

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R SM.1541-6 (08/2015)

Unwanted emissions in the out-of-band domain

SM Series
Spectrum management



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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

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RECOMMENDATION ITU-R SM.1541-6*

Unwanted emissions in the out-of-band domain**

(2001-2002-2006-01/2011-09/2011-2013-2015)

Scope

This Recommendation provides out-of-band (OoB) domain emission limits for transmitters in the frequency range of 9 kHz to 300 GHz.

The ITU Radiocommunication Assembly,

considering

- a) that Recommendation ITU-R SM.329 – Unwanted emissions in the spurious domain, relates to the effects, measurements and limits to be applied to unwanted emissions in the spurious domain;
- b) that Recommendations ITU-R SM.329 and ITU-R SM.1539 provide guidance for determining the boundary between the out-of-band (OoB) and spurious domains in a transmitted radio frequency spectrum;
- c) that considerations of OoB domain and necessary bandwidths are included by necessity in Recommendation ITU-R SM.328 – Spectra and bandwidth of emissions;
- d) that unwanted emissions occur after a transmitter is brought into operation and can be reduced by system design;
- e) that OoB domain emission limits have been successfully used as national or regional regulations in areas having a high radiocommunications density; such limits are generally designed according to specific and detailed local needs for coexistence with other systems;
- f) that nevertheless there is a need, for each service, for a limited number of a more broadly generic ITU-R OoB domain emission limits, generally based on an envelope of the least restrictive OoB domain emission limits described in the above *considering* e);
- g) that where frequency assignments are provided to the Radiocommunication Bureau (BR) in accordance with Appendix 4 of the Radio Regulations (RR), the necessary bandwidth of an emission with a single carrier is given by the bandwidth portion of the emission designator;
- h) that the necessary bandwidth, referred to in RR Appendix 4 is for a single carrier transmission, and may not adequately cover the case of systems with multiple carriers,

recognizing

that the following terms are defined in the RR.

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4, 5, 6 and 7.

** Although OoB emissions are generally predominant in the OoB domain, spurious emissions may also occur in the OoB domain. It is important to note that the limits in this Recommendation apply to all the unwanted emissions in the OoB domain, both OoB emissions and spurious emissions.

Unwanted emissions

«1.146 unwanted emissions*: Consist of spurious emissions and out-of-band emissions.»

Spurious emission

«1.145 *spurious emission**: Emission on a frequency or frequencies which are outside the *necessary bandwidth* and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic *emissions*, parasitic *emissions*, intermodulation products and frequency conversion products, but exclude *out-of-band emissions*.»

Out-of-band emission

«1.144 *out-of-band emission**: Emission on a frequency or frequencies immediately outside the *necessary bandwidth* which results from the modulation process, but excluding *spurious emissions*.»

Occupied bandwidth

«1.153 *occupied bandwidth*: The width of a frequency band such that, below the lower and above the upper frequency limits, the *mean powers* emitted are each equal to a specified percentage $\beta/2$ of the total *mean power* of a given *emission*.

Unless otherwise specified in an ITU-R Recommendation for the appropriate *class of emission*, the value of $\beta/2$ should be taken as 0.5%.»

Necessary bandwidth

«1.152 *necessary bandwidth*: For a given *class of emission*, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.»

Assigned frequency band

«1.147 *assigned frequency band*: The frequency band within which the *emission* of a *station* is authorized; the width of the band equals the *necessary bandwidth* plus twice the absolute value of the *frequency tolerance*. Where *space stations* are concerned, the assigned frequency band includes twice the maximum Doppler shift that may occur in relation to any point of the Earth's surface.»

Assigned frequency

«1.148 *assigned frequency*: The centre of the frequency band assigned to a *station*.»

noting

a) that Recommendation ITU-R SM.1540 additionally covers cases of unwanted emissions in the OoB domain falling into adjacent allocated bands;

b) that the studies required by Question ITU-R 222/1, approved by Radiocommunication Assembly 2000, could have formal and substantial impact to basic definitions used in this Recommendation. It may be necessary to revise this Recommendation in the future to reflect the results of these studies,

recommends

1 Terminology and definitions

that the following additional terms and definitions should be used:

1.1 Spurious domain¹

(of an emission): the frequency range beyond the OoB domain in which spurious emissions generally predominate.

1.2 OoB domain¹

(of an emission): the frequency range, immediately outside the necessary bandwidth but excluding the spurious domain, in which OoB emissions generally predominate.

1.3 dBsd and dBasd

dBsd: decibels relative to the maximum value of power spectral density (psd) within the necessary bandwidth. The maximum value of psd of a random signal is found by determining the mean power in the reference bandwidth when that reference bandwidth is positioned in frequency such that the result is maximized. The reference bandwidth should be the same regardless of where it is centred and is as specified in § 1.6.

dBasd: decibels relative to the average value of psd within the necessary bandwidth. The average value of psd of a random signal is found by computing the mean power in the reference bandwidth and averaging that result over the necessary bandwidth. The reference bandwidth is as specified in § 1.6.

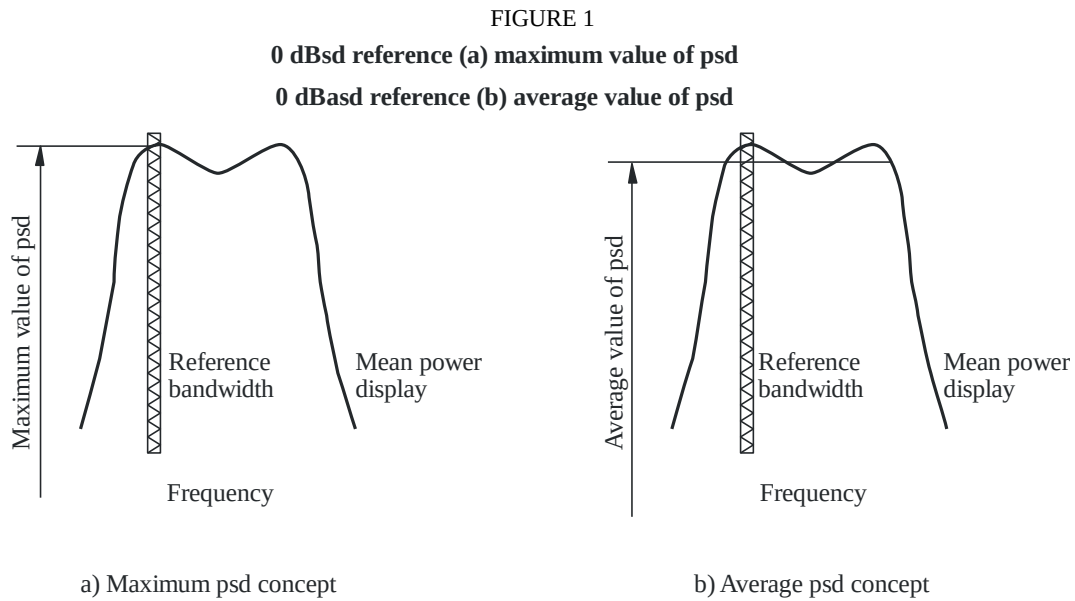
1.4 dBc

Decibels relative to the unmodulated carrier power of the emission. In the cases which do not have a carrier, for example in some digital modulation schemes where the carrier is not accessible for measurement, the reference level equivalent to dBc is dB relative to the mean power P .

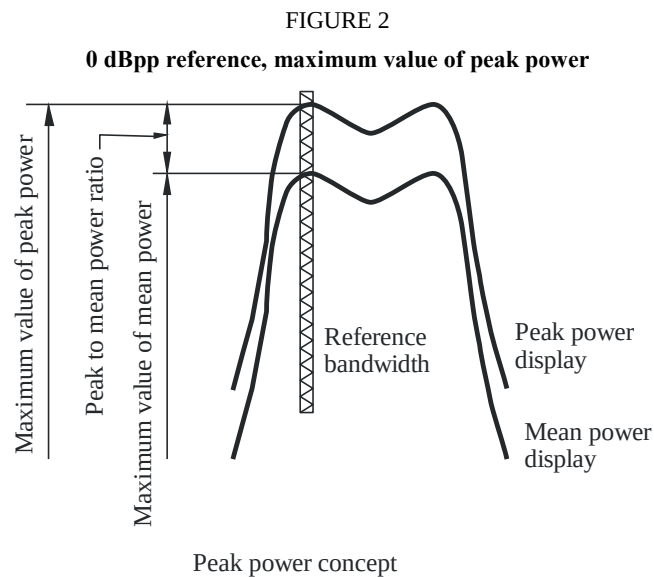
1.5 dBpp

Decibels relative to the maximum value of the peak power, measured with the reference bandwidth within the occupied bandwidth. The in-band peak power is expressed in the same reference bandwidth as the OoB peak power. Both the in-band and the unwanted emissions should be evaluated in terms of peak values. For radar systems, the reference bandwidth should be selected according to Recommendation ITU-R M.1177.

¹ The terms “OoB domain” and “spurious domain” have been introduced in order to remove some inconsistency now existing between, on one hand, the definition of the terms “out-of-band emission” and “spurious emission” in RR Article 1 and, on the other hand, the actual use of these terms in RR Appendix 3, as revised by World Radiocommunication Conference (Istanbul, 2000) (WRC-2000). OoB and spurious limits apply, respectively, to all unwanted emissions in the OoB and spurious domains.



SM1541-01



SM1541-02

1.6 Reference bandwidth

The bandwidth required for uniquely defining the OoB domain emission limits. If not explicitly given with the OoB domain emission limit, the reference bandwidth should be 1% of the necessary bandwidth. For radar systems the reference bandwidth should be selected in line with Recommendation ITU-R M.1177.

1.7 Measurement bandwidth

The bandwidth which is technically appropriate for the measurement of a specific system. In common spectrum analysers this is generally referred as the resolution bandwidth.

NOTE 1 – The measurement bandwidth may differ from the reference bandwidth, provided the results can be converted to the required reference bandwidth.

1.8 psd

For the purpose of this Recommendation, psd is the mean power per reference bandwidth.

1.9 Mean power

Power integrated over a specified frequency band using measurements of the psd or an equivalent method.

1.10 Adjacent channel mean power

Power integrated over the bandwidth of a channel adjacent to an occupied channel using measurements of the psd or an equivalent method.

1.11 Peak power

Power measured with the peak detector using a filter the width and shape of which is sufficient to accept the signal bandwidth.

1.12 Adjacent channel peak power

Peak power measured in the bandwidth of a channel adjacent to an occupied channel using a specified channel filter.

1.13 Total assigned band

Sum of contiguous assigned bands of a system consistent with the RR Appendix 4 data provided to the BR and as authorized by an administration.

NOTE 1 – For space services, when a system has multiple transponders/transmitters that operate in adjacent bands separated by a guardband, the total assigned band should include the guardbands. In such cases, the guardbands should be a small percentage of the transponder/transmitter bandwidth.

1.14 Total assigned bandwidth

The width of the total assigned band;

2 Application of definitions

that, when applying this Recommendation, guidance should be taken from the following:

2.1 OoB domain emissions

Any emission outside the necessary bandwidth which occurs in the frequency range separated from the assigned frequency of the emission by less than 250% of the necessary bandwidth of the emission will generally be considered an emission in the OoB domain. However, this frequency separation may be dependent on the type of modulation, the maximum symbol rate in the case of digital modulation, the type of transmitter, and frequency coordination factors. For example, in the case of some digital, broadband, or pulse modulated systems, the frequency separation may need to differ from the 250% factor.

Transmitter non-linearities may also spread in-band signal components into the frequency band of the OoB frequency ranges described in Annex 1, § 1.3. Further, transmitter oscillator sideband noise also may extend into that frequency range described in Annex 1, § 1.3. Since it may not be practical to isolate these emissions their level will tend to be included during OoB power measurements.

2.2 Spurious domain emissions

For the purpose of this Recommendation all emissions, including intermodulation products, conversion products and parasitic emissions, which fall at frequencies separated from the centre frequency of the emission by 250% or more of the necessary bandwidth of the emission will generally be considered as emissions in the spurious domain. However, this frequency separation may be dependent on the type of modulation, the maximum symbol rate in the case of digital modulation, the type of transmitter, and frequency coordination factors. For example, in the case of some digital, broadband, or pulse-modulated systems, the frequency separation may need to differ from the 250% factor.

For multichannel or multicarrier transmitters/transponders, where several carriers may be transmitted simultaneously from a final output amplifier or an active antenna, the centre frequency of the emission is taken to be the centre of either the assigned bandwidth of the station or of the –3 dB bandwidth of the transmitter/transponder, using the lesser of the two bandwidths.

2.3 Necessary bandwidth and OoB domain

In the case of narrow-band or wideband emissions (as defined in Recommendation ITU-R SM.1539), the extent of the OoB domain should be determined by using Table 1.

TABLE 1
Start and end of OoB domain

Type of emission	If necessary bandwidth B_N is:	Offset ($\pm$) from the centre of the necessary bandwidth for the start of the OoB domain	Frequency separation between the centre frequency and the spurious boundary
Narrow-band	$< B_L$ (see Note 1)	$0.5 B_N$	$2.5 B_L$
Normal	B_L to B_U	$0.5 B_N$	$2.5 B_N$
Wideband	$> B_U$	$0.5 B_N$	$B_U + (1.5 B_N)$

NOTE 1 – When $B_N < B_L$, no attenuation of unwanted emissions is recommended at frequency separations between $0.5 B_N$ to $0.5 B_L$.

NOTE 2 – B_L and B_U are given in Recommendation ITU-R SM.1539.

2.3.1 Single carrier emissions

The value of necessary bandwidth that should be used for checking whether a single carrier emission complies with limits in the OoB domain should coincide with the value in the emission designator provided to the BR in accordance with RR Appendix 4.

Some systems specify the OoB mask in terms of channel bandwidth or channel separation. These may be used as a substitute for necessary bandwidth provided they are found in ITU-R Recommendations or in relevant regional and national regulations.

2.3.2 Multicarrier emissions

Multicarrier transmitters/transponders are those where multiple carriers may be transmitted simultaneously from a final amplifier or an active antenna.

For systems with multiple carriers, the OoB domain should start at the edges of the total assigned bandwidth. For satellite systems, the necessary bandwidth used in the OoB masks provided in Annex 5 of this Recommendation and to determine the width of the OoB domain should be taken to

be the lesser of 3 dB transponder bandwidth or the total assigned bandwidth (Annex 2 provides two examples showing how to calculate the start and end of the OoB domain for multicarrier systems with single and multiple transponders per satellite).

For space services, the above definition of necessary bandwidth applies when all or some of the carriers are being transmitted simultaneously.

2.4 Considerations on dBsd, dBc, and dBpp

2.4.1 Positive and negative signs for dBsd, dBc, and dBpp

Since dBsd is defined as relative to some reference power spectral density, the OoB dBsd value is expressed using a negative number (for the usual case where the OoB psd is lower than the reference psd). However, if a term such as “dBsd below” or “Attenuation (dBsd)” is used, then the OoB domain emission value is expressed using a positive number.

Since dBc is defined as relative to some reference power, the OoB dBc value is expressed using a negative number. However, if a term such as “dBc below” or “Attenuation (dBc)” is used, then the OoB domain emission value is expressed using a positive number.

Since dBpp is defined as relative to some reference peak power, the OoB dBpp value is expressed using a negative number. However, if a term such as “dBpp below” or “Attenuation (dBpp)” is used, then the OoB domain emission value is expressed using a positive number.

Annex 3 provides the way to label X and Y axes on dBc and dBsd masks.

2.4.2 Comparisons of dBsd and dBc

Since dBsd and dBc do not have the same 0 dB reference, the same numeric dB value may cause dBsd emission limits that are more stringent than dBc emission limits. The chosen reference bandwidth will affect the amount of this difference. Thus, the type of mask, reference bandwidth, and mask values need to be established together.

2.4.3 Practical application of dBsd, dBc, and dBpp limits

dBsd may be more practical for the following applications:

- digital modulation;
- modulation formats in which measurement of the carrier is impractical.

dBc may be more practical for the following applications:

- analogue modulation;
- specific digital modulation systems;
- subsidiary limits for discrete emissions contained in the OoB domain when spectral density is specified in dBsd values.

dBpp may be more practical for the following applications:

- specific pulsed modulation systems, e.g. radar, and certain specific analogue transmission systems;

3 Methods to determine conformance to OoB domain emission limits

that the adjacent channel and alternate adjacent channel power method or the OoB spectrum mask method described in Annex 1 should be used to determine conformance to OoB domain emission requirements;

4 OoB domain emission limits for transmitters in the range of 9 kHz to 300 GHz²

that the spectrum limits specified in this Recommendation should be regarded as generic limits, which generally constitute the least restrictive OoB emission limits successfully used as national or regional regulations. These are sometimes called safety net limits. They are intended for use in bands where tighter limits are not otherwise required to protect specific applications (e.g. in areas having a high radiocommunications density).

On this basis, the OoB domain emissions, to be applied to transmitters in the range of 9 kHz to 300 GHz, should be limited as given in Table 2.

The applicability of Recommendations ITU-R SM.1541 and ITU-R SM.1540 is described in Annex 14.

The development of more specific OoB domain emission limits for each system and in each frequency band should be encouraged by administrations. These limits would take into account the actual application, modulation, filtering capabilities of the system and would take care about co-frequency or adjacent bands operating systems, with a view to enhancing compatibility with other radio services.

Examples of ITU-R Recommendations providing such more specific OoB emission limits for some systems in some frequency bands are listed in Annex 4.

TABLE 2
OoB domain emission spectrum limiting curves

Service category in accordance with RR Article 1, or equipment type	Emission mask
Space services (earth and space stations)	See Annex 5
Broadcast television	See Annex 6
Sound broadcasting	See Annex 7
Radar	See Annex 8
Amateur services	See Annex 9
Land mobile service	See Annex 10
Maritime and aeronautical mobile services	See Annex 11
Fixed service	See Annex 12

Compliance with emission limits contained in this Recommendation may not preclude the occurrence of interference. Therefore, compliance with the standard does not obviate the need for cooperation in resolving and implementing engineering solutions to harmful interference problem;

5 Adaptation of OoB masks provided in Annexes 5 to 12 in the cases of narrow-band and wideband systems

- that in cases where the necessary bandwidth B_N is less than B_L as defined in Recommendation ITU-R SM.1539, the OoB mask should be scaled. This can be done by replacing B_N by B_L ;
- in cases where the necessary bandwidth B_N is greater than B_U as defined in Recommendation ITU-R SM.1539, the value of B_N will remain unchanged in the application of the OoB mask

² OoB domain emission limits apply to unwanted emissions (both OoB and spurious emissions) in the OoB domain.

but the mask should be truncated. Accordingly, the OoB mask will only be applicable from 50% of B_N to $(150 + 100 B_U/B_N)\%$ of B_N ;

6 Measurement methods

that the methods for measurement of OoB described in detail in Annex 13 should be used.

Annex 1

Methods to determine conformance to OoB domain emission limits

Two possible methods can be used to quantify the OoB emission energy. Section 1 provides a method by which the power is measured in an adjacent channel. Section 2 discusses a method of assessment based on the determination of the power spectral density in the OoB domain.

1 Adjacent channel and alternate adjacent channel power method

This methodology is based on the concept defined in Recommendation ITU-R SM.328 – Spectra and bandwidth of emissions, § 1.12 and has become popular since the commercial availability of spectrum analysers with digital signal processing capability which can perform numerical integration within a specified bandwidth.

A limit for permissible OoB domain power can be derived from the limits imposed by a permissible OoB spectrum mask by integrating the mathematical expression for the curve over a specified frequency band. An example of this translation is provided in Appendix 1 for an example emission mask used in the land mobile service, the primary user of this method. Comparisons of limits so derived with actual limits adopted in mobile service standards reveal that mobile radio industry practice has been to establish limits significantly more stringent than those derived from an OoB mask in order to achieve spectrum efficiency.

One key advantage of this method in a defined bandwidth approach is that the same approach is defined in Recommendation ITU-R SM.329 for limits of the power of spurious domain emissions displaced relatively far in the frequency spectrum from a transmitter's assigned frequency band (i.e. channel).

Another advantage is that it tends to facilitate frequency management if the reference bandwidth is chosen comparable to that of receivers used in the assigned frequency bands adjacent to that of a transmitter as this leads to more efficient use of the electromagnetic spectrum. This can be especially significant in new channel splitting "refarming" environments wherein the close packing of channels in an allocated band has resulted in frequency assignment coordination based on adjacent channel considerations in addition to co-channel considerations. It also provides a convenient means of assessing the interference potential between two different modulation methods used on adjacent channels or bands. This has proved useful in spectrum allocation planning in various countries to determine compatible neighbouring technologies and link directions.

1.1 Parameters to be measured

The parameters to be measured are the occupied bandwidth of an emission, and the mean power in several defined bands. The same modulation condition is employed for all measurement bands.

The maximum value of 99% power occupied bandwidth permitted by a particular emission mask can be determined by calculating the frequency difference between the 23 dB attenuation levels for any emission mask.

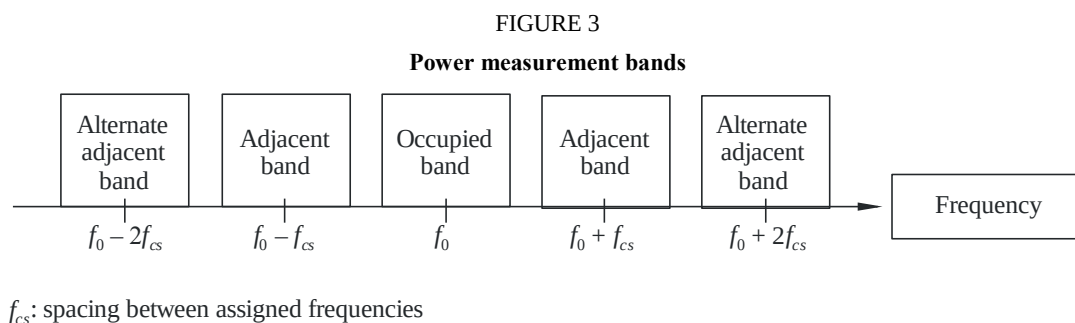
1.2 Units of measurement

The units of power measurement are the same as those used for measurement of spurious domain emissions, as given in Annex 1 of Recommendation ITU-R SM.329 (mean power is specified for most measurements). Appropriate conversion factors (discussed in more detail in § 1.1.1 and § 1.1.2 of Annex 13) must be used to correct for differences between:

- the detection method employed in the signal analyser used to perform a measurement and the detection method specified for the limits; as well as
- the resolution bandwidth of the filter contained in the signal analyser used to perform a measurement and the detection method specified for the limits.

1.3 Measurement bands

Figure 3 graphically portrays the succeeding band descriptions.



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1.3.1 Adjacent band

The band properties follow, which provide several means for assessment of the amount of interference power that might be intercepted by a receiver on the adjacent channel. The power in this band is termed the adjacent band power (ABP).

1.3.1.1 Location of the adjacent band

This band is centred on the adjacent assigned frequency band in the allocated band in which the transmitter operates.

For worst-case considerations, this band is located closer to the transmitter by an amount equal to that of the permissible frequency drift of the transmitter, plus any Doppler frequency difference.

1.3.1.2 Bandwidth of the adjacent band

Its width is equal to the equivalent noise bandwidth of the adjacent channel receiver. If not known then the default value should be equal to the transmitter's occupied bandwidth.

1.3.2 Alternate adjacent band

This band is centred relative to the adjacent band in the same manner in which the adjacent band is centred relative to the assigned frequency band. Its width equals that of the adjacent band.

In some services (e.g. FM broadcast) channels are assigned by alternating two interlaced sets of assigned frequency band plans so this provides an assessment of the amount of interference power that might be intercepted by a receiver on the adjacent authorized channel. The power in this band is termed the alternate ABP.

For worst-case considerations, the centre of this band is located closer to the transmitter by an amount equal to that of the permissible frequency drift of the transmitter, plus that of a typical receiver used on the adjacent channel, plus any Doppler frequency difference.

1.4 Adjacent band power ratio (ABPR)

ABPR is calculated in the following manner:

- in power, as $ABPR = P/P_{ad}$
- in decibels, as $ABPR = P - P_{ad}$ (dB)

where:

P : transmitter mean power

P_{ad} : mean power in the adjacent frequency band.

This calculation is performed as a routine operation automatically on many modern spectrum analysers equipped with digital signal processing capabilities.

The concept of measuring the power in the bandwidth of an adjacent channel can be extended to neighbouring bands in an allocated band which are N times further displaced than the adjacent band, where N is an integer multiple of the assigned frequency band. The designation $ABPR_N$ should be used to denote the power of the OoB emission in the N -th adjacent channel.

2 OoB mask method

This methodology is based on the concept defined in Recommendation ITU-R SM.328 § 1.10.

2.1 Parameters to be measured

The transmitter spectrum should be measured using a measurement bandwidth in line with *recommends* 1.7 and should be characterized in terms of dBsd, dBc or dBpp.

2.2 Measurement range

Measurements are to be conducted in the OoB domain which is between the assigned frequency band boundary and the boundary between the OoB and spurious domains.

2.3 OoB mask

In accordance with Note 1 of § 1.10 of Recommendation ITU-R SM.328, the mask does not limit emissions within the necessary bandwidth as it is applicable in the OoB domain of the spectrum.

NOTE 1 – Within the OoB domain, there may be line spectra present at levels higher than the OoB mask. A mask which allows for these individual spectra might not be stringent enough. Therefore an approach may need to be considered for some emissions which allows for a limited number of such spectra at given levels above the mask; those specific limits, when necessary, are specified in the relevant Annexes dealing with specific radiocommunication services.

Appendix 1 to Annex 1

Example calculation of a permissible OoB power ratio and power limits from a permissible OoB mask

1 Introduction

Integration of an OoB mask over a specific frequency range permits calculation of the maximum permitted OoB domain power in that band permitted by that mask and serves to relate the two methods used for limiting OoB domain emissions. This relationship may be calculated using either a discrete method or a continuous method. The former method emulates the manner in which a spectrum analyser or a vector signal analyser with digital power measurement capability functions while the latter provides a purely mathematical approach. Due to advances in digital technology this capability is now available in many commercially available spectrum analyser families. Both methods are valid and lead to the same resultant within negligible difference as will be demonstrated in the following examples.

The examples will utilize the digital emission mask formula described in Table 3 used in many countries, sometimes referred to as emission mask G. This example calculates the total power in an adjacent band of 25 kHz width. Simple adjustment of the integration range limits permit calculation for other bandwidths.

TABLE 3

Attenuation equations for emission mask G
(used in some countries for non-voice transmitters used with 25 kHz
channel spacing (based on RBW = 300 Hz))

Frequency range	Attenuation limits (dB)
$5 \text{ kHz} < fd < 10 \text{ kHz}$	$83 \log (fd/5)$
$10 \text{ kHz} < fd < 2.5 \times \text{ABW}$	The lesser of $116 \log (fd/6.1) \text{ dB}$, or $50 + 10 \log (P) \text{ dB}$, or 70 dB

ABW : authorized bandwidth (larger of either occupied bandwidth or necessary bandwidth).

fd : displacement frequency from carrier frequency (kHz).

RBW : reference bandwidth in which the power of the OoB domain emissions is specified.

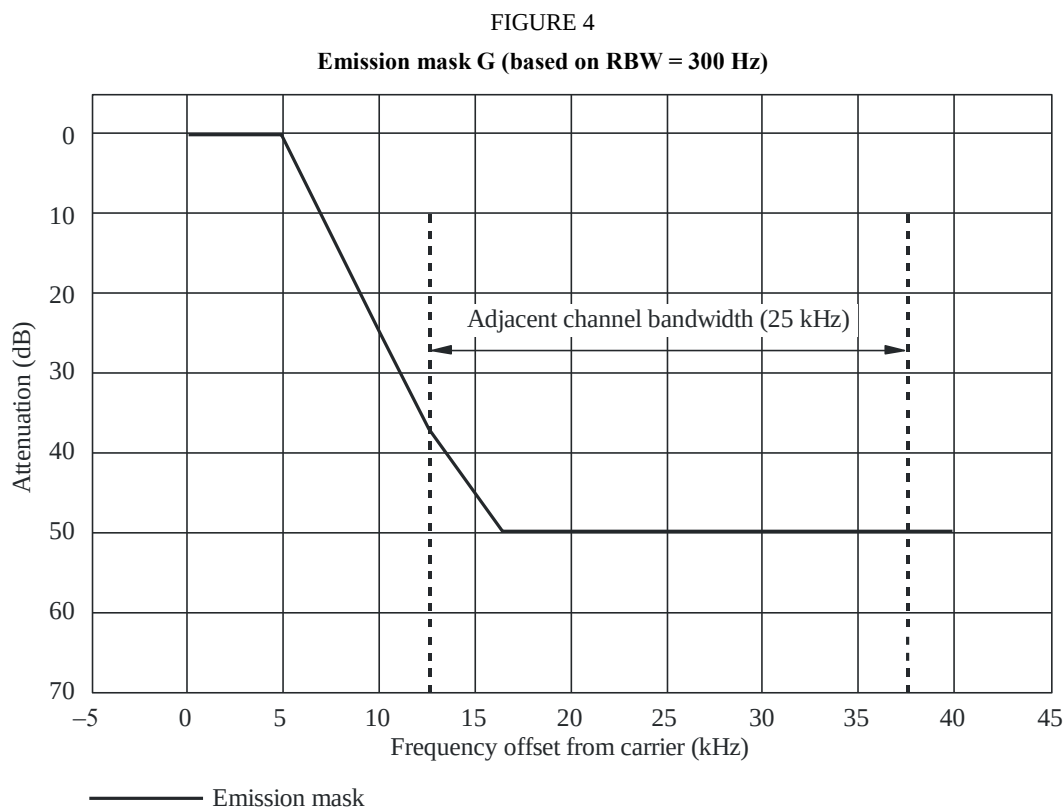
Discontinuities in the mask formula (i.e. breakpoints) of $P = 1 \text{ W}$ transmitter occur, as evident in Table 4 and Fig. 4, necessitating integration over multiple ranges.

TABLE 4

Breakpoints in OoB mask G
(based on RBW = 300 Hz)

Frequency displacement from carrier (kHz)	Attenuation (dB)
12.5	36.14
16.46	50

The G mask is graphically portrayed in Fig. 4.



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2 Discrete method

This example is for a 1 W transmitter and notation follows that is used in a software program to calculate the results. This mask has a transition in the midst of the adjacent frequency band, and 2 breakpoint frequency displacements from the centre of the emission need to be determined. First is a transmitter power level dependent frequency breakpoint at which attenuation reaches $50 + 10 \log(P)$ dB, where P is the transmitter power (W). Second is the breakpoint at which attenuation equals 70 dB. For the side of the adjacent band which is nearest the emission, the power level independent attenuation formula for the example power spectral density attenuation mask is given in equation (1), while equation (11) contains the power level dependent formula for the frequency range on the far side of the appropriate breakpoint frequency. Power in both regions must be summed to determine the total adjacent band power.

In the following equations the notation “:=” means “defined as” and “[]”, when used in mathematical equations, are not temporary but agreed text.

The near side attenuation equation is represented in this Appendix by:

$$AN(fd) := 116 \log(fd / 6.1) \quad \text{dB} \quad (1)$$

where fd is the frequency displacement (kHz) from the centre of the emission.

To determine the adjacent band power it is necessary to convert this logarithmic representation of the permissible emission spectral power density limit to a linear representation, so the attenuation can be integrated or summed over the frequency range of the adjacent band, using:

$$an(fd) := 10^{-AN(fd)/10} \quad (2)$$

To determine the power limited by the mask, the attenuation must be summed at equal intervals equal to the resolution bandwidth specified for emission mask measurements (i.e. numerical integration) over the frequency band being assessed. For this mask:

$$RBW := 0.3 \quad \text{kHz} \quad (3)$$

and the adjacent band is assigned a bandwidth of 25 kHz. The adjacent band is centred at a displacement of 25 kHz, thus the adjacent assigned band starts at a frequency displacement of $25 - 25/2 = 12.5$ kHz and ends at 37.5 kHz. However, an adjustment equal to half the bandwidth of the resolution filter bandwidth is needed to preclude inclusion of energy outside the adjacent band, so power summation needs to begin at $12.5 + 0.3/2 = 12.65$ kHz. The power level dependent breakpoint frequency, fb , is given by rearranging equation (1) to be:

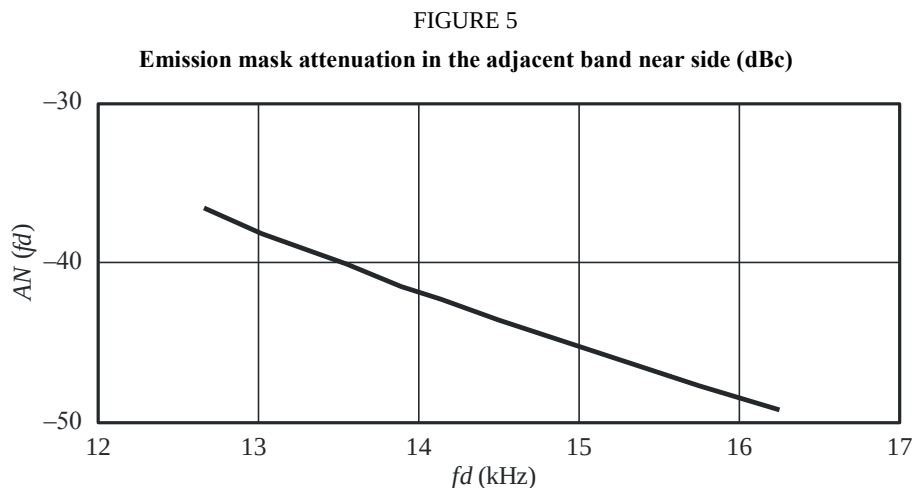
$$fb := 6.1 \times 10^{[(50 + 10 \log(P))/116]} \quad (4)$$

For a $P = 1$ W transmitter the 50 dB breakpoint lies at 16.46 kHz. The 70 dB breakpoint, which applies as well to all transmitters of 100 W or more power, occurs at 24.48 kHz.

The power attenuation in the near side region of the adjacent band may then be determined by summing over the frequency displacement range 12.65 kHz to 16.46 kHz which, after adjustment, is represented by:

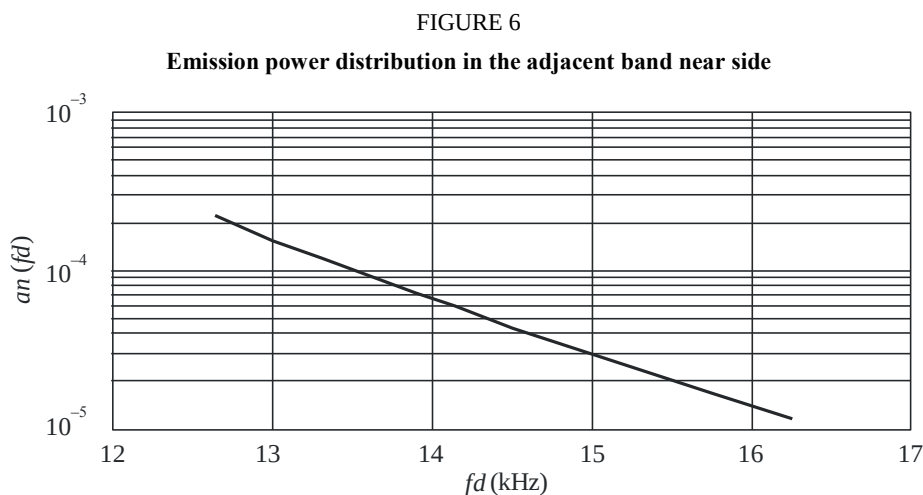
$$fd := 12.65, 12.95, \dots, 16.31 \quad \text{kHz} \quad (5)$$

The near side portion of the emission mask in the adjacent band logarithmically appears in Fig. 5:



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and the linear representation for this mask follows in Fig. 6.



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The total adjacent band power relative to the total emission power is a ratio which is determined by summing the power in the adjacent band bandwidth shown in Fig. 6 using the following equation:

$$abprn := \sum_{fd} an(fd) \quad (6)$$

This equates to:

$$abprn = 8.99 \times 10^{-4} \quad (7)$$

This can be converted back to attenuation for the adjacent band power limit (dB) using:

$$ABPRN := 10 \log(abprn) \quad (8)$$

which evaluates as:

$$ABPRN = -30.46 \quad \text{dB} \quad (9)$$

The formula for the example psd attenuation mask in the far side region of the adjacent frequency band for a 1 W radio is:

$$AF(fd) := 50 + 10 \log(1) \quad \text{dB} \quad (10)$$

where fd is the frequency displacement in kHz from the centre of the emission.

To determine the adjacent band power it is necessary to convert this logarithmic representation of the emission psd to a linear representation, so the power can be integrated or summed over the frequency range of the adjacent band, using:

$$af(fd) := 10^{\frac{-AF(fd)}{10}} \quad (11)$$

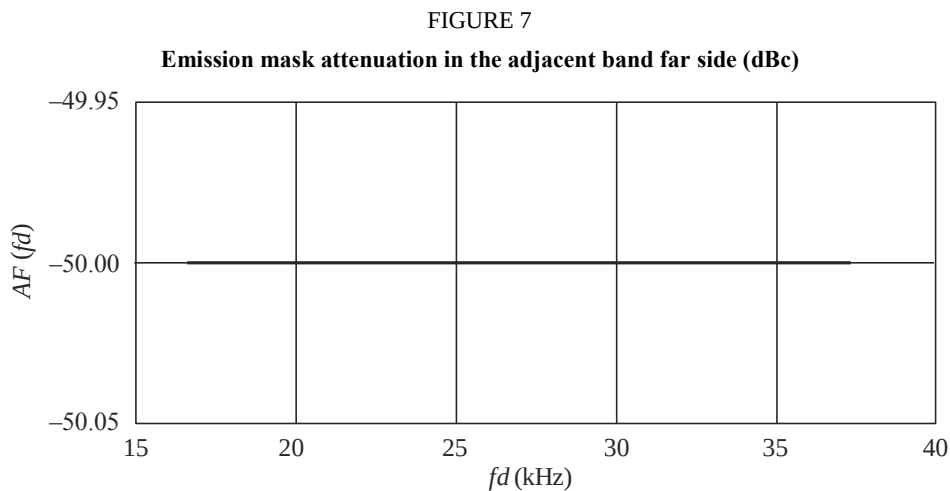
To determine the power limited by the mask the power must be summed at equal intervals equal to the resolution bandwidth specified for emission mask measurements (i.e. numerical integration) over the frequency band being assessed. For this mask:

$$RBW := 0.3 \quad \text{kHz} \quad (12)$$

The adjacent band power limit relative to the total emission power may then be calculated by summing the attenuation over the range 16.46 kHz to 37.5 kHz which, after adjustment, is represented in this Appendix by:

$$fd := 16.61, 16.91, \dots, 37.35 \quad \text{kHz} \quad (13)$$

The far side of the emission mask in the adjacent band logarithmically appears in Fig. 7.



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The total ABP relative to the total emission power is a ratio which is determined by summing the power in the adjacent band bandwidth using the following formulation:

$$abprf := \sum_{fd} af(fd) \quad (14)$$

This equates to:

$$abprf = 7 \times 10^{-4} \quad (15)$$

and evaluates as:

$$ABPRF = -31.55 \quad \text{dB} \quad (16)$$

The total power is the sum of those in equations (6) and (14):

$$abpr = abprn + abprf \quad (17)$$

which evaluates to:

$$abpr = 15.99 \times 10^{-4} \quad (18)$$

This translates to:

$$ABPR := -10 \log(abpr) \quad \text{dB} \quad (19)$$

which evaluates as:

$$ABPR = 27.96 \quad \text{dB} \quad (20)$$

This attenuation establishes $ABPR_1 = +30 \text{ dBm} - 27.96 \text{ dB}$, i.e. 2.04 dBm.

3 Continuous method

In general, the emission mask curves have several line segments and the power spectral density can be represented by a linear equation on each segment.

$$S_{\text{dB}}(f) = af + b \quad (21)$$

To calculate the unwanted power levels injected into the adjacent band, it is needed to relate spectra measured with 300 Hz bandwidth, denoted by G , to the true power spectral density, denoted by S . If we assume that power levels of G are also represented by a linear equation $G = a'f + b'$, the problem is to relate the linear line coefficients a' and b' of the G function behaviour to the S function coefficients a and b . The relationship between $G(f_c)$ and $S(f_c)$ can be represented as follows:

$$\begin{aligned} G(f_c) &= \int_{f_c-B/2}^{f_c+B/2} S(f) df \\ &= \int_{f_c-B/2}^{f_c+B/2} 10^{[S_{\text{dB}}(f)/10]} df = \int_{f_c-B/2}^{f_c+B/2} 10^{[(af+b)/10]} df = \int_{f_c-B/2}^{f_c+B/2} e^{\ln 10 [(af+b)/10]} df \\ &= \int_{f_c-B/2}^{f_c+B/2} \exp(k(af+b)) df = \frac{1}{ka} e^{kb} [e^{kaf}]_{f_c-B/2}^{f_c+B/2} \\ &= \exp(k(af_c+b)) \frac{\sinh(\alpha B)}{\alpha} \end{aligned} \quad (22)$$

where $k = \ln(10)/10$, $\alpha = ka/2$ and f_c is the centre frequency of resolution bandwidth B . Also the measured power spectral density in decibels based on resolution bandwidth is calculated by equation (23) and equating the coefficients yields (24) and (25).

$$G_{\text{dB}}(f_c) = 10 \log(G(f_c)) = \frac{1}{k} \ln(G(f_c)) = a'f_c + b' \quad (23)$$

$$a = a' \quad (24)$$

$$b = b' - \frac{1}{k} \ln \left(\frac{\sinh(\alpha B)}{\alpha} \right) \quad (25)$$

If a' approaches zero, the equation for b becomes:

$$b = b' - \frac{1}{k} \ln(B) \quad (26)$$

To calculate the permissible OoB domain power using the above procedure, one must first derive the equation $S_{dB}(f) = af + b$ and integrate this equation over the adjacent channel bandwidth.

$$\text{Permissible out-of-band domain power} = \int_W 10^{[S_{dB}(f)/10]} df$$

where W is the adjacent channel bandwidth.

Using transmitter power P equal to 1 W in a 25 kHz band system, based on a resolution bandwidth of 300 Hz the emission mask appears as shown in Fig. 5. Also, the breakpoint reference levels of emission mask are given in Table 4 so the calculation interval can be divided into two sub intervals adjacent channel bandwidth according to the emission curve shape, that is, (12.5 kHz-16.46 kHz) and (16.46 kHz-37.5 kHz). From Table 3, we can get a linear function equation (27) based on Table 4 breakpoints (12.5 kHz, -36.14 dB) and (16.46 kHz, -50 dB). And also, in the frequency range larger than 16.46 kHz, a constant level of -50 dB results as given by equation (28).

$$\text{For } 12.5 \text{ kHz} \leq f \leq 16.46 \text{ kHz} \quad G_{dB}(f) = 7.61 - 3.5 f \quad (27)$$

$$\text{For } 12.46 \text{ kHz} \leq f \leq 37.5 \text{ kHz} \quad G_{dB}(f) = -50 \quad (28)$$

Equations (27) and (28) can be converted to the following equations using (24), (25) and (26).

$$\text{For } 12.5 \text{ kHz} \leq f \leq 16.46 \text{ kHz} \quad S_{dB}(f) = 12.84 - 3.5 f \quad (29)$$

$$\text{For } 12.46 \text{ kHz} \leq f \leq 37.5 \text{ kHz} \quad S_{dB}(f) = -44.77 \quad (30)$$

The total power levels in adjacent channel bandwidth are the summation of two integration results over respective sub intervals.

Permissible OoB emission attenuation:

$$\begin{aligned} &= \int_{12.5}^{16.46} 10^{[(12.84-3.5f)/10]} df + \int_{16.46}^{37.5} 10^{[-44.77/10]} df \\ &= 0.00095 + 0.0007 = 0.00165 \end{aligned} \quad (31)$$

In decibels, the above attenuation requirement is converted as follows:

$$10 \log(0.00165) = -27.8 \quad \text{dB} \quad (32)$$

This attenuation establishes $ABP_1 = +30 \text{ dBm} - 27.8 \text{ dB}$, i.e. 2.2 dBm, a result very close to that obtained using the discrete method.

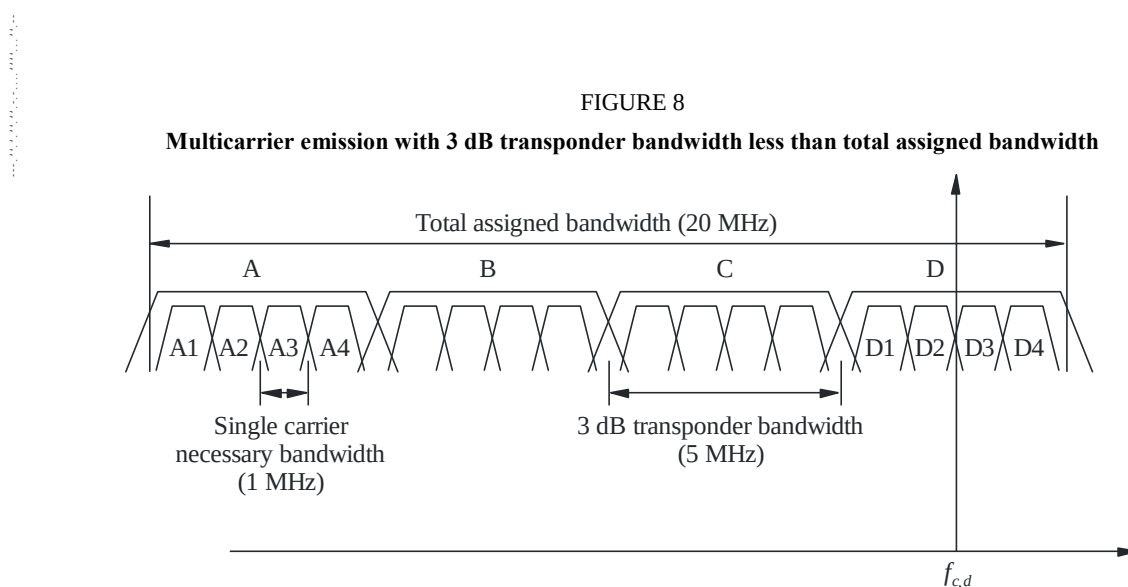
Annex 2

Calculation of the start and end of the OoB domain for multicarrier systems with single and multiple transponders per satellite

This annex provides two examples showing how to calculate the start and end of the OoB domain for multicarrier systems with single and multiple transponders per satellite.

1 Example 1: Multiple transponders per satellite serving the same service area

Figure 8 is one example of a satellite with multiple transponders. In this example, the width of the band in which the satellite is licensed or authorized to transmit is 20 MHz, the 3 dB bandwidth of the transponder is 5 MHz, and the necessary bandwidth of a single carrier emission is 1 MHz.



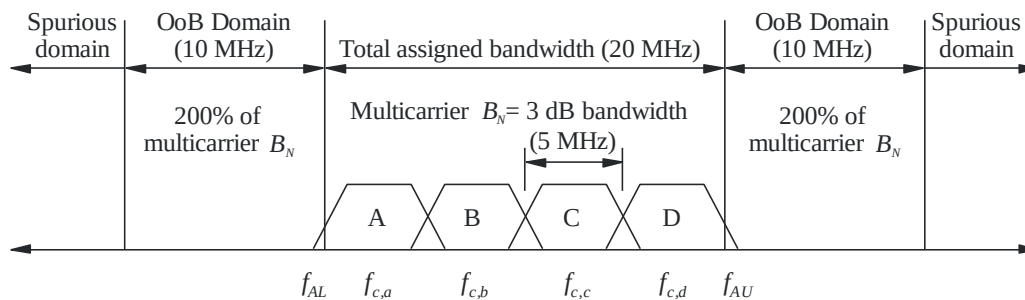
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This Recommendation equates necessary bandwidth, B_N , of a multicarrier emission to the lesser of the -3 dB bandwidth of the transponder and of total assigned bandwidth. Hence, for the example above, the necessary bandwidth would be 5 MHz. The OoB domain begins at the edges of each total assigned bandwidth that is part of the band over which the system is authorized.

The OoB domain is taken to be those frequencies that are separated from the centre frequency by more than 50% of the necessary bandwidth and less than 250% of the necessary bandwidth (the bandwidth of transponders A and D). Consequently, the width of the OoB domain is 200% of the necessary bandwidth. So for the example shown in Fig. 9, the width of OoB domain above f_{AU} and below f_{AL} is 10 MHz. The OoB and spurious domains are shown in Fig. 9.

FIGURE 9

OoB and spurious emission domains for multicarrier system shown in Fig. 8



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2 Example 2: Single transponder per satellite

When all carriers in Fig. 8, A1 through D4, are passed through a single transponder the OoB domain should start at the edges of the total assigned bandwidth and the width of the OoB domain should equal 200% of the necessary bandwidth where the necessary bandwidth is set to the minimum of the total assigned bandwidth and 3 dB transponder bandwidth.

Annex 3

Graph labelling for dBc and dBsd masks

This annex shows the way to label the axes of dBc and dBsd spectrum masks.

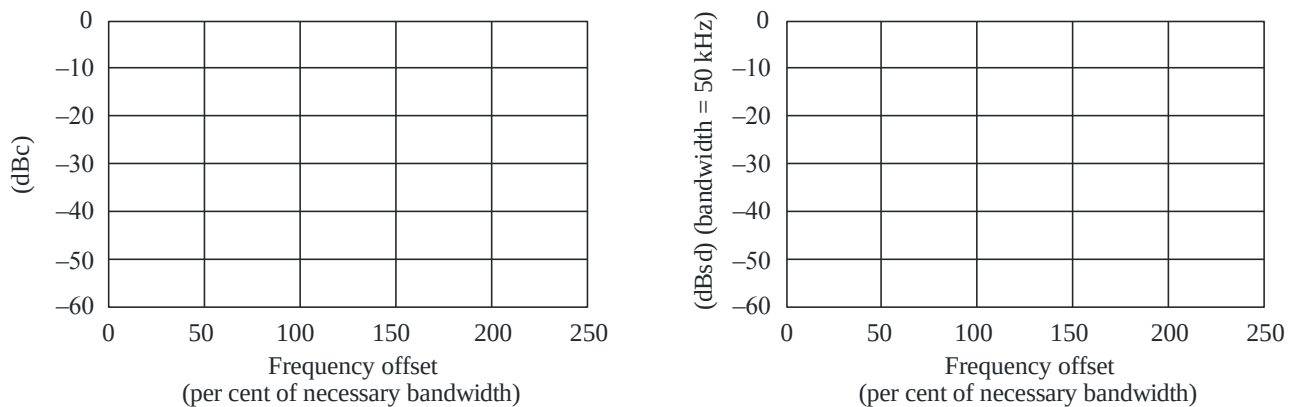
1 Y-axis labelling of OoB masks

Figure 10 shows the preferred way to label the Y-axis on dBc and dBsd spectrum masks, where negative relative level values are used. Figure 11 shows an alternate way using positive attenuation values. Note that the masks for symmetric limits are drawn the same in Figs 10 and 11; only the labelling of the Y-axis is different. For dBsd graphs, the reference bandwidth should be included in the label, e.g. dBsd (BW = 50 kHz).

The convention of having zero at the top of the Y-axis follows the usual industry practice for specifying limit masks and displaying spectra on spectrum analysers and other test equipment.

FIGURE 10

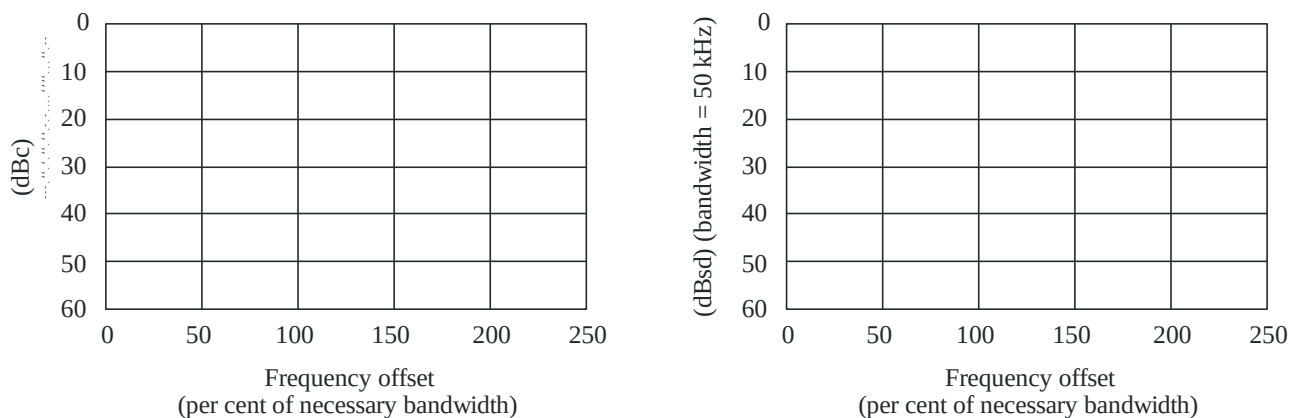
Examples of preferred Y-axis labelling of symmetric OoB masks, using relative levels



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FIGURE 11

Examples of alternate Y-axis labelling of symmetric OoB masks, using attenuation levels



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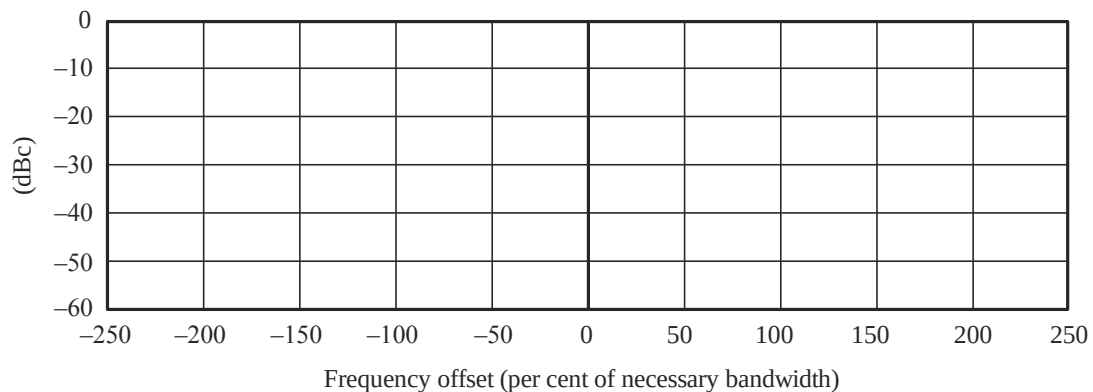
2 X-axis labelling of OoB masks

The frequency offset is usually given as the per cent of necessary bandwidth, but sometimes it may be more convenient to give it as a per cent of channel bandwidth. The frequency offset may also be given in absolute units of kHz or MHz.

Usually, the mask limits are symmetric about the centre frequency, and only positive frequency offset values are shown; which are interpreted to be absolute values that represent both positive and negative frequency offsets. In this case, only the positive frequency offset values are shown. However, for limits that are asymmetric about the centre frequency, the X-axis needs to include both positive and negative frequency offsets. Figure 12 shows an example graph that can be used for either asymmetric or symmetric limits.

FIGURE 12

Example of graph labelling of asymmetric or symmetric OoB masks



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Annex 4

List of ITU-R texts concerning OoB domain emissions related to specific services

Recommendation ITU-R F.1191 – Necessary and occupied bandwidths and unwanted emissions of digital fixed service systems

Recommendation ITU-R M.478 – Technical characteristics of equipment and principles governing the allocation of frequency channels between 25 and 3 000 MHz for the FM land mobile service

Recommendation ITU-R M.1580 – Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-2000

Recommendation ITU-R M.1581 – Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-2000

Report ITU-R M.2014 – Digital land mobile systems for dispatch traffic

Recommendation ITU-R BS.1114 – Systems for terrestrial digital sound broadcasting to vehicular, portable and fixed receivers in the frequency range 30-3 000 MHz

Recommendation ITU-R BT.1206 – Spectrum limit masks for digital terrestrial television broadcasting

Recommendation ITU-R M.1480 – Essential technical requirements of mobile earth stations of geostationary mobile-satellite systems that are implementing the global mobile personal communications by satellite (GMPCS) – Memorandum of understanding arrangements in parts of the frequency bands 1-3 GHz

Recommendation ITU-R M.1343 – Essential technical requirements of mobile earth stations for global non-geostationary mobile-satellite service systems in the bands 1-3 GHz

NOTE 1 – Recommendation ITU-R M.1343 could be applied also to terminals in regional non-geostationary satellite systems, although the title refers to global systems.