German DRM Platform
- DRM+ Technical Expert Group -

Planning Parameters for DRM Mode E (‘DRM+’)

concerning the use in VHF bands I, II and III

DIGITAL radio mondiale

V 3.0 –04/05/2011

TABLE OF CONTENTS

1 Scope

Digital Radio Mondiale™ (DRM) was originally designed by the DRM Consortium as a digital broadcasting system for the radio bands below 30 MHz and it is standardized as ETSI ES 201 980 [ETSI-DRM]. In 2009, DRM was extended by a mode E – called 'DRM+' – to use DRM in radio bands up to 174 MHz.

The University of Applied Sciences in Kaiserslautern[1] (Germany) and the University of Hannover[2] (Germany) successfully conducted laboratory measurements and field trials with DRM in VHF band II and in VHF band III, resp. Demonstrations were also given successfully in Paris in VHF band I by the University of Applied Sciences in Kaiserslautern. Other field trials all over the world, especially in Brazil, Italy, Sri Lanka, the United Kingdom, and in the Republic of Korea have completed the tests.

The measurements and field trials have confirmed the technical parameters, and comparisons of coverage area have been performed between FM in VHF band II and DRM also as with DAB in VHF band III and DRM. In addition, protection ratio measurements have been performed and planning models have been used to predict coverage. The results from both German sites show that DRM works well in all VHF bands including VHF band III.

From these results and based on the therefore relevant ITU recommendations this document defines a framework for calculating all relevant DRM network planning parameters in all VHF bands. The focus lies on VHF band II (87.5 - 108 MHz) and VHF band III (174 - 230 MHz) in ITU Region 1, however where the values for the VHF Band I (47 – 68 MHz) are available, they are given.

Other frequency allocations in VHF bands assigned to broadcasting services are not exhaustively covered yet, e.g. areas in ITU Region 1 where allocations of the Wiesbaden T-DAB Agreement 1995 are still used (230 – 240 MHz) or in some Southern African countries, where the VHF band III is allocated to the broadcasting services up to 254 MHz, or the broadcasting bands in ITU Region 2 and 3, perhaps the OIRT FM band (65.8 - 74 MHz) or the Japanese FM band (76 - 90 MHz), respectively, that can later be adapted. Planning parameters for these unconsidered cases can be derived or taken from the given values, considering 254 MHz as the international top boundary of the VHF broadcasting spectrum[3].

To calculate the relevant planning parameters minimum median field strength and protection ratios, firstly receiver and transmitter characteristics, system parameters as well as transmission aspects as common basis for concrete DRM transmission network planning are determined. All parameters are either derived or the reference to the source of origin is given. Various typical reception scenarios are taken into account to match as much as possible planning and prediction scenarios.

[1] http://www.fh-kl.de; http://www.drm-radio-kl.eu

[2] http://www.ikt.uni-hannover.de/

[3] ITU Radio Regulations for Region 1, Footnote 5.252: in Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe, the bands 230-238 MHz and 246-254 MHz are allocated to the broadcasting service on a primary basis, subject to agreement obtained under No. 9.21.

2 Reception Modes

2.1 Fixed Reception (FX)

Fixed reception is defined as reception where a 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 [ITU-GE06].

A location probability of 70% is assumed to obtain a good reception situation.

2.2 Portable Reception

In general, portable reception means a reception where a portable receiver with an attached or built-in antenna is used outdoors or indoors at no less than 1.5 m above ground level.

A location probability of 95% is assumed to obtain a good reception situation.

Two receiving locations will be distinguished:

- **Indoor reception** with a reception place in a building
- **Outdoor reception** with a reception place outside a building

Within these receiving locations two opposed receiving conditions will be distinguished additionally due to the great variability of portable reception situations with different receiver-/antenna-types and also different reception conditions:

- **Portable reception:** This situation models the reception situation with good reception conditions for both situations indoor and outdoor, resp., and a receiver with an omnidirectional VHF antenna pattern as given in [ITU-GE06].
- **Portable handheld reception:** This situation models the reception situation with bad reception conditions and a receiver with an external antenna (for example telescopic antennas or the cable of wired headsets) as given in [EBU-3317].

2.2.1 Portable Indoor Reception (PI)

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 on the ground floor and with a window in an external wall. It is assumed that optimal receiving conditions will be found by moving the antenna up to 0.5 m in any direction and the portable receiver is not moved during reception and large objects near the receiver are also not moved [ITU-GE06]. A suburban area is assumed.

2.2.2 Portable Outdoor Reception (PO)

Portable outdoor reception is defined as reception by a portable receiver with battery supply and an attached or built-in antenna which is used outdoors at no less than 1.5 m above ground level [ITU-GE06]. A suburban area is assumed in this case.

2.2.3 Portable Handheld Reception (PI-H, PO-H)

Portable reception is defined as reception by a portable handheld receiver with battery supply and an external antenna as given in [EBU-3317] for both reception situations indoor and outdoor, respectively. An urban area is assumed in this case.

2.3 Mobile Reception (MO)

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 [ITU-GE06]. A rural area with hilly terrain is assumed in this case.

3 Correction Factors for Field Strength Predictions

[ITU-1546] forms the basis of a field strength prediction method applicable for the broadcasting services amongst other services. Predictions can be made from 30 MHz up to 3000 MHz within a path distance of 1 to 1000 km, percentage of time of 1 to 50%, and for various transmitting antenna heights. The method draws a distinction between paths over land, cold seas and warm seas, makes due allowance for location variability for land area-service predictions and takes account of local clutter surrounding the receiving location. It also provides procedures for handling negative effective transmitting antenna heights and mixed-path propagation (i.e. with combinations of land and sea).

The wanted field strength level values predicted with [ITU-1546] refer always to the median value at a receiving location with a receiving antenna in 10 m height above ground level. This antenna height is a generic value, used as stated only in rural or suburban areas, with constructions or vegetation below 10m height. Otherwise the wanted field strength values are predicted at the average construction or vegetation height at the receiving location. The true receiving antenna height influences the height loss correction factor (see section 3.4).

To take into account different receiving modes and circumstances into network planning correction factors have to be included to carry the minimum receiver input power level (as given in section 5.5) or the minimum field strength level over to the median minimum field strength level for predictions with [ITU-1546] (as given in section 6.1).

3.1 Reference Frequencies

The planning parameters and correction factors in this document are calculated for the reference frequencies given in Table 1.

TABLE 1

Reference frequencies for calculations

VHF band (frequency range)		I (47 – 68 MHz)	II (87.5 – 108 MHz)	III (174 – 230 MHz)
Reference frequency	[MHz]	65	100	200

3.2 Antenna Gain

The antenna gain G_D [dBd] references to a half-wave dipole.

3.2.1 Antenna Gain for Fixed Reception

In [ITU-599] and [ITU-GE06] the antenna pattern for fixed reception are given for both VHF band II (4 dB) and VHF band III (7 dB). In [ETSI-DVB] the antenna pattern for fixed reception is given for VHF band I (3 dB).

Taking into account the current use of roof-top antenna systems with omnidirectional dipole antennas or ground plane antennas for future planning it is recommended that an omnidirectional antenna pattern with a gain of 0 dBd is used (see Table 2).

TABLE 2

Antenna gain G_D for fixed reception

Frequency	[MHz]	65	100	200
Antenna gain G_D	[dBd]	0	0	0

3.2.2 Antenna Gain for Portable Reception

[ITU-GE06] assumes an omnidirectional VHF antenna pattern with an antenna gain of -2.2 dBd for standard portable receiver planning, e.g. for DAB reception. From this reference, the antenna gains G_D for portable reception are assumed to -2.2 dBd as given in Table 3.

TABLE 3
Antenna gain G_D for portable reception

Frequency	[MHz]	65	100	200
Antenna gain G_D	[dBd]	-2.2	-2.2	-2.2

3.2.3 Antenna Gain for Portable Handheld Reception

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

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

The antenna gain for portable handheld reception in VHF band I and VHF band II can be calculate by the computation given in Annex 2, section 2.1 [KRAUS]. From it the antenna gains G_D [dB] for portable handheld reception modes with an external antenna are given in Table 4.

TABLE 4
Antenna gains G_D for portable handheld reception

Frequency	[MHz]	65	100	200
Gain variation ΔG referenced to 200 MHz	[dB]	-9.76	-6.02	0.00
Antenna gain G_D for receiver integrated antenna	[dBd]	-26.76	-23.02	-17.00
Antenna gain G_D for portable handheld reception (external antenna, telescopic or wired headsets)	**[dBd]**	**-22.76**	**-19.02**	**-13.00**

3.2.4 Antenna Gain for Mobile Reception

For mobile reception an omnidirectional VHF antenna pattern with an antenna gain G_D of -2.2 dBd [ITU-GE06] is assumed, see Table 5.

TABLE 5
Antenna gains G_D for mobile reception

Frequency	[MHz]	65	100	200
Antenna gain G_D for adapted antenna (mobile reception)	[dBd]	-2.2	-2.2	-2.2

3.3 Feeder Loss

The feeder loss L_f expresses the signal attenuation from the receiving antenna to the receiver’s RF input. The feeder loss L_f for fixed reception at 200 MHz is given in [ITU-GE06] with 2 dB for 10 m cable length. The frequency dependent cable attenuation per unit length L'_f is assumed to be equal to:

$$L'_{\mathrm{f}}\,[\mathrm{dB/m}] = \frac{2}{10}\sqrt{\frac{f\,[\mathrm{MHz}]}{200}} \qquad (1)$$

with f the frequency in [MHz]. The feeder loss values per unit length L'_f are given in Table 6.

TABLE 6

Feeder loss L'_f per unit length

Frequency	[MHz]	65	100	200
Feeder loss L'_f	[dB/m]	0.11	0.14	0.2

The feeder loss L_f is given by

$$L_{\mathrm{f}}\,[\mathrm{dB}] = L'_{\mathrm{f}}\,l = \frac{2}{10}\sqrt{\frac{f\,[\mathrm{MHz}]}{200}}\;l\,[m] \qquad (2)$$

with l the length of the feeder cable in [m].

The cable length l for the different reception modes are given in Table 7, and the feeder losses L_f for different frequencies and reception modes are given in Table 8.

TABLE 7

Cable length l for reception modes

Reception mode		Fixed reception (FX)	Portable reception (PO, PI, PO-H, PI-H)	Mobile reception (MO)
Cable length l	[m]	10	0	2

TABLE 8

Feeder loss L_f for different reception modes

Frequency		[MHz]	65	100	200
Feeder loss L_f	for fixed reception (FX)	[dB]	1.1	1.4	2.0
	for portable reception (PO, PI, PO-H, PI-H)	[dB]	0.0	0.0	0.0
	for mobile reception(MO)	[dB]	0.22	0.28	0.4

3.4 Height Loss Correction Factor

For portable reception a receiving antenna height of 1.5 m above ground level (outdoor and mobile) or above floor level (indoor) is assumed. The propagation prediction method usually provides field strength values at 10 metres. To correct the predicted value from 10 metres to 1.5 m above ground level a height loss factor L_h [dB] has to be applied.

The height loss correction factor L_h for an antenna height of 1.5 m is given in [ITU-GE06] as follows:

L_h = 12 dB at 200 MHz
L_h = 16 dB at 500 MHz
L_h = 18 dB at 800 MHz

Therefore, the height loss correction factor L_h [dB] at 100 MHz is assumed to 10 dB, and at 65 MHz to 8 dB, for portable and mobile reception modes The high loss correction factor L_h for handheld reception with external antenna is given in [EBU-3317] for VHF band III as 19 dB in urban areas and is assumed to 17 dB at 100 MHz and to 15 dB at 65 MHz.

The height loss correction factor L_h for different reception modes is given in Table 9.

TABLE 9

Height loss correction factor L_h for different reception modes

Frequency		[MHz]	65	100	200
Height loss correction factor L_h	for fixed reception (FX)	[dB]	0	0	0
	for portable and mobile reception (PO, PI, MO)	[dB]	8	10	12
	for portable handheld reception (PO-H, PI-H)	[dB]	15	17	19

3.5 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 [dB] is the mean building penetration loss.

The mean building penetration loss L_b in VHF band III is given in [ITU-GE06] and [EBU-3317] as 9 dB which is proposed to be used for VHF band II, too. The mean building penetration loss for VHF band I is given in [ETSI-DVB] as 8 dB. The standard deviation of the building penetration loss σ_b is always given by 3 dB.

The mean building penetration losses L_b and standard deviations σ_b are given in Table 10.

TABLE 10

Building penetration loss L_b and standard deviation σ_b

Frequency	[MHz]	65	100	200
Mean building penetration loss L_b	[dB]	8	9	9
Standard deviation of the building penetration loss σ_b	[dB]	3	3	3

3.6 Allowance for Man-made Noise

The allowance for man-made noise, MMN [dB], takes into account the effect of the man-made noise received by the antenna on the system performance. The system equivalent noise figure F_s [dB] to be used for coverage calculations is calculated from the receiver noise figure F_r [dB] and MMN [dB] (for details see Annex 2, section 2.2):

$$\mathrm{F_s}\,[\mathrm{dB}] = \mathrm{F_r} + \mathrm{MMN}\,[\mathrm{dB}] \quad (3)$$

The allowance for man-made noise is calculated from an antenna noise factor f_a, which takes into account the man-made noise received by the antenna:

$$\mathrm{MMN}\,[\mathrm{dB}] = 10\log_{10}\left(1 + \frac{\mathrm{f_a}-1}{\mathrm{f_r}}\right)[\mathrm{dB}] \quad (4)$$

where f_r is the receiver noise factor: $\mathrm{f_r} = 10^{\frac{\mathrm{F_r}}{10}}$ (5)

and f_a is the antenna noise factor: $\mathrm{f_a} = 10^{\frac{\mathrm{F_a}}{10}}$ (6)

where F_a is the antenna noise figure.

3.6.1 Allowance for Man-made Noise for Fixed, Portable and Mobile Reception

[ITU-372] gives the legal values to calculate the allowance of man-man noise in different areas and frequencies with the definitions of the antenna noise figure, its mean values $F_{a,med}$ and the values of decile variations (10% and 90%) measured in different regions as a function of the frequency. The equation to calculate the antenna noise figure is given in [ITU-372] by:

$$F_{a,med}[dB] = c - d \cdot \log_{10}(f\,[MHz])[dB] \tag{7}$$

For all reception modes the residential area (Curve B in [ITU-372]) is assumed. In this case the values for the variables c and d are given by

c = 72.5 d = 27.7

Herewith the values of the medium antenna noise figure $F_{a,med}$ [dB] can be computed. The results are shown in Table 11.

TABLE 11
Medium antenna noise figure $F_{a,med}$

Frequency	[MHz]	65	100	200
Medium antenna noise figure $F_{a,med}$ for residential area (curve B)	[dB]	22.28	17.10	8.76

Herewith the MMN [dB], taking into account a receiver noise figure F_r of 7 dB (see section 0), can be computed. The results are shown in Table 12.

TABLE 12
Allowance for man-made noise MMN for fixed, portable and mobile reception

Frequency	[MHz]	65	100	200
Allowance for man-made noise for fixed, portable and mobile reception (F_r = 7 dB)	[dB]	15.38	10.43	3.62

[ITU-372] gives the value of decile location variations (10% and 90%) in residential area by 5.8 dB. For 90% location probability the distribution factor μ = 1.28. Therefore the standard deviation of MMN for fixed, portable and mobile reception σ_{MMN} = 4.53 dB, see Table 13.

TABLE 13
Standard deviation of MMN σ_{MMN} for fixed, portable and mobile reception

Frequency	[MHz]	65	100	200
Standard deviation of MMN σ_{MMN}	[dB]	4.53	4.53	4.53

The standard deviation of MMN has to be considered in the calculation of the combined standard deviation for the wanted field strength level (see section 3.8.2).

3.6.2 Allowance for Man-made Noise for Portable Handheld Reception

The antenna gain is the product of directivity and efficiency. The lowest realistic directivity is the one of a short dipole (length l << λ) and it has the value 1.5 (1.8 dBi). Any gain lower than 1.8 dBi (-0.4 dBd) is due to an antenna efficiency η lower than 1. The interference power at the receiver input is reduced accordingly and the MMN equation is (see Annex 2, section 2.2):

$$MMN\,[dB] = 10\log_{10}\left(1 + \eta\,\frac{f_a - 1}{f_r}\right)[dB] \tag{8}$$

The efficiency η can be calculated from the antenna gain G_D [dB] for gains lower than -0.4 dBd:

$$\eta = 10^{\frac{G_D+0.4}{10}} \tag{9}$$

The MMN for portable handheld reception, taking the receiver noise figure as 7 dB (see section 0), are given in Table 14.

TABLE 14
Allowance for man-made noise for portable handheld reception (external antenna)

Frequency	[MHz]	65	100	200
Handheld antenna gain G_D	[dBd]	-22.8	-19	-13
Efficiency η		0.0058	0.0138	0.055
Calculated MMN allowance	[dB]	0.42	0.30	0.14
Allowance for man-made noise for portable handheld reception	**[dB]**	**0.0**	**0.0**	**0.0**

In the further calculations the allowance for man-mad-noise is specified to 0 dB due to the very low calculated values.

3.7 Implementation Loss Factor

Implementation loss of the non ideal receiver is considered in the calculation of the minimum receiver input power level with an additional implementation loss factor L_i of 3 dB, see Table 15.

TABLE 15
Implementation loss factor L_i

Frequency	[MHz]	65	100	200
Implementation loss factor L_i	[dB]	3	3	3

3.8 Correction Factors for Location Variability

The random variation of the received signal field strength 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 macro-scale area (typically a square with edge lengths of 100 m to 500 m). Considering the received signal field strength level E [dBµV/m], the lognormal distribution is transformed in a Gaussian distribution with mean (and median) E_{med} in [dB] and standard deviation σ in [dB].

The field strength level $E(p)$ [dBµV/m], used for coverage and interference predictions in the different reception modes, which will be exceeded for p [%] of locations for a land receiving/mobile antenna location, is given by:

$$E(p)\ [\text{dBV/m}\ ] = E_{\text{med}}\ \ [\text{dBV/m}\ ] + C_{\text{l}}(p)[\text{dB}];\ \text{for } 50\ \%\ \le p \le 99\ \% \tag{10}$$

with $C_{\text{l}}(p)\ [dB]$: Location correction factor

E_{med} [dBµV/m]: Field strength value for 50% of locations and 50% of time

The location correction factor $C_l(p)$ [dB] depends on the so called combined standard deviation σ_c [dB] of the wanted field strength level that sums the single standard deviations of all relevant signal parts that have to be taken into account and the so-called distribution factor $\mu(p)$, namely

$$C_{\text{l}}(p)[\text{dB}] = \ \mu(p)\ \cdot \sigma_{\text{C}}\ [\text{dB}] \tag{11}$$

with $\mu(p) = \phi^{-1}\left(\frac{p}{100}\right)$ the distribution factor and

$\phi(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}} \mathrm{d}z$ (Standard Normal Gaussian CDF)

σ_C: the combined standard deviation of the wanted field strength level in [dB]

3.8.1 Distribution Factor

The distribution factors *μ(p)* of the different location probabilities taking into account the different receiving modes (see section 2) are given in Table 16.

TABLE 16

Distribution factor μ

Percentage of receiving locations *p*	70%	95%	99%
Reception mode	fixed	portable	mobile
Distribution factor μ	0.524	1.645	2.326

3.8.2 Combined Standard Deviation

The combined standard deviation σ_c [dB] takes into account the standard deviation of the wanted field strength level σ_m [dB], the standard deviation of the MMN σ_{MMN} [dB], and, in the case of indoor reception, the standard deviation of the building penetration loss, σ_b [dB], respectively.

Since the statistics of the received wanted field strength level for macro-scale, the statistics of the MMN σ_{MMN} [dB], and the statistics of the building attenuation can be assumed to be statistically uncorrelated, the combined standard deviation σ_c [dB] is calculated by:

$$\sigma_c\ [\mathrm{dB}] = \sqrt{\sigma_m^2 + \sigma_b^2 + \sigma_{MMN}^2} \qquad (12)$$

The values of the standard deviations of the building penetration loss σ_b [dB] and of the MMN σ_{MMN} [dB] are given in section 3.5 and 3.6, respectively.

The values of standard deviation σ_m [dB] of the wanted field strength level *E* are dependent on frequency and environment, and empirical studies have shown a considerable spread. Representative values for areas of 500 m × 500 m are given by [ITU-1546] as well as the expression to calculate the standard deviation σ_m [dB]:

$$\sigma_m\ [\mathrm{dB}] = K\ [\mathrm{dB}] + 1.3 \log_{10}(f\ [MHz]) \qquad (13)$$

where:

K = 1.2, for receivers with antennas below clutter height in urban or suburban environments for mobile systems with omnidirectional antennas at car-roof height

K = 1.0, for receivers with rooftop antennas near the clutter height

K = 0.5, for receivers in rural areas

f required frequency [MHz].

Furthermore, the following fixed values are given:

Broadcasting, analogue at 100 MHz (i.e. FM): σ_m = 8.3 dB

Broadcasting, digital (more than 1 MHz bandwidth, i.e. DAB): σ_m = 5.5 dB

The standard deviations σ_m [dB] for FM and DAB are given in Table 17 whereas those for DRM in urban and suburban areas as well as in rural areas are given in Table 18.

TABLE 17

Standard deviation for DAB $\sigma_{m,DAB}$ and FM $\sigma_{m,FM}$

Frequency		[MHz]	65	100	200
Standard deviation	for FM $\sigma_{m,FM}$	[dB]	---	8.3	---
	for DAB $\sigma_{m,DAB}$	[dB]	---	---	5.5

TABLE 18

Standard deviation for DRM $\sigma_{m,DRM}$

Frequency		[MHz]	65	100	200
Standard deviation for DRM $\sigma_{m,DRM}$	in urban and suburban areas	[dB]	3.56	3.80	4.19
	in rural areas	[dB]	2.86	3.10	3.49

These values of the standard deviation take into account only the effects of slow fading, but not the effects of fast fading. Therefore it must be ensured that the determination of the minimum C/N value (see section 5.4) consider the effects of the fast fading. Otherwise a margin depending to the bandwidth of the signal of 1.6 dB at 8 MHz, 2.3 dB at 1.5 MHz and 4.6 dB at 120 kHz has to be added.

For DRM the effects of fast fading are included into the measurement method and therefore they don't have to be added.

For the different reception modes more or less parts of the given particular standard deviations have to be taken into account, see Table 19.

Due to these differences the combined standard deviation σ_c [dB] for the respective reception modes are given in Table 20.

TABLE 19

Allowance for the particular standard deviations for the different reception modes

Particular standard deviations			σ_m	σ_m	σ_m	σ_{MMN}	σ_b
Frequency		[MHz]	65	100	200	all	all
Reception modes	fixed (FX) and portable outdoor (PO)	[dB]	3.56	3.80	4.19	4.53	0.00
	portable handheld outdoor (PO-H)	[dB]	3.56	3.80	4.19	0.00	0.00
	mobile (MO)	[dB]	2.86	3.10	3.49	4.53	0.00
	portable indoor (PI)	[dB]	3.56	3.80	4.19	4.53	3.00
	portable handheld indoor (PI-H)	[dB]	3.56	3.80	4.19	0.00	3.00

TABLE 20

Combined standard deviation σ_c for the different reception modes

Frequency		[MHz]	65	100	200
Combined standard deviation σ_c for reception mode	fixed (FX) and portable outdoor (PO)	[dB]	5.76	5.91	6.17
	portable handheld outdoor (PO-H)	[dB]	3.56	3.80	4.19
	mobile (MO)	[dB]	5.36	5.49	5.72
	portable indoor (PI)	[dB]	6.49	6.63	6.86
	portable handheld indoor (PI-H)	[dB]	4.65	4.84	5.15

3.8.3 Combined Location Correction Factor for Protection Ratios

The needed protection of a wanted signal against an interfering signal is given as the basic protection ratio PR_{basic} [dB] for 50% of location probability.

In the case of higher location probability as given for all reception modes a so called combined location correction factor CF in [dB] is used as a margin that has to be added to the basic protection ratio PR_{basic}, valid for the wanted field strength level and the nuisance field strength level, to the protection ratio $PR(p)$ corresponding to the needed percentage p [%] of locations for the wanted service [ITU-GE06].

$$PR(p)\ [\text{dB}] = PR_{\text{basic}}[\text{dB}] + CF(p)\ [\text{dB}];\ \text{for } 50\ \% \le p \le 99\ \% \tag{14}$$

$$\text{with} \qquad CF(p)\ [dB] = \mu(p)\ \sqrt{\sigma_{\text{w}}^2 + \sigma_{\text{n}}^2}\ [dB] \tag{15}$$

where σ_w and σ_n, both in [dB], denote the standard deviation of location variation for the wanted signal for the nuisance signal, respectively. The values for σ_w and σ_n are given in section 3.8.2 for the different broadcasting systems as σ_m.

3.9 Polarization Discrimination

In principal it is possible to take advantage of polarization discrimination for fixed reception. [ITU-GE84] does not take into account polarization discrimination in the planning procedure for VHF band II, except in specific cases with the agreement of administrations concerned. In such cases, a value of 10 dB was used for orthogonal polarization discrimination.

[ITU-GE06] gives that in VHF band III polarization discrimination shall not be taken into account in the DAB planning procedures.

For the planning procedures of digital sound broadcasting systems in the VHF bands no polarization discrimination will be taken into account for all reception modes.

3.10 Calculation of Minimum Median Field Strength Level

The calculation of the minimum median field strength level at 10 m above ground level for 50% of time and for 50% of locations is given in [ITU-GE06] by the following steps 1-5:

1. Determine the receiver noise input power level P_n

$$P_{\text{n}}\ [\text{dBW}] = F\ [\text{dB}] + 10\log_{10}(k \cdot T_0 \cdot B) \tag{16}$$

with:
- F: Receiver noise figure [dB]
- k: Boltzmann's constant, $k = 1.38\ 10^{-23}$ [J/K]
- T_0: Absolute temperature [K]
- B: Receiver noise bandwidth [Hz]

2. Determine the minimum receiver input power level $P_{s,min}$

$$P_{s,min}\ [\text{dBW}] = (C/N)_{\min}\ [\text{dB}] + P_{\text{n}}\ [\text{dBW}] \tag{17}$$

with: $(C/N)_{min}$: Minimum carrier-to-noise ratio at the DRM decoder input in [dB]

3. Determine the minimum power flux-density (i.e. the magnitude of the Poynting vector) at receiving place φ_{min}

$$\varphi_{\min}\ [\text{dBW/m}^2] = P_{\text{s,min}}\ [\text{dBW}] - A_{\text{a}}\ [\text{dBm}^2] + L_{\text{f}}\ [\text{dB}] \tag{18}$$

with:
- L_f: Feeder loss in [dB]
- A_a: Effective antenna aperture in [dBm^2]

$$A_{\text{a}}\ [\text{dBm}^2] = 10 \cdot \log\left(\frac{1.64}{4\pi}\left(\frac{300}{f\ [MHz]}\right)^2\right) + G_D[dB] \tag{19}$$

4. Determine the minimum RMS field strength level at the location of the receiving antenna E_{min}

$$E_{\mathrm{min}}[\mathrm{dB\mu V/m}] \;=\; \varphi_{\mathrm{min}}[\mathrm{dBW/m^2}] + 10\log_{10}(Z_{\mathrm{F0}})\ [\mathrm{dB\Omega}] + 20\log_{10}\left(\frac{1\ \mathrm{V}}{1\ \mu\mathrm{V}}\right) \tag{20}$$

with $Z_{\mathrm{F0}}=\sqrt{\frac{\mu_0}{\varepsilon_0}} \approx 120\pi\ [\Omega]$, the characteristic impedance in free space, (21)

resulting in

$$E_{\mathrm{min}}[\mathrm{dB\mu V/m}] \;=\; \varphi_{\mathrm{min}}[\mathrm{dBW/m^2}] + 145.8\ [\mathrm{dB\Omega}] \tag{22}$$

5. Determine the minimum median RMS field strength level E_{med}
   For the different receiving scenarios the minimum median RMS field strength is calculated as follows:

for fixed reception: $\mathrm{Emed} = \mathrm{Emin} + \mathrm{Pmmn} + \mathrm{Cl}$ (23)

for portable outdoor and mobile reception: $E_{\mathrm{med}} = E_{\mathrm{min}} + P_{\mathrm{mmn}} + C_{\mathrm{l}} + L_{\mathrm{h}}$ (24)

for portable indoor reception: $E_{\mathrm{med}} = E_{\mathrm{min}} + P_{\mathrm{mmn}} + C_{\mathrm{l}} + L_{\mathrm{h}} + L_{\mathrm{b}}$ (25)

4 DRM System Parameters

The description of the DRM system parameters refers to Mode E of the DRM system [ETSI-DRM].

4.1 Modes and Code Rates

4.1.1 Overview of SDC and MSC Code Rates

[ETSI-DRM] defines the SDC code rates summarized in Table 21 and the MSC modes with code rates R given in Table 22.

TABLE 21

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

TABLE 22

MSC code rates

Protection level	**Code rate *R* for MSC mode 11: 4-QAM**		**Code rate *R* combinations for MSC mode 00: 16-QAM**			
	$\mathbf{R_{all}}$	R_0	$\mathbf{R_{all}}$	R_0	R_1	RY_{lcm}
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

The net bit rate of the MSC varies from 37 kbit/s to 186 kbit/s depending of the used parameter set.

4.1.2 SDC and MSC Code Rates for Calculations

Several of the derived parameters depend on the characteristic of the transmitted DRM signal. To limit the amount of tests two typical parameters sets were chosen as basic sets, see Table 23:

- **DRM with 4-QAM** as a high protected signal with a lower data rate which is suited for a robust audio signal with a low data rate data service.
- **DRM with 16-QAM** as a low protected signal with a high data rate which is suited for several audio signals or for an audio signal with a high data rate data service.

TABLE 23

MSC code rates for calculations

MSC mode	11 - 4-QAM	00 - 16-QAM
MSC protection level	1	2
MSC code rate *R*	1/3	1/2
SDC mode	1	1
SDC code rate *R*	0.25	0.25
Bit rate approx.	49.7 kbit/s	149.1 kbit/s

4.2 Propagation-Related OFDM Parameters

The propagation-related OFDM parameters of DRM are given in Table 24.

TABLE 24
OFDM parameters

Elementary time period T	83 1/3 µs
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 B	96 kHz
Carrier spacing $1/T_u$	444 4/9 Hz
Carrier number space	K_{min}= -106; K_{max}= 106
Unused carriers	none

4.3 Single Frequency Operation Capability

DRM transmitter can be operating in single frequency networks (SFN). The maximum transmitter distance that has to go below to prevent self interferences depends on the length of the OFDM guard interval.

The maximum transmitter distance is calculated with the maximum echo delay which is given by

$$D_{\text{echo(max)}}\ [\text{km}] = T_g \cdot c_0 \tag{26}$$

with $c_0 = 300 \cdot 10^3$ [km/s];

$T_g = 0.25$ [s]

Since the length T_g of the DRM guard interval is 0.25 ms, see Table 24, the maximum echo delay, and, therefore, the maximum transmitter distance, yields 75 km.

4.4 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 and can result in Doppler shift.

For calculation of the different reception modes the channel models are given in Table 25 [ETSI-DRM] have been assumed and investigated. These channel models are considering the fading characteristics for different reception environments. For receivers with higher frequencies the fading in time direction is normally short, so the interleaving and error correction algorithms can work. With slow receiver velocities flat fading over a time, longer than the interleaver (600 ms) can result in signal drop outs.

TABLE 25
Channel models in the ETSI Standard for DRM

Channel model (Name)	Velocity	Remark
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

5 DRM Receiver Parameters

5.1 General Characteristics

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

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

- Noise figure F_r [dB], measured from the antenna input to the *I/Q* base band DRM decoder input (including down conversion and A/D conversion).
- Receiver noise input power P_n [dBW]
- Minimum carrier-to-noise ratio $(C/N)_{min}$ [dB] at the DRM decoder input.
- Minimum receiver input power level $P_{s,min}$ [dBW]

5.2 Receiver Noise Figure

In [ITU-GE06] a receiver noise figure of 7 dB is been used for both DVB-T and T-DAB. For having cost effective DRM receiver solutions the receiver noise figure F is assumed to be F_r = 7 dB too for all VHF bands, see Table 26.

TABLE 26
Receiver noise figure F_r

Frequency	[MHz]	65	100	200
Receiver noise figure F_r	[dB]	7	7	7

5.3 Receiver Noise Input Power

With B = 100 kHz and T = 290 K, the thermal receiver noise input power level P_n for DRM Mode E yields

$$P_n[\mathrm{dBW}] = F_r\,[\mathrm{dB}] + 10\log_{10}(k \cdot T_0 \cdot B) = -146.98\,[\mathrm{dBW}] \quad (27)$$

5.4 Minimum Carrier to Noise Ratio

On basis on the channel models in the respective reception mode (see section 4.4) the required minimum values of the $(C/N)_{min}$ had been calculated. Therefore effects of the narrowband system like fast fading are included in the calculated values of the $(C/N)_{min.}$

[ETSI-DRM] gives a required $(C/N)_{min}$ for a transmission in VHF band II to achieve an average coded bit error ratio BER = $1{\cdot}10^{-4}$ [bit] after the channel decoder for different channel models, see Table 27.

TABLE 27
$(C/N)_{min}$ with different channel models

		$(C/N)_{min}$ [dB] for	
Reception mode	**Channel model**	**4-QAM, R= 1/3**	**16-QAM, R= 1/2**
Fixed reception	Channel 7 (AWGN)	1.3	7.9
Portable reception	Channel 8 (Urban@60km/h)	7.3	15.4
	Channel 9 (Rural)	5.6	13.1
	Channel 10 (Terrain obstructed)	5.4	12.6
Mobile reception	Channel 11 (Hilly terrain)	5.5	12.8
	Channel 12 (SFN)	5.4	12.3

5.5 Minimum Receiver Input Power Level

Based on the above equations and including the implementation loss factor (see 3.7), the minimum receiver input power level at the receiving location can be calculated for both 16-QAM and 4-QAM, see Table 28 and Table 29.

TABLE 28

Minimum receiver input power level $P_{s,min}$ for 4-QAM, R=1/3

Reception mode		**fixed**	**portable**	**mobile**
Receiver noise figure	F_r [dB]	7	7	7
Receiver noise input power level	P_n [dBW]	-146.98	-146.98	-146.98
Representative minimum C/N ratio	$(C/N)_{min}$ [dB]	1.3	7.3	5.5
Implementation loss factor	L_i [dB]	3	3	3
Minimum receiver input power level	$P_{s,min}$ **[dBW]**	**-142.68**	**-136.68**	**-138.48**

TABLE 29

Minimum receiver input power level $P_{s,min}$ for 16-QAM, R=1/2

Reception mode		**fixed**	**portable**	**mobile**
Receiver noise figure	F_r [dB]	7	7	7
Receiver noise input power level	P_n [dBW]	-146.98	-146.98	-146.98
Representative minimum C/N ratio	$(C/N)_{min}$ [dB]	7.9	15.4	12.8
Implementation loss factor	L_i [dB]	3	3	3
Minimum receiver input power level	$P_{s,min}$ **[dBW]**	**-136.08**	**-128.58**	**-131.18**

6 DRM Planning Parameters

6.1 Minimum Median Field Strength Level

Based on the equations in section 3, the minimum median field strength level for the respective reception modes had been calculated for both 16-QAM and 4-QAM, for VHF band I, II and III, see Table 30 to Table 35.

6.1.1 VHF Band I

TABLE 30
Minimum median field strength level E_{med} for 4-QAM, R = 1/3 in VHF band I

DRM modulation		4-QAM. R=1/3					
Receiving situation		FX	PI	PI-H	PO	PO-H	MO
Minimum receiver input power level	$P_{s.min}$ [dBW]	-142.68	-136.68	-136.68	-136.68	-136.68	-138.48
Antenna gain	G_D [dBd]	0.00	-2.20	-22.76	-2.20	-22.76	-2.20
Effective antenna aperture	A_a [dBm^2]	4.44	2.24	-18.32	2.24	-18.32	2.24
Feeder-loss	L_c [dB]	1.10	0.00	0.00	0.00	0.00	0.22
Minimum power flux-density at receiving place	φ_{min} [dBW/m^2]	-146.02	-138.92	-118.36	-138.92	-118.36	-140.50
Minimum field strength level at receiving antenna	E_{min} [dBµV/m]	-0.25	6.85	27.41	6.85	27.41	5.27
Allowance for man-made noise	P_{mmn} [dB]	15.38	15.38	0.00	15.38	0.00	15.38
Antenna height loss	L_h [dB]	0.00	8.00	15.00	8.00	15.00	8.00
Building penetration loss	L_b [dB]	0.00	8.00	8.00	0.00	0.00	0.00
Location probability		*70%*	*95%*	*95%*	*95%*	*95%*	*99%*
Distribution factor	μ	*0.52*	*1.64*	*1.64*	*1.64*	*1.64*	*2.33*
Standard deviation of DRM field strength	σ_m [dB]	*3.56*	*3.56*	*3.56*	*3.56*	*3.56*	*2.86*
Standard deviation of MMN	σ_{MMN} [dB]	*4.53*	*4.53*	*0.00*	*4.53*	*0.00*	*4.53*
Standard deviation of building penetration loss	σ_b [dB]	*0.00*	*3.00*	*3.00*	*0.00*	*0.00*	*0.00*
Location correction factor	C_l [dB]	3.02	10.68	7.65	9.47	5.85	12.46
Minimum median field strength level	E_{med} **[dBµV/m]**	**18.15**	**48.91**	**58.06**	**39.71**	**48.26**	**41.11**

TABLE 31
Minimum median field strength level E_{med} for 16 QAM, R = 1/2 in VHF band I

DRM modulation		16-QAM. R = ½					
Receiving situation		FX	PI	PI-H	PO	PO-H	MO
Minimum receiver input power level	$P_{s.min}$ [dBW]	-136.08	-128.58	-128.58	-128.58	-128.58	-131.18
Antenna gain	G_D [dBd]	0.00	-2.20	-22.76	-2.20	-22.76	-2.20
Effective antenna aperture	A_a [dBm^2]	4.44	2.24	-18.32	2.24	-18.32	2.24
Feeder-loss	L_c [dB]	1.10	0.00	0.00	0.00	0.00	0.22
Minimum power flux-density at receiving place	φ_{min} [dBW/m^2]	-139.42	-130.82	-110.26	-130.82	-110.26	-133.20
Minimum field strength level at receiving antenna	E_{min} [dBµV/m]	6.35	14.95	35.51	14.95	35.51	12.57
Allowance for man-made noise	P_{mmn} [dB]	15.38	15.38	0.00	15.38	0.00	15.38

Antenna height loss	L_h [dB]	0.00	8.00	15.00	8.00	15.00	8.00
Building penetration loss	L_b [dB]	0.00	8.00	8.00	0.00	0.00	0.00
Location probability		*70%*	*95%*	*95%*	*95%*	*95%*	*99%*
Distribution factor	μ	*0.52*	*1.64*	*1.64*	*1.64*	*1.64*	*2.33*
Standard deviation of DRM field strength	σ_m [dB]	*3.56*	*3.56*	*3.56*	*3.56*	*3.56*	*2.86*
Standard deviation of MMN	σ_{MMN} [dB]	*4.53*	*4.53*	*0.00*	*4.53*	*0.00*	*4.53*
Standard deviation of building penetration loss	σ_b [dB]	*0.00*	*3.00*	*3.00*	*0.00*	*0.00*	*0.00*
Location correction factor	C_l [dB]	3.02	10.68	7.65	9.47	5.85	12.46
Minimum median field strength level	$\mathbf{E_{med}}$ **[dBμV/m]**	**24.75**	**57.01**	**66.16**	**47.81**	**56.36**	**48.41**

6.1.2 VHF Band II

TABLE 32

Minimum median field strength level E_{med} for 4-QAM, R = 1/3 in VHF band II

DRM modulation		4-QAM. R = 1/3					
Receiving situation		FX	PI	PI-H	PO	PO-H	MO
Minimum receiver input power level	$P_{s.min}$ [dBW]	-142.68	-136.68	-136.68	-136.68	-136.68	-138.48
Antenna gain	G_D [dBd]	0.00	-2.20	-19.02	-2.20	-19.02	-2.20
Effective antenna aperture	A_a [dBm^2]	0.70	-1.50	-18.32	-1.50	-18.32	-1.50
Feeder-loss	L_c [dB]	1.40	0.00	0.00	0.00	0.00	0.28
Minimum power flux-density at receiving place	φ_{min} [dBW/m^2]	-141.97	-135.17	-118.35	-135.17	-118.35	-136.69
Minimum field strength level at receiving antenna	E_{min} [dBμV/m]	3.79	10.59	27.41	10.59	27.41	9.07
Allowance for man-made noise	P_{mmn} [dB]	10.43	10.43	0.00	10.43	0.00	10.43
Antenna height loss	L_h [dB]	0.00	10.00	17.00	10.00	17.00	10.00
Building penetration loss	L_b [dB]	0.00	9.00	9.00	0.00	0.00	0.00
Location probability		*70%*	*95%*	*95%*	*95%*	*95%*	*99%*
Distribution factor	μ	*0.52*	*1.64*	*1.64*	*1.64*	*1.64*	*2.33*
Standard deviation of DRM field strength	σ_m [dB]	*3.80*	*3.80*	*3.80*	*3.80*	*3.80*	*3.10*
Standard deviation of MMN	σ_{MMN} [dB]	*4.53*	*4.53*	*0.00*	*4.53*	*0.00*	*4.53*
Standard deviation of building penetration loss	σ_b [dB]	*0.00*	*3.00*	*3.00*	*0.00*	*0.00*	*0.00*
Location correction factor	C_l [dB]	3.10	10.91	7.96	9.73	6.25	12.77
Minimum median field strength level	$\mathbf{E_{med}}$ **[dBμV/m]**	**17.32**	**50.92**	**61.37**	**40.74**	**50.66**	**42.27**

TABLE 33

Minimum median field strength level E_{med} for 16-QAM, R = 1/2 in VHF band II

DRM modulation		16-QAM R = ½					
Receiving situation		FX	PI	PI-H	PO	PO-H	MO
Minimum receiver input power	$P_{s.min}$ [dBW]	-136.08	-128.58	-128.58	-128.58	-128.58	-131.18

level							
Antenna gain	G_D [dBd]	0.00	-2.20	-19.02	-2.20	-19.02	-2.20
Effective antenna aperture	A_a [dBm^2]	0.70	-1.50	-18.32	-1.50	-18.32	-1.50
Feeder-loss	L_c [dB]	1.40	0.00	0.00	0.00	0.00	0.28
Minimum power flux-density at receiving place	φ_{min} [dBW/m^2]	-135.37	-127.07	-110.25	-127.07	-110.25	-129.39
Minimum field strength level at receiving antenna	E_{min} [dBμV/m]	10.39	18.69	35.51	18.69	35.51	16.37
Allowance for man-made noise	P_{mmn} [dB]	10.43	10.43	0.00	10.43	0.00	10.43
Antenna height loss	L_h [dB]	0.00	10.00	17.00	10.00	17.00	10.00
Building penetration loss	L_b [dB]	0.00	9.00	9.00	0.00	0.00	0.00
Location probability		*70%*	*95%*	*95%*	*95%*	*95%*	*99%*
Distribution factor	μ	*0.52*	*1.64*	*1.64*	*1.64*	*1.64*	*2.33*
Standard deviation of DRM field strength	σ_m [dB]	*3.80*	*3.80*	*3.80*	*3.80*	*3.80*	*3.10*
Standard deviation of MMN	σ_{MMN} [dB]	*4.53*	*4.53*	*0.00*	*4.53*	*0.00*	*4.53*
Standard deviation of building penetration loss	σ_b [dB]	*0.00*	*3.00*	*3.00*	*0.00*	*0.00*	*0.00*
Location correction factor	C_l [dB]	3.10	10.91	7.96	9.73	6.25	12.77
Minimum median field strength level	**E_{med} [dBμV/m]**	**23.92**	**59.02**	**69.47**	**48.84**	**58.76**	**49.57**

6.1.3 VHF Band III

TABLE 34

Minimum median field strength level E_{med} for 4-QAM, R = 1/3 in VHF band III

DRM modulation		4-QAM. R = 1/3					
Receiving situation		FX	PI	PI-H	PO	PO-H	MO
Minimum receiver input power level	$P_{s.min}$ [dBW]	-142.68	-136.68	-136.68	-136.68	-136.68	-138.48
Antenna gain	G_D [dBd]	0.00	-2.20	-13.00	-2.20	-13.00	-2.20
Effective antenna aperture	A_a [dBm^2]	-5.32	-7.52	-18.32	-7.52	-18.32	-7.52
Feeder-loss	L_c [dB]	2.00	0.00	0.00	0.00	0.00	0.40
Minimum power flux-density at receiving place	φ_{min} [dBW/m^2]	-135.35	-129.15	-118.35	-129.15	-118.35	-130.55
Minimum field strength level at receiving antenna	E_{min} [dBμV/m]	10.41	16.61	27.41	16.61	27.41	15.21
Allowance for man-made noise	P_{mmn} [dB]	3.62	3.62	0.00	3.62	0.00	3.62
Antenna height loss	L_h [dB]	0.00	12.00	19.00	12.00	19.00	12.00
Building penetration loss	L_b [dB]	0.00	9.00	9.00	0.00	0.00	0.00
Location probability		*70%*	*95%*	*95%*	*95%*	*95%*	*99%*
Distribution factor	μ	*0.52*	*1.64*	*1.64*	*1.64*	*1.64*	*2.33*
Standard deviation of DRM field strength	σ_m [dB]	*4.19*	*4.19*	*4.19*	*4.19*	*4.19*	*3.49*
Standard deviation of MMN	σ_{MMN} [dB]	*4.53*	*4.53*	*0.00*	*4.53*	*0.00*	*4.53*
Standard deviation of building penetration loss	σ_b [dB]	*0.00*	*3.00*	*3.00*	*0.00*	*0.00*	*0.00*
Location correction factor	C_l [dB]	3.24	11.29	8.48	10.15	6.89	13.31

Minimum median field strength level	E_{med} **[dBμV/m]**	**17.26**	**52.52**	**63.89**	**42.38**	**53.30**	**44.13**

TABLE 35

Minimum median field strength level E_{med} for 16-QAM, R = 1/2 in VHF band III

DRM modulation		16-QAM. R = ½					
Receiving situation		FX	PI	PI-H	PO	PO-H	MO
Minimum receiver input power level	$P_{s.min}$ [dBW]	-136.08	-128.58	-128.58	-128.58	-128.58	-131.18
Antenna gain	G_D [dBd]	0.00	-2.20	-13.00	-2.20	-13.00	-2.20
Effective antenna aperture	A_a [dBm^2]	-5.32	-7.52	-18.32	-7.52	-18.32	-7.52
Feeder-loss	L_c [dB]	2.00	0.00	0.00	0.00	0.00	0.40
Minimum power flux-density at receiving place	φ_{min} [dBW/m^2]	-128.75	-121.05	-110.25	-121.05	-110.25	-123.25
Minimum field strength level at receiving antenna	E_{min} [dBμV/m]	17.01	24.71	35.51	24.71	35.51	22.51
Allowance for man-made noise	P_{mmn} [dB]	3.62	3.62	0.00	3.62	0.00	3.62
Antenna height loss	L_h [dB]	0.00	12.00	19.00	12.00	19.00	12.00
Building penetration loss	L_b [dB]	0.00	9.00	9.00	0.00	0.00	0.00
Location probability		*70%*	*95%*	*95%*	*95%*	*95%*	*99%*
Distribution factor	μ	*0.52*	*1.64*	*1.64*	*1.64*	*1.64*	*2.33*
Standard deviation of DRM field strength	σ_m [dB]	*4.19*	*4.19*	*4.19*	*4.19*	*4.19*	*3.49*
Standard deviation of MMN	σ_{MMN}[dB]	*4.53*	*4.53*	*0.00*	*4.53*	*0.00*	*4.53*
Standard deviation of building penetration loss	σ_b [dB]	*0.00*	*3.00*	*3.00*	*0.00*	*0.00*	*0.00*
Location correction factor	C_l [dB]	3.24	11.29	8.48	10.15	6.89	13.31
Minimum median field strength level	E_{med} **[dBμV/m]**	**23.86**	**60.62**	**71.99**	**50.48**	**61.40**	**51.43**

6.2 Position of DRM Frequencies

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

Referring to the legal frequency plans in ITU Region 1 this document covers DRM

- in VHF band I as well as in VHF band II regarding to [ITU-GE84],
- in VHF band III regarding to [ITU-GE06].

Other areas in the VHF bands assigned for sound broadcasting services, e.g. areas in ITU Region 1 where allocations of the Wiesbaden T-DAB Agreement 1995 are still used (230 – 240 MHz) or in southern Africa, where the VHF band III is allocated to the broadcasting services up to 254 MHz, or the broadcasting bands in ITU Region 2 and 3, perhaps the OIRT FM band (65.8 - 74 MHz) or the Japanese FM band (76 - 90 MHz), respectively, are not yet covered in this section and can be adapted later.

6.2.1 VHF Band I and VHF Band II

The DRM centre frequencies are positioned in 100 kHz distance according to the FM frequency grid in VHF band II. The nominal carrier frequencies are, in principle, integral multiples of 100 kHz [ITU-GE84]. The DRM system is designed to be used with this raster [ETSI-DRM].

The table of centre frequencies of DRM in VHF band II is given in Annex 2.

On the other hand it has to be considered to allow a spacing of 50 kHz in VHF band II to achieve the full potential of the DRM hybrid mode and to alleviate the deployment of new DRM transmitters in the overcrowded FM band.

6.2.2 VHF Band III

The frequency band of a DAB block has a bandwidth of 1.536 MHz [ITU-GE06] with lower and upper guard channels to fit into the 7 MHz channels of VHF band III.

The DRM centre frequencies are positioned in 100 kHz distance beginning by 174.05 MHz and integral multiples of 100 kHz up to the end of VHF band III.

The table of the centre frequencies of DRM in VHF band III in the range from 174 to 230 MHz is given in Annex 2.

6.3 Out-of-band Spectrum Mask

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

The spectrum characteristics of an OFDM system are given in [ITU-328, Annex 6, Chapter 5].

6.3.1 VHF Band I and VHF Band II

An out-of-band spectrum mask for DRM in VHF band I and VHF band II, resp., as minimum transmitter requirement is proposed in Figure 1 and Table 36. The vertices of the symmetric out-of-band spectrum mask for FM transmitters are given in [ETSI-FM].

Note that the out-of-band spectrum masks are defined for a resolution bandwidth [RBW] of 1 kHz.

FIGURE 1

Out-of-band spectrum masks for FM in VHF band II and DRM in VHF band I and II

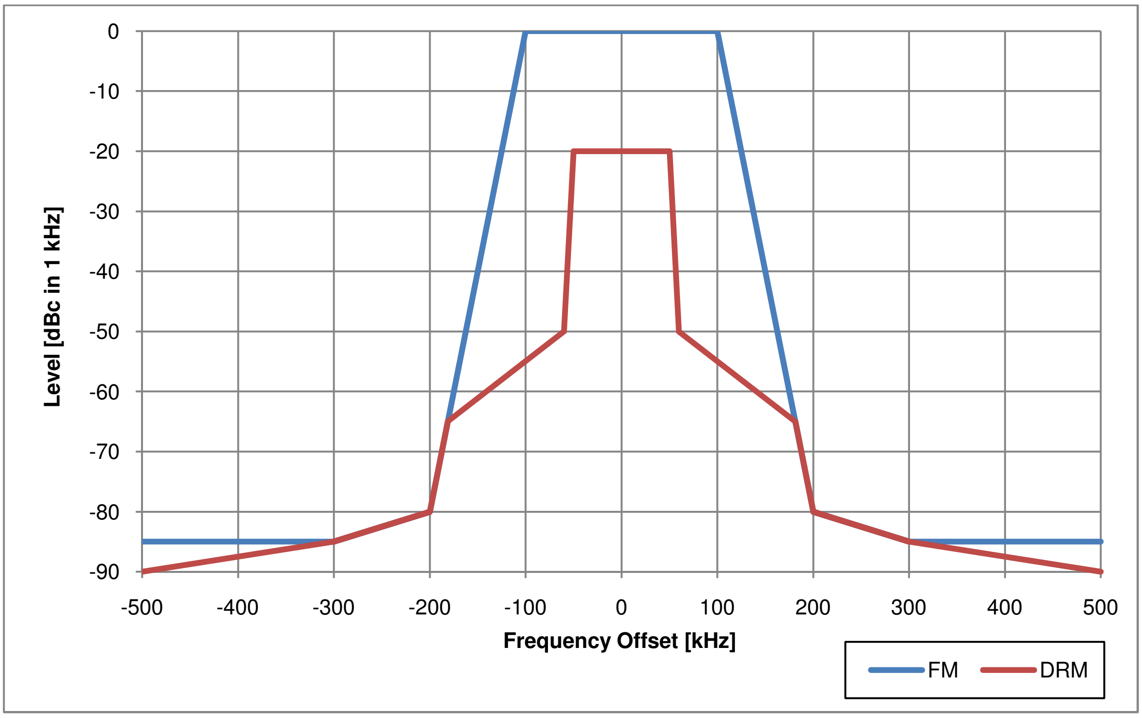

TABLE 36
Out-of-band spectrum masks for FM in VHF band II and DRM in VHF band I and II

Spectrum mask (100 kHz channel) / relative level for FM	
Frequency offset [kHz]	Level [dBrc]/[1 kHz]
0	0
± 50	0
± 100	0
± 181.25	-65
± 200	-80
± 300	-85
± 500	-85

Spectrum mask (100 kHz channel) / relative level for DRM	
Frequency offset [kHz]	Level [dBc]/[1 kHz]
0	-20
± 50	-20
± 60	-50
± 181.25	-65
± 200	-80
± 300	-85
± 500	-90

6.3.2 VHF Band III

The vertices of the symmetric out-of-band spectrum masks for DAB transmitters are given in [ITU-1660]. An out-of-band spectrum mask for DRM is proposed that fits into the DAB masks, see Figure 2 and Table 37.

Note that the out-of-band spectrum masks are defined for a resolution bandwidth [RBW] of 4 kHz. Thus the value of -14 dBr results for DRM.

FIGURE 2
Out-of-band spectrum masks for DAB and DRM in VHF band III

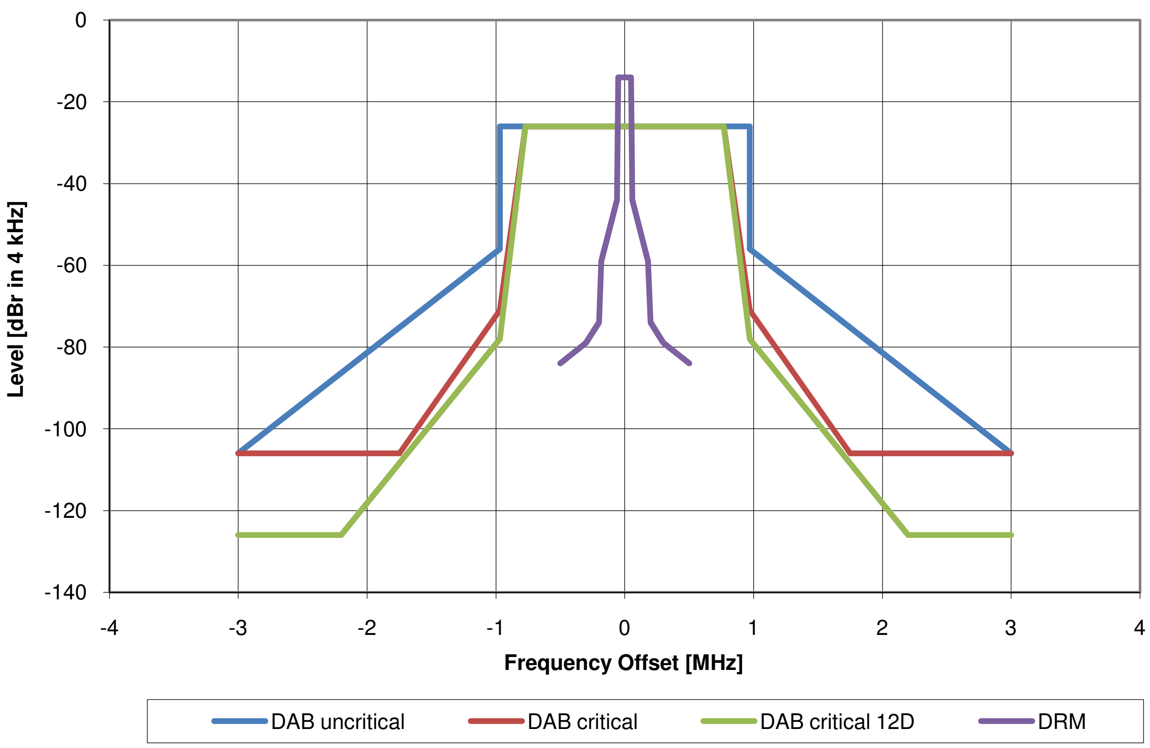

TABLE 37
Out-of-band spectrum masks for DAB and DRM in VHF band III

Spectrum mask (1.54 MHz channel) / relative level for DAB			
Frequency offset [MHz]	Level [dBc] (non-critical cases)	Level [dBc] (critical cases)	Level [dBc] (critical cases / 12D)
± 0.77	---	-26	-26
< ± 0.97	-26	---	---
± 0.97	-56	-71	-78
± 1.75	---	-106	---
± 2.2	---	---	-126
± 3.0	-106	-106	-126

Spectrum mask (100 kHz channel) relative level for DRM	
Frequency offset [kHz]	Level [dBc]
0	-14
± 50	-14
± 60	-44
± 181.25	-59
± 200	-74
± 300	-79
± 500	-84

6.4 Protection Ratios

The minimum acceptable ratio between a wanted signal and interfering signals to protect the reception of the wanted signal is defined as the protection ratio *PR* [dB]. The values of protection ratios are given as

- **Basic protection ratio** PR_{basic} for a wanted signal interfered with by an unwanted signal at 50% location probability. These values have to be determined on the legal base of ITU-R. BS.641.
- **Combined location correction factor** *CF* [dB] as a margin that has to be added to the basic protection ratio for a wanted signal interfered with by an unwanted signal for the calculation of protection ratios at location probability greater as 50%. The equation for the calculation is given in section 3.8.3.
- **Corresponding protection ratio** *PR(p)* for a wanted digital signal interfered with by an unwanted signal at location probability greater than 50% taking into account the respective location probability of the corresponding reception modes that have higher protection requirements due to the higher location probability to be protected.

6.4.1 Protection Ratios for DRM

The DRM signal parameters are given in section 4.1.

6.4.1.1 DRM interfered with by DRM

The basic protection ratio PR_{basic} for DRM is valid for all VHF bands, see Table 38. For the standard deviation of DRM differs in the respective VHF bands the combined location correction factors CF, see Table 39, are different in the respective VHF bands as well as the corresponding protection ratios *PR(p),* see Table 40 for 4-QAM and Table 41 for 16-QAM.

TABLE 38
Basic protection ratios PR_{basic} for DRM interfered with by DRM

Frequency offset	[kHz]	0	± 100	± 200
DRM (4-QAM, *R* = 1/3)	PR_{basic} [dB]	4	-16	-40
DRM (16-QAM, *R* = 1/2)	PR_{basic} [dB]	10	-10	-34

TABLE 39

Combined location correction factor *CF* for DRM interfered with by DRM

Reference frequency Band		65 MHz VHF band I			100 MHz VHF band II			200 MHz VHF Band III		
Location probability *p*		70%	95%	99%	70%	95%	99%	70%	95%	99%
Combined location correction factor **in urban and suburban area for fixed and portable reception**	*CF* [dB]	2.64	8.27	11.70	2.82	8.84	12.50	3.11	9.75	13.79
Combined location correction factor **in rural area for mobile reception**	*CF* [dB]	2.12	6.65	9.40	2.30	7.21	10.20	2.59	8.12	11.49

TABLE 40

Corresponding protection ratios *PR*(p) to reception modes for DRM (4-QAM. *R* = 1/3) interfered with by DRM

Reference frequency Band		65 MHz VHF band I		
Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	6.64	-13.36	-37.36
Portable reception (PO, PI, PO-H, PI-H)	PR(p) [dB]	12.27	-7.73	-31.73
Mobile reception (MO)	PR(p) [dB]	13.40	-6.60	-30.60

Reference frequency Band		100 MHz VHF band II		
Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	6.82	-13.18	-37.18
Portable reception (PO, PI, PO-H, PI-H)	PR(p) [dB]	12.84	-7.16	-31.16
Mobile reception (MO)	PR(p) [dB]	14.20	-5.80	-29.80

Reference frequency Band		200 MHz VHF band III		
Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	7.11	-12.89	-36.89
Portable reception (PO. PI. PO-H. PI-H)	PR(p) [dB]	13.75	-6.25	-30.25
Mobile reception (MO)	PR(p) [dB]	15.49	-4.51	-28.51

TABLE 41

Corresponding protection ratios *PR*(p) to reception modes for DRM (16-QAM. *R* = 1/2) interfered with by DRM

Reference frequency Band		65 MHz VHF band I		
Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	12.64	-7.36	-31.36
Portable reception (PO. PI. PO-H. PI-H)	PR(p) [dB]	18.27	-1.73	-25.73
Mobile reception (MO)	PR(p) [dB]	19.40	-0.60	-24.60

Reference frequency Band		100 MHz VHF band II		
Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	12.82	-7.18	-31.18
Portable reception (PO, PI, PO-H, PI-H)	PR(p) [dB]	18.84	-1.16	-25.16
Mobile reception (MO)	PR(p) [dB]	20.20	0.20	-23.80

Reference frequency Band		200 MHz VHF band III		
Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	13.11	-6.89	-30.89
Portable reception (PO, PI, PO-H, PI-H)	PR(p) [dB]	19.75	-0.25	-24.25
Mobile reception (MO)	PR(p) [dB]	21.49	1.49	-22.51

6.4.1.2 DRM interfered with by FM in VHF band II

The basic protection ratio PR_{basic} for DRM interfered with by FM in VHF band II is given in Table 42. The values for the combined location correction factors *CF* are given in Table 43, and for the corresponding protection ratios *PR(p),* are given in Table 44 for 4-QAM and in Table 45 for 16-QAM, respectively.

TABLE 42

Basic protection ratios PR_{basic} for DRM interfered with by FM

Frequency offset	[kHz]	0	± 100	± 200
DRM (4-QAM. *R* = 1/3) interfered with by FM (stereo)	PR_{basic} [dB]	11	-13	-54
DRM (16-QAM. *R* = 1/2) interfered with by FM (stereo)	PR_{basic} [dB]	18	-9	-49

TABLE 43

Combined location correction *CF* factor for DRM interfered with by FM

Location probability *p*		70%	95%	99%
Combined location correction factor **in urban and suburban area for fixed and portable reception**	*CF* [dB]	4.79	15.02	21.24
Combined location correction factor **in rural area for mobile reception**	*CF* [dB]	4.65	14.57	20.61

TABLE 44

Corresponding protection ratios *PR*(p) to reception modes for DRM (4-QAM. *R* = 1/3) interfered with by FM stereo

Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	15.79	-8.21	-49.21
Portable reception (PO, PI, PO-H, PI-H)	PR(p) [dB]	26.02	2.02	-38.98
Mobile reception (MO)	PR(p) [dB]	31.61	7.61	-33.39

TABLE 45
Corresponding protection ratios *PR*(p) to reception modes for DRM (16-QAM. *R* = 1/2) interfered with by FM stereo

Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	22.79	-4.21	-44.21
Portable reception (PO, PI, PO-H, PI-H)	PR(p) [dB]	33.02	6.02	-33.98
Mobile reception (MO)	PR(p) [dB]	38.61	11.61	-28.39

6.4.1.3 DRM interfered with by DAB in VHF band III

The basic protection ratio PR_{basic} for DRM interfered with by DAB in VHF band III is given in Table 46. The values for the combined location correction factors CF are given in Table 47, and for the corresponding protection ratios *PR(p),* are given in Table 48 for 4-QAM and in Table 49 for 16-QAM, respectively.

TABLE 46
Basic protection ratios PR_{basic} of DRM interfered with by DAB

Frequency offset	[kHz]	0	± 100	± 200
Basic protection ratio for DRM (4-QAM. *R* = 1/3)	PR_{basic} [dB]	-7	-36	-40
Basic protection ratio for DRM (16-QAM. *R* = 1/2)	PR_{basic} [dB]	-2	-18	-40

TABLE 47
Combined location correction factor *CF* of DRM interfered with by DAB

Location probability *p*		70%	95%	99%
Combined location correction factor **in urban and suburban area for fixed and portable reception**	*CF* [dB]	3.63	11.37	16.09
Combined location correction factor **in rural area for mobile reception**	*CF* [dB]	3.42	10.72	15.16

TABLE 48
Corresponding protection ratios *PR*(p) to reception modes for DRM (4-QAM. *R* = 1/3) interfered with by DAB

Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	-3.37	-32.37	-50.37
Portable reception (PO, PI, PO-H, PI-H)	PR(p) [dB]	4.37	-24.63	-42.63
Mobile reception (MO)	PR(p) [dB]	8.16	-20.84	-38.84

TABLE 49
Corresponding protection ratios *PR*(p) to reception modes for DRM (16-QAM. *R* = 1/2) interfered with by DAB

Frequency offset	[kHz]	0	± 100	± 200
Fixed reception (FX)	PR(p) [dB]	1.63	-14.37	-45.37
Portable reception (PO, PI, PO-H, PI-H)	PR(p) [dB]	9.37	-6.63	-37.63
Mobile reception (MO)	PR(p) [dB]	13,16	-2,84	-33,84

6.4.1.4 DRM interfered with by DVB-T in VHF band III

Since the impact mechanisms of DAB into DRM is the same as that of DVB-T it is proposed that the same protection ratios for DRM interfered with by DVB-T in VHF band III can be assumed as for DRM interfered with by DAB in VHF band III.

6.4.2 Protection Ratios for Broadcasting Systems interfered with by DRM

6.4.2.1 Protection Ratios for FM in VHF band II

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

[ITU-412, Annex 5] states that interferences can be caused by intermodulation of strong FM signals in a frequency offset greater than 400 kHz. This cross modulation effect from a high interfering signal level in a range up to 1 MHz offset has also to be taken into account when planning OFDM systems into the VHF band II. Therefore not only the protection ratios PR_{basic} are given in the range 0 kHz to ±400 kHz, cf. Table 50, and for ±500 kHz and ±1000 MHz, too. The values for ±600 kHz to ±900 kHz can be found by linear interpolation.

TABLE 50

Basic protection ratios PR_{basic} for FM interfered with by DRM

Frequency offset	[kHz]	0	± 100	± 200	± 300	± 400	± 500	± 1000
Basic protection ratio for FM (stereo)	PR_{basic} [dB]	49	30	3	-8	-11	-13	-21

6.4.2.2 Protection Ratios for DAB in VHF band III

The DAB signal parameters are given in [ITU-1660] In [RRC-06] it is given that the T-DAB planning should be able to deal with mobile reception with a location probability of 99%, and with portable indoor reception with a location probability of 95%, respectively. In addition the values for fixed reception with a location probability of 70% are given.

The basic protection ratios for DAB interfered with by DRM are given in Table 51, the related combined location correction factors are given in Table 52, and the corresponding protection ratios *PR*(p) are given in Table 53, respectively.

TABLE 51

Basic protection ratios PR_{basic} for DAB interfered with by DRM

Frequency offset	[kHz]	0	± 100	± 200
Basic protection ratio for T-DAB	PR_{basic} [dB]	10	-40	-40

TABLE 52

Combined location correction factor *CF* for DAB interfered with by DRM

Location probability *p*		70%	95%	99%
Combined location correction factor **in urban and suburban area for fixed and portable reception**	*CF* [dB]	3.63	11.37	16.09
Combined location correction factor i**n rural area for mobile reception**	*CF* [dB]	3.42	10.72	15.16

TABLE 53
Corresponding protection ratios *PR*(p) to reception modes for DAB interfered with by DRM

Frequency offset	[kHz]	0	± 100	± 200
DAB fixed reception	PR(p) [dB]	13.63	-36.37	-36.37
DAB portable reception	PR(p) [dB]	21.37	-28.63	-28.63
DAB mobile reception	PR(p) [dB]	25.16	-24.84	-24.84

6.4.2.3 Protection Ratios for DVB-T in VHF band III

The DVB-T signal parameters are given in [ITU-1368].

In VHF band III not only DAB but also may be DVB-T operated additionally as an interferer into DRM or to be interfered with by DRM.

DRM as an interferer against a DAB wanted signal has the same impact as a DAB interferer under the assumption that more than one DRM interferer with different frequencies in a DAB block has to be included, see Table 51.

The same proposal can be assumed if DVB-T is the wanted signal. If there is more than one DRM interferer with different frequencies in a DVB-T channel the impact may be the same as it is caused by a DAB signal. Therefore It is proposed that the protection ratios of DVB-T interfered with by DRM are the same as DVB-T is interfered with by DAB.

In [ITU-1368] the basic protection ratios for DVB-T interfered with DAB are given, see Table 54. These protection rations are proposed for the interferences by a DRM signal also. In the adjacent channels no impact is proposed.

TABLE 54
Co-channel basic protection ratios PR_{basic} for DVB-T interfered with by DAB [ITU-1368] and by DRM

Wanted signal DVB-T Constellation - Code rate	PR [dB]
QPSK - 1/2	10
QPSK - 2/3	12
QPSK - 3/4	14
16-QAM - 1/2	15
16-QAM - 2/3	18
16-QAM - 3/4	20
64-QAM - 1/2	20
64-QAM - 2/3	24
64-QAM - 3/4	26
64-QAM - 7/8	31

6.4.3 Protection Ratios for Other Services interfered with by DRM

6.4.3.1 Other Services below the Radio Broadcasting VHF band II

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. Provided sufficient additional band pass filtering of the output of the transmitter is applied, the interference potential of DRM into narrowband FM (BOS) reception is not substantially higher than that of a standard FM broadcast signal [BNetzA07].

6.4.3.2 Other Services above the Radio Broadcasting VHF band II

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. For frequency offsets of less than 200 kHz, the interference potential of DRM into VOR and ILS localizer reception is much less than of a standard FM broadcast signal (up to 30 dB less). For larger frequency offsets, both signals produce roughly the same interference, provided sufficient additional band pass filtering of the output of the transmitter is deployed [BNetzA07].

6.4.3.3 Other Services in the Radio Broadcasting VHF band III

The values and the procedures to take into account other services in VHF band III is given in [ITU-GE06]. For DRM the same values as for DAB shall be applied.

6.5 Calculation of the Resulting Sum Field Strength of Interferers

To calculate the resulting interfering sum field strength level from several signal sources E_{sum}

- **in VHF Band I and VHF Band II** the simplified multiplication method [ITU-R945] shall be applied according to [ITU-GE84],
- **in VHF Band III** the log-normal methods [ITU-R945] according to the planning procedures of T-DAB and DVB-T [ITU-GE06] shall be applied.

ANNEX 1 – Normative References

1 Symbols and Abbreviations

For the purposes of the present document, the following symbols and abbreviations apply:

φ_{min}	Minimum power flux density at receiving place [$^{\mathrm{dBW/m2}}$]
A_{a}	Effective Antenna Aperture [dBm^2]
B	Receiver noise bandwidth [Hz]
CF	Combined location correction factor [dB]
C_{l}	Location correction factor [dB]
c_0	Velocity of light in free space [kms^{-1}]
d	Antenna directivity
DAB	Digital Audio Broadcasting
$D_{\mathrm{echo(max)}}$	Maximum echo delay distance [km]
DRM+	DRM Mode E
E	RMS field strength level [dB]
E_{min}	Equivalent minimum RMS field strength level at receiving place [dBμVm^{-1}]
E_{med}	Equivalent median RMS field strength level, planning value [dBμVm^{-1}]
F_a	Antenna noise figure [dB]
$F_{a,med}$	Antenna noise figure mean value [dB]
F_r	Receiver noise figure [dB]
F_s	System equivalent noise figure [dB]
FM	Frequency modulation
f_a	Antenna noise factor
f_r	Receiver noise factor
g	Linear antenna gain [dB]
G	Antenna gain [dB]
G_{D}	Antenna gain with reference to half-wave dipole [dBd]
ΔG	Antenna gain variation [dB]
η	Antenna efficiency
k	Boltzman's constant [J/K]
K	Correction factor for the macro-scale standard deviation σ_{m} [dB]
l	Cable length [m]
λ	Wavelength [m]
L_{b}	Mean building penetration loss [dB]
L_{f}	Feeder loss [dB]
L'_{f}	Feeder loss per unit length [dBm^{-1}]
L_{h}	Height loss correction factor (10 m a.g.l. to 1,5 m. a.g.l.) [dB]
μ	Distribution factor
MMN	Allowance for man-made noise
MSC	Main Service Channel
N_{s}	Number of symbols per frame in DRM mode E [ms]
OFDM	Orthogonal Frequency Division Multiplexing
p	Percentage of receiving locations (Location probability) [%]
PL	Protection level in DRM Mode E

P_{mmn}	Man-made noise level [dB]
P_n	Receiver noise input power [dBW]
PR	Protection ratio [dB]
PR_{basic}	Basic protection ratio [dB]
$P_{S,min}$	Minimum receiver signal input power [dBW]
QAM	Quadrature Amplitude Modulation
R	Code rate
R_L	Antenna loss resistance [Ω]
R_r	Antenna radiation resistance [Ω]
σ_b	Building penetration loss standard deviation [dB]
σ_c	Combined standard deviation [dB]
σ_m	Macro-scale standard deviation [dB]
$\sigma_{m,DRM}$	Macro-scale standard deviation for DRM [dB]
$\sigma_{m,DAB}$	Macro-scale standard deviation for DAB [dB]
$\sigma_{m,FM}$	Macro-scale standard deviation for FM [dB]
σ_{MMN}	Man-made noise standard deviation [dB]
SDC	Service Description Channel
SFN	Single frequency network
T	Elementary time period of DRM mode E [ms]
T_f	Duration of transmission frame of DRM mode E [ms]
T_g	Duration of guard interval of DRM mode E [ms]
T_s	Duration of OFDM symbol of DRM mode E [ms]
T_u	Duration of useful (orthogonal) part of DRM mode E [ms]
T_0	Absolute temperature [K]
VHF	Very high frequency
Z_{F0}	Characteristic impedance in free space [Ω]

2 References

[BNetzA07] Documentation G531/00328/07, Compatibility Measurements DRM120, DRM and HD Radio interfering with FM Broadcast, Narrowband FM (BOS) and Aeronautical Radionavigation, German Network Agency and University of Applied Science of Kaiserslautern, September 2007

[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

[ECC-FM45] ECC Working Group Frequency Management Project Team FM PT45, Digital Broadcasting Issues; Initial first draft for a supplement to the ECC report 141 on future possibilities for the digitalisation of Band II; Technical Elements and Parameters for Digital Terrestrial Broadcasting in Band II

[ETSI-DRM] ETSI EN 201 980; Digital Radio Mondiale (DRM); System Specification

[ETSI-DVB] ETSI TR 101 190; Digital Video Broadcasting (DVB); Implementation guidelines for DVB terrestrial services; Transmission aspects

[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-328] ITU-R SM.328-11; Spectra and bandwidth of emissions

[ITU-372] ITU-R P.372-8; Radio Noise

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

[ITU-599] ITU-R BS.599; Directivity of Antennas for the Reception of Sound Broadcasting in Band 8 (VHF)

[ITU-641] ITU-R BS.641; Determination of radio-frequency protection ratios for frequency-modulated sound broadcasting

[ITU-1368] ITU-R BT.1368-8; Planning criteria for digital terrestrial television services in the VHF/UHF bands

[ITU-1546] ITU-R P.1546-4; Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz.

[ITU-1660] ITU-R BS.1660-3; Technical basis for planning of terrestrial digital sound broadcasting in the VHF band

[ITU-R945] ITU-Report 945-2; Methods for the Assessment of Multiple Interference

[ITU-GE06] 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

[ITU-GE84] Final Acts of the Regional Administrative Conference for the Planning of VHF Sound Broadcasting (Region 1 and Part of Region 3); Geneva 1984

[KRAUS] Kraus, J.D. "Antennas", Mc Graw Hill College; 3rd revised edition (Dec. 2001)

3 Authors

Eulig, N. Norddeutscher Rundfunk, Hugh-Greene-Weg 1, 22529 Hamburg, Germany; N.Eulig@ndr.de

Kühn, M. mobile broadcast consulting, Dresdener Straße 25B, 15566 Schöneiche, Germany; mbc.kuehn@t-online.de

Lehnert, J. Landeszentrale für Medien und Kommunikation Rheinland-Pfalz (LMK), Turmstraße 10, 67059 Ludwigshafen, Germany; lehnert@lmk-online.de

Maier, F. Leibniz Universität Hannover, Appelstr. 9A, 30167, Hannover, Germany; friederike.maier@ikt.uni-hannover.de

Schramm, R. Institut für Rundfunktechnik GmbH, Floriansmühlstraße 60 , 80939 München, Germany, schramm@irt.de

Steil, A. University of Applied Sciences of Kaiserslautern, Morlauterer Straße 31, 67657 Kaiserslautern, Germany; andreas.steil@fh-kl.de

Teuscher, S. Bayerischer Rundfunk, Rundfunkplatz 1, 80300 München, Germany, stefan.teuscher@brnet.de

ANNEX 2 – Technical References

1 Position of DRM frequencies

1.1 VHF Band II

The DRM centre frequencies are positioned in 100 kHz distance according to the FM frequency grid and [ETSI-DRM]. The nominal carrier frequencies are, in principle, integral multiples of 100 kHz [ITU-GE84], see Table 55. A 50 kHz channel spacing is considered (see section 0).

TABLE 55

Position of DRM frequencies in VHF band II (87.5 – 108 MHz)

DRM channel center frequency f_C [MHz]	DRM channel number	DRM channel center frequency f_C [MHz]	DRM channel number	DRM channel center frequency f_C [MHz]	DRM channel number	DRM channel center frequency f_C [MHz]	DRM channel number
87,6	1	92,7	52	97,8	103	102,9	154
87,7	2	92,8	53	97,9	104	103,0	155
87,8	3	92,9	54	98,0	105	103,1	156
87,9	4	93,0	55	98,1	106	103,2	157
88,0	5	93,1	56	98,2	107	103,3	158
88,1	6	93,2	57	98,3	108	103,4	159
88,2	7	93,3	58	98,4	109	103,5	160
88,3	8	93,4	59	98,5	110	103,6	161
88,4	9	93,5	60	98,6	111	103,7	162
88,5	10	93,6	61	98,7	112	103,8	163
88,6	11	93,7	62	98,8	113	103,9	164
88,7	12	93,8	63	98,9	114	104,0	165
88,8	13	93,9	64	99,0	115	104,1	166
88,9	14	94,0	65	99,1	116	104,2	167
89,0	15	94,1	66	99,2	117	104,3	168
89,1	16	94,2	67	99,3	118	104,4	169
89,2	17	94,3	68	99,4	119	104,5	170
89,3	18	94,4	69	99,5	120	104,6	171
89,4	19	94,5	70	99,6	121	104,7	172
89,5	20	94,6	71	99,7	122	104,8	173
89,6	21	94,7	72	99,8	123	104,9	174
89,7	22	94,8	73	99,9	124	105,0	175
89,8	23	94,9	74	100,0	125	105,1	176
89,9	24	95,0	75	100,1	126	105,2	177
90,0	25	95,1	76	100,2	127	105,3	178
90,1	26	95,2	77	100,3	128	105,4	179
90,2	27	95,3	78	100,4	129	105,5	180
90,3	28	95,4	79	100,5	130	105,6	181
90,4	29	95,5	80	100,6	131	105,7	182
90,5	30	95,6	81	100,7	132	105,8	183

DRM channel center frequency f_C [MHz]	DRM channel number	DRM channel center frequency f_C [MHz]	DRM channel number	DRM channel center frequency f_C [MHz]	DRM channel number	DRM channel center frequency f_C [MHz]	DRM channel number
90,6	31	95,7	82	100,8	133	105,9	184
90,7	32	95,8	83	100,9	134	106,0	185
90,8	33	95,9	84	101,0	135	106,1	186
90,9	34	96,0	85	101,1	136	106,2	187
91,0	35	96,1	86	101,2	137	106,3	188
91,1	36	96,2	87	101,3	138	106,4	189
91,2	37	96,3	88	101,4	139	106,5	190
91,3	38	96,4	89	101,5	140	106,6	191
91,4	39	96,5	90	101,6	141	106,7	192
91,5	40	96,6	91	101,7	142	106,8	193
91,6	41	96,7	92	101,8	143	106,9	194
91,7	42	96,8	93	101,9	144	107,0	195
91,8	43	96,9	94	102,0	145	107,1	196
91,9	44	97,0	95	102,1	146	107,2	197
92,0	45	97,1	96	102,2	147	107,3	198
92,1	46	97,2	97	102,3	148	107,4	199
92,2	47	97,3	98	102,4	149	107,5	200
92,3	48	97,4	99	102,5	150	107,6	201
92,4	49	97,5	100	102,6	151	107,7	202
92,5	50	97,6	101	102,7	152	107,8	203
92,6	51	97,7	102	102,8	153	107,9	204

1.2 VHF Band III

The frequency band of a DAB block has a bandwidth of 1.536 MHz [ITU-GE06] with lower and upper guard channels to fit into the 7 MHz channels of VHF band III. The DRM centre frequencies are positioned in 100 kHz distance beginning by 174.05 MHz and integral multiples of 100 kHz up to 229.95 MHz, see Table 56.

The nomenclature of the DRM channel identifier is given by

[No. of the VHF channel] – [No. of the DRM channel suffix in the VHF channel],

e.g for the first DRM channel in this table is the identifier '5-1'.

TABLE 56
Position of DRM frequencies in VHF band III (174 – 230 MHz)

DRM channel suffix	DRM channel center frequency f_C [MHz] in VHF Channel [number]							
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	174,050	181,050	188,050	195,050	202,050	209,050	216,050	223,050
2	174,150	181,150	188,150	195,150	202,150	209,150	216,150	223,150
3	174,250	181,250	188,250	195,250	202,250	209,250	216,250	223,250
4	174,350	181,350	188,350	195,350	202,350	209,350	216,350	223,350
5	174,450	181,450	188,450	195,450	202,450	209,450	216,450	223,450
6	174,550	181,550	188,550	195,550	202,550	209,550	216,550	223,550
7	174,650	181,650	188,650	195,650	202,650	209,650	216,650	223,650

DRM channel suffix	DRM channel center frequency f_C [MHz] in VHF Channel [number]							
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**
8	174,750	181,750	188,750	195,750	202,750	209,750	216,750	223,750
9	174,850	181,850	188,850	195,850	202,850	209,850	216,850	223,850
10	174,950	181,950	188,950	195,950	202,950	209,950	216,950	223,950
11	175,050	182,050	189,050	196,050	203,050	210,050	217,050	224,050
12	175,150	182,150	189,150	196,150	203,150	210,150	217,150	224,150
13	175,250	182,250	189,250	196,250	203,250	210,250	217,250	224,250
14	175,350	182,350	189,350	196,350	203,350	210,350	217,350	224,350
15	175,450	182,450	189,450	196,450	203,450	210,450	217,450	224,450
16	175,550	182,550	189,550	196,550	203,550	210,550	217,550	224,550
17	175,650	182,650	189,650	196,650	203,650	210,650	217,650	224,650
18	175,750	182,750	189,750	196,750	203,750	210,750	217,750	224,750
19	175,850	182,850	189,850	196,850	203,850	210,850	217,850	224,850
20	175,950	182,950	189,950	196,950	203,950	210,950	217,950	224,950
21	176,050	183,050	190,050	197,050	204,050	211,050	218,050	225,050
22	176,150	183,150	190,150	197,150	204,150	211,150	218,150	225,150
23	176,250	183,250	190,250	197,250	204,250	211,250	218,250	225,250
24	176,350	183,350	190,350	197,350	204,350	211,350	218,350	225,350
25	176,450	183,450	190,450	197,450	204,450	211,450	218,450	225,450
26	176,550	183,550	190,550	197,550	204,550	211,550	218,550	225,550
27	176,650	183,650	190,650	197,650	204,650	211,650	218,650	225,650
28	176,750	183,750	190,750	197,750	204,750	211,750	218,750	225,750
29	176,850	183,850	190,850	197,850	204,850	211,850	218,850	225,850
30	176,950	183,950	190,950	197,950	204,950	211,950	218,950	225,950
31	177,050	184,050	191,050	198,050	205,050	212,050	219,050	226,050
32	177,150	184,150	191,150	198,150	205,150	212,150	219,150	226,150
33	177,250	184,250	191,250	198,250	205,250	212,250	219,250	226,250
34	177,350	184,350	191,350	198,350	205,350	212,350	219,350	226,350
35	177,450	184,450	191,450	198,450	205,450	212,450	219,450	226,450
36	177,550	184,550	191,550	198,550	205,550	212,550	219,550	226,550
37	177,650	184,650	191,650	198,650	205,650	212,650	219,650	226,650
38	177,750	184,750	191,750	198,750	205,750	212,750	219,750	226,750
39	177,850	184,850	191,850	198,850	205,850	212,850	219,850	226,850
40	177,950	184,950	191,950	198,950	205,950	212,950	219,950	226,950
41	178,050	185,050	192,050	199,050	206,050	213,050	220,050	227,050
42	178,150	185,150	192,150	199,150	206,150	213,150	220,150	227,150
43	178,250	185,250	192,250	199,250	206,250	213,250	220,250	227,250
44	178,350	185,350	192,350	199,350	206,350	213,350	220,350	227,350
45	178,450	185,450	192,450	199,450	206,450	213,450	220,450	227,450
46	178,550	185,550	192,550	199,550	206,550	213,550	220,550	227,550
47	178,650	185,650	192,650	199,650	206,650	213,650	220,650	227,650
48	178,750	185,750	192,750	199,750	206,750	213,750	220,750	227,750
49	178,850	185,850	192,850	199,850	206,850	213,850	220,850	227,850
50	178,950	185,950	192,950	199,950	206,950	213,950	220,950	227,950

DRM channel suffix	DRM channel center frequency f_C [MHz] in VHF Channel [number]							
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**
51	179,050	186,050	193,050	200,050	207,050	214,050	221,050	228,050
52	179,150	186,150	193,150	200,150	207,150	214,150	221,150	228,150
53	179,250	186,250	193,250	200,250	207,250	214,250	221,250	228,250
54	179,350	186,350	193,350	200,350	207,350	214,350	221,350	228,350
55	179,450	186,450	193,450	200,450	207,450	214,450	221,450	228,450
56	179,550	186,550	193,550	200,550	207,550	214,550	221,550	228,550
57	179,650	186,650	193,650	200,650	207,650	214,650	221,650	228,650
58	179,750	186,750	193,750	200,750	207,750	214,750	221,750	228,750
59	179,850	186,850	193,850	200,850	207,850	214,850	221,850	228,850
60	179,950	186,950	193,950	200,950	207,950	214,950	221,950	228,950
61	180,050	187,050	194,050	201,050	208,050	215,050	222,050	229,050
62	180,150	187,150	194,150	201,150	208,150	215,150	222,150	229,150
63	180,250	187,250	194,250	201,250	208,250	215,250	222,250	229,250
64	180,350	187,350	194,350	201,350	208,350	215,350	222,350	229,350
65	180,450	187,450	194,450	201,450	208,450	215,450	222,450	229,450
66	180,550	187,550	194,550	201,550	208,550	215,550	222,550	229,550
67	180,650	187,650	194,650	201,650	208,650	215,650	222,650	229,650
68	180,750	187,750	194,750	201,750	208,750	215,750	222,750	229,750
69	180,850	187,850	194,850	201,850	208,850	215,850	222,850	229,850
70	180,950	187,950	194,950	201,950	208,950	215,950	222,950	229,950

2 Computations of Correction Factors

2.1 Computation of the Antenna Gain for Portable Handheld Reception

The antenna (linear) gain *g* is the product of directivity *d* and efficiency η [KRAUS].

$$g = \eta \cdot d \qquad (28)$$

For lossless antennas the efficiency equals one and the gain equals the directivity.

Portable handheld reception antennas are very lossy, and therefore the gain is much lower than directivity. They are also short linear antennas, with small dimensions compared to wavelength, and have a constant directivity of about 1.5 (1.8 dBi or -0.4 dBd). The gain changes with frequency only due to efficiency.

To estimate the efficiency change with frequency a transmitting antenna is considered. That leads to the values for a receiving antenna also, because antennas are reciprocal; their directivity, efficiency and gain are the same as receiving or transmitting antenna [KRAUS].

To transfer the maximum energy from a port to an antenna or vice versa the antenna has to be matched to the port impedance. A matched antenna has an equivalent series circuit with radiation resistance R_r, antenna loss resistance and a matching circuit loss resistance. We consider the reactive part of the serial impedance as zero. The radiation resistance is small and the transmitted energy is dissipated mostly in the antenna loss resistance and the matching circuit. Only the energy in R_r is radiated. Combining all losses in R_L the antenna efficiency:

$$\eta = \frac{R_r}{R_r + R_L} \approx \frac{R_r}{R_L} \qquad (29)$$

R_r can be neglected in the denominator, because R_r is much lower than R_L.

For the antenna length $l << \lambda$ the radiation resistance magnitude is proportional to the square of the antenna length l relative to wavelength λ [KRAUS]:

$$R_r = k \cdot \left(\frac{l}{\lambda}\right)^2 = k' \cdot (l \cdot f)^2 \ [\Omega] \qquad (30)$$

where λ was substituted by c/f, with c the light velocity.

If the antenna dimension is not changed, and it is considered that the losses in the antenna and the matching circuit does not change significantly in the frequency range of interest, the efficiency η_2 at a frequency f_2, compared to the efficiency η_1 at a frequency f_1, changes as follows:

$$\frac{\eta_2}{\eta_1} = \left(\frac{f_2}{f_1}\right)^2 = \frac{G_2}{G_1} \qquad (31)$$

The same is true for the gain G [dB], since the directivity does not change.

Changing the frequency from f_1 to f_2 the gain changes with:

$$\Delta G = 20\log_{10}\left(\frac{f_2}{f_1}\right) \ [\mathrm{dB}] \qquad (32)$$

2.2 Computation of Man-made Moise Allowance from the Antenna Noise Factor

Definition of the antenna noise factor

An antenna for terrestrial communications with efficiency one receives from its environment, no matter what shape its receiving diagram has, thermal noise with a power ***n***:

$$n = kTB$$

where:

k = Bolzmann-constant

T = environment temperature in K (290)

B = bandwidth in Hz

If the antenna receives in the same bandwidth B Gaussian noise like man-made noise with a power ***i***, the total power received is:

$$p_a = n + i$$

We can define an antenna noise factor f_a as:

$$f_a = \frac{p_a}{n} = \frac{n+i}{n} = 1 + \frac{i}{n}$$

and an antenna noise figure F_a given in dB [KRAUS]:

$$F_a = 10\log_{10}(f_a)$$

The man-made noise allowance for coverage calculations

In a link budget used for coverage calculations, the receiver is taken into account by its noise figure F_r. It can be shown, that the effect of the man-made noise ***i*** received by the antenna is equivalent to an increase of the receiver noise figure F_r by an amount **MMN** in dB, called man-made noise allowance.

If the antenna does not receive man-made noise, the total equivalent noise at a receiver input is:

$$p = p_r + n$$

with:

p = power sum in W

p_r = receiver noise corresponding to the noise figure and the bandwidth, in W

n = thermal noise (*kTB*) in W

f_r = receiver noise factor calculated from the noise figure ($f_r = 10^{\frac{F_r}{10}}$)

The receiver noise factor is defined as:

$$f_r = \frac{p}{n} = \frac{p_r + n}{n} = 1 + \frac{p_r}{n}$$

If man-made noise ***i*** is received, the power at the receiver input is:

$$p = p_r + n + i$$

The interference power is increased by a factor ***mmn***:

$$mmn = \frac{p_r + n + i}{p_r + n} = 1 + \frac{i}{p_r + n} = 1 + \frac{\frac{i}{n}}{1 + \frac{p_r}{n}}$$

but

$$\frac{p_r}{n} = f_r - 1$$

and

$$\frac{i}{n} = f_a - 1$$

The factor ***mmn*** can be expressed as a function of f_r and f_a:

$$mmn = 1 + \frac{f_a - 1}{f_r}$$

or in dB, the allowance for man-made noise ***MMN***:

$$MMN = 10\log(1 + \frac{f_a - 1}{f_r})$$

The system equivalent noise figure to be used for coverage calculations is increased to:

$$F_s = F_r + MMN$$

Special case with antenna gain below 1.8 dBi

The antenna gain is the product of directivity and efficiency. The lowest realistic directivity is the one of a short dipole (length << λ) and it has the value 1.5 (1.8 dBi). Any gain lower than 1.8 dB_i (-0.4 dBd) is due to an antenna efficiency η lower than 1.

If the antenna efficiency is η, from the received wanted signal w only $\eta * w$ reaches the receiver, but the Gaussian noise and the man-made noise getting into the receiver are also reduced to $\eta * n$ and $\eta * i$.

The interference power at the receiver input is increased due to man-made noise interference i by the factor ***mmn***:

$$mmn = \frac{p_r + n + \eta i}{p_r + n} = 1 + \frac{\eta i}{p_r + n} = 1 + \frac{\frac{\eta i}{n}}{1 + \frac{p_r}{n}}$$

$$MMN = 10\log(1 + \eta\frac{f_a - 1}{f_r})$$

The efficiency η can be calculated from the antenna gain G_D, for gains lower than -0.4 dBd:

$$\eta = 10^{\frac{G_D + 0.4}{10}}$$