use does neither cause greater interference nor demand higher protection than the reference system indicated in the plan [GE84, Ch. 3.1].

7.2 DRM+ assignment planning

7.2.1 Substituting an existing FM transmitter with DRM+

In case that an existing FM broadcast is to be replaced by a DRM+ broadcast, a reduction of effective radiation power by 5 dB is proposed to protect existing broadcasting networks.

7.2.2 Planning of a new DRM+ transmitter

In case that a new DRM+ transmitter is to be introduced into existing broadcasting networks, the planning should rely on the coordination rules in force based on the protection ratios given in Tab. 28.

7.3 DRM+ SFN planning

The coordination procedures could be the same as for DAB, esp. the calculation of the interference situation, see [GE06].

8 REFERENCES

- [ETSI-DRM] ETSI EN 301 980 Digital Radio Mondiale (DRM); System Specification
- [FHKL] Laboratory and field measurements of DRM+ in Kaiserslautern, University of Applied Sciences of Kaiserslautern (Germany). To be published on http://drm-radio-kl.eu/berichte_vortraege.htm
- [EBU-3317] EBU - TECH 3317 Planning parameters for hand held reception concerning the use of DVB-H and T-DMB in Bands III, IV, V and the 1.5 GHz band, July 2007
- [ITU-599] ITU-R BS.599 Directivity of Antennas for the Reception of Sound Broadcasting in Band 8 (VHF)
- [ITU-1546] ITU-R P.1546-1 Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz
- [RRC06] Final Acts of the Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (RRC-06) Annex 3: Technical basis and characteristics
- [ETSI-FM] ETSI EN 302 018-2 Electromagnetic compatibility and Radio spectrum Matters (ERM); Transmitting equipment for the Frequency Modulated (FM) sound broadcasting service
- [ITU-412] ITU-R BS.412.9 Planning standards for terrestrial FM sound broadcasting at VHF
- [GE84] Final Acts of the Regional Administrative Conference for the Planning of VHF Sound Broadcasting (Region 1 and Part of Region 3), Geneva 1984