CEPT ECC
Electronic Communications Committee

ECC Report 141
Technical supplement

TECHNICAL SUPPLEMENT TO ECC REPORT 141
FUTURE POSSIBILITIES FOR THE DIGITALISATION OF BAND II (87.5 - 108 MHz)

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0 EXECUTIVE SUMMARY

This supplement to ECC Report 141 provides the technical elements and parameters needed for the consideration of introduction of digital radio systems in Band II. The introduction of such digital services in Band II can be achieved on the basis of sharing the spectrum with existing FM services providing appropriate sharing criteria are adhered to. The sharing criteria for three digital standards, Digital Radio Mondiale (DRM), HD Radio and RAVIS, are presented comprising of technical characteristics, protection ratios and criteria for the protection of other services. A list of references is also included to aid those wishing to contemplate the more general planning aspects.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
CEPT	European Conference of Postal and Telecommunications Administrations
DRM	Digital Radio Mondiale
FM	Frequency Modulation
HD Radio	Hybrid Digital Radio
MSC	Main Service Channel
PL	Primary Lower
PR	Protection Ratio
PU	Primary Upper
QAM	Quadrature amplitude modulation
QPSK	Quadrature Phase Shift Keying
RAVIS	Realtime AudioVisual Information System
SDC	Service Description Channel
T-DAB	Terrestrial-Digital Audio Broadcasting
VHF	Very high frequency

1 INTRODUCTION

Any conceivable introduction of digital terrestrial broadcasting in Band II can be achieved only on the basis of sharing the spectrum with existing FM services. To this end appropriate sharing criteria need to be adhered to. Relevant technical parameters in this context are summarized in this supplement to ECC Report 141 [1]. The purpose of this document is NOT to provide a planning handbook for digital terrestrial broadcasting systems in VHF Band II.

FM frequency allocation in Band II may be used for digital terrestrial broadcasting services with characteristics that may be different from those appearing in the GE84 Plan [2] but within the envelope of their Plan entry or aggregate entries under the provisions of GE84 [2], and that their administrations agree that any such use will be afforded protection to the levels defined by the interfering field strengths as arising from their frequency allocations, taking into account any relevant bilateral agreements. This means any such alternative usage of Band II frequencies must not produce more interference nor claim more protection than the corresponding frequency allocation of GE84 [2].

2 GENERAL TECHNICAL CHARACTERISTICS OF CANDIDATE DIGITAL TERRESTRIAL BROADCASTING SYSTEMS FOR BAND II

2.1 DIGITAL RADIO MONDIALE (DRM)

The DRM standard, defined in ETSI ES 201 980 [3], provides configurations for broadcast frequencies below 30 MHz as well as for broadcast frequencies above 30 MHz in Mode 'E' (often referred to as 'DRM+'), including the VHF Band II. The parameters and statements given in this section refer to the latter set of DRM configurations.

2.1.1 System Parameters of DRM

2.1.1.1 DRM Signal Parameters

Two different modulation configurations in DRM robustness mode E are considered as given in Table 1.

The first one is a low protected DRM signal which is defined by the set of parameters:

> Mode E, MSC Mode 0 (16-QAM), SDC Mode 1 (code rate = 0.25), MSC Protection level 2 (code rate = 1/2), MSC equal error protection, net bit rate 149.1 kbit/s.

The second modulation configuration represents a high protected DRM signal with the parameters:

> MSC Mode 4 (4-QAM), SDC Mode 1 (code rate = 0.25), MSC Protection level 1 (code rate = 1/3), MSC equal error protection, net bit rate 49.7 kbit/s.

Table 1: MSC code rates for DRM

DRM signal	High protected	Low protected
MSC mode	11 - 4-QAM	00 - 16-QAM
MSC protection level	1	2
MSC code rate	1/3	1/2
SDC mode	1	1
SDC code rate	0.25	0.25
Bit rate approx.	49.7 kbit/s	149.1 kbit/s

The propagation-related OFDM parameters of DRM are given in Table 2.

Table 2: OFDM parameters

Parameter Name	Value
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

2.1.1.2 DRM Frequency Rasters

The DRM frequencies can be positioned in a 100 kHz raster in Band II. The nominal centre carrier frequencies are, in principle, integral multiples of 100 kHz [2].

2.2 HD RADIO

HD Radio system provides numerous configurations. Certain configurations are proposed for planning for Band II in Europe. These configurations allow for different bandwidth settings, frequency positioning, band combining and different throughput. These configurations are captured (or being updated at the present time) in standards documents, such as NRSC-5C [4]. These configurations are also briefly described in the present document in conjunction with the provided planning parameters and deployment aspects, such as sharing criteria.

It has to be noted that for the purpose of this report the same digital signal blocks of either 70 kHz each or 100 kHz bandwidth each are employed in constituting the system configurations. In some configurations the system allows employing a single digital block. In other configurations the system allows employing two digital blocks, while the power level of each block is set independently to that of the other block.

The system also allows linking an analogue signal to adjacent digital block or two blocks in terms of provided services, while the power level of each digital block and that of the analogue signal may be set independently of each other. The spectral location of a digital block is relative to a reference analogue signal frequency. This reference frequency is purely for calculation purposes. As noted above a digital block may or may not be associated with an analogue signal, Whether such a link is employed or not is not of relevance for planning purpose in Band II, and the analogue signal is dealt with as an independent FM signal according to ITU-R Recommendation BS.412 [5]. For common description and convenience, the linking of the analogue signal and adjacent digital signal is referred to as ‘Hybrid’ configuration or ‘Hybrid’ Waveform. Similarly, when not employing such a link, whether the analogue signal is present or not, is referred to as ‘all-digital’ configuration or ‘all-digital’ waveform. More details on the spectral layout can be found in section 2.2.1.2.

2.2.1 HD Radio System Parameters

2.2.1.1 HD Radio Signal Parameters

The system can be configured to use a single frequency block that employs 70 kHz digital signal bandwidth or 100 kHz digital signal bandwidth. The configuration is defined by system modes, and provides various combinations of logical channels, bit rates and protection levels.

When configured to use 70 kHz bandwidth, the system may be configured by mode *MP9*. It then employs logical channel *P1* and provides a throughput (net bit rate) of 98.3kbit/s. The employed modulation is QPSK.

When configured to use 100 kHz bandwidth, the system may be configured to mode *MP8* or mode *MP19*. When configured to mode *MP8*, the system employs logical channel *P1* and provides a throughput (net bit rate) of 98.3kbit/s. When configured to mode *MP19*, the system employs logical channels *P1*and *P3*, and provides a throughput (net bit rate) of 122.9kbit/s. The employed modulation is QPSK.

While it is treated as two independent signals, in the context of planning, sharing and compatibility for Band II in Europe, HD Radio system also supports joint configurations of two digital bands. Joint configurations provide higher robustness or support higher bit rate. When configured to use 2 x 70 kHz bandwidth, the system may be configured by mode *MP1*. It then employs logical channel *P1* and provides a throughput (net bit rate) of 98.3kbit/s. When configured to use 2 x 100 kHz bandwidth, the system may be configured by mode *MP11*. It then employs logical channels *P1*, *P3* and *P4*, and provides a throughput (net bit rate) of 147.5kbit/s.

The general characteristics of HD Radio system configurations (operating modes) are summarized in Table 3.

Table 3: General Characteristics of HD Radio System Operating Modes

System Mode	Used BW (kHz)	Total[1] bit rate	Channel P1		Channel P2		Channel P3		Comments
			Code rate	Bit[1] rate	Code rate	Bit[1] rate	Code rate	Bit[1] rate	Interleaver span
MP9	70	98.3	4/5	98.3	-	-	-	-	P1: ~1.5s
MP8	100	98.3	4/7	98.3	-	-	-	-	P1: ~1.5s; additional diversity delay
MP19	100	122.9	4/5	98.3	1/2	24.6	-	-	P1: ~1.5s; P3: ~3s
MP1[2]	2 × 70	98.3	2/5	98.3	-	-	-	-	P1: ~1.5s
MP11[2]	2 × 100	147.5	2/5	98.3	1/2	24.6	½	24.6	P1: ~1.5s; P3/P4: ~3s

Note 1 The bit rates reflect the throughput ('net' bit rate) by the application layer, and do not include the overhead used by the physical layer.

Note 2 Joint configuration of two digital signal blocks for enhanced performance or features. The digital blocks are treated independently in the context of Band II in Europe.

Additional HD Radio system signal parameters (physical layer) for Band II are provided in Table 4.

Table 4: HD Radio System physical layer parameters

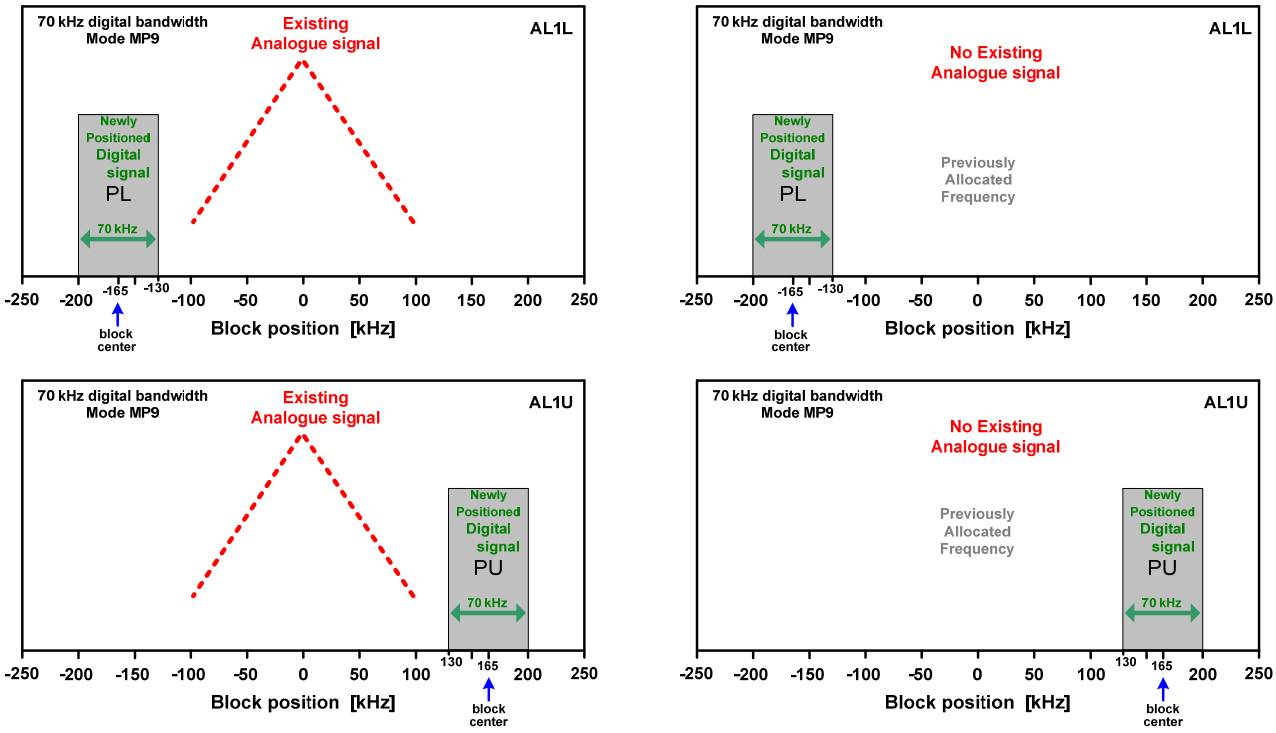
Parameter Name	Computed Value (rounded)
Cyclic Prefix Width α	0.1586 ms
Symbol Duration (with prefix) T_s	2.902 ms
Number of symbols in a block	32
Block Duration T_b	9.288 ms
Number of blocks in a frame	16
Frame Duration T_f	1.486 s
OFDM Subcarrier Spacing Δf	363.4 Hz
Number of carriers	70 kHz band : 191 100 kHz band: 267
Used bandwidth	70 kHz band : 69.4 kHz 100 kHz band: 97.0 kHz

2.2.1.2 HD Radio Frequency Rasters

In Europe, planning is based on a 100 kHz channel raster in Band II. In the US the fundamental channel raster is based on a 200 kHz spacing. The HD Radio system presumes that the digital signal blocks are at pre-defined positions. As can be seen from the diagrams in Figure 1 and Figure 2 these positions are not centred on the 100 kHz (or 200 kHz) raster but in between. It has to be noted that the block position of 0 kHz in the figures below corresponds to the reference analogue frequency for the HD Radio signal as discussed in section 2.2.

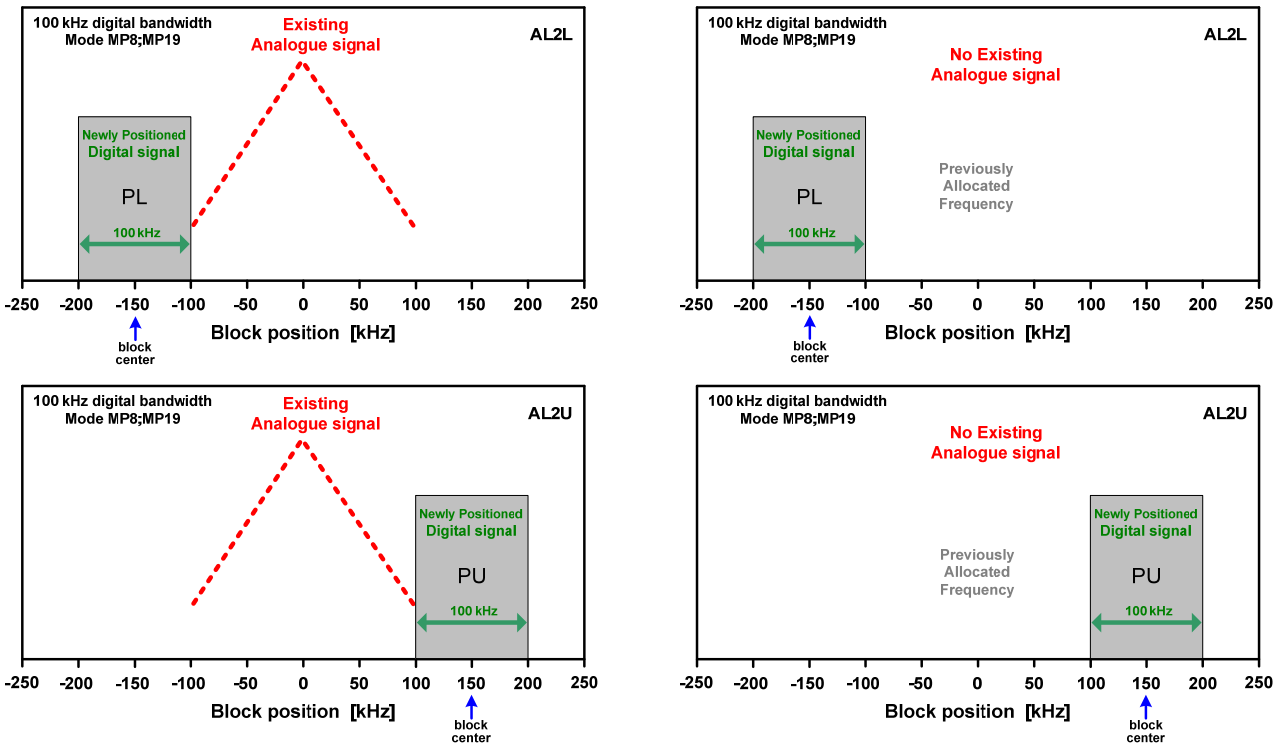
The centre frequencies of an HD Radio single OFDM block lie in the following frequency separation to the nominal carrier frequency of an FM signal (that are, in principle, integral multiples of 100 kHz):

- in the case of the 100 kHz OFDM block in the multiples of 50 kHz, i.e. ±(50 + n×100) kHz, (n=0, 1, 2, ...)
- in the case of the 70 kHz OFDM block in the multiples of 35 kHz, i.e. ±(35 + n×100) kHz or of 65 kHz, i.e. ±(65 + n×100) kHz.



Note: PL and PU are used for indicating lower positioning and upper positioning (respectively) of the digital block. The indication is for convenience only, and does not suggest an actual difference in the signal.

Figure 1: HD Radio 70 kHz digital block positioning examples



Note: PL and PU are used for indicating lower positioning and upper positioning (respectively) of the digital block. The indication is for convenience only, and does not suggest an actual difference in the signal.

Figure 2: HD Radio 100 kHz digital block positioning examples

2.3 RAVIS

The RAVIS standard is intended for digital broadcasting in VHF Bands I and II [6].

2.3.1 RAVIS System Parameters

2.3.1.1 RAVIS Signal Parameters

RAVIS (Realtime Audiovisual Information System) supports:

- three types of radio channel bandwidth: 100, 200 and 250 kHz.
- three different coding rates for the logical channel of main service: 1/2, 2/3 and 3/4.
- three different modulation types for logical channel of main service: QPSK, 16-QAM and 64-QAM.

Rounded bit rates for different combinations of system parameters are given in Table 5.

Table 5: Bit rates for RAVIS

Modulation type	Code rate	Bit rate (kbps)		
		100 kHz channel	200 kHz channel	250 kHz channel
QPSK	1/2	80	160	200
	2/3	100	210	270
	3/4	120	240	300
16-QAM	1/2	150	320	400
	2/3	210	420	530
	3/4	230	470	600
64-QAM	1/2	230	470	600
	2/3	310	630	800
	3/4	350	710	900

The propagation-related OFDM parameters of RAVIS are given in Table 6.

Table 6: OFDM parameters for RAVIS

Parameter Name	Value		
Duration of useful (orthogonal) part T_u	2.25 ms		
Duration of guard interval T_g	0.28125 ms		
Duration of symbol $T_s = T_u + T_g$	2.53125 ms		
T_g/T_u	1/8		
Duration of transmission frame T_f	103.78125 ms		
Number of symbols per frame N_s	41		
Carrier spacing $1/T_u$	444 4/9 Hz		
Channel bandwidth B	100 kHz	200 kHz	250 kHz
Number of carriers K_{total}	215	439	553
Used bandwidth $(K_{total} + 1)/T_u$	96.0 kHz	195.6 kHz	246.2 kHz

2.3.1.2 RAVIS Frequency Rasters

The RAVIS frequencies can be positioned in a 100 kHz raster in Band II. The nominal centre carrier frequencies are integral multiples of 100 kHz [2].

2.4 T-DAB

Initially, T-DAB was considered as a candidate system for digital terrestrial audio broadcasting in Band II as a successor to FM. However, this option is no longer pursued. Information for the planning of T-DAB is available within the original Wiesbaden 95 documentation [7] and also the GE06 [8] documentation.

3 SHARING PARAMETERS

3.1 FM

Spectrum masks for FM in VHF band II as a minimum transmitter requirement are given in [5]. Note that the spectrum masks are defined for a resolution bandwidth of 1 kHz.

Table 7: FM spectrum mask

Spectrum mask (100 kHz channel) / relative level for FM)	
Frequency offset (kHz)	Level (dBc/ 1 kHz)
0	0
± 100	0
± 200	-80
± 300	-85
± 500	-85

3.2 DRM

3.2.1 Out-of-Band Emissions

Spectrum masks for DRM in VHF band II are given in Figure 3 and Table 8.

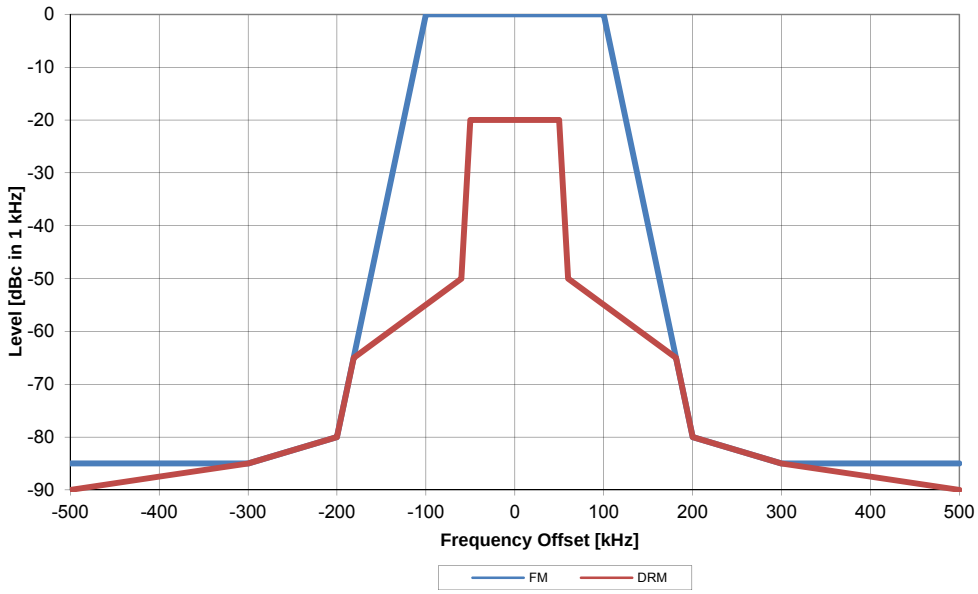


Figure 3: Spectrum masks for FM and DRM in VHF Band II

Table 8: Spectrum masks for FM and DRM in VHF Band II

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

3.3 HD RADIO

3.3.1 Out-of-Band Emissions

The out-of-band spectral emission masks for HD Radio transmissions using a single digital block in reference to the FM radio broadcast spectral mask, as indicated in the ETSI EN 302 018-1 [9], are given in Tables 9 and 10 and in Figure 4. These spectrum mask values differ from the values given in Recommendation ITU-R BS.1114-7 [11] since the tables in the ITU documentation cover different systems modes which are not used in Europe. However, it has to be noted that this figure has been drawn in such a way for comparison purposes only. The digital blocks of HD Radio will not be located at any of possible positions of the European spectrum raster in Band II. Rather, the blocks will be positioned as depicted in Figure 1 and Figure 2.

Table 9: Out-of-band spectrum mask for 100 kHz bandwidth HD Radio transmissions in Band II

Frequency Offset (kHz)	Level (dBc/1 kHz)
± 50 kHz	-20
± 57.5 kHz	-53
± 100 kHz	-62
± 150 kHz	-72.5
± 181 kHz	-90
± 500 kHz	-90

Table 10: Out-of-band spectrum mask for 70 kHz bandwidth HD Radio transmissions in Band II

Frequency Offset (kHz)	Level (dBc/1 kHz)
± 35 kHz	-18.5
± 42.5 kHz	-51.5
± 100 kHz	-62
± 135 kHz	-71
± 166 kHz	-88.5
± 500 kHz	-88.5

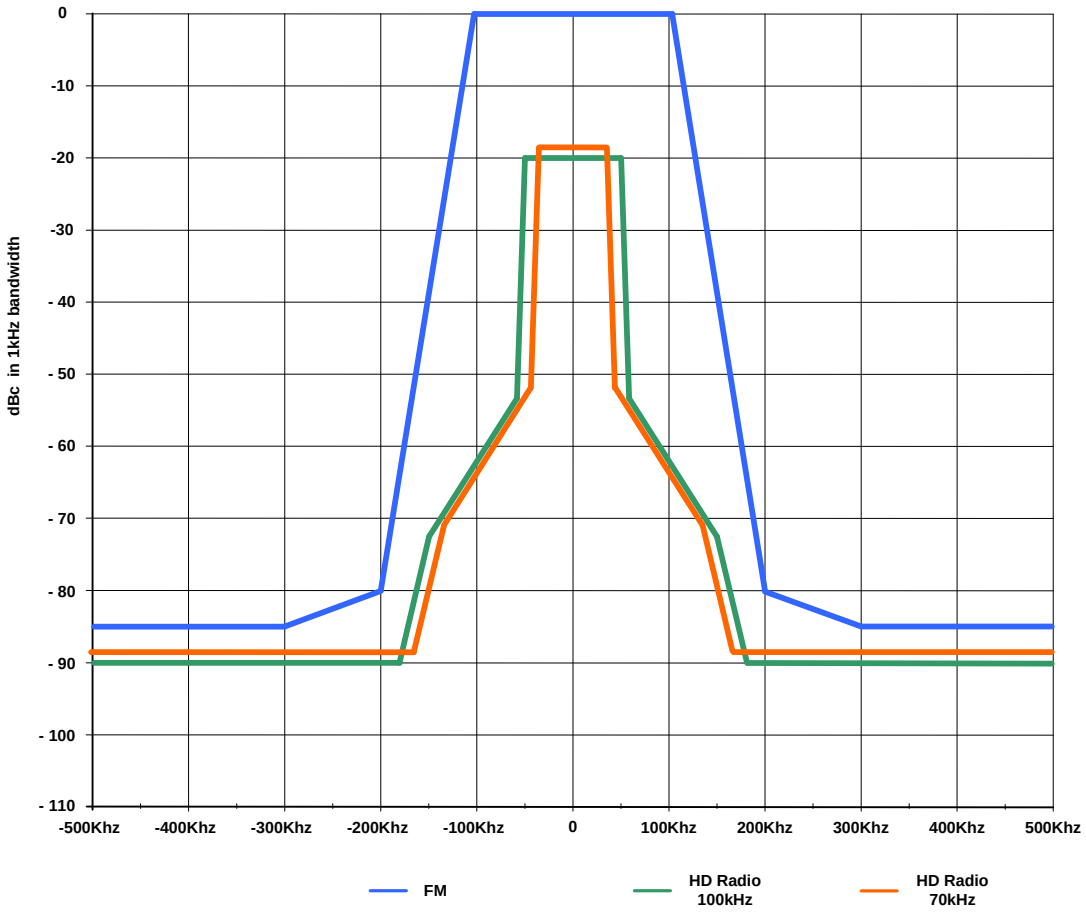


Figure 4: Out-of-band spectrum mask for HD Radio transmissions in Band II

3.4 RAVIS

3.4.1 Out-of-Band Emissions

The spectrum masks for RAVIS transmission (for three types of channel bandwidth) are given in Table 11, Table 12 and Table 13. RAVIS spectrum masks are fitting into analogue FM spectrum mask. Figure 5 sketches all three masks together with the FM spectrum mask as a reference.

Table 11: Spectrum Mask for RAVIS transmission 100 kHz bandwidth

Frequency Offset (kHz)	Level (dBc/1 kHz)
0 kHz	-20
± 50 kHz	-20
± 70 kHz	-50
± 100 kHz	-70
± 200 kHz	-80
± 300 kHz	-85
± 500 kHz	-85

Table 12: Spectrum Mask for RAVIS transmission 200 kHz bandwidth

Frequency Offset (kHz)	Level (dBc/1 kHz)
0 kHz	-23
± 100 kHz	-23
± 120 kHz	-50
± 150 kHz	-70
± 200 kHz	-80
± 300 kHz	-85
± 500 kHz	-85

Table 13: Spectrum Mask for RAVIS transmission 250 kHz bandwidth

Frequency Offset (kHz)	Level (dBc/1 kHz)
0 kHz	-24
± 125 kHz	-24
± 145 kHz	-50
± 175 kHz	-70
± 200 kHz	-80
± 300 kHz	-85
± 500 kHz	-85

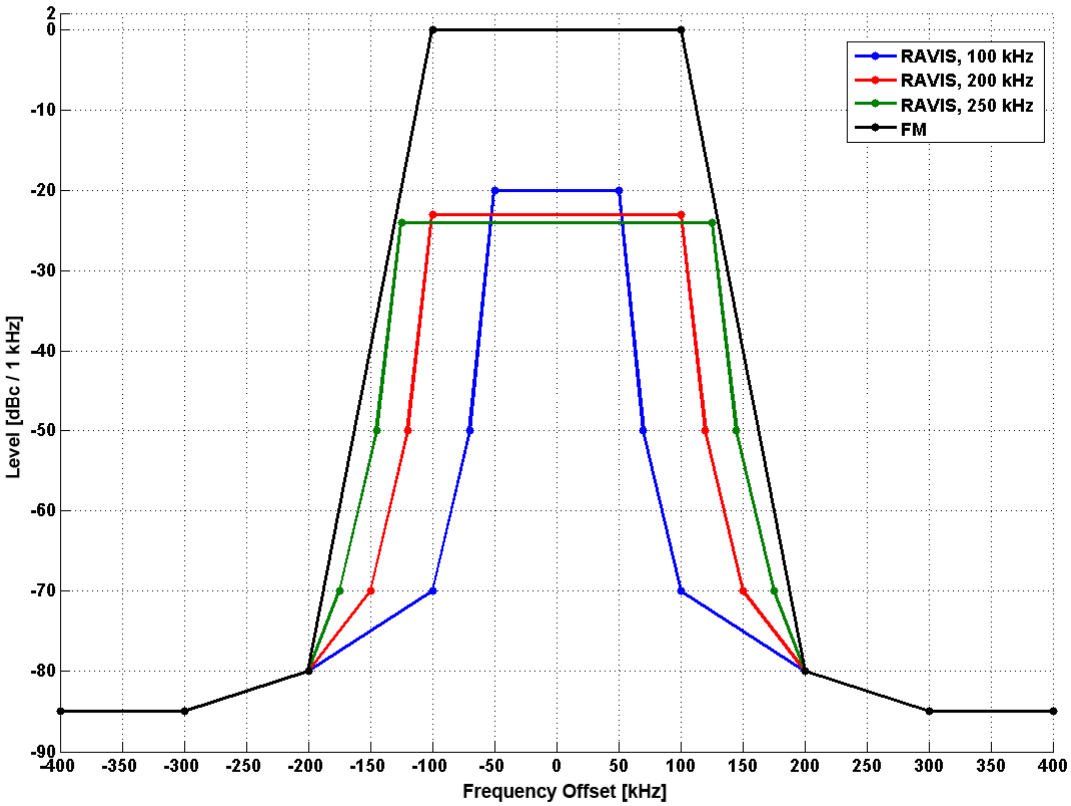


Figure 5: Out-of-band spectrum mask for RAVIS transmissions in Band II

4 PROTECTION RATIOS FOR FM

The minimum acceptable ratio between a wanted signal and interfering signals to protect the reception of the wanted signal defines the protection ratio *PR* (dB). The values of protection ratios given in this section refer to a location probability of 50%. They were determined by application of Recommendation ITU-R BS.641 [4].

The assessment of FM being interfered with by FM has to be carried out in accordance with Recommendation ITU-R BS.641 [4]. This recommendation shall be applied correspondingly in those cases where FM is interfered with by one of the digital signal types described in this report. The FM interferer has to be replaced by the digital interfering signal. The spectrum of the digital signal should resemble the shape of the corresponding spectrum mask as closely as possible.

The protection ratio for the digital systems listed below is applied to the presence of a single digital block. In the case of more than one digital block interfering with the wanted FM signal the out-of-band emission mask is applied to each digital signal block individually and each signal is treated individually for compatibility issues in Band II. It has to be noted that their aggregate impact has to be taken into account when evaluating compatibility.

4.1 FM INTERFERED WITH BY DRM

The protection ratios for FM interfered with by DRM are given in Table 14.

Table 14: Protection ratios PR_{basic} for FM interfered with by DRM

Frequency separation between centre frequencies (kHz)	0	± 100	± 200	± 300	± 400	± 500	± 1000
Basic protection ratio (dB)	49	30	3	-8	-11	-13	-21

4.2 FM INTERFERED WITH BY HD RADIO

The protection ratios for FM interfered with by a HD Radio digital signal are provided in Table 15 for 100 kHz block bandwidth and in Table 16 for 70 kHz bandwidth.

The frequency separation mentioned in the tables refers to the spectral distance between the centre of the digital HD Radio block and the centre frequency of the interfered FM signal. In the case of the 100 kHz digital block the frequency separation between this and a conceivable FM signal can take multiples of 50 kHz, i.e. *±(50 + n×100) kHz, (n=0, 1, 2, ...)*. For the case of a 70 kHz digital block the separations are *±(35 + n×100) kHz or ±(65 + n×100) kHz.*

Table 15: Protection ratios PR_{basic} for FM interfered with by HD Radio 100 kHz bandwidth

Frequency separation between centre frequencies(kHz)	± 50	± 150	± 250	± 350	± 450	± 950
Basic protection ratio (dB)	45	-4	-8	-9	-12	-26

Table16: Protection ratios PR_{basic} for FM interfered with by HD Radio 70 kHz bandwidth

Frequency separation between centre frequencies (kHz)	± 35	± 65	± 135	± 165	± 235	± 265	± 335	± 365	± 435
Basic protection ratio (dB)	44	43	-4	-5	-8	-9	-10	-10	-13

4.3 FM INTERFERED WITH BY RAVIS

The protection ratios for FM interfered with by RAVIS are given in Table 17 for 100 kHz bandwidth, in Table 18 for 200 kHz bandwidth and in Table 19 for 250 kHz bandwidth.

Table 17: Protection ratios PR_{basic} for FM interfered with by RAVIS 100 kHz bandwidth

Frequency separation between centre frequencies (kHz)	0	± 100	± 200	± 300	± 400	± 500	± 1000
Basic protection ratio (dB)	50	32	-3	-8	-10	-12	-20

Table 18: Protection ratios PR_{basic} for FM interfered with by RAVIS 200 kHz bandwidth

Frequency separation between centre frequencies (kHz)	0	± 100	± 200	± 300	± 400	± 500	± 1000
Basic protection ratio (dB)	49	46	25	-8	-10	-12	-20

Table 19: Protection ratios PR_{basic} for FM interfered with by RAVIS 250 kHz bandwidth

Frequency separation between centre frequencies (kHz)	0	± 100	± 200	± 300	± 400	± 500	± 1000
Basic protection ratio (dB)	48	45	26	-8	-10	-12	-20

5 SHARING CRITERIA WITH OTHER SERVICES

Analogue broadcasting compatibility with aeronautical services is fully specified in Recommendation ITU-R SM.1009 [10]. Digital broadcasting will have to comply with the same requirements. All broadcasting signals by definition must have the main power content contained completely within the broadcasting band.

It has to be noted that there is on-going work at the ITU to provide the necessary recommendations for the new digital transmission formats and their compatibility with aeronautical systems. Further study on this item is required. In any case restrictions need to be applied for the usage of frequencies at the boundaries of Band II.

ANNEX 1: LIST OF REFERENCES

[1] ECC Report 141: Future possibilities for the digitalisation of band II (87.5-108 MHz) (http://www.erodocdb.dk/doks/doccategoryECC.aspx?doccatid=4)

[2] GE84: Final Acts of the Regional Administrative Conference for the Planning of VHF Sound Broadcasting (Region 1 and Part of Region 3); Geneva 1984 (www.itu.int)

[3] ETSI ES 201 980: Digital Radio Mondiale (DRM); System Specification (www.etsi.org)

[4] NRSC-5C In-band/on-channel Digital Radio Broadcasting Standard

[5] Recommendation ITU-R BS.412-9: Planning standards for terrestrial FM sound broadcasting at VHF (www.itu.int)

[6] Russian Federation National Standard GOST R 54309-2011: Realtime audiovisual information system (RAVIS). Framing structure, channel coding and modulation for digital terrestrial narrowband broadcasting system for VHF band. Technical specification

[7] The Wiesbaden, 1995, Special Arrangement, as revised in Constanţa 2007 (http://www.cept.org/ecc/topics/broadcasting/t-dab)

[8] 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 (www.itu.int)

[9] ETSI EN 302 018-1 V1.2.1: Electromagnetic compatibility and Radio spectrum Matters (ERM); Transmitting equipment for the Frequency Modulated (FM) sound broadcasting service (www.etsi.org)

[10] Recommendation ITU-R SM.1009: Compatibility between the sound-broadcasting service in the band of about 87-108 MHz and the aeronautical services in the band 108-137 MHz (www.itu.int)

[11] Recommendation ITU-R BS.1114-7: Systems for terrestrial digital sound broadcasting to vehicular, portable and fixed receivers in the frequency range 30-3 000 MHz (www.itu.int)