RECOMMENDATION ITU-R BS.1615

"Planning parameters" for digital sound broadcasting at frequencies below 30 MHz

(Question ITU-R 223/10)

(2003)

The ITU Radiocommunication Assembly,

considering

a) that ITU-R is carrying out urgent studies on the development of digital broadcasting modulation emissions in the bands allocated to the broadcasting service below 30 MHz;

b) Recommendation ITU-R BS.1514 describing a digital system suitable for broadcasting in the bands below 30 MHz;

c) that values of RF protection ratios to be applied for all relevant combinations of wanted and unwanted analogue and digital emissions have not been included in the Recommendation mentioned in *considering* b);

d) that values of minimum usable field strength for wanted digital emissions have not been included in the Recommendation mentioned in *considering* b);

e) that the analogue emissions will remain in use in the LF, MF and HF bands for some time;

f) that the availability of consistent sets of "planning parameters" will facilitate the introduction of digital emissions in these bands,

recommends

1 that the relevant minimum usable field strength values[1] given in Annex 1 should be used as a guideline for the introduction of digital broadcasting services in the bands below 30 MHz;

2 that the values of RF protection ratios[2] given in Annexes 2 and 3 to this Recommendation could be used as a guideline for the introduction of digital broadcasting services in the bands referred to in *recommends* 1,

invites ITU-R

1 to develop suitable computer software for the introduction of digital broadcasting emissions in the LF, MF and HF broadcasting bands, taking into account the "planning parameters" covered in the Annexes to this Recommendation, and to participate actively in this development.

---

[1] As far as the minimum usable field strength values given in Annex 1 related to the tropical broadcasting bands are concerned, these values are a first approximation and field tests will be needed to verify these values.

[2] The parameters for digital broadcasting in the LF and MF frequency bands given in this Recommendation need to be agreed to by a competent radiocommunication conference. However, until such a conference is held, these parameters may be used, on a provisional basis, in order to enable introduction of digital broadcasting systems on an experimental basis.

Annex 1

Minimum usable field strengths for digital sound broadcasting (DSB) (Digital Radio Mondiale (DRM) system) at frequencies below 30 MHz

1 Introduction

The information on minimum usable field strength contained in this Annex relies upon measurements made using the DRM system. The values are derived from results on *S*/*N* after applying the procedure given in Appendix 1 to this Annex. The influence of the variety of system parameters as well as of the propagation conditions in the different frequency bands has been considered during the evaluation of the *S*/*N* values.

2 Relevant transmission parameters

2.1 DRM robustness modes

In the DRM specification, four robustness modes with different parameters (subcarrier number and spacing, useful symbol and guard interval length, etc.) for the orthogonal frequency division multiplex (OFDM) transmission scheme are defined for the various propagation conditions in the LF, MF and HF bands (see Table 1).

TABLE 1

DRM robustness modes

Robustness mode	Typical propagation conditions	Preferred frequency bands
A	Ground-wave channels, with minor fading	LF, MF
B	Time – and frequency-selective channels, with longer delay spread	MF, HF
C	As robustness mode B, but with higher Doppler spread	Only HF
D	As robustness mode B, but with severe delay and Doppler spread	Only HF

2.2 Spectrum occupancy types

For each robustness mode the occupied signal bandwidth can be varied dependent on the frequency band and on the desired application. The specified spectrum occupancy types are shown in Table 2.

TABLE 2

Bandwidths for DRM robustness mode combinations (kHz)

Robustness mode	Spectrum occupancy type			
	0	1	2	3
A	4.208	4.708	8.542	9.542
B	4.266	4.828	8.578	9.703
C	–	–	–	9.477
D	–	–	–	9.536
Nominal bandwidth (kHz)	4.5	5	9	10

The bandwidths in the last row of Table 2 are the nominal bandwidths for the respective spectrum occupancy types of the DRM signal and the values given in lines A to D are the exact signal bandwidths for the different robustness mode combinations.

2.3 Modulation and protection levels

Audio services are transmitted in the main service channel (MSC) of the DRM multiplex. For all robustness modes two different modulation schemes (16- or 64-QAM) are defined for the MSC, which can be used in combination with one of two (16-QAM) or four (64-QAM) protection levels, respectively.

Each protection level is characterized by a specific parameter set for the two (16-QAM) or three (64-QAM) convolutional encoders, resulting in a certain average code rate for the overall multilevel encoding process in the modulator. For 16-QAM protection level, No. 0 corresponds to an average code rate of 0.5; No. 1 to 0.62. For 64-QAM the protection levels, Nos. 0 to 3 correspond to average code rates of 0.5, 0.6, 0.71 and 0.78.

3 Computation of minimum usable field strength

To achieve a sufficiently high quality of service for a DRM digital audio service, a BER of about 1×10^{-4} is needed. The *S*/*N* required at the receiver input to achieve this BER is dependent, apart from the system parameters, also on the wave propagation conditions in the different frequency bands. Corresponding details can be found in Appendices 2 and 3 to this Annex.

On the basis of these *S*/*N* values, the minimum usable field strength can be computed applying the procedure proposed in Appendix 1 to this Annex. The relevant resulting values can be found in Tables 3 to 6. For the LF and MF bands (Tables 3 to 5), only results for the DRM robustness mode A are included. If one of the other robustness modes is intended to be used in these bands, the corresponding field strength values can be computed with the help of *S*/*N* values for these modes given in Appendix 2 to this Annex.

TABLE 3

Minimum usable field strength (dB(μV/m)) to achieve BER of 1×10^{-4} for DRM robustness mode A with spectrum occupancy types 0 or 2 (4.5 or 9 kHz) dependent on modulation scheme and protection level for the LF frequency band (ground-wave propagation)

Modulation scheme	Protection level No.	Average code rate	Robustness mode/spectrum occupancy type	
			A/0 (4.5 kHz)	A/2 (9 kHz)
16-QAM	0	0.5	39.3	39.1
	1	0.62	41.4	41.2
64-QAM	0	0.5	44.8	44.6
	1	0.6	46.3	45.8
	2	0.71	48.0	47.6
	3	0.78	49.7	49.2

TABLE 4

Minimum usable field strength (dB(μV/m)) to achieve BER of 1×10^{-4} for DRM robustness mode A with different spectrum occupancy types dependent on protection level and modulation scheme for the MF frequency band (ground-wave propagation)

Modulation scheme	Protection level No.	Average code rate	Robustness mode/spectrum occupancy type	
			A/0 (4.5 kHz), A/1 (5 kHz)	A/2 (9 kHz), A/3 (10 kHz)
16-QAM	0	0.5	33.3	33.1
	1	0.62	35.4	35.2
64-QAM	0	0.5	38.8	38.6
	1	0.6	40.3	39.8
	2	0.71	42.0	41.6
	3	0.78	43.7	43.2

TABLE 5

Minimum usable field strength (dB(μV/m)) to achieve BER of 1×10^{-4} for DRM robustness mode A with different spectrum occupancy types dependent on protection level and modulation scheme for the MF frequency band (ground-wave plus sky-wave propagation)

Modulation scheme	Protection level No.	Average code rate	Robustness mode/spectrum occupancy type	
			A/0 (4.5 kHz), A/1 (5 kHz)	A/2 (9 kHz), A/3 (10 kHz)
16-QAM	0	0.5	34.3	33.9
	1	0.62	37.2	37.0
64-QAM	0	0.5	39.7	39.4
	1	0.6	41.1	40.8
	2	0.71	44.2	43.7
	3	0.78	47.4	46.5

TABLE 6

Range of minimum usable field strengths (dB(μV/m)) to achieve BER of 1×10^{-4} for DRM robustness mode B with spectrum occupancy types 1 or 3 (5 or 10 kHz) dependent on protection level and modulation scheme for the HF frequency band

Modulation scheme	Protection level No.	Average code rate	Robustness mode/spectrum occupancy type	
			B/1 (5 kHz)	B/3 (10 kHz)
16-QAM	0	0.5	19.2-22.8	19.1-22.5
	1	0.62	22.5-25.6	22.2-25.3
64-QAM	0	0.5	25.1-28.3	24.6-27.8
	1	0.6	27.7-30.4	27.2-29.9

NOTE 1 – The derivation of the values in Tables 3 to 6 is based on the intrinsic noise level of a digital receiver as given in the last row of the Table in Appendix 1 to this Annex. However, when the effect of the external noise is greater than that of the receiver intrinsic noise, then the external noise value should replace the corresponding value of the intrinsic noise in Appendix 1 to this Annex. The adaptation of the values for minimum usable field strength in Tables 3 to 6 can be done afterwards according to the procedure described in Appendix 1 to this Annex.

Not considered in the computation of the field strength up to now are any changes in antenna design and integration into modern receivers (see also Appendix 1 to this Annex).

Table 6 shows the range for minimum usable field strength needed to achieve the BER target on HF channels using robustness mode B. This range gives an impression on the spread of the results caused by varying propagation channel conditions (for details on the system performance evaluation see Appendix 2 to this Annex). As for LF and MF bands, field strength values for other robustness modes can be computed with the *S*/*N* values given in Appendix 2 to this Annex. Only mode A is not applicable to HF transmission due to the lack of robustness in the OFDM parameters (length of the guard interval and frequency spacing of the subcarriers).

In contrast to the entries in Tables 3 to 5, results for protection level Nos. 2 and 3 in combination with 64-QAM are not included in Table 6 for HF bands, due to the occurrence of bit-error floors even at higher *S*/*N*, which are caused by the weak error protection. Therefore these protection levels are not recommended for HF transmission on channels with strong time – and/or frequency-selective behaviour (see Appendices 2 and 3 to this Annex).

4 Further remarks

In DRM field tests it was also recognized that the fading depth with the digital broadband OFDM signal was distinctly less than with the analogue AM transmission (mainly the carrier) under the same propagation conditions. This fact has to be considered either in the algorithms for prediction of median field strength (Recommendation ITU-R P.533) or for computation of transmission reliability (Recommendation ITU-R P.842) by modification of corresponding fading margins.

Furthermore, Recommendation ITU-R P.842 – Computation of reliability and compatibility of HF systems, makes simplifying assumptions that are unlikely to apply to specific digital modulation.

Appendix 1
to Annex 1

Procedure for estimation of the minimum usable field strength

1 Receiving by receivers using built-in antenna, as defined in Recommendation ITU-R BS.703 – Characteristics of AM sound broadcasting reference receivers for planning purposes.

2 Receiver sensitivity

<table>
<tr><th colspan="2"></th><th colspan="2">Double sideband (DSB) (AM)</th><th colspan="2">Digital</th></tr>
<tr><td colspan="2">1 Required receiving quality</td><td colspan="2">Audio frequency S/N:
26 dB with 30%
(−10.5 dB) modulation
(Rec. ITU-R BS.703)</td><td colspan="2">BER = 1×10^{-4}</td></tr>
<tr><td colspan="2">2 Required C/N for the above quality (dB)</td><td colspan="2">26 + 10.5 = 36.5</td><td colspan="2">x</td></tr>
<tr><td colspan="2">3 Receiver IF bandwidth (kHz)</td><td colspan="2">8</td><td colspan="2">10
(1 dB higher receiver intrinsic noise than DSB)</td></tr>
<tr><td rowspan="3">4 Receiver sensitivity for the above C/N (dB(μV/m))</td><td>LF</td><td>66</td><td rowspan="3">Required in Recommendation ITU-R BS.703</td><td>30.5 + x</td><td rowspan="3">(x dB above the receiver intrinsic noise)</td></tr>
<tr><td>MF</td><td>60</td><td>24.5 + x</td></tr>
<tr><td>HF</td><td>40</td><td>4.5 + x</td></tr>
<tr><td rowspan="3">5 Receiver intrinsic noise related to field strength, for the above sensitivity (dB(μV/m))</td><td>LF</td><td>29.5</td><td rowspan="3">(36.5 dB (C/N) below the sensitivity)</td><td>30.5</td><td rowspan="3">(1 dB higher than DSB)</td></tr>
<tr><td>MF</td><td>23.5</td><td>24.5</td></tr>
<tr><td>HF</td><td>3.5(1)</td><td>4.5</td></tr>
</table>

(1) This value, 3.5 dB(μV/m), is also indicated in Annex 4 to Recommendation ITU-R BS.560.

NOTE 1 – In the case of the digital receiver, the expression *S*/*N* should be used instead of *C*/*N* which is used for the analogue DSB receiver.

NOTE 2 – Intrinsic noise of the reference DSB receiver can be calculated as 36.5 dB below the sensitivity.

NOTE 3 – Intrinsic noise of the reference digital receiver is estimated about 1 dB higher than DSB due to IF bandwidth difference. And the sensitivity of the reference digital receiver for *x* dB *S*/*N* is calculated as *x* dB above that. The value *x* is taken from Table 8.

NOTE 4 – The increase of antenna loss for any receiver that uses a small-sized built-in antenna directly increases the receiver intrinsic noise related to the field strength. This should be taken into account.

3 Other factors to be considered

The external noise level (increasing man-made noise) and the pulse nature of some of the external noise have to be considered. Recommendation ITU-R P.372 deals with radio noise, including some information on impulsive noise. This provides some indication of the noise levels encountered by a digital system. The integrated effects of distant thunderstorms are also included and the statistical characteristics of the amplitude probability density function are modelled. The method of applying the information is given in Recommendation ITU-R P.372.

Appendix 2 to Annex 1

Required *S*/*N* ratios for DRM reception

1 Introduction

In Recommendation ITU-R BS.1514, the use of the DRM system was recommended for DSB in the broadcasting frequency bands below 30 MHz. To achieve a sufficiently high quality of service for a digital audio programme transmitted via this system, a BER of about 1×10^{-4} is needed. In the following values on *S*/*N* ratios required to achieve this BER are given for typical propagation conditions on the relevant frequency bands. The values were derived by tests with receiver equipment recently developed on the basis of the current DRM specification published as TS 101 980 (V1.1.1) in September 2001 by the European Telecommunications Standards Institute (ETSI). With these *S*/*N* values the corresponding minimum usable field strengths can be computed applying the procedure proposed in Appendix 1 to Annex 1.

2 *S*/*N* values for LF/MF bands

In Appendix 3 to Annex 1 a detailed description of transmission channel models used to evaluate the system performance can be found. Channel model No. 1 represents the typical behaviour of a transmission channel with ground-wave propagation during daytime in LF and MF bands. In Table 7 the required *S*/*N* for the different robustness modes and their typical spectrum occupancy types (2 for mode A, i.e. nominal channel bandwidth of 9 kHz, and 3, i.e. 10 kHz, for the others) to achieve a BER of 1×10^{-4} on this channel is given.

TABLE 7

S/N (dB) to achieve BER of 1×10^{-4} for all DRM robustness modes with spectrum occupancy types 2 or 3 (9 or 10 kHz) dependent on modulation scheme and protection level for channel model No. 1

Modulation scheme	Protection level No.	Average code rate	Robustness mode/spectrum occupancy type			
			A/2 (9 kHz)	B/3 (10 kHz)	C/3 (10 kHz)	D/3 (10 kHz)
16-QAM	0	0.5	8.6	9.3	9.6	10.2
	1	0.62	10.7	11.3	11.6	12.1
64-QAM	0	0.5	14.1	14.7	15.1	15.9
	1	0.6	15.3	15.9	16.3	17.2
	2	0.71	17.1	17.7	18.1	19.1
	3	0.78	18.7	19.3	19.7	21.4

For real transmissions based on ground-wave propagation only the use of robustness mode A is recommended because of the higher achievable service data rate. The values for the other modes are included in Table 7 only for reference. The degradation of their performance in S/N compared with mode A can be explained by the fact that the ratio between the numbers of data and pilot subcarriers is varying from mode to mode. With the robustness of the mode the number of pilot subcarriers, which are boosted in power in comparison with data subcarriers, also increases and therefore the average usable power of the remaining data subcarriers decreases.

For simulcast applications in a nominal channel bandwidth of 9 or 10 kHz DRM spectrum occupancy types 0 and 1 are suitable. Only robustness modes A and B are providing this feature. The corresponding S/N values for channel model No. 1 can be found in Table 8.

TABLE 8

S/N (dB) to achieve BER of 1×10^{-4} for DRM robustness modes A and B with spectrum occupancy type 0 or 1 (4.5 or 5 kHz) dependent on modulation scheme and protection level for channel model No. 1

Modulation scheme	Protection level No.	Average code rate	Robustness mode/spectrum occupancy type	
			A/0 (4.5 kHz)	B/1 (5 kHz)
16-QAM	0	0.5	8.8	9.5
	1	0.62	10.9	11.5
64-QAM	0	0.5	14.3	14.9
	1	0.6	15.8	16.2
	2	0.71	17.5	17.9
	3	0.78	19.2	19.5

For the application of robustness mode A with spectrum occupancy types 1 or 3 or mode B with 0 or 2 the *S*/*N* values in Tables 7 and 8 are also recommended, because differences in performance are less than 0.1 dB.

In contrast to channel model No. 1 the channel model No. 2 represents a wave propagation model for MF bands at night-time including a delayed sky wave in addition to the ground wave. The required *S*/*N* for this channel model is shown in Table 9. Only results for the relevant robustness modes A and B are given (also for lower spectrum occupancy types).

TABLE 9

S/N (dB) to achieve BER of 1×10^{-4} for DRM robustness modes A and B with different spectrum occupancy types dependent on modulation scheme and protection level for channel model No. 2

Modulation scheme	Protection level No.	Average code rate	Robustness mode/spectrum occupancy type			
			A/0 (4.5 kHz)	A/2 (9 kHz)	B/1 (5 kHz)	B/3 (10 kHz)
16-QAM	0	0.5	9.8	9.4	10.3	10.2
	1	0.62	12.7	12.5	13.2	13.1
64-QAM	0	0.5	15.2	14.9	15.8	15.6
	1	0.6	16.6	16.3	17.3	16.9
	2	0.71	19.7	19.2	20.4	19.7
	3	0.78	22.9	22.0	22.8	22.3

Compared with pure ground-wave propagation the system performance degrades due to the increased frequency-selectivity and especially the slowly time-selective channel behaviour caused by the sky wave. The values indicate the correlation between the strength of the channel coding and the *S*/*N* impairment, i.e. with increasing coding rate the impairment increases, too. But for correct interpretation of the results it has to be considered that under the assumption of the same noise power as for pure ground-wave propagation the additional sky-wave power would lead to a gain in received signal power of approximately 1 dB, i.e. the resulting impairment in that case is only marginal, at least for a sufficient strength of the applied error protection scheme (protection levels Nos. 0 and 1).

3 *S*/*N* values for HF bands

In Tables 10 to 13 the *S*/*N* values for the three robustness modes suited for HF transmission are given for channel models Nos. 3 to 6. Mode A is not able to be applied for HF due to the lack of robustness in the OFDM parameters (length of the guard interval and frequency spacing of the subcarriers). In the case of mode B, results both for spectrum occupancy type 1 and 3 are included. Only robustness mode D is applicable also for channels with extremely long path delays and Doppler spreads as defined with channel model No. 6, which is a typical example for tropical-near-vertical incidence sky-wave propagation.

TABLE 10

S/N (dB) to achieve BER of 1×10^{-4} for DRM robustness mode B with spectrum occupancy type 1 dependent on modulation scheme and protection level for channel model Nos. 3 to 6

Modulation scheme	Protection level No.	Average code rate	Channel model No.			
			3	4	5	6
16-QAM	0	0.5	18.3	16.2	14.7	–
	1	0.62	21.1	19.3	18.0	–
64-QAM	0	0.5	23.8	21.5	20.6	–
	1	0.6	25.9	23.7	23.2	–
	2	0.71	29.0(1)	27.0(1)	29.4(1)	–
	3	0.78	31.2(1)	30.0(1)	–	–

(1) Protection levels not recommended for use in HF propagation conditions with severe time- and frequency-selective fading.

TABLE 11

S/N (dB) to achieve BER of 1×10^{-4} for DRM robustness mode B with spectrum occupancy type 3 dependent on modulation scheme and protection level for channel model Nos. 3 to 6

Modulation scheme	Protection level No.	Average code rate	Channel model No.			
			3	4	5	6
16-QAM	0	0.5	18.0	16.0	14.6	–
	1	0.62	20.8	19.0	17.7	–
64-QAM	0	0.5	23.3	21.3	20.1	–
	1	0.6	25.4	23.5	22.7	–
	2	0.71	28.3(1)	26.8(1)	27.0(1)	–
	3	0.78	30.9(1)	29.7(1)	–	–

(1) Protection levels not recommended for use in HF propagation conditions with severe time- and frequency-selective fading.

TABLE 12

S/N (dB) to achieve BER of 1×10^{-4} for DRM robustness mode C with spectrum occupancy type 3 dependent on modulation scheme and protection level for channel model Nos. 3 to 6

Modulation scheme	Protection level No.	Average code rate	Channel model No.			
			3	4	5	6
16-QAM	0	0.5	18.0	16.5	14.6	–
	1	0.62	20.9	19.1	17.6	–
64-QAM	0	0.5	23.6	21.3	20.2	–
	1	0.6	25.6	23.7	22.3	–
	2	0.71	29.0(1)	26.8(1)	26.4(1)	–
	3	0.78	32.3(1)	29.6(1)	33.3(1)	–

(1) Protection levels not recommended for use in HF propagation conditions with severe time- and frequency-selective fading.

TABLE 13

S/N (dB) to achieve BER of 1×10^{-4} for DRM robustness mode D with spectrum occupancy type 3 dependent on modulation scheme and protection level on channel model Nos. 3 to 6

Modulation scheme	Protection level No.	Average code rate	Channel model No.			
			3	4	5	6
16-QAM	0	0.5	18.5	16.9	15.3	16.0
	1	0.62	21.2	19.9	18.3	19.2
64-QAM	0	0.5	24.2	22.2	20.8	22.1
	1	0.6	26.3	24.5	22.9	25.2
	2	0.71	29.2(1)	27.6(1)	27.2(1)	29.3(1)
	3	0.78	32.1(1)	31.7(1)	35.5(1)	32.5(1)

(1) Protection levels not recommended for use in HF propagation conditions with severe time- and frequency-selective fading.

For 16-QAM modulation and also for 64-QAM with strong error protection (protection levels Nos. 0 and 1) robustness mode B achieves the best performance, i.e. the lowest S/N values are required to achieve high quality audio transmission. On channel model No. 5, where the fast-fading on the two paths is dominating, the better robustness of mode C and D in view of synchronization and channel estimation plays a more and more important role in the case of reduced coding strength.

Nevertheless, the results for protection level Nos. 2 and 3 in combination with 64-QAM show an increasing performance degradation due to the occurrence of a bit-error floor even at higher S/N. Therefore these protection levels are not recommended for HF transmission on channels with strong time- and/or frequency-selective behaviour like channel models Nos. 3 to 6. It also has to be kept in mind that the results given in the different tables may represent typical bad cases for HF transmission, but not necessarily the worst ones. The *S*/*N* values for HF and also for MF with sky-wave propagation have to be seen as a useful index for the achievement of the required quality of service, but cannot guarantee it under all circumstances.

Appendix 3
to Annex 1

Prediction and modelling of radiowave propagation for DSB at frequencies below 30 MHz

1 Introduction

For the introduction of DSB the effect of the radio channels on the reception quality in the LF, MF and HF bands has to be considered. In principle all three are multipath channels, because the surface of the Earth and the ionosphere are involved in the mechanism of electromagnetic wave propagation. In the following parts of this Appendix, methods to predict and to simulate the multipath profiles are described.

2 Prediction of HF sky-wave propagation

For sky-wave propagation, Recommendation ITU-R P.533 – HF propagation prediction method, provides within the method parameters for wave propagation mode and field strength. The time delay of an individual wave propagation mode, as predicted in this Recommendation for ranges up to 7 000 km, is given by:

$$\tau = (p'/c) \times 10^3 \qquad \text{ms}$$

where:

p': virtual slant range (km)

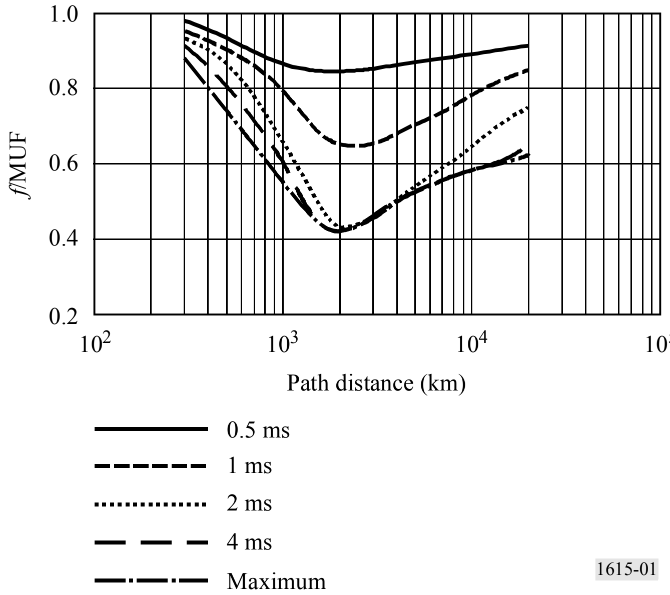
c: velocity of light (km/s).

The values of time delay for each individual mode may be used in conjunction with the predicted field strength for each mode, as determined according to the procedure in § 5.1.3 of the Recommendation ITU-R P.533 to give the median time-delay profile, thereby estimating multipath time spread.

When a single propagation mode (e.g. one-hop F) is operational, the propagation may comprise up to four multipath components, as there can be both O and X (magneto-ionic polarization components), and both high- and low-angle rays at frequencies near the maximum usable frequency (MUF). When the ratio of working frequency/MUF exceeds 0.9, the magneto-ionic components are resolvable and there are two to four rays with equal relative powers and total time dispersion about 0.3 to 0.6 ms. As the ratio of working frequency/MUF decreases below 0.9 the O and X modes merge and the high-angle ray becomes defocused and disappears, limiting the total dispersion for the path. As guidance, typical values for the maximum multipath spread are shown in Fig. 1 for various ranges and ratios of the working frequency to the instantaneous path MUF.

FIGURE 1

Multipath delay time



These values may not apply for paths which traverse the equatorial (low magnetic dip) region after sunset, or the auroral regions during times of ionospheric disturbance. In such cases, the time dispersion may increase up to a maximum of about 4 ms. This is likely to be most severe during the major periods of occurrence of equatorial ionospheric irregularities, i.e. March-April, June and September-October.

As assistance in gauging the mode structure and the multimode fading of HF sky-wave signals, each mode may be approximately described by a Rice-Nakagami distribution, where the *k*-factor will describe the ratio of the specular to diffuse reflection from the layer.

3 Prediction of MF ground- and sky-wave propagation

As regards MF, the simplistic approach of Recommendation ITU-R P.1321 – Propagation factors affecting systems using digital modulation techniques at LF and MF is recommended for both ground-wave and sky-wave predictions.

4 Modelling of propagation channels

The approach is to use stochastic time-varying models with stationary statistics and define models for good, moderate and bad conditions by taking appropriate parameter values of the general model. One of those models with adaptable parameters is the wide sense stationary uncorrelated scattering (WSSUS) model. The justification for the stationary approach with different parameter sets is that results on real channels lead to BER curves between best and worst cases found in the simulation.

The channel models have been generated from the following equations where $e(t)$ and $s(t)$ are the complex envelops of the input and output signals respectively:

$$s(t) = \sum_{k=1}^{n} \rho_k c_k(t)\, e(t - \Delta_k) \tag{1}$$

This is a tapped delay-line where:

ρ_k: attenuation of the path number k (listed in Table 14)

Δ_k: relative delay of the path number k (listed in Table 14).

The time-variant tap weights $\{c_k(t)\}$ are zero mean complex-valued stationary Gaussian random processes. The magnitudes $|c_k(t)|$ are Rayleigh-distributed and the phases $\Phi(t)$ are uniformly distributed.

For each weight $\{c_k(t)\}$ there is one stochastic process, characterized by its variance and its power density spectrum (PDS). The variance is a measure for the average signal power, which is received via this path and is defined by the relative attenuation ρ_k, and the PDS determines the average speed of variation in time. The width of the PDS is quantified by a number and is referred to as the Doppler spread, D_{sp}, of that path (listed in Table 14).

There might be also a non-zero centre frequency of the PDS, which can be interpreted as an average frequency shift or Doppler shift, D_{sh}, (listed in Table 14).

The PDS is modelled by filtering white noise (i.e. with constant PDS) and is equal to:

$$\varphi_{n_t n_t}(f) = N_0 |H(f)|^2 \tag{2}$$

$H(f)$ is the transfer function of the filter. The stochastic processes belonging to every individual path then become Rayleigh processes. For the ionospheric path, a Gaussian shape has proven to be a good approach with respect to real observations.

The Doppler profile on each path k is then defined as:

$$|H(f)|^2 = \frac{1}{\sqrt{2\pi\sigma_d^2}}\, e^{-\frac{(f - D_{sh})^2}{2\sigma_d^2}} \tag{3}$$

The Doppler spread is specified as two-sided and contains 68% of the power:

$$D_{sp} = 2\sigma_d \tag{4}$$

TABLE 14

Set of transmission channel models

Channel model No. 1 **(additive white Gaussian noise)**		**Good:** **LF, MF, HF** **Typical/moderate:** **LF with variable S/N** **Bad:**		
	Path 1			
Delay, Δ_k (ms)	0			
Path gain, r.m.s., ρ_k	1			
Doppler shift, D_{sh} (Hz)	0			
Doppler spread, D_{sp} (Hz)	0			

Channel model No. 2 **(ground wave + sky wave)**		**Good:** **Typical/moderate:** **MF, HF** **Bad:**		
	Path 1	Path 2		
Delay, Δ_k (ms)	0	1		
Path gain, r.m.s., ρ_k	1	0.5		
Doppler shift, D_{sh} (Hz)	0	0		
Doppler spread, D_{sp} (Hz)	0	0.1		

Channel model No. 3		**Good:** **Typical/moderate:** **HF** **Bad:** **MF**		
	Path 1	Path 2	Path 3	Path 4
Delay, Δ_k (ms)	0	0.7	1.5	2.2
Path gain, r.m.s., ρ_k	1	0.7	0.5	0.25
Doppler shift, D_{sh} (Hz)	0.1	0.2	0.5	1.0
Doppler spread, D_{sp} (Hz)	0.1	0.5	1.0	2.0

Channel model No. 4		**Good:** **Typical/moderate:** **Bad** **HF**		
	Path 1	Path 2		
Delay, Δ_k (ms)	0	2		
Path gain, r.m.s., ρ_k	1	1		
Doppler shift, D_{sh} (Hz)	0	0		
Doppler spread, D_{sp} (Hz)	1	1		

TABLE 14 (*end*)

Channel model No. 5		**Good:** **Typical/moderate:** **Bad: HF**		
	Path 1	Path 2		
Delay, Δ_k (ms)	0	4		
Path gain, r.m.s., ρ_k	1	1		
Doppler shift, D_{sh} (Hz)	0	0		
Doppler spread, D_{sp} (Hz)	2	2		

Channel model No, 6 (near vertical incidence in tropical zones)		**Good:** **Typical/moderate:** **Bad: HF**		
	Path 1	Path 2	Path 3	Path 4
Delay, Δ_k (ms)	0	2	4	6
Path gain, r.m.s., ρ_k	0.5	1	0.25	0.0625
Doppler shift, D_{sh} (Hz)	0	1.2	2.4	3.6
Doppler spread, D_{sp} (Hz)	0.1	2.4	4.8	7.2

Annex 2

RF protection ratios for DSB (DRM system) at frequencies below 30 MHz

1 Introduction

The DRM specification allows for several robustness modes (A to D) and spectrum occupancy types (0 to 5) of DRM signals. Only certain combinations of robustness modes (A to D) and spectrum occupancy types (0 to 3) are used in this Annex. The parameters for the used mode combinations, i.e. the respective number of subcarriers and the corresponding subcarrier spacing in the OFDM signal, lead to the bandwidths in rows A to D of Table 15.

TABLE 15

Bandwidths for DRM mode combinations (kHz)

Robustness mode	**Spectrum occupancy type**			
	0	**1**	**2**	**3**
A	4.208	4.708	8.542	9.542
B	4.266	4.828	8.578	9.703
C				9.477
D				9.536
Nominal bandwidth (kHz)	4.5	5	9	10

The bandwidths in the last row of Table 15 are the nominal bandwidths for the respective spectrum occupancies of the DRM signal, and the values given in lines A to D are the exact signal bandwidths for the different mode combinations.

2 RF protection ratios

The combinations of spectrum occupancy types and robustness modes lead to several transmitter RF spectra, which cause different interference and therefore require different RF protection ratios. The applied calculation method is described in detail in Appendix 2 to this Annex. The differences in protection ratios for the different DRM robustness modes are quite small. Therefore, the RF protection ratios presented in the following tables are restricted to the robustness mode B. More calculation results are presented in Appendix 1 to this Annex.

Table 16 shows calculation results for AM interfered with by digital and Table 17, digital interfered with by AM. These values are calculated for AM signals with high compression. The RF protection ratios for digital interfered with by digital are given in Table 18. Correction values for DRM reception using different modulation schemes and protection levels are given in Table 19.

The values in Tables 16 to 18 represent relative RF protection ratios, $A_{RF\_relative}$. For the pure AM case, the relative protection ratio is the difference in dB between the protection ratio when the carriers of the wanted and unwanted transmitters have a frequency difference of Δf Hz and the protection ratio when the carriers of these transmitters have the same frequency (Recommendation ITU-R BS.560), i.e. the co-channel RF protection ratio, A_{RF}, which corresponds to the audio frequency (AF) protection ratio, A_{AF}. In the case of a digital signal its nominal frequency instead of the carrier frequency is the relevant value for the determination of the frequency difference. For spectrum occupancy types 2 and 3 the nominal frequency corresponds to the centre frequency of the OFDM block, for the types 0 and 1 the centre frequency is shifted about 2.2 and 2.4 kHz, respectively, above the nominal frequency. Due to the fact that the spectrum of the interference signal is different from the AF spectrum of analogue AM, the values for relative RF protection ratio in the case of co-channel interference are not equal to zero.

To adjust Table 16 to a given AM planning scenario, the relevant AF protection ratio has to be added to the values in the Table to get the required RF protection ratio (see Appendix 2 to this Annex). Relevant values may be determined taking into account:

– for HF, the AF protection ratio of 17 dB, which was adopted for HFBC planning by WARC HFBC-87 for AM interfered with by AM;

– for LF/MF, the AF protection of 30 dB, which was adopted by the Regional Administrative LF/MF Broadcasting Conference for Regions 1 and 3 (Geneva, 1975) for AM interfered with by AM.

With DRM as the wanted signal, the AF protection ratio as a parameter for the quality of service has to be replaced by the S/I required to achieve a certain BER. A BER threshold of 1×10^{-4} is supposed for the calculations (see Annex 1). The protection ratio values in Tables 17 and 18 are based on 64-QAM modulation and protection level No. 1. For other combinations the correction values in Table 19 have to be added to the S/I values given in the Tables.

TABLE 16

Relative RF protection ratios between broadcasting systems below 30 MHz (dB)
AM interfered with by digital

Wanted signal	Unwanted signal	Frequency separation, $f_{unwanted} - f_{wanted}$ (kHz)													Parameters	
		–20	–18	–15	–10	–9	–5	0	5	9	10	15	18	20	B_{DRM} (kHz)	A_{AF} [(1),(2)] (dB)
AM	DRM_B0[(3)]	–50.4	–50.4	–49	–35.5	–28.4	6.4	6.6	–30.9	–46.7	–48.2	–50.4	–50.4	–50.4	4.5	–
AM	DRM_B1[(4)]	–51	–50.5	–47.6	–32	–23.8	6	6	–31.1	45.7	47.4	–51	–51	–51	5	–
AM	DRM_B2	–48.8	–46.9	–43.5	–34.4	–29.7	3.4	6.5	3.4	–29.7	–34.4	–43.5	–46.9	–48.8	9	–
AM	DRM_B3	–47.2	–45.3	–41.9	–32	–25.9	3	6	3	–25.9	–32	–41.9	–45.3	–47.2	10	–

B_{DRM}: nominal bandwidth of DRM signal

DRM_B0: DRM signal, robustness mode B, spectrum occupancy type 0

(1) The RF protection ratio for AM interfered with by digital can be calculated by adding a suitable value for the AF protection ratio according to a given planning scenario to the values in the table.

(2) The values presented in this table refer to the specific case of high AM compression. For consistency with Table 17, the same modulation depth, namely that associated with high compression, has been assumed for the AM signal. In order to offer adequate protection to AM signals with normal levels of compression (as defined in Appendix 1 to Annex 2), each value in the Table should be increased to accommodate the difference between normal and high compression.

(3) The centre frequency of DRM_B0 transmission is shifted about 2.2 kHz above the nominal frequency.

(4) The centre frequency of DRM_B1 transmission is shifted about 2.4 kHz above the nominal frequency.

TABLE 17

Relative RF protection ratios between broadcasting systems below 30 MHz (dB)
Digital (64-QAM, protection level No. 1) interfered with by AM

Wanted signal	Unwanted signal	Frequency separation, $f_{unwanted} - f_{wanted}$ (kHz)													Parameters	
		–20	–18	–15	–10	–9	–5	0	5	9	10	15	18	20	B_{DRM} (kHz)	S/I (dB)
DRM_B0[(1)]	AM	–57.7	–55.5	–52.2	–46.1	–45	–36.2	0	–3.5	–30.9	–41.1	–46.9	–50.6	–53	4.5	4.6
DRM_B1[(2)]	AM	–57.4	–55.2	–51.9	–45.9	–44.7	–36	0	–0.2	–22	–37.6	–46	–49.6	–52	5	4.6
DRM_B2	AM	–54.6	–52.4	–48.8	–42.8	–33.7	–6.4	0	–6.4	–33.7	–42.8	–48.8	–52.4	–54.6	9	7.3
DRM_B3	AM	–53.9	–51.5	–48	–39.9	–25	–3.1	0	–3.1	–25	–39.9	–48	–51.5	–53.9	10	7.3

S/*I*: signal-to-interference ratio for a BER of 1×10^{-4}

(1) The centre frequency of DRM_B0 transmission is shifted about 2.2 kHz above the nominal frequency.

(2) The centre frequency of DRM_B1 transmission is shifted about 2.4 kHz above the nominal frequency.

TABLE 18

Relative RF protection ratios between broadcasting systems below 30 MHz (dB)
Digital (64-QAM, protection level No. 1) interfered with by digital

Wanted signal	Unwanted signal	Frequency separation, $f_{unwanted} - f_{wanted}$ (kHz)													Parameters	
		–20	–18	–15	–10	–9	–5	0	5	9	10	15	18	20	B_{DRM} (kHz)	*S/I* (dB)
DRM_B0	DRM_B0	–60	–59.9	–60	–55.2	–53.2	–40.8	0	–40.8	–53.2	–55.2	–60	–59.9	–60	4.5	16.2
DRM_B0	DRM_B1	–60.1	–60	–59.5	–52.5	–50.4	–37.4	0	–40	–51.6	–53.6	–59.8	–60	–60.1	5	15.7
DRM_B0	DRM_B2	–57.4	–55.7	–52.9	–46.7	–45.1	–36.6	0	–0.8	–35.6	–38.4	–47.7	–51.5	–53.6	9	13.2
DRM_B0	DRM_B3	–55.2	–53.6	–50.7	–44.5	–42.9	–33.1	0	–0.1	–13.6	–36.2	–45.5	–49.3	–51.4	10	12.6
DRM_B1	DRM_B0	–59.4	–59.5	–59.5	–55	–53	–40.8	0	–37.9	–51.7	–53.9	–59.4	–59.5	–59.4	4.5	16.2
DRM_B1	DRM_B1	–60	–60	–59.5	–52.8	–50.8	–37.8	0	–37.8	–50.8	–52.8	–59.5	–60	–60	5	16.2
DRM_B1	DRM_B2	–57.1	–55.4	–52.6	–46.4	–44.9	–36.4	0	–0.1	–13.7	–36.8	–46.6	–50.5	–52.7	9	13.2
DRM_B1	DRM_B3	–55.5	–53.8	–51	–44.8	–43.3	–33.5	0	–0.1	–8.1	–35.2	–45	–48.9	–51.1	10	13.2
DRM_B2	DRM_B0	–57	–56.8	–54.8	–43.4	–39.1	–0.7	0	–40.6	–52.2	–53.9	–57	–57	–57	4.5	15.9
DRM_B2	DRM_B1	–56.9	–56.1	–52.7	–40.2	–14.1	–0.1	0	–39.7	–50.8	–52.5	–56.9	–57	–57	5	15.4
DRM_B2	DRM_B2	–55.1	–53.1	–49.5	–40.7	–38.1	–3.7	0	–3.7	–38.1	–40.7	–49.5	–53.1	–55.1	9	15.9
DRM_B2	DRM_B3	–52.9	–51	–47.4	–38.6	–16.6	–3.2	0	–3.2	–16.6	–38.6	–47.4	–51	–52.9	10	15.4
DRM_B3	DRM_B0	–56.4	–56.2	–53.8	–41.1	–14.1	–0.1	0	–37.7	–50.9	–52.8	–56.4	–56.4	–56.4	4.5	15.9
DRM_B3	DRM_B1	–56.8	–55.7	–52.1	–38.2	–8.2	–0.1	0	–37.6	–50.1	–51.9	–56.7	–57	–57	5	15.9
DRM_B3	DRM_B2	–54.3	–52.3	–48.6	–39.3	–16.7	–3.1	0	–3.1	–16.7	–39.3	–48.6	–52.3	–54.3	9	15.9
DRM_B3	DRM_B3	–52.7	–50.7	–47	–37.7	–11.1	–3.1	0	–3.1	–11.1	–37.7	–47	–50.7	–52.7	10	15.9

TABLE 19

S/I correction values in Tables 17 and 18 to be used for other combinations of modulation scheme and protection level No.

Modulation scheme	Protection level No.	Average code rate	Correction values (dB) for DRM robustness mode/spectrum occupancy type	
			B/0 (4.5 kHz), B/1 (5 kHz)	B/2 (9 kHz), B/3 (10 kHz)
16-QAM	0	0.5	–6.7	–6.6
	1	0.62	–4.7	–4.6
64-QAM	0	0.5	–1.3	–1.2
	1	0.6	0.0	0.0
	2	0.71	1.7	1.8
	3	0.78	3.3	3.4

3 RF power reduction for DSB

For the introduction of a digitally modulated signal in an existing environment, it has to be ensured that this new signal will not cause more interference to other AM stations than the AM signal which is replaced by the digitally modulated signal. Values for the required power reduction to fulfil this requirement can easily be found when the RF protection ratios for AM interfered with by AM and AM interfered with by digital are known.

The RF protection ratio is the required power difference between the wanted and the unwanted signal which ascertains a stated quality (either analogue audio or digital S/N). When the wanted audio quality is comparable for AM interfered with by AM and AM interfered with by digital, the difference in RF protection ratio is the required power reduction.

Recommendation ITU-R BS.560 contains relative RF protection ratios for AM interfered with by AM (see Table 20).

TABLE 20

Relative RF protection ratios for AM interfered with by AM

Wanted signal	Unwanted signal	Frequency separation, $f_{unwanted} - f_{wanted}$ (kHz)												
		–20	–18	–15	–10	–9	–5	0	5	9	10	15	18	20
AM	AM	–55.4	–53.3	–49.5	–35.5	–29.0	–2.5	0.0	–2.5	–29.0	–35.5	–49.5	–53.3	–55.4

With that knowledge, the required power reduction for the different DRM modes can be calculated as the difference of the values of Table 23 and of Table 20. The result is given in Table 21.

TABLE 21

Required power reduction

Replaced signal	New signal	Frequency separation, $f_{unwanted} - f_{wanted}$ (kHz)													Parameter	
		–20	–18	–15	–10	–9	–5	0	5	9	10	15	18	20	B_{DRM} (kHz)	A_{AF} (dB)
AM	DRM_A0	5	2.9	0.4	–0.1	0.5	9	6.6	–28.6	–17.9	–12.8	–0.9	2.9	5	4.5	–
AM	DRM_A1	4.5	2.7	1.6	3	4.5	8.6	6.1	–28.8	–17	–12.2	–1.4	2.4	4.5	5	–
AM	DRM_A2	6.5	6.3	5.9	1	–0.8	5.9	6.6	5.9	–0.8	1	5.9	6.3	6.5	9	–
AM	DRM_A3	8	7.8	7.4	3.1	2.5	5.6	6.1	5.6	2.5	3.1	7.4	7.8	8	10	–
AM	DRM_B0	5	2.9	0.5	0	0.6	8.9	6.6	–28.4	–17.7	–12.7	–0.9	2.9	5	4.5	–
AM	DRM_B1	4.4	2.8	1.9	3.5	5.2	8.5	6	–28.6	–16.7	–11.9	–1.5	2.3	4.4	5	–
AM	DRM_B2	6.6	6.4	6	1.1	–0.7	5.9	6.5	5.9	–0.7	1.1	6	6.4	6.6	9	–
AM	DRM_B3	8.2	8	7.6	3.5	3.1	5.5	6	5.5	3.1	3.5	7.6	8	8.2	10	–
AM	DRM_C3	7.9	7.7	7.3	2.9	2.3	5.6	6.1	5.6	2.3	2.9	7.3	7.7	7.9	10	–
AM	DRM_D3	8	7.8	7.3	3.1	2.5	5.6	6.1	5.6	2.5	3.1	7.3	7.8	8	10	–

In Table 21, it can be seen that for some modes the required power reduction to restrict the interference to AM transmissions at certain frequency separations is somewhat higher than the co-channel value. In that case it has to be considered if the digitally modulated signal appears somewhere as interferer with one of these frequency separations and if it is the strongest interferer. If that is the case, the higher value has to be taken into account.

Appendix 1
to Annex 2

Calculated RF protection ratios for DSB (DRM system) at frequencies below 30 MHz

1 Introduction

In this Appendix, more information on calculated RF protection ratios, which are required for AM and DRM reception, is given. The RF protection ratios are derived using the parameters given in § 1 of Appendix 2 to this Annex and applying the calculation method described in § 2 of the same Appendix.

2 Calculation parameters

2.1 Analogue signal

AM transmitter

– Cut-off frequency or bandwidth: F_{tx} = 4.5 kHz, i.e. B = 9 kHz

– Low-pass AF filter slope: –60 dB/octave, starting with 0 dB at F_{tx}

(See Fig. 6 of Appendix 2 to this Annex.)

– Harmonic distortion: $k_2 = 0$ $k_3 = 0.7\%$ (–43 dB)

– Intermodulation: $d_3 = -40$ dB

– Noise floor: –60.3 dBc/kHz

With the above parameters the calculated RF spectrum is compliant with the spectrum mask included in Recommendation ITU-R SM.328.

AM modulation

– Modulating signal for unwanted wave: coloured noise according to Recommendation ITU-R BS.559

– Modulation depth: $m_{r.m.s.} = 25\%$ (corresponds to a programme signal with normal compression)

– High compression: increases the sideband power by 6.5 dB with normal compression

AM receiver

– Selectivity curve: B_{af} = 2.2 kHz, slope = 35 dB/octave, see Figs. 2 and 3

– Audio signal evaluation: r.m.s. used for signal evaluation[3]

– AF protection ratio: desired value.

2.2 DRM signal

The DRM specification allows for several robustness modes (A to D) and spectrum occupancy types (0 to 5) of DRM signals. Only certain combinations of robustness modes (A to D) and spectrum occupancy types (0 to 3) are used in this Appendix. The parameters for the used mode combinations, i.e. the respective number of subcarriers and the corresponding subcarrier spacing in OFDM signal lead to the bandwidths in rows A to D of Table 22.

TABLE 22

Bandwidths for DRM mode combinations (kHz)

Robustness mode	**Spectrum occupancy type**			
	0	**1**	**2**	**3**
A	4.208	4.708	8.542	9.542
B	4.266	4.828	8.578	9.703
C				9.477
D				9.536
Nominal bandwidth (kHz)	4.5	5	9	10

[3] Psophometric weighting according to Recommendation ITU-R BS.468.

The bandwidths in the last row of Table 22 are the nominal bandwidths for the respective spectrum occupancies of the DRM signal, and the values given in lines A to D are the exact signal bandwidths for the different mode combinations.

Transmitter for digital signals

– Bandwidths: see Table 22

– Spectrum masks: calculated according to Recommendation ITU-R SM.328, § 6.3.3 of Annex 1 using the exact bandwidths F of Table 22. This includes a 30 dB attenuation at ±0.53 F, beyond this point there is a slope of –12 dB/octave to –60 dB. Examples of the masks for spectrum occupancy types 1 (5 kHz) and 3 (10 kHz) are given in Figs. 2 and 3 (including also the filter curves for AM and digital receivers).

Receiver/demodulator for digital signals

– Bandwidths: see Table 22

– Shoulder distance: 52 dB[4]

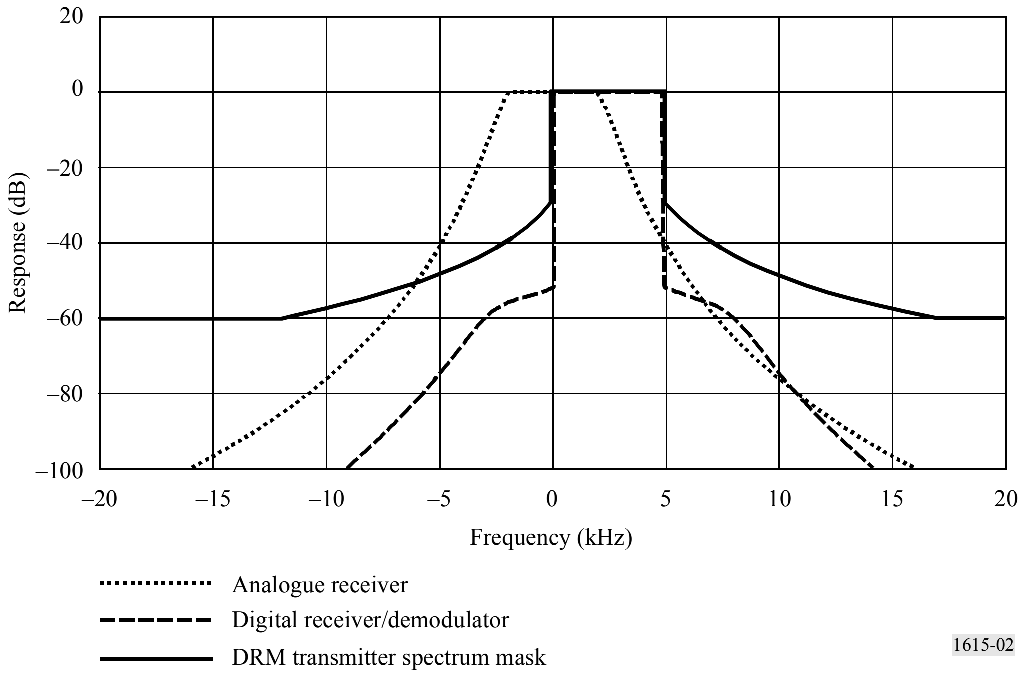
– Additional IF filter: B_{IF} = nominal DRM bandwidth + 6 kHz, slope = 35 dB/octave[4]

– Selectivity curve: see Figs. 2 and 3

– Required S/I for a BER = 1×10^{-4}: valid for 64-QAM, protection level No. 1

FIGURE 2

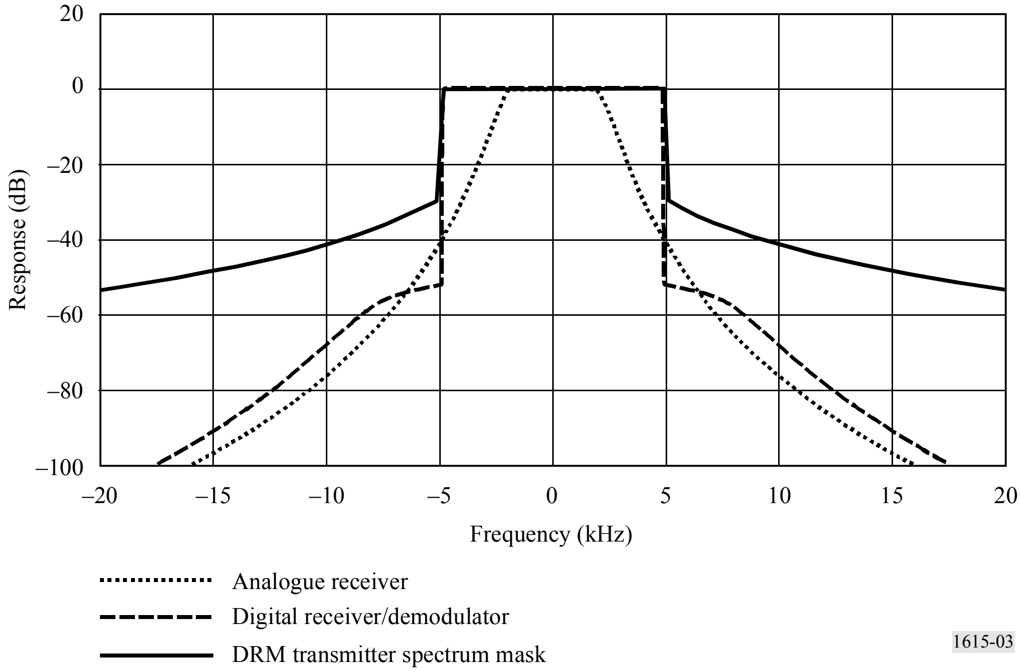
Transmitter spectrum mask and receiver/demodulator selectivity curves for DRM robustness mode B and spectrum occupancy type 1 (5 kHz)



[4] These parameters were chosen to approximate the calculated RF protection ratios to the measured values.

FIGURE 3

Transmitter spectrum mask and receiver/demodulator selectivity curves for DRM robustness mode B and spectrum occupancy type 3 (10 kHz)



3 RF protection ratios

The combinations of spectrum occupancy types and robustness modes lead to several transmitter RF spectra, which cause different interference and therefore require different RF protection ratios. The applied calculation method is described in detail in Appendix 2 to this Annex.

Table 23 shows calculation results for AM interfered with by digital and Table 24, digital interfered with by AM. These values are calculated for AM signals with high compression. The RF protection ratios for digital interfered with by digital are given in Table 25 for all the digital mode combinations, but only for identical mode combination pairings, e.g. digital mode B3 (robustness mode B, spectrum occupancy 3) interfered with by digital B3. Table 26 shows RF protection ratios between identical and different spectrum occupancies, but only for the robustness mode B. Correction factors for the different modulation schemes are given in Tables 27 to 29.

TABLE 23

Relative RF protection ratios between broadcasting systems below 30 MHz (dB)
AM interfered with by digital

Wanted signal	Unwanted signal	Frequency separation, $f_{unwanted} - f_{wanted}$ (kHz)													Parameters	
		–20	–18	–15	–10	–9	–5	0	5	9	10	15	18	20	B_{DRM} (kHz)	A_{AF} (1),(2) (dB)
AM	DRM_A0	–50.4	–50.4	–49.1	–35.6	–28.5	6.5	6.6	–31.1	–46.9	–48.3	–50.4	–50.4	–50.4	4.5	–
AM	DRM_A1	–50.9	–50.6	–47.9	–32.5	–24.5	6.1	6.1	–31.3	–46	–47.7	–50.9	–50.9	–50.9	5	–
AM	DRM_A2	–48.9	–47	–43.6	–34.5	–29.8	3.4	6.6	3.4	–29.8	–34.5	–43.6	–47	–48.9	9	–
AM	DRM_A3	–47.4	–45.5	–42.1	–32.4	–26.5	3.1	6.1	3.1	–26.5	–32.4	–42.1	–45.5	–47.4	10	–
AM	DRM_B0	–50.4	–50.4	–49	–35.5	–28.4	6.4	6.6	–30.9	–46.7	–48.2	–50.4	–50.4	–50.4	4.5	–
AM	DRM_B1	–51	–50.5	–47.6	–32	–23.8	6	6	–31.1	–45.7	–47.4	–51	–51	–51	5	–
AM	DRM_B2	–48.8	–46.9	–43.5	–34.4	–29.7	3.4	6.5	3.4	–29.7	–34.4	–43.5	–46.9	–48.8	9	–
AM	DRM_B3	–47.2	–45.3	–41.9	–32	–25.9	3	6	3	–25.9	–32	–41.9	–45.3	–47.2	10	–
AM	DRM_C3	–47.5	–45.6	–42.2	–32.6	–26.7	3.1	6.1	3.1	–26.7	–32.6	–42.2	–45.6	–47.5	10	–
AM	DRM_D3	–47.4	–45.5	–42.2	–32.4	–26.5	3.1	6.1	3.1	–26.5	–32.4	–42.2	–45.5	–47.4	10	–

A_{AF}: audio frequency protection ratio

DRM_A0: DRM signal, robustness mode A, spectrum occupancy type 0

(1) The RF protection ratio for AM interfered with by digital can be calculated by adding a suitable value for the AF protection ratio according to a given planning scenario to the values in this Table.

(2) The values presented in this Table refer to the specific case of high AM compression. For consistency with Table 25, the same modulation depth, namely that associated with high compression, has been assumed for the AM signal. In order to offer adequate protection to AM signals with normal levels of compression (as defined in Appendix 1 to Annex 2), each value in the Table should be increased to accommodate the difference between normal and high compression.

TABLE 24

Relative RF protection ratios between broadcasting systems below 30 MHz (dB)
Digital (64-QAM, protection level No. 1) interfered with by AM

Wanted signal	Unwanted signal	Frequency separation, $f_{unwanted} - f_{wanted}$ (kHz)													Parameters	
		–20	–18	–15	–10	–9	–5	0	5	9	10	15	18	20	B_{DRM} (kHz)	*S*/*I* (dB)
DRM_A0	AM	–57.7	–55.5	–52.2	–46.2	–45	–36.7	0	–3.5	–31.2	–41.1	–47	–50.7	–53	4.5	4.2
DRM_A1	AM	–57.5	–55.2	–52	–45.9	–44.8	–36.6	0	–0.6	–22.8	–38.4	–46.1	–49.8	–52.2	5	4.2
DRM_A2	AM	–54.7	–52.4	–48.8	–42.9	–34	–6.5	0	–6.5	–34	–42.9	–48.8	–52.4	–54.7	9	6.7
DRM_A3	AM	–54	–51.7	–48.1	–40.6	–25.8	–3.6	0	–3.6	–25.8	–40.6	–48.1	–51.7	–54	10	6.7
DRM_B0	AM	–57.7	–55.5	–52.2	–46.1	–45	–36.2	0	–3.5	–30.9	–41.1	–46.9	–50.6	–53	4.5	4.6
DRM_B1	AM	–57.4	–55.2	–51.9	–45.9	–44.7	–36	0	–0.2	–22	–37.6	–46	–49.6	–52	5	4.6
DRM_B2	AM	–54.6	–52.4	–48.8	–42.8	–33.7	–6.4	0	–6.4	–33.7	–42.8	–48.8	–52.4	–54.6	9	7.3
DRM_B3	AM	–53.9	–51.5	–48	–39.9	–25	–3.1	0	–3.1	–25	–39.9	–48	–51.5	–53.9	10	7.3
DRM_C3	AM	–54	–51.7	–48.1	–40.9	–26.1	–3.8	0	–3.8	–26.1	–40.9	–48.1	–51.7	–54	10	7.7
DRM_D3	AM	–54	–51.7	–48.1	–40.7	–25.8	–3.6	0	–3.6	–25.8	–40.7	–48.1	–51.7	–54	10	8.6

TABLE 25

Relative RF protection ratios between broadcasting systems below 30 MHz (dB) Digital (64-QAM, protection level No. 1) interfered with by digital (identical robustness modes and spectrum occupancy types)

Wanted signal	Unwanted signal	Frequency separation, $f_{unwanted} - f_{wanted}$ (kHz)													Parameters	
		–20	**–18**	**–15**	**–10**	**–9**	**–5**	**0**	**5**	**9**	**10**	**15**	**18**	**20**	B_{DRM} (kHz)	S/I (dB)
DRM_A0	DRM_A0	–60.1	–60	–60	–55.4	–53.4	–41.2	0	–41.2	–53.4	–55.4	–60	–60	–60.1	4.5	15.8
DRM_A1	DRM_A1	–60	–60	–59.7	–53.3	–51.3	–38.4	0	–38.4	–51.3	–53.3	–59.7	–60	–60	5	15.8
DRM_A2	DRM_A2	–55.1	–53.1	–49.6	–40.8	–38.3	–3.8	0	–3.8	–38.3	–40.8	–49.6	–53.1	–55.1	9	15.3
DRM_A3	DRM_A3	–53	–51	–47.3	–38.1	–12.1	–3.2	0	–3.2	–12.1	–38.1	–47.3	–51	–53	10	15.3
DRM_B0	DRM_B0	–60	–59.9	–60	–55.2	–53.2	–40.8	0	–40.8	–53.2	–55.2	–60	–59.9	–60	4.5	16.2
DRM_B1	DRM_B1	–60	–60	–59.5	–52.8	–50.8	–37.8	0	–37.8	–50.8	–52.8	–59.5	–60	–60	5	16.2
DRM_B2	DRM_B2	–55.1	–53.1	–49.5	–40.7	–38.1	–3.7	0	–3.7	–38.1	–40.7	–49.5	–53.1	–55.1	9	15.9
DRM_B3	DRM_B3	–52.7	–50.7	–47	–37.7	–11.1	–3.1	0	–3.1	–11.1	–37.7	–47	–50.7	–52.7	10	15.9
DRM_C3	DRM_C3	–53.2	–51.1	–47.5	–38.3	–12.6	–3.2	0	–3.2	–12.6	–38.3	–47.5	–51.1	–53.2	10	16.3
DRM_D3	DRM_D3	–53	–51	–47.4	–38.1	–12.2	–3.2	0	–3.2	–12.2	–38.1	–47.4	–51	–53	10	17.2

TABLE 26

Relative RF protection ratios between broadcasting systems below 30 MHz (dB)
Digital (64-QAM, protection level No. 1) interfered with by digital

Wanted signal	Unwanted signal	Frequency separation, $f_{unwanted} - f_{wanted}$ (kHz)													Parameters	
		–20	–18	–15	–10	–9	–5	0	5	9	10	15	18	20	B_{DRM} (kHz)	*S/I* (dB)
DRM_B0	DRM_B0	–60	–59.9	–60	–55.2	–53.2	–40.8	0	–40.8	–53.2	–55.2	–60	–59.9	–60	4.5	16.2
DRM_B0	DRM_B1	–60.1	–60	–59.5	–52.5	–50.4	–37.4	0	–40	–51.6	–53.6	–59.8	–60	–60.1	5	15.7
DRM_B0	DRM_B2	–57.4	–55.7	–52.9	–46.7	–45.1	–36.6	0	–0.8	–35.6	–38.4	–47.7	–51.5	–53.6	9	13.2
DRM_B0	DRM_B3	–55.2	–53.6	–50.7	–44.5	–42.9	–33.1	0	–0.1	–13.6	–36.2	–45.5	–49.3	–51.4	10	12.6
DRM_B1	DRM_B0	–59.4	–59.5	–59.5	–55	–53	–40.8	0	–37.9	–51.7	–53.9	–59.4	–59.5	–59.4	4.5	16.2
DRM_B1	DRM_B1	–60	–60	–59.5	–52.8	–50.8	–37.8	0	–37.8	–50.8	–52.8	–59.5	–60	–60	5	16.2
DRM_B1	DRM_B2	–57.1	–55.4	–52.6	–46.4	–44.9	–36.4	0	–0.1	–13.7	–36.8	–46.6	–50.5	–52.7	9	13.2
DRM_B1	DRM_B3	–55.5	–53.8	–51	–44.8	–43.3	–33.5	0	–0.1	–8.1	–35.2	–45	–48.9	–51.1	10	13.2
DRM_B2	DRM_B0	–57	–56.8	–54.8	–43.4	–39.1	–0.7	0	–40.6	–52.2	–53.9	–57	–57	–57	4.5	15.9
DRM_B2	DRM_B1	–56.9	–56.1	–52.7	–40.2	–14.1	–0.1	0	–39.7	–50.8	–52.5	–56.9	–57	–57	5	15.4
DRM_B2	DRM_B2	–55.1	–53.1	–49.5	–40.7	–38.1	–3.7	0	–3.7	–38.1	–40.7	–49.5	–53.1	–55.1	9	15.9
DRM_B2	DRM_B3	–52.9	–51	–47.4	–38.6	–16.6	–3.2	0	–3.2	–16.6	–38.6	–47.4	–51	–52.9	10	15.4
DRM_B3	DRM_B0	–56.4	–56.2	–53.8	–41.1	–14.1	–0.1	0	–37.7	–50.9	–52.8	–56.4	–56.4	–56.4	4.5	15.9
DRM_B3	DRM_B1	–56.8	–55.7	–52.1	–38.2	–8.2	–0.1	0	–37.6	–50.1	–51.9	–56.7	–57	–57	5	15.9
DRM_B3	DRM_B2	–54.3	–52.3	–48.6	–39.3	–16.7	–3.1	0	–3.1	–16.7	–39.3	–48.6	–52.3	–54.3	9	15.9
DRM_B3	DRM_B3	–52.7	–50.7	–47	–37.7	–11.1	–3.1	0	–3.1	–11.1	–37.7	–47	–50.7	–52.7	10	15.9

TABLE 27

S/I correction values to be used in Tables 24 and 25 for other combinations of modulation scheme and protection level No.

Modulation scheme	Protection level No.	Average code rate	Correction values (dB) for DRM robustness mode/spectrum occupancy type	
			A/0 (4.5 kHz), A/1 (5 kHz)	A/2 (9 kHz), A/3 (10 kHz)
16-QAM	0	0.5	–7.0	–6.7
	1	0.62	–4.9	–4.6
64-QAM	0	0.5	–1.5	–1.2
	1	0.6	0.0	0.0
	2	0.71	1.7	1.8
	3	0.78	3.4	3.4

TABLE 28

S/I correction values to be used in Tables 24, 25 and 26 for other combinations of modulation scheme and protection level No.

Modulation scheme	Protection level No.	Average code rate	Correction values (dB) for DRM robustness mode/spectrum occupancy type	
			B/0 (4.5 kHz), B/1 (5 kHz)	B/2 (9 kHz), B/3 (10 kHz)
16-QAM	0	0.5	–6.7	–6.6
	1	0.62	–4.7	–4.6
64-QAM	0	0.5	–1.3	–1.2
	1	0.6	0.0	0.0
	2	0.71	1.7	1.8
	3	0.78	3.3	3.4

TABLE 29

S/I correction values to be used in Tables 24 and 25 for other combinations of modulation scheme and protection level No.

Modulation scheme	Protection level No.	Average code rate	Correction values (dB) for DRM robustness mode/spectrum occupancy type	
			C/3 (10 kHz)	D/3 (10 kHz)
16-QAM	0	0.5	–6.7	–7.0
	1	0.62	–4.7	–5.1
64-QAM	0	0.5	–1.2	–1.3
	1	0.6	0.0	0.0
	2	0.71	1.8	1.9
	3	0.78	3.4	4.2

The values in Tables 23 to 26 represent relative RF protection ratios, $A_{RF\_relative}$. For the pure AM case, the relative protection ratio is the difference (dB) between the protection ratio when the carriers of the wanted and unwanted transmitters have a frequency difference of Δf Hz, and the protection ratio when the carriers of these transmitters have the same frequency (Recommendation ITU-R BS.560), i.e. the co-channel RF protection ratio, A_{RF}, which corresponds to the AF protection ratio, A_{AF}. In the case of a digital signal, its nominal frequency instead of the carrier frequency is the relevant value for the determination of the frequency difference. For spectrum occupancy types 2 and 3, the nominal frequency corresponds to the centre frequency of the OFDM block; for the types 0 and 1, the centre frequency is shifted about 2.2 and 2.4 kHz, respectively, above the nominal frequency. Due to the fact that the spectrum of the interference signal is different from the AF spectrum of analogue AM, the values for relative AF protection ratio in the case of co-channel interference are not equal to zero.

To adjust Table 23 to a given AM planning scenario, the relevant AF protection ratio has to be added to the values in the Table to get the required RF protection ratio (see Appendix 2 to this Annex). Relevant values may be determined taking into account:

– for HF, the AF protection ratio of 17 dB, which was adopted for HFBC planning by WARC HFBC-87 for AM interfered with by AM;

– for LF/MF, the AF protection ratio of 30 dB, which was adopted by the Regional Administrative LF/MF Broadcasting Conference for Regions 1 and 3 (Geneva, 1975) for AM interfered with by AM.

With DRM as the wanted signal the AF protection ratio as a parameter for the quality of service has to be replaced by the S/I required to achieve a certain BER. A BER threshold of 1×10^{-4} is supposed for the calculations (see Annex 1). The protection ratio values in Tables 24 and 25 are based on 64-QAM modulation and protection level No. 1. For other combinations, the correction values in Table 26 have to be added to the S/I values given in the Tables.

Appendix 2
to Annex 2

Method of measurements and determination of RF protection ratios

1 Method of measurements in accordance with Recommendation ITU-R BS.559

1.1 Calculation method

It has been decided that RF protection ratios should be determined using the calculation method outlined in § 2 of this Appendix.

1.2 RF power relationship AM/digital

The RF power of an AM signal is the power of the AM carrier, whereas the RF power of a digital signal is the total power within the bandwidth of the wanted signal.

1.3 Receiver characteristics

1.3.1 AM receiver selectivity curve

It was decided to take for calculations of RF protection ratios the selectivity curve of a modern AM receiver (audio frequency bandwidth = 2.2 kHz; slope = 35 dB/octave). Further reasons for this decision were that the influence on protection ratios is expected to be low and the latter selectivity curve is not too optimistic.

1.3.2 Digital receiver: required *S*/*I*

For the calculation of RF protection ratios, measured *S*/*I* for the digital system shall be used and stated together with the respective protection ratios. Thus the provided values could later be reviewed, taking into account future developments.

1.4 Use of the DRM spectrum mask

Because digital signals must not cause higher interference to existing transmissions than AM transmissions, it was decided that it is appropriate to apply the measured DRM spectrum mask for the calculation of RF protection ratios.

1.5 Frequency separations

RF protection ratios should be given for the following frequency separations:

– 9 kHz channel spacing: 0 kHz, 9 kHz, 18 kHz

– 10 kHz channel spacing: 0 kHz, 5 kHz, 10 kHz, 15 kHz, 20 kHz.

2 Determination of RF protection ratios for DSB in the broadcasting bands below 30 MHz

2.1 Introduction

For the introduction of DRM in an existing environment, it has to be ensured that the digitally modulated signal causes no more interference to other AM stations than the AM signal which is replaced by DRM. On the other hand, the interference from existing AM stations has to be low enough to allow for a reliable reception of the digital signal. Therefore, protection ratios are needed for the following four cases:

– AM reception interfered with by AM transmissions (AM-AM).

– AM reception interfered with by digitally modulated signals (AM-DIG).

– Reception of digitally modulated signals interfered with by AM transmissions (DIG-AM).

– Reception of digitally modulated signals interfered with by digitally modulated signals (DIG-DIG).

The RF protection ratios may either be measured using directly the method described in Recommendation ITU-R BS.559 or using an adapted method, taking into account the different modulation characteristics or they may be calculated. The first case above (AM-AM) is covered by the existing protection ratio curves in Recommendation ITU-R BS.560. In order to restrict the number of complicated measurements, and as long as only a few receivers for digitally modulated signals exist, it may be helpful to calculate the RF protection ratios for the other cases. The calculation of protection ratios has the additional advantage that the applied system parameters may easily be changed.

For the determination of protection ratios, a calculation model was developed based on a numerical method for the calculation of RF protection ratios for AM transmission systems and on Recommendation ITU-R BS.559. Using this model leads, under certain assumptions, to protection ratios quite similar to those given in Recommendation ITU-R BS.560. The differences between calculated values for AM-AM and the ITU protection ratio curves are negligible (Table 30, last two columns ΔA_{RI}/dB). Therefore, this model can also be used to calculate RF protection ratios with sufficient accuracy for AM interfered with by DRM.

RF protection ratios for the cases DRM interfered with by AM or DRM may also be calculated using this model, but there are larger uncertainties because the performance of DRM receivers and the influence of the AM carrier to DRM reception are not known well enough.

2.2 Calculation model

2.2.1 Calculation method

The RF protection ratios are calculated by simulating the transmitters for desired and undesired signals and feeding their signals at different channel separations into a model receiver (see Fig. 4). The required RF protection ratio is then the difference between the response to the undesired and the desired signal.

The total interference to the desired signal is calculated by taking the power sum of the interference caused by the sidebands of the undesired signal and the interference caused by the RF carrier (in case of AM signals).

This calculation leads to relative RF protection ratios. The required absolute RF protection ratio to protect the existing AM service is derived by adding the wanted AF protection ratio (see § 3.4) using the following equation:

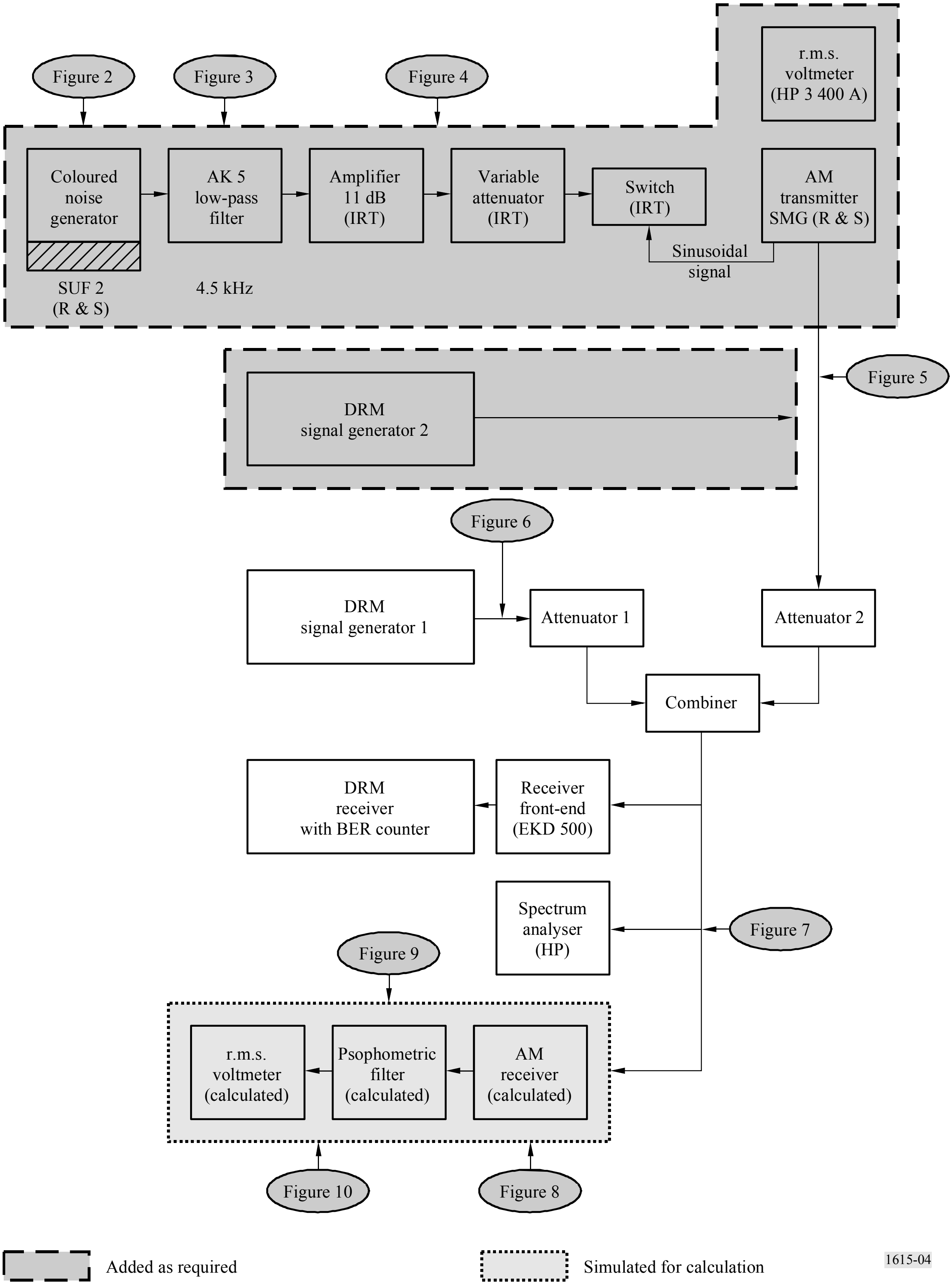
$$A_{RF} = A_{RF\_relative} + A_{AF} \tag{5}$$

The RF protection for DRM is derived by a similar calculation. Instead of the AF protection ratio the required *S*/*I* ratio (see § 3.7) for a specified BER is taken into account:

$$A_{RF} = A_{RF\_relative} + S/I \tag{6}$$

FIGURE 4

Calculation and/or measurement of RF protection ratios test set-up



2.3 Transmitter model

The complete set of transmitter parameters used for the calculation are given in § 3.

In case of AM transmissions, a modulation with coloured noise according to Recommendation ITU-R BS.559 is assumed (see § 3.3), as it is recommended for the measurement of AM protection ratios. The spectral distribution of the radiated signal is composed of the modulating signal, harmonic distortion, intermodulation, transmitter filter and noise floor (see § 3.1 and 3.2).

For digitally modulated transmitters, the measured spectra of DRM transmitters or an assumed theoretical spectrum that fulfils the requirement for out-of-band emissions are used (see § 3.1, 3.5 and 3.6).

2.4 Receiver model

The complete set of receiver parameters used for the calculation are given in § 3.

For the verification of the calculation method for AM reception the characteristics of the measurement receiver with band-pass filter (MBF) is used (see § 3.4 and Fig. 11a). The spectral components falling in its pass-band are weighted according to Recommendation ITU-R BS.468 (see Fig. 12) and their power is summed up, either as desired or undesired signal.

The characteristics of a receiver for digitally modulated signals is described by its selectivity (see § 3.1 and 3.7). The power of all spectral components falling in its pass-band is summed up, either as desired or undesired signal.

2.5 Future extension of the calculation model

It may be necessary to expand the calculation model in order to allow for the calculation of RF protection ratios for simulcast transmissions, which leads to five additional interference cases:

– AM reception interfered with by simulcast transmissions (AM-SIM).

– Reception of digitally modulated signals interfered with by simulcast transmissions (DIG-SIM).

– Simulcast reception interfered with by AM transmissions (SIM-AM).

– Simulcast reception interfered with by digitally modulated signals (SIM-DIG).

– Simulcast reception interfered with by simulcast transmissions (SIM-SIM).

3 Assumed system parameters

3.1 Spectrum masks

The spectrum masks for AM transmissions are based on a model taking into account the non-linear distortion of the transmitter and/or the modulating signal as well as a certain noise floor. For amplitude modulated transmitters second- and third-order harmonic distortion as well as third-order intermodulation are incorporated in the calculation model. For digitally modulated transmitters, measured or assumed spectra are used.

The spectrum shaping for the AM transmitter is performed by using a low-pass filter with the parameters given in § 3.2 (see Figs. 5, 6 and 7). The selectivity curve of the AM receiver is given under § 3.4.

The parameters given in § 3.2, 3.3 and 3.4 were chosen for the AM transmitter and receiver models because they are usual for AM transmissions and, moreover, they lead in the case AM interfered with by AM to the RF protection ratios of Recommendation ITU-R BS.560.

The receiver selectivity curves and the spectrum masks resulting from the parameters specified in the following clauses are presented graphically in Figs. 8, 9, 10 and 11.

3.2 AM transmitter (Figs. 5 to 8)

– sideband power: $N_{sb} = N_c * m^2/2$

– total power: $N_{total} = N_c * (1 + m^2/2)$

– cut-off frequency or bandwidth: $F_{tx} = \pm 4.5$ kHz, i.e. $B = 9$ kHz

– low-pass AF filter slope: 60 dB/octave, starting with 0 dB at F_{tx}
(see Fig. 6)

– harmonic distortion: $k_2 = 0$ $k_3 = 0.7\%$ (–43 dB)

– intermodulation: $d_3 = -40$ dB

– noise floor: –60.3 dBc/kHz.

With the above parameters, the calculated RF spectrum of the AM signal is compliant with the spectrum mask included in Recommendation ITU-R SM.328.

3.3 AM modulation (Figs. 5 to 7)

– modulating signal: coloured noise according to Recommendation ITU-R BS.559

– modulation depth: $m_{r.m.s.}$ = 25% (corresponding to a programme signal with normal compression)

– high compression: increase of the modulating signal power by 6.5 dB (this may be achieved by a compressor with a compression gain of 15 dB and a compression ratio of 2:1).

3.4 AM receiver (Figs. 11a and 11b)

– selectivity curve: as MBF, or a modern AM receiver with B = 4.4 kHz, slope = 35 dB/octave[5]

– audio signal measurement: r.m.s.[6]

– AF protection ratio: desired value.

3.5 Transmitter for digital signals

– sideband power: $N_{sb} = N_{total}$

– carrier power: $N_c = 0$

– bandwidth: B = 9 kHz or 10 kHz.

3.6 Digital modulation (Figs. 9a and 9b)

– spectrum: defined by measured transmitter signal or required spectrum mask.

3.7 Receiver for digital signals (Fig. 9a)

– bandwidth: B = 9 kHz or 10 kHz

– selectivity curve: receiver spectrum (Figs. 2 and 3)

– required S/I: S/I required to achieve BER of 1×10^{-4} dependent on robustness mode, spectrum occupancy type, modulation scheme and protection level.

---

[5] As modern AM receiver, a receiver with an AF bandwidth of 2.2 kHz and a selectivity curve having a slope of 35 dB/octave is used. This leads to an attenuation of about 41.5 dB at 5 kHz frequency separation (see Fig. 11b). The choice of such a receiver is based on measurements of 27 AM receivers performed by "Deutsche Welle" during the time period between 1989 and 1997.

[6] Psophometric weighting according to Recommendation ITU-R BS.468.

FIGURE 5

Characteristic of noise shaping filter

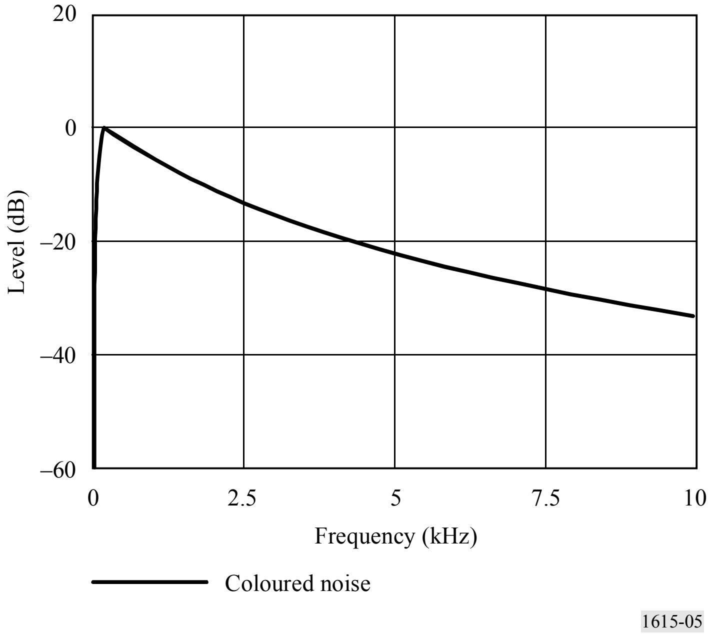


FIGURE 6

Low-pass filter used in AM transmission

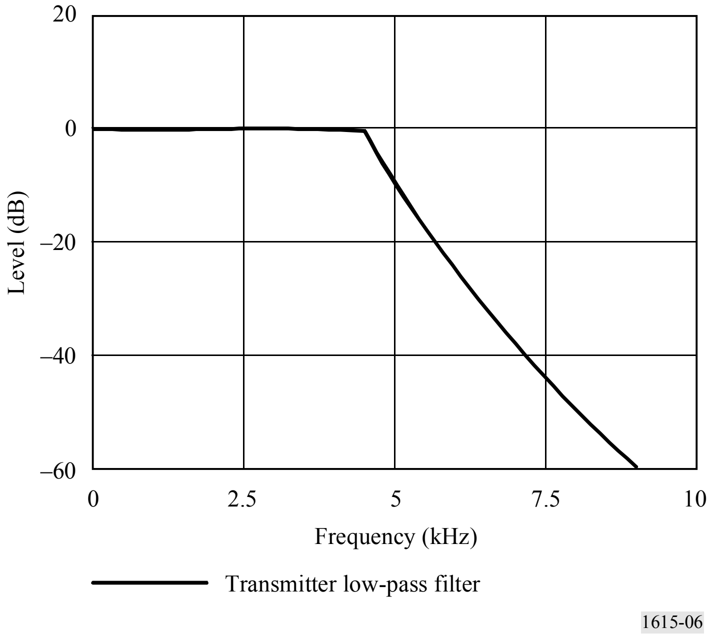


FIGURE 7

Modulating signal for AM

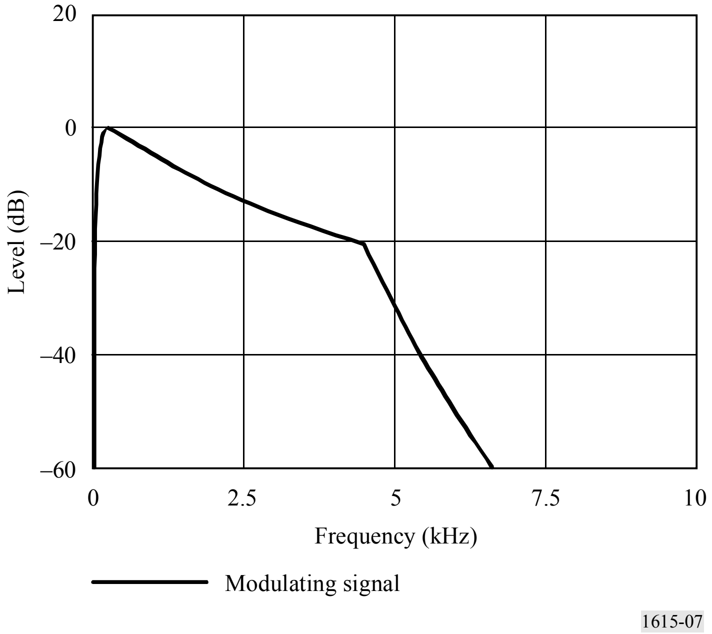


FIGURE 8

AM signal modulated with coloured noise

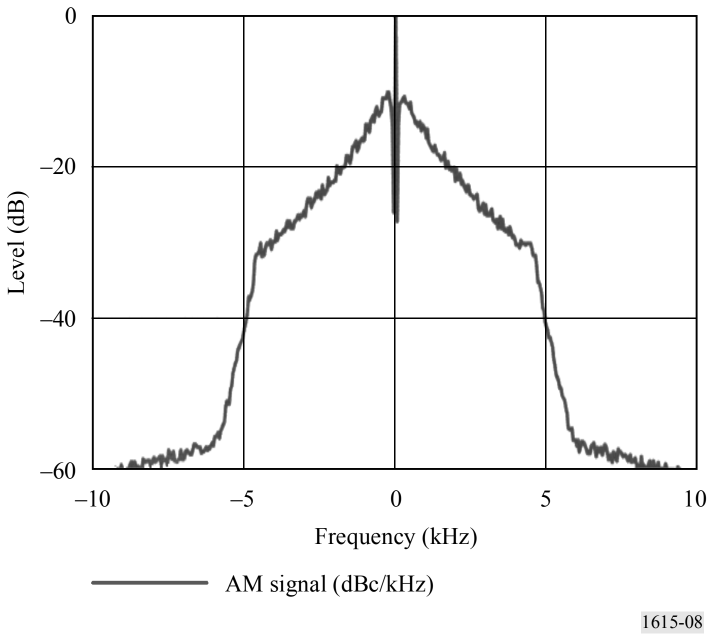


FIGURE 9a

DRM synthesizer signal (64-QAM, 9 kHz)

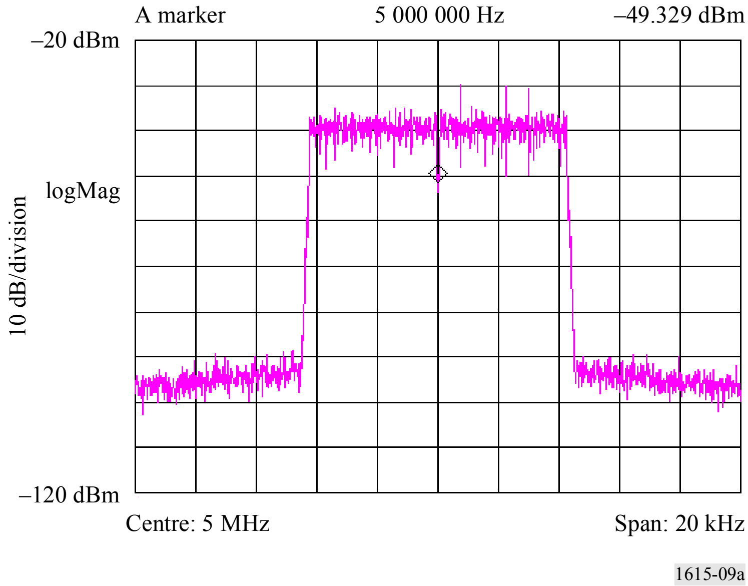


FIGURE 9b

DRM synthesizer signal (64-QAM, 9 kHz)
and ITU spectrum mask

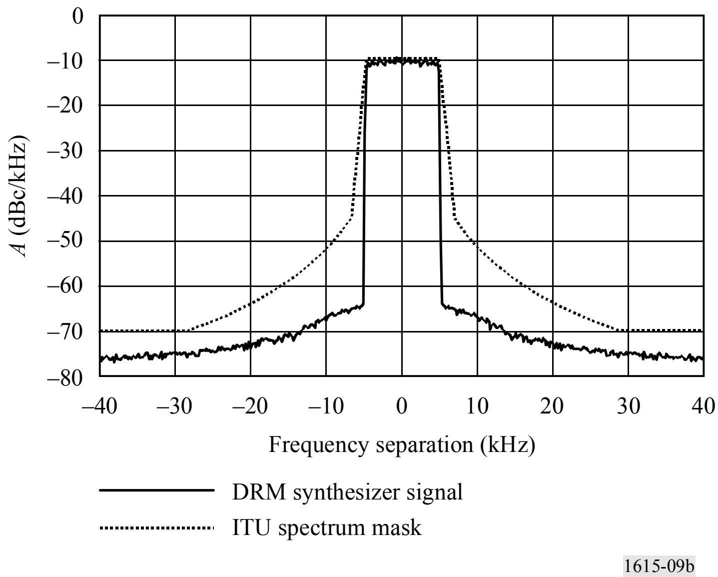
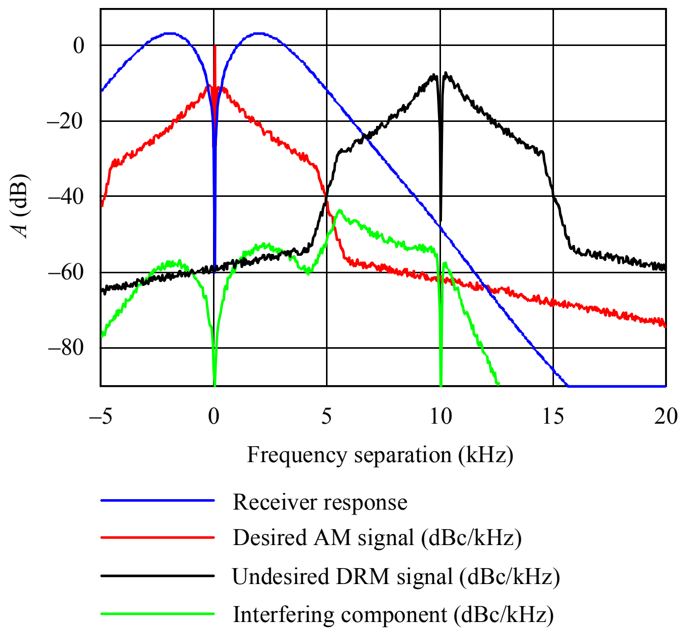


FIGURE 10a

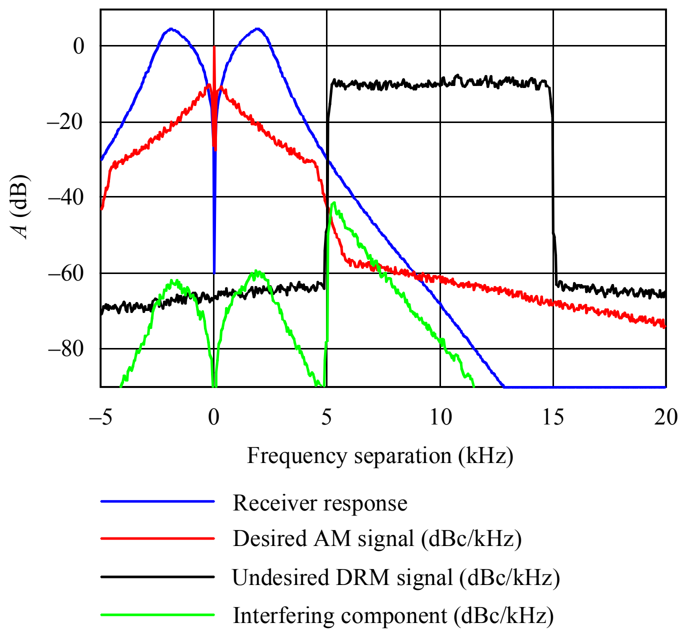
AM signal interfered with by AM signal



1615-10a

FIGURE 10b

AM signal interfered with by DRM signal



1615-10b

FIGURE 11a

Selectivity curve of MBF receiver

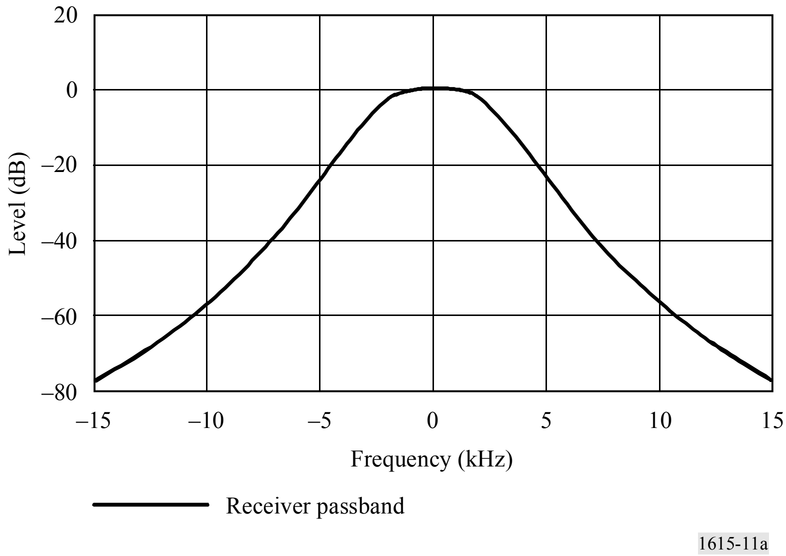


FIGURE 11b

Selectivity curve of a modern AM receiver

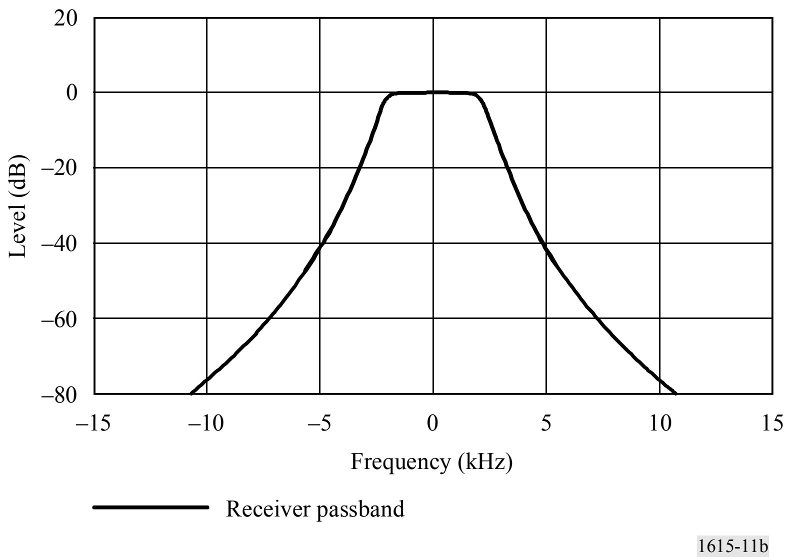


FIGURE 12

Signal shaping of psophometric filter

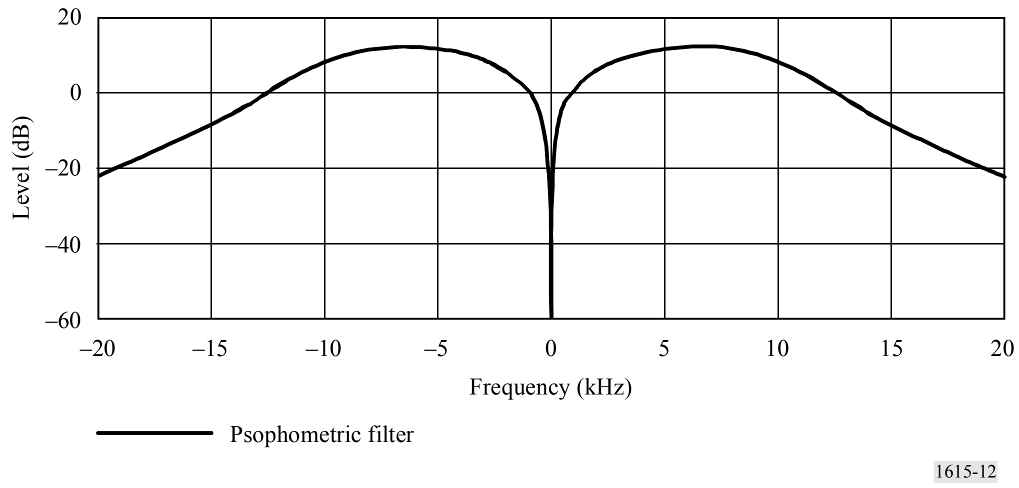
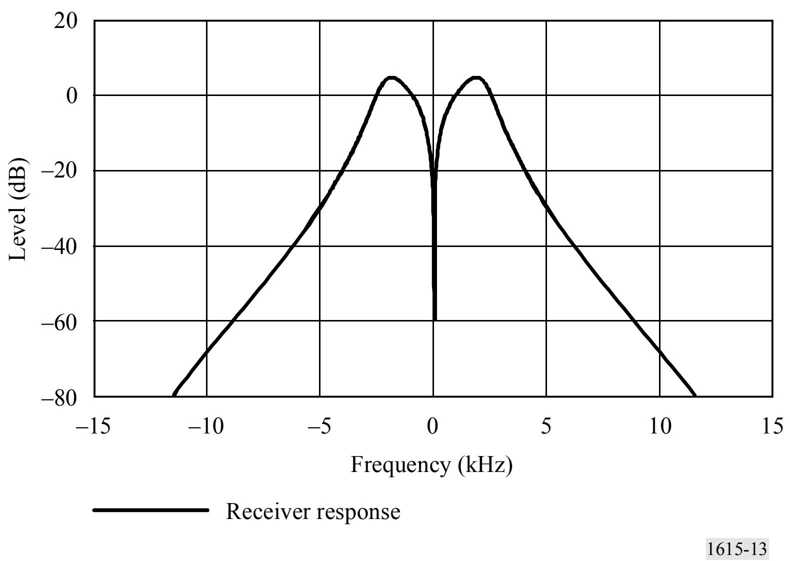


FIGURE 13

Receiver response including selectivity curve and psophometric filter



4 Verification of calculation method

Using the developed calculation model and the system parameters of § 3 and an AF protection ratio of 30 dB led in the case AM interfered with by AM (AM-AM) to the results presented in Table 30 and Figs. 14 and 15. The calculated RF protection ratios are given for frequency separations up to 20 kHz for normal and high compression of the transmitted AM signals. In Fig. 14, only the relative RF protection ratio values are drawn in the diagram.

TABLE 30

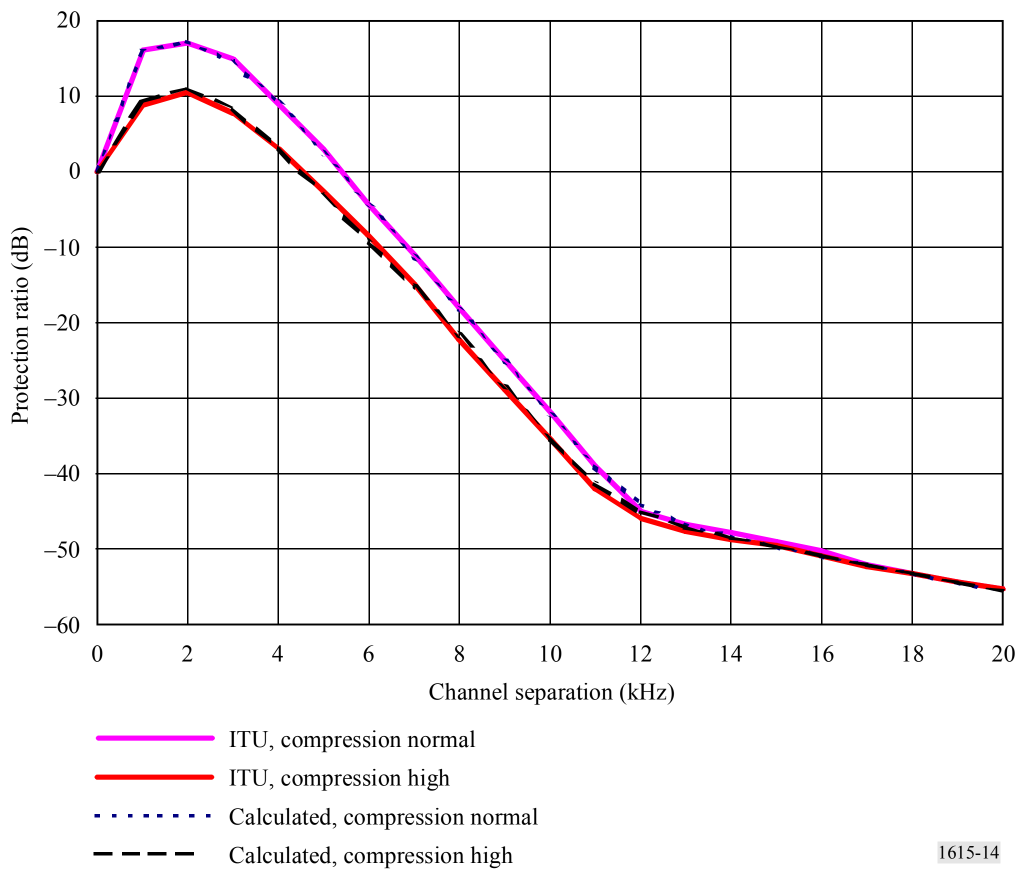
Calculated RF protection ratios A_{RF} for AM, ITU values A_{ITU} and calculation error ΔA_{RI} for AM transmissions

Desired: AM			**Undesired: AM**		**A_{AF}: 30 dB**	
Δ*f*/kHz	**A_{RF}/dB**		**A_{ITU}/dB**		**ΔA_{RI}/dB**	
0	30	30	30	30	0	0
5	32.4	27	33	27.5	–0.6	–0.5
9	4.7	1.4	5	1	–0.3	0.4
10	–2.4	–5.4	–2	–5.5	–0.4	0.1
15	–19.6	–19.7	–19	–19.5	–0.6	–0.2
18	–23.3	–23.3	–23.3	–23.3	0	0
20	–25.6	–25.7	–25.4	–25.4	–0.2	–0.3
	Normal compression	High compression	Normal compression	High compression	Normal compression	High compression

The comparison of calculated values with the RF protection ratios of Recommendation ITU-R BS.560 shows that the calculation error is less than 0.6 dB.

FIGURE 14

Relative RF protection ratios AM interfered with by AM



5 Application for digitally modulated signals

The small calculation error for the determination of RF protection ratios in the case AM interfered with by AM shows that this method can also be used with sufficient accuracy to calculate RF protection ratios for AM interfered with by digitally modulated signals, under the condition that the spectrum of the interfering digital signal is known.

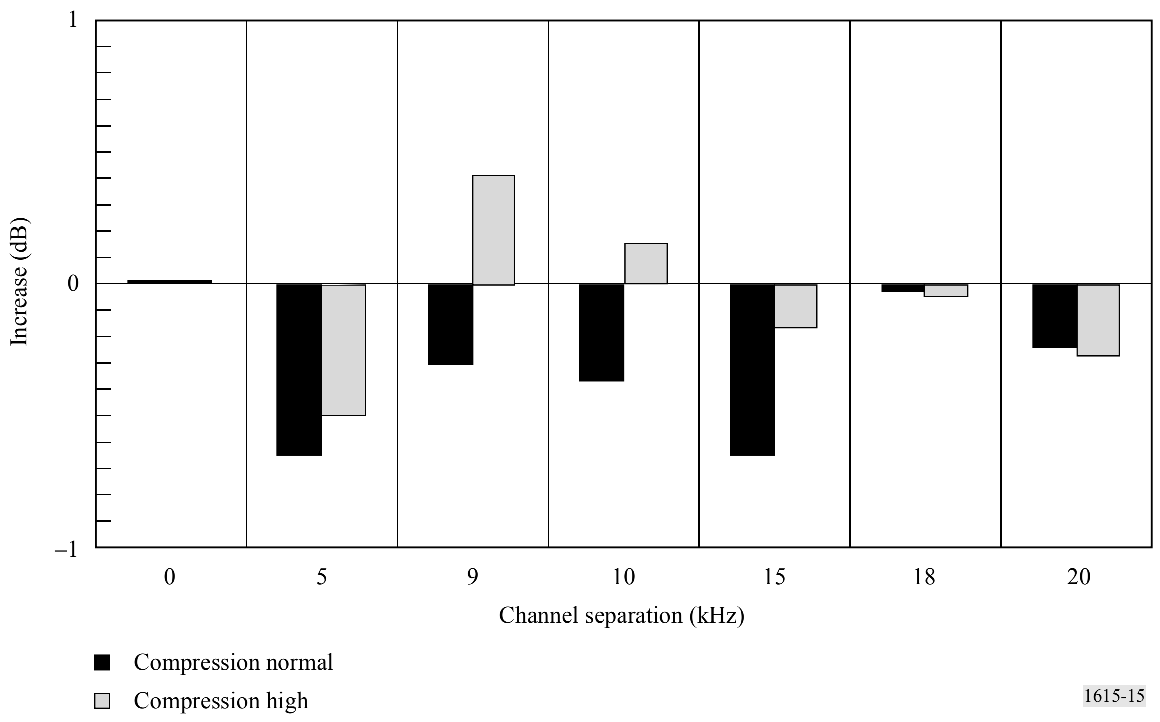
For digitally modulated signals interfered with by AM or digitally modulated signals, the selectivity curve and the demodulation characteristics of the receiver have to be known. Therefore, this method can only be applied with some restrictions, e.g. to investigate the influence of different spectra based on known measurement results.

6 Summary

The described calculation model has been used for the determination of RF protection ratios for DSB in the broadcasting bands below 30 MHz. The achieved accuracy is sufficient for planning purposes. The calculations should be based on measured transmitter spectra or on a spectrum mask which is needed to fulfil the requirements for out-of-band emissions. Only if it is necessary should the calculation results be checked and completed by measurement results.

FIGURE 15

Calculation error for RF protection ratios AM interfered with by AM



Annex 3

Measured RF protection ratios for IBOC (in band on-channel) DSB system in the MF band

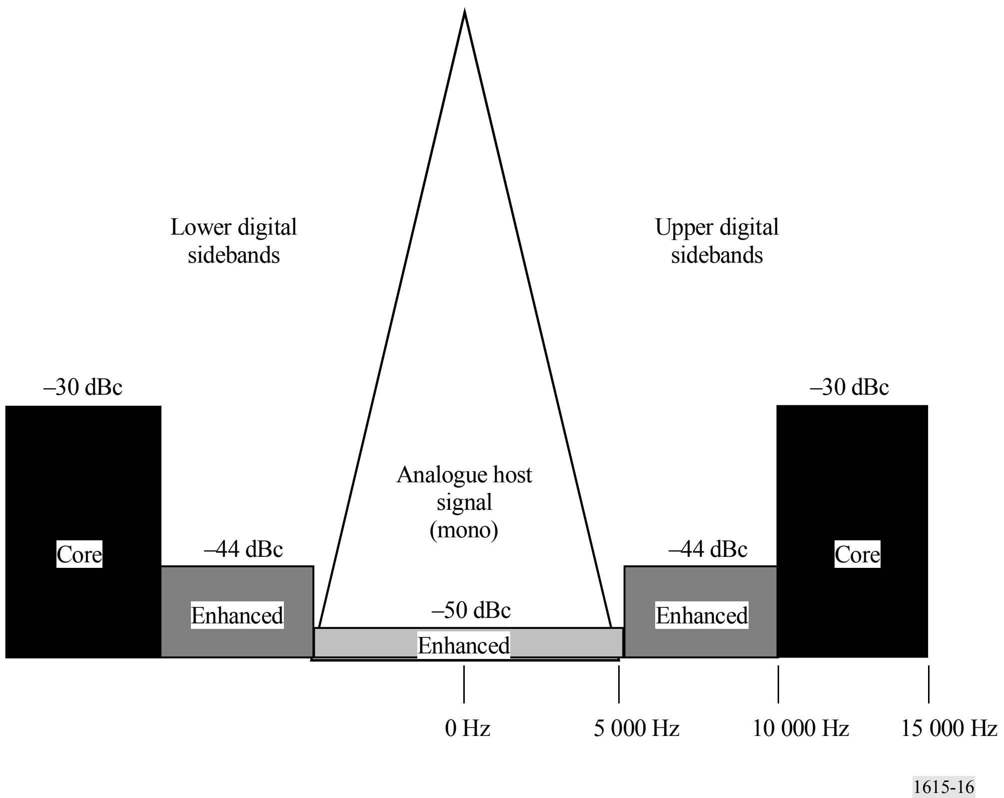
1 Introduction

The IBOC DSB system operates in two modes: hybrid and all-digital. It is designed to operate in the existing analogue spectrum and thus designed to operate with the levels of interference that currently exist. The IBOC DSB system's performance is primarily limited by interference from existing analogue transmissions, and is limited in power so as to protect adjacent channel broadcasts.

The term "hybrid" refers to simultaneous transmission of an analogue DSB signal with the digital signal, as represented in Fig. 16. This Figure shows the various low-power digital components. These consist of the "core" components located in the band ±10 to 15 kHz from the centre frequency of the DSB signal, plus the "enhanced" components interior to the "core" signal that add to the quality of the audio signal when the *S*/*N* so permits.

FIGURE 16

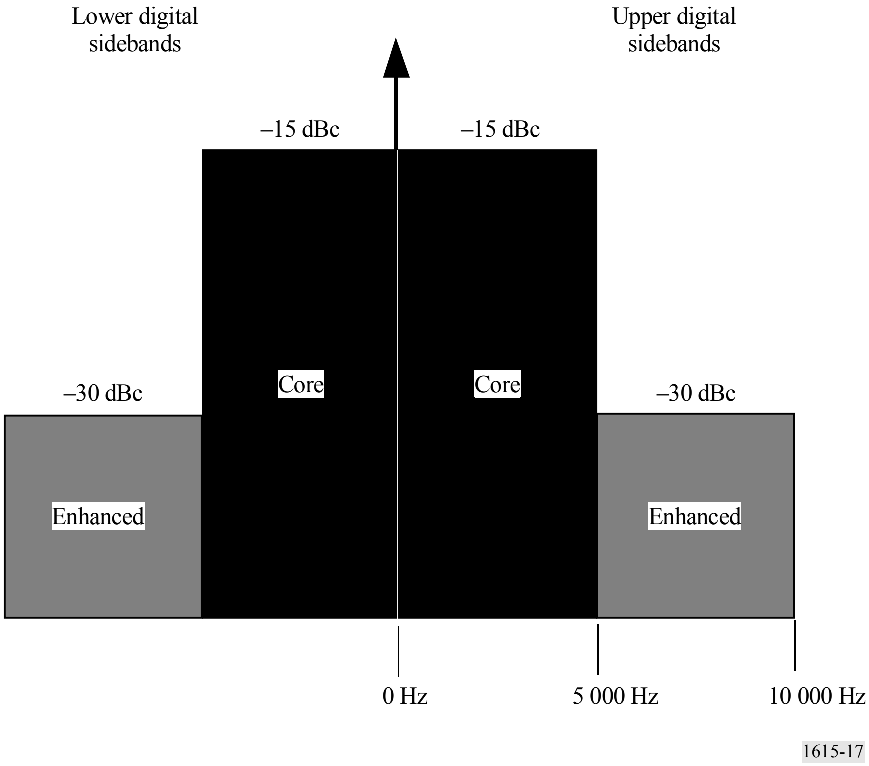
Hybrid MF IBOC DSB power spectral density



The term "all-digital" refers to a digital-only signal, whose power level and spectral composition are shown in Fig. 17.

FIGURE 17

All-digital MF IBOC DSB power spectral density



2 RF protection ratios

Tables 31 to 33 are derived from laboratory measurements using Generation 2 IBOC exciters and reference receivers. The interferer was a hybrid transmission with its analogue component modulated by processed pulsed noise to +125, –99% modulation depth.

The desired/undesired ratios are expressed for the core and enhanced audio quality. The desired/undesired ratio for the enhanced audio represents the point of change to core audio in the hybrid and all-digital modes. The desired/undesired ratios for the core audio represent the point of change to analogue for the hybrid mode and point of failure for all-digital.

TABLE 31

RF protection ratios
Digital component of hybrid mode interfered with by hybrid mode

Hybrid interferer	Core audio (dB)	Enhanced audio (dB)
Co-channel	9.2	11.0
First adjacent	–14.5	6.8
Second adjacent(1)	–62.5	–44.0

(1) In the case of second adjacent channel performance, the primary source of failure for the digital core audio is front-end overload.

TABLE 32

RF protection ratios
Digital component of hybrid mode interfered with by all-digital mode

Hybrid interferer	Core (dB)	Enhanced (dB)
Co-channel	1.75	1.5
First adjacent	–14.25	7.0
Second adjacent(1)	–62.5	–44.5

(1) In the case of second adjacent channel performance, the primary source of failure for the digital core audio is front-end overload.

TABLE 33

RF protection ratios
All-digital mode interfered with by all-digital mode

Digital interferer	Core (dB)	Enhanced (dB)
Co-channel	12	12
First adjacent(1)	–23/–29	–23/–29
Second adjacent(2)	–	–

(1) The system has difficulty acquiring with a first adjacent interferer greater than −23 dB. However, once acquired, the interferer can be increased to −29 dB before failure.

(2) In the case of second adjacent channel performance, the primary source of failure for the digital core and enhanced audio is front-end overload.

3 Channel spacing

The protection ratios in this Recommendation are based on 10 kHz channel spacing. Amended protection ratios for other channel spacings will be released when laboratory measurements have been completed.

4 Night-time and considerations for sky-wave protection

The protection ratios in this Recommendation are representative of steady state conditions and should serve well for daytime planning. Administrations may wish to take into consideration an additional factor to compensate for fading conditions under sky-wave fading conditions.

5 Conclusion

The performance of the system in the presence of co- and adjacent channel performance demonstrates the reliability of the system and its ability to function within the existing analogue environment.