



**Fixed Radio Systems;
Point-to-point equipment;
Derivation of receiver interference parameters useful for
planning fixed service point-to-point systems operating
different equipment classes and/or capacities**

Reference

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

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Introduction

The present document explains how the assignment criteria between Digital Fixed Service systems, occupying different bandwidths and using different types of modulation are determined.

The primary aim of spectrum management is to use limited spectrum in the most efficient and effective manner. Thus the maintenance of interference free operation, alongside the sometime conflicting desire to establish a maximum link density with guaranteed system availability, are the primary aims of any spectrum management system.

1 Scope

The present document gives, initially, a basic overview of how a fixed point-to-point system is allocated an EIRP guaranteeing predetermined link availability. It then reviews the methodology for deriving the parameters necessary for the sharing of FS systems in an environment with different equipment classes and capacity. The methodology is based on the limitation of noise and is not exclusive. In addition a method for calculation of RSL based on normalized values is presented.

The present document highlights the primary parameters from European standards, which are vital to the development of an assignment system. These parameters are:

- Transmitter radiation patterns.
- Receiver sensitivity.
- Receiver adjacent channel rejection.
- Receiver co-channel rejection.

In addition to these parameters the antenna radiation profile and, if fitted, the ATPC operating characteristics will have a major effect on link density.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] Recommendation ITU-R P.530: "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems".
- [i.2] Recommendation ITU-R P.676: "Attenuation by atmospheric gases".
- [i.3] Recommendation ITU-R F.746: "Radio-frequency arrangements for fixed service systems".
- [i.4] Recommendation ITU-R SM.328-11: "Spectra and bandwidth of emissions".
- [i.5] ETSI EN 302 217-2: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2: Digital systems operating in frequency bands from 1 GHz to 86 GHz; Harmonised Standard for access to radio spectrum of article 3.2 of Directive 2014/53/EU".
- [i.6] ETSI TR 103 053 (V1.1.1) (2014-09): "Fixed Radio Systems; Parameters affecting the Signal-to-Noise Ratio (SNR) and the Receiver Signal Level (RSL) threshold in point-to-point receivers; Theory and practice".
- [i.7] ETSI EN 302 217-1: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 1: Overview, common characteristics and system-independent requirements".

- [i.8] ETSI TR 103 103: "Fixed Radio Systems; Point-to-point systems; ATPC, RTPC, Adaptive Modulation (mixed-mode) and Bandwidth Adaptive functionalities; Technical background and impact on deployment, link design and coordination".
- [i.9] ETSI GR mWT 015: "Frequency Bands and Carrier Aggregation Systems; Band and Carrier Aggregation".
- [i.10] ECC/REC(01)05: "List of parameters of digital point-to-point fixed radio links used for national planning".
- [i.11] Recommendation ITU-R F.758: "System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

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

dB	deciBel
dBW	deciBel relative to one Watt
dBW/Hz	deciBel relative to one Watt per Hertz
f_n	Nyquist frequency
GHz	GigaHertz
Hz	Hertz
k	boltzmann's constant
MHz	MegaHertz
Mbit/s	Megabit per second
N	Modulation scheme
r_{of}	Cosine roll-off factor
T	Temperature in degrees Kelvin

3.3 Abbreviations

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

ACM	Adaptive Code and Modulation
ATPC	Automatic Transmit Power Control
BB	BroadBand
BCA	Bands and Carriers Aggregation
BER	Bit Error Rate
BW(U)	BandWidth Unwanted
BW(W)	BandWidth Wanted
C/I	Carrier to Interference
CCDP	Co-Channel Dual Polarization
CPM	Continuous Phase Modulation
CS	Channel Spacing
CW	Continuous Wave
EIRP	Equivalent Isotropically Radiated Power
FEC	Forward Error Correction
FET	Field-Effect Transistor
FM	Fade Margin
FS	Fixed Service
FSPL	Free Space Path Loss
GBR	Gross Bit-Rate
GR	Group Report

IF	Intermediate Frequency
IM _F	Industrial Margin
ITU-R	International Telecommunication Union - Radio sector (formerly CCIR)
N/I	Noise to Interference
NF	Noise Figure
NFD	Net Filter Discrimination
PDH	Plesiochronous Digital Hierarchy
QAM	Quadrature Amplitude Modulation
RE	Radio Equipment
RF	Radio Frequency
RIC	Radio Interface Capacity
RS	Reed–Solomon
RSL	Receive Signal Level
Rx	Receiver
S/N	Signal to Noise
SDH	Synchronous Digital Hierarchy
STM	Synchronous Transport Module
Tx	Transmitter
W/U	Wanted to Unwanted
XPD	Cross-Polar Discrimination

4 Overview of fundamental approach to noise limited assignments

4.1 The Link Budget

4.1.1 Introduction

A link budget ensures that the Equivalent Isotropically Radiated Power (EIRP) allocated to the transmitter maintains a pre-determined level of service defined by error performance and availability. For example, a Bit Error Rate (BER) better than 10^{-6} and desired availability (usually at least 99,99 % of time are commonly used as service levels, see note 1). Figure 1 illustrates the major elements of propagation loss that are taken into consideration when assigning transmitter EIRPs to Fixed Service (FS) systems. All elements of propagation loss are frequency and path length dependent. Fade margin and gaseous absorption characteristics are addressed in Recommendation ITU-R P.530 [i.1] and Recommendation ITU-R P.676 [i.2] respectively.

NOTE 1: In modern digital systems implementing Adaptive Code and Modulation (ACM, "mixed-mode" systems defined in ETSI EN 302 217-1 [i.7] and better described in ETSI TR 103 103 [i.8]) such availability is usually applied for the "reference mode" used for planning purpose. In some cases, a lower availability might also be acceptable, e.g. in Bands and Carriers Aggregation (BCA systems described in ETSI GR mWT 015 [i.9]) systems where high availability is guaranteed by the carrier(s) in the lower band, while the carrier(s) in the higher band might not physically exhibit sufficient fade margin for that; therefore, lower availability (best effort) is still acceptable for their "supplementary" payload.

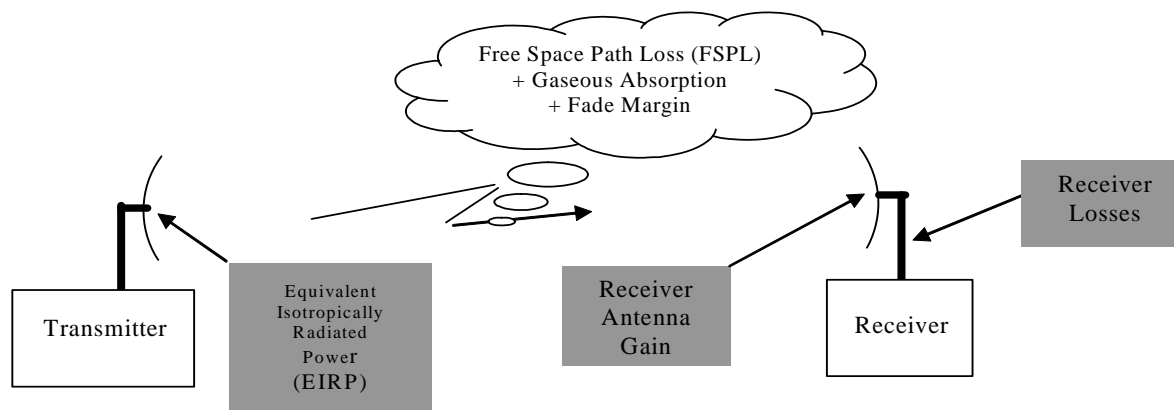


Figure 1: Fixed Link Budget

Rx Reference Sensitivity Level =

= Tx EIRP - FSPL - Fade Margin - Gaseous Absorption + Rx Antenna Gain - Rx Losses.

Tx EIRP =

= Rx Reference Sensitivity Level - Rx Antenna Gain + Rx Losses + Gaseous Absorption + FSPL + Fade Margin.

NOTE 2: Rx Losses are typically due to feeder losses connecting antenna port to indoor Rx equipment; when outdoor equipment front ends are concerned, no Rx losses are usually present.

4.1.2 Receiver input level

The reference sensitivity calculated using the methodologies shown in tables 1 and 2 may be used as a theoretical guide figure. The level of reference sensitivity in most practical cases will be within a few dB of this theoretical level. When best practice noise figure and fixed losses are used in the calculation most, if not all, practical receiver reference sensitivities will be at or above the theoretical level but below that quoted in the relevant European standard.

See annex D for guidance on S/N ratios and Noise Figure (NF) values.

Table 1 sets out an example calculation for RSL. This method of calculation may be used in conjunction with a noise limited assignment system.

Table 1: Example showing calculation of RSL

Factor	Notes	Example values
Channel Bandwidth (MHz)		14
Payload rate (Mbit/s)		34,368
Gross bit rate (Mbit/s) (including FEC and service channel)	~ 1,1 x Payload rate (without FEC) ~1,15 x payload rate (with FEC) = 1,15 × 34,368 Mbit/s	39,523
Modulation scheme	16 QAM (2 ⁿ states, n = 4)	
Thermal Noise kT (dBW/Hz)	10 log [k (Boltzmann's constant) × T (288 K)]	-204
Rx noise Bandwidth Factor B (dBHz)	10 log [1,4 (Gross bit rate/n)] = 10 log [1,4 (39,523 × 10 ⁶ /4)]	71,4
Receiver Noise kTB (dBW)	Thermal Noise (kT) + Bandwidth Factor (B)	-132,6
Noise Figure (dB)	See annex D	7
S/N for BER = 10 ⁻⁶ (dB)	See annex D	17,6
Fixed System Losses (dB)	Assume 4 dB	4
Interference Margin (dB) (see clause 4.2.2)	Assume 1 dB	1
RSL for BER = 10 ⁻⁶ (dBW)	kTB + Noise Figure + Fixed System Losses + Interference Margin + S/N	-102
Median Rx Input Level (dBW)	≈ RSL plus calculated fade margin	-102 + FM
NOTE 1: Where figures are quoted they are shown as an example and do not relate to any specific frequency band, equipment type or European standard.		
NOTE 2: Column 3 uses as an example a 34 Mbit/s, 16 QAM system with FEC and occupying a bandwidth of 14 MHz.		

An alternative method for calculation of RSL is set out below. This approach calculates a normalized value of RSL where the bit rate is normalized to a value of 1 Mbit/s and NF = 0 dB. The normalized RSL value may be calculated using the well established equation (1), in conjunction with the example calculations set out in table 3:

$$RSL_{norm}(dBm/MHz) = -114 + Noise\ Figure + 10 * \log_{10}(Symbol\ Rate) + \left(\frac{S}{N}\right) \quad (1)$$

where Noise Figure NF = 0 dB

The actual RSL (rated, typical value) may be calculated using equation (2):

$$RSL(dBm) = RSL_{norm} + 10 * \log_{10}(B_{MHz}) + NF + IM_F + IM_S \quad (2)$$

where:

IM_F = Noise Figure Industrial Margin in dB

IM_S = S/N Industrial Margin in dB

Table 2 shows typical Noise Figures (inclusive of simple duplexers) and associated Industrial Margin values (e.g. temperature extremes, production spread of FET devices and of RF circuits/filter attenuation) in the frequency range: 6 GHz to 42 GHz. These values may be used in conjunction with equation (2).

A value of 1 dB may be considered appropriate for the S/N Industrial Margin where the BER is in the range 10^{-3} to 10^{-6} .

Typical S/N ratios (normalized to a noise bandwidth equal to the symbol-rate) are presented in table 3. Coded values are valid for the referenced coding algorithm only; use of other coding algorithms would result in different S/N values and different symbol-rates.

Table 3 gives two normalized RSL values with respect to each of the system coding examples shown, one based on a BER = 10^{-3} and one based on a BER = 10^{-6} (derived from ETSI TR 103 053 [i.6], from table contained in archive tr_103053v010101p0).

Table 2: Typical Noise Figures (NF) and associated Industrial Margins (IM_F)

Frequency band (GHz)	Typical Noise Figure (NF) (dB)	Industrial margin (IM _F) (dB)
1,3 to 3	~4	+3
3 to 5	~5	+3
6 to 15	~5	+3
18 to 23	~6	+3
26 to 28	~7	+3
32	~7	+3
38 to 42	~8	+3
48 to 50	~9	+3
52 to 55	~10	+3
71 to 76 / 81 to 86	~13	+4

Table 3: Examples of S/N normalized to the symbol rate and RSL normalized to NF = 0 dB and B = 1 Mbit/s

Modulation format	4CPM-2RC h = 0,25 (see note 1)		4PSK		16 QAM		32 QAM		64 QAM		128 QAM		
	Un-coded	Coded (RS 255,243)	Un-coded	Coded (RS 255,243)	Un-coded	Coded (16TCM- 4D+RS 255,243)	Un-coded	Coded (32TCM- 2D+RS 255,243)	Un-coded	Coded (64TCM- 4D+RS 255,243)	Un-coded	Coded (128TCM- 4D+RS 249,243)	Coded (RS 255,241)
Gross Bit rate	B	$B \times (255/243)$	B	$B \times (255/243)$	B	$B \times (4/3,5) \times (255/243)$	B	$B \times (5/4,5) \times (255/243)$	B	$B \times (6/5,5) \times (255/243)$	B	$B \times (7/6,5) \times (249/243)$	$B \times (255/241)$
Symbol rate factor "n"	2	2	2	2	4	4	5	5	6	6	7	7	7
Symbol rate	B/2	$(B/2) \times (255/243)$	B/2	$(B/2) \times (255/243)$	B/4	$(B/3,5) \times (255/243)$	B/5	$(B/4) \times (255/243)$	B/6	$(B/5,5) \times (255/243)$	B/7	$(B/6,5) \times (249/243)$	$(B/7) \times (255/241)$
S/N (BER = 10 ⁻³)	13,5	12	11	9,6	18,2	13,2	21,5	15,2	24,5	19,9	27,6	24	27,2
S/N (BER = 10 ⁻⁶)	17,5	14	14,2	10,5	21,3	13,7	25	16,4	28	20,5	31,4	25	28,5
RSL at BER = 10 ⁻³ (see note 2)	-103,5	-104,8	-106,0	-107,2	-101,8	-106,0	-99,5	-104,6	-97,3	-101,3	-94,9	-98,0	-95,0
RSL at BER = 10 ⁻⁶ (see note 2)	-99,5	-102,8	-102,8	-106,3	-98,7	-105,5	-96,0	-103,4	-93,8	-100,7	-91,1	-97,0	-93,7

B = Payload Bit-rate

NOTE 1: Technical background for Continuous Phase Modulation (CPM) formats may be found in ITU-R Recommendation SM.328-11 [i.4].

NOTE 2: Normalized to NF = 0 dB and B = 1 Mbit/s.

NOTE 3: Uncoded values = theoretically achievable values.

Coded values = typically measured in a mass production environment by one manufacturer (these are not the limits for testing, nor the guaranteed values provided to customers).

4.1.3 Fade margin (FM)

The two main factors considered that cause the wanted signal to fade are multipath clear air fading and rain fade. Multipath clear air fading is considered dominant below about 10 GHz and rain fade is dominant above about 15 GHz. Consequently, depending on the frequency band under consideration, the multipath, rain, or a combination of the two fade margins, are calculated to ensure that system performance requirements are met. Fade margin is dependent on frequency, path length and level of service availability required (see clause 4.1).

4.2 Interference assessment

4.2.1 General

The radio link to be assigned needs to be co-ordinated with all existing links within a defined co-ordination zone. Interference levels into/from the new link need to be assessed and compared against defined limits, ERC/REC(01)05 [i.10] gives common guidelines on limits for use in typical link planning. The co-ordination distance is dependent on propagation conditions and therefore, in general, decreases as FS bands increase in frequency.

Interference levels to and from the proposed link are assessed taking into account such factors as receiver sensitivity, path profile, antenna gain, antenna radiation pattern and antenna cross-polar response. When fitted, the operating profile of ATPC also needs to be taken into consideration. The correct implementation of the ATPC profile into the assignment process will significantly improve link density.

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4.2.2 Wanted to Unwanted (W/U) ratios

Wanted to Unwanted (W/U) ratios are determined for each single interferer combination of wanted and unwanted signal types. In a noise limited assignment system the correct inclusion of these figures, into the assignment link budget calculation, will limit the increase in noise floor, caused by interference between FS systems sharing the same frequency band, below a predetermined level.

The principle behind noise limited assignments is illustrated in figure 2. It shows the elements involved in determining W/U for a single co-channel interferer. For interference scenarios where the wanted and unwanted channels are not co-channel and have a degree of NFD (see clause 4.2.4) the W/U ratio is modified to take into account the additional protection given by the NFD. The derivation of single interferer W/U ratios is covered in clause 4.2.5.

When link is first planned in absence of any significant interference ($W/U \rightarrow \infty$), the inclusion of a multiple interferer allowance may be appropriate. This additional protection takes into account the fact that the victim receiver is very likely, in future, to experience new interference signals from a number of sources, in particular from multiple FS links in the same co-ordination zone (e.g. interference margin up to 3 dB as provided by ECC/REC(01)05 [i.10]), but also from emissions from other services sharing the same band; the latter contribution, if any, is defined by specific sharing studies, based on Recommendation ITU-R F.758 [i.11], which, in most cases, are based on a globally permitted $I/N \leq -10$ dB, that would imply an additional protection of 0,5 dB.

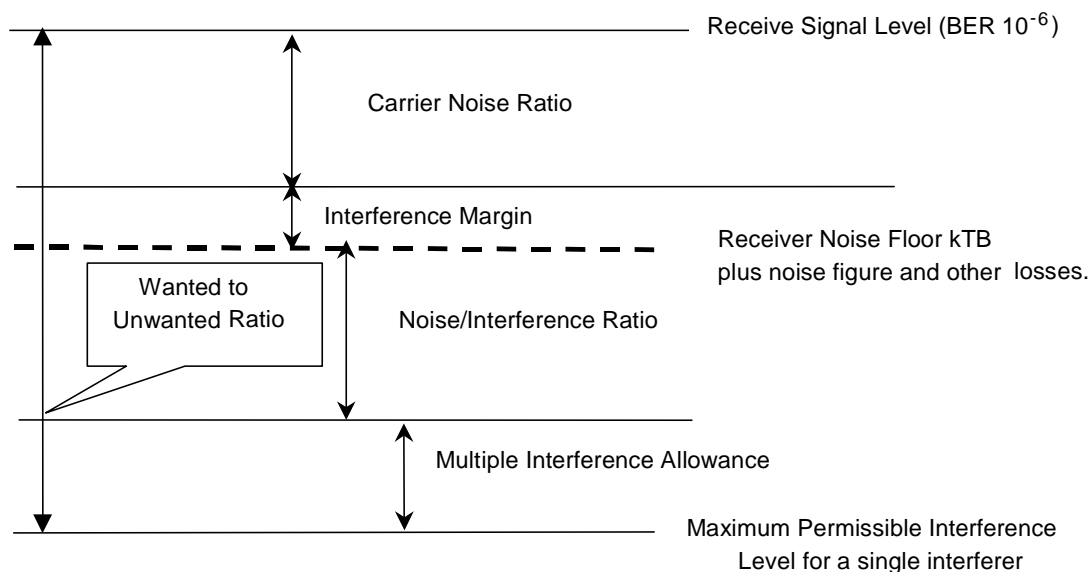


Figure 2: Derivation of single interferer co-channel interference limit

4.2.3 Receiver selectivity evaluation

An overall receiver selectivity mask for a given system type, obtained by a combination of RF, IF and base band filtering, can, in theory, be derived from the corresponding transmitter spectrum mask. It is common practice for digitally modulated systems to have Tx and Rx channel shaping such that, as far as possible, the ideal transfer function for pulses with even attenuation characteristics is equally split between the Tx and Rx.

In the absence of specific equipment data the following two methods may be used to support link assignment:

- a conservative approach of the above method is shown in annex E;
- a more realistic approach of the above method is shown in annex F.

NOTE: These approaches should not imply supplementary requirements on the equipment.

4.2.4 Net Filter Discrimination (NFD)

It is common practice in co-existence studies between transmitters and receivers of different symbol rate and modulation formats to use the concept of Net Filter Discrimination (NFD).

NFD is defined in Recommendation ITU-R F.746 [i.3] as (see notes 1 and 2):

$$\text{NFD} = \frac{\text{Adjacent channel received power}}{\text{Adjacent channel power received by the main receiver after RF,IF,BB filters}} \quad (3a)$$

NOTE 1: The term "adjacent channel received power" is intended as the interfering power at antenna port (i.e. without any filter contribution).

For the purpose of that Recommendation, it is formally defined for the adjacent channel separation, but it is common practice to consider NFD concept extended to any frequency spacing between wanted Rx frequency and unwanted interference frequency.

It is also common practice, when using C/I performance available in ETSI EN 302 217-2 [i.5], dealing with like wanted and unwanted signals (i.e. with same CS and class of modulation), to consider NFD according to formula (3b) below, (see notes 2 and 3):

$$\text{NFD} \cong 10 \log (P_c/P_a) \quad (3b)$$

Where:

- P_c is the total interfering power received (in W and U operating at same frequency) after co-channel RF, IF and base band filtering.

- P_a is the total interfering power received (in W and U operating at offset frequency) after offset RF, IF and base band filtering.

NOTE 2: In the definition of NFD according 3a) and 3b) the following assumptions are made:

- adjacent channels XPD, if any, is not been taken into account;
- a single sideband interfering channel only is considered; for double side like-modulated interferences a NFD 3 dB lower should be taken into account.

As pointed out in Recommendation ITU-R F.746 [i.3], this value is produced purely by the Tx spectrum and by the overall Rx filtering. It does not include any other decoupling (e.g. antenna discrimination, XPD or the actual interfering power level).

NOTE 3: Comparing equations (3a) and (3b) it is evident that there is a slight difference represented by the ratio:

$$NFD(0) = \frac{\text{Adjacent channel received power (unfiltered)}}{P_C} \text{ (dB);}$$

however, in modern digital systems, where tight roll-off shaping is usually implemented, and when W and U signals are alike, the factor is quite less than 1 dB.

When W and U signals are different, NFD(0) is not negligible and, when using formula (3b), should be taken into account for NFD calculation as shown in clause 4.2.5.

When comparing to assessment parameters available in ETSI EN 302 217-2 [i.5], equations (3a or 3b) might be written (see note 3) as:

$$NFD_{ad-channel} \cong \frac{C}{I}(\text{cochannel}) - \frac{C}{I}(\text{adjacent channel}) \quad (3c)$$

In formula (3c), de facto equivalent to formula (3b), the C/I (dB) are the prescribed values for 1 dB degradation of guaranteed threshold for BER=10⁻⁶; NFD value calculated with equation (3c) also represents a guaranteed value for all equipment assessed according ETSI EN 302 217-2 [i.5] for RE Directive compliance.

For frequency planning purpose, an estimation of real NFD can be made using the following integral calculations. (Reference to the diagrams in annex C will help the reader to understand the procedure).

With Tx and Rx masks aligned in the co-channel configuration (see topmost diagram in annex C):

- 1) Draw the transmitter spectrum mask and receiver filter mask. Integration step size to be dependent on the bandwidth of the narrowest system.
- 2) Add corresponding Rx and Tx values. Obviously in practice the transmitted signal will experience a degree of attenuation throughout its bandwidth, however minor, when processed through the filter (i.e. producing the NFD(0) described in note 2 above). This step is purely a scaling exercise.
- 3) Convert decibel sum calculated in 2) to absolute.
- 4) Integrate the absolute values calculated in 3).
- 5) Offset the Tx mask as necessary and repeat action 1) to 4).
- 6) Divide the co-channel integral result by the offset integral result.
- 7) Convert the value found in 6) to a decibel value.

The actions above can be summarized in the following formula:

$$NFD = 10 * \log_{10} \left(\left[\int_{f_0-\Delta_-}^{f_0+\Delta_+} 10^{\frac{(Tc+Rc)}{10}} * df \right] / \left[\int_{f_0-\Delta_-}^{f_0+\Delta_+} 10^{\frac{(To+Rc)}{10}} * df \right] \right) \quad (4)$$

Where:

- Tc = Interferent transmission power density mask shape - co-channel (dB)
- Rc = Wanted receiver attenuation mask - co-channel (dB)

- T_o = Interferent transmission power density mask shape - offset (dB)
- f_o = Wanted RX centre frequency
- Δ_- = Suitable lower frequency with significant values of R_c , T_c or T_o
- Δ_+ = Suitable upper frequency with significant values of R_c , T_c or T_o

It can be seen that, since:

$$P_c = \left[\int_{f_o - \Delta_-}^{f_o + \Delta_+} 10^{\frac{(T_c + R_c)}{10}} * df \right] \quad \text{and} \quad P_a = \left[\int_{f_o - \Delta_-}^{f_o + \Delta_+} 10^{\frac{(T_o + R_c)}{10}} * df \right] \quad (5)$$

Equation (4) is equivalent to equation (3b).

4.2.5 The Carrier to Interference (C/I) ratio in mixed payload environment

Figure 3 shows NFD values plotted against frequency separation. Values for mixed systems can be calculated and are shown on the same graph. Where the transmission bandwidth exceeds receiver bandwidth i.e. not all the transmitted power falls within the receiver bandwidth, a factor equal to $10 \times \log(\text{bandwidth of interferer}/\text{bandwidth of victim})$ needs to be applied when calculating the necessary wanted to unwanted ratio. Scenarios illustrating the change in NFD for three systems using the same modulation order but transferring different traffic rates are shown:

- 1) When the traffic rate for an interferer is four times that of the victim the transmitted bandwidth will be four times the receiver bandwidth. A bandwidth factor of 6 dB ($10 \times \log 4$) is added to the NFD.
- 2) When the interferer and the victim's rates are equal there is no bandwidth factor.
- 3) When the victim's bandwidth exceeds that of the interferer, the NFD out to approximately three times the mean sum of both bandwidths will be below the value for "like with like" systems. This is because within this range of frequencies the transmitted power lies within the receiver bandwidth over a greater number of channel offsets.

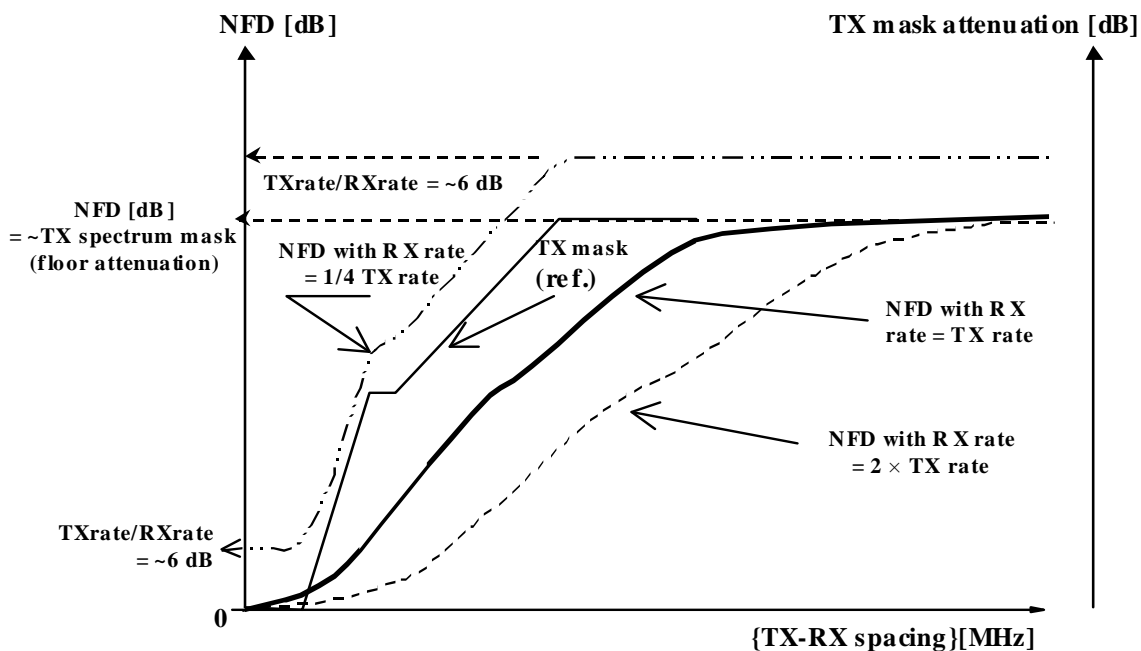


Figure 3: Qualitative examples of mixed NFD among different rate systems of the same class

Where a managing authority allocates channels and EIRPs that authority will ensure that the established network and the new system will co-exist without degradation in system performance. This is achieved by keeping interference levels below defined limits whilst ensuring that transmission EIRPs (see clause 4.1) are sufficient to maintain the required level of system performance. The necessary protection is achieved by ensuring that the level of interference from individual transmissions is kept below defined limits. These protection levels, the ratio between required signal and interferer, are referred to as wanted to unwanted ratios. The evaluation of W/U is covered in clause 4.2.6.

4.2.6 Evaluation of the Wanted to Unwanted (W/U) ratios

NFD is evaluated at all possible frequency offsets and for all possible Tx and Rx system combinations. Once calculated, the values are subtracted from the co-channel or in mixed systems, a co-channel-equivalent (i.e. when $BW(U) > BW(W)$), taking into account the bandwidth ratio as shown in clause 4.2.5), W/U (see clause 4.2.2). Tables of typical W/U ratios for two sets of systems combinations are given in annex B.

$$W/U = \text{Co-channel/co-channel-equivalent W/U} - \text{NFD}$$

5 Interference limited assignments

The noise limited approach described earlier makes two assumptions regarding the number of multiple interferers and in addition it also sets a pre-determined level of noise floor degradation. Both of these elements can impose limitations and can, in some cases, be overcome by the adoption of an interference limited approach. An explanation of this is given in annex A.

6 Summary

The present document has concentrated on equipment performance and not considered the major contribution to spectrum engineering made by the antenna. Obviously parameters such as off axis and cross-polar performance of antennas in a mixed FS environment significantly affect the level of interference experienced by a victim receiver. A generic approach has been taken although a modern computer based assignment system will provide facilities which enhance link density by utilizing guaranteed performance when the guaranteed level exceeds the generic limit.

Annex B: Wanted to Unwanted (W/U) ratios

Tables B.1 and B.2, shown as examples, give the wanted to unwanted ratios for two system types. All possible interference sources are shown and protection ratios out to at least three times the wanted channel spacing are shown.

When the wanted and unwanted channels of digital systems are not equal, Step 1 in the Wanted to Unwanted tables is equal to 1/2 the narrowest bandwidth. Thereafter the step sizes are equivalent to the narrowest bandwidth. When the wanted and unwanted channels are the same, all step sizes are equal to the bandwidth of these systems.

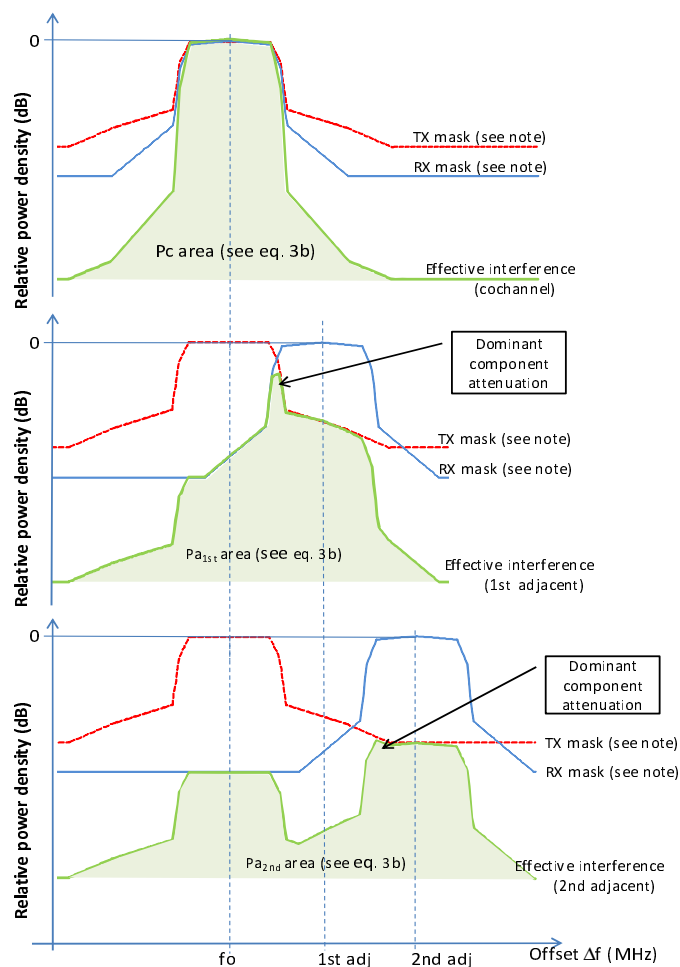
Table B.1: Wanted System 49 Mb/s in 14 MHz (38 GHz, 4H)

Spectral efficiency class	Unwanted System		Wanted/Unwanted Ratio (dB) versus Step Size (see annex B)														
	Mbps	Channel Spacing [MHz]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	4	3.5	30	30	23.6	-7.5	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6
2	8	7	30	29.6	-8.6	-12	-12.4	-12	-12	-12	-12	-12	-12	-12.4	-12	-12	-12.4
2	16	14	30	26.6	-14	-15	-14.7	-15	-15	-15	-15	-15	-15	-14.7	-15	-15	-14.7
2	32	28	33	32.4	0.1	-9.8	-12.2	-12	-12	-12	-12	-12	-12	-12.2	-12	-12	-12.2
4L	8	3.5	30	30	23.6	-8.7	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6
4L	16	7	30	29.7	-11	-12	-12.4	-12	-12	-12	-12	-12	-12	-12.4	-12	-12	-12.4
4L	32	14	30	26.6	-20	-21	-21	-21	-21	-21	-21	-21	-21	-21	-21	-21	-21
4H	49	14	30	26.6	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15
4L	64	28	33	32.6	-3.7	-11	-12.2	-12	-12	-12	-12	-12	-12	-12.2	-12	-12	-12.2
4H	98	28	33	32.7	-7.1	-12	-12.2	-12	-12	-12	-12	-12	-12	-12.2	-12	-12	-12.2

Table B.2: Wanted system 215 Mb/s in 28 MHz (11 GHz, class 8A)

Spectral efficiency class	Unwanted System		Wanted/Unwanted Ratio (dB) versus Step Size (see annex B)														
	Mbps	Channel Spacing [MHz]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	4	3.5	50	50	48.7	46.3	38.9	14	12	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
2	8	7	50	49.8	40.3	10.7	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
2	16	14	50	48.6	9.4	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
2	32	28	50	46.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
4L	8	3.5	50	50	48.7	46.3	38.8	8.4	3	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3
4L	16	7	50	49.8	40.1	3.9	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
4L	32	14	50	48.6	3.5	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6
4H	49	14	50	48.6	1.2	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7
4L	64	28	50	45.9	-4	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7
4H	98	28	50	46	-5.1	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7

Annex C: Diagram showing the NFD procedure



NOTE: TX and RX masks may be substituted by any appropriate shape/formulas suitably approximating real equipment behaviour (see annex F). When TX mask from ETSI EN 302 217-2 [i.5] is used, the positive k_1 [dB] value could be reduced to 0 dB (considered as average value along the main lobe of emission).

Figure C.1: Example of the integration process for calculating the NFD

Figure C.1 shows the areas representing the integral of the effective received interference power after the RX filter chain, which will affect the data decision process.

Being the integral based on linear values the integral numerical result is dominated by the maximum components levels (dominant component attenuation). In particular, the 2nd adjacent case shows the importance that the RX mask maximum attenuation floor is lower than the TX mask floor; e.g. when lower than 6 dB the NFD result will be affected less than 1 dB by the residual interference of the main carrier. For the same reason, the cochannel P_c area (used in formula (3b), for like TX and RX equipment and signals, is practically equal to the power obtained integrating the whole TX mask area (used in ITU-R formula (3a)).

Annex D:

Table of typical values for noise figure and signal/noise at BER = 10⁻⁶

Table D.1 of Noise Figure and Signal/Noise values shown below is based on ETSI TR 103 053 [i.6]. The Noise Figure values shown may be considered typical for equipment operating the modulation schemes indicated. The S/N ratios for a BER = 10⁻⁶ are shown as a range of values. The actual S/N value will depend on whether forward error correction and coded modulation schemes are employed and on the actual improvement on the un-coded performance. It has been assumed that error correction is used with systems operating 16 QAM modulation and higher and that an improvement of 2 dB with respect to un-coded values is (currently) achieved.

The reference standard for all the frequencies band is ETSI EN 302 217-2 [i.5].

The NF and S/N value are derived from ETSI TR 103 053 [i.6]

Table D.1: Noise Figure and Signal/Noise values

Frequency band	1,350 GHz to 1,517 GHz					3,6 GHz to 4,2 GHz					
System Option Capacity (Mbit/s) in Bandwidth (MHz) unless stated otherwise (Modulation scheme)	64 kbit/s in 75 kHz (4 State)	192 kbit/s in 250 kHz (4 State)	704 kbit/s in 500 kHz (4 State)	704 kbit/s in 1 (2 State)	2 in 1 (16 QAM)	2 in 1,75 (4 State)	2 × 2 in 1,75 (16 QAM)	2 × 2 in 3,5 (4 State)	8 in 3,5 (16 QAM)	8 in 7 (4 State)	
NF (dB)	4	4	4	4	4	5	5	5	5	5	
S/N (dB)	10,5 to 14,2	10,5 to 14,2	10,5 to 14,2	10,5	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	
Frequency band	3,6 GHz to 4,2 GHz										
System Option Capacity (Mbit/s) in Bandwidth (MHz) unless stated otherwise (Modulation scheme)	2 × 8 in 7 (16 QAM)	2 × 8 in 14/15 (4 State)	34 in 14/15 (16 QAM)	2 × 34 in 14/15 (64 QAM)	51 in 14/15 (32 QAM)	51 in 20 (16 QAM)	34 in 29/30 (4 State)	2 × 34 in 29/30 (16 QAM)	51 in 29/30 (16 QAM)	140/STM-1 in 29/30 (128 QAM)	2 × STM-1 in 40 (CCDP) (64/128 QAM)
NF (dB)	5	5	5	5	5	5	5	5	5	5	5
S/N (dB)	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	20,5 to 26	16,4 to 23	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	13,7 to 19,3	23,6 to 29,4	20,5 to 26/23,6 to 29,4

Frequency band	5,925 GHz to 6,425 GHz					6,425 GHz to 7,125 GHz				
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	34 in 29,65 (4 State)	2 × 34 in 29,65 (16 QAM)	51 in 29,65 (16 QAM)	140/STM-1 in 29,65 (128 QAM)	2 × STM-1 in 29,65 (CCDP) (128 QAM)	51 in 20 (16 QAM)	2 × STM-1 in 40 (CCDP) (64/128 QAM)	2 × STM-1 in 40 (512 QAM)		
NF (dB)	5	5	5	5	5	5	5	5		
S/N (dB)	10,5 to 14,2	13,7 to 19,3	13,7 to 19,3	23,6 to 29,4	23,6 to 29,4	13,7 to 19,3	20,5 to 26/ 23,6 to 29,4	31,1 to 33,5		
Frequency band	7,425 GHz to 7,9 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	8 in 7 (4 State)	2 × 8 in 7 (16 QAM)	2 × 8 in 14 (4 State)	34 in 14 (16 QAM)	2 × 34 in 14 (64 QAM)	51 in 14 (32 QAM)	51 in 20 (16 QAM)	34 in 28 (4 State)	2 × 34 in 28 (16 QAM)	51 in 28 (16 QAM)
NF (dB)	5	5	5	5	5	5	5	5	5	5
S/N (dB)	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	20,5 to 26	16,4 to 23	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	13,7 to 19,3
Frequency band	7,425 GHz to 7,9 GHz		10,7 GHz to 11,7 GHz			12,75 GHz to 13,25 GHz				
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	STM-1 in 28 (128 QAM)	2 × STM-1 in 28 (CCDP) (128 QAM)	STM-4/ 4 × STM-1 in 40 (CCDP) (512 QAM)	2 × STM-1 in 40 (CCDP) (64/128 QAM)	2 × STM-1 in 40 (512 QAM)	2 in 1,75 (4 State)	2 × 2 in 1,75 (16 QAM)	2 × 2 in 3,5 (4 State)	8 in 3,5 (16 QAM)	8 in 7 (4 State)
NF (dB)	5	5	5	5	5	5	5	5	5	5
S/N (dB)	23,6 to 29,4	23,6 to 29,4	31,1 to 33,5	20,5 to 26/ 23,6 to 29,4	31,1 to 33,5	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2
Frequency band	12,75 GHz to 13,25 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	2 × 8 in 7 (16 QAM)	2 × 8 in 14 (4 State)	34 in 14 (16 QAM)	51 in 14 (32 QAM)	51 in 28 (16 QAM)	34 in 14 (16 QAM)	34 in 28 (4 State)	2 × 34 in 28 (16 QAM)	STM-1 in 28 (128 QAM)	2 × STM-1 in 28 (CCDP) (128 QAM)
NF (dB)	5	5	5	5	5	5	5	5	5	5
S/N (dB)	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	16,4 to 23	13,7 to 19,3	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	23,6 to 29,4	23,6 to 29,4

Frequency band	14,5 GHz to 15,35 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	2 in 1,75 (4 State)	2 × 2 in 1,75 (16 QAM)	2 × 2 in 3,5 (4 State)	8 in 3,5 (16 QAM)	8 in 7 (4 State)	2 × 8 in 7 (16 QAM)	2 × 8 in 14 (4 State)	34 in 14 (16 QAM)	51 in 14 (32 QAM)	51 in 28 (16 QAM)
NF (dB)	5	5	5	5	5	5	5	5	5	5
S/N (dB)	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	16,4 to 23	13,7 to 19,3
Frequency band	14,5 GHz to 15,35 GHz					17,7 GHz to 19,7 GHz				
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	34 in 28 (4 State)	2 × 34 in 28 (16 QAM)	STM-1 in 28 (128 QAM)	2 × STM-1 in 28 (CCDP) (128 QAM)	2 × STM-1 in 56 (128 QAM)	2 × 8 in 13,75 (4 State)	34 in 13,75 (16 QAM)	51 in 14 (32 QAM)	51 in 28 (16 QAM)	34 in 27,5 (16 QAM)
NF (dB)	5	5	5	5	5	6	6	6	6	6
S/N (dB)	10,5 to 14,2	13,7 to 19,3	23,6 to 29,4	23,6 to 29,4	23,6 to 29,4	10,5 to 14,2	13,7 to 19,3	16,4 to 23	13,7 to 19,3	13,7 to 19,3
NOTE: ETSI EN 302 217-2 [i.5] allows for STM-4/4 × STM-1 using two 2 × STM-1 carriers.										
Frequency band	17,7 GHz to 19,7 GHz						22,0 GHz to 23,6 GHz			
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	2 × 34 in 27,5 (16 QAM)	9,792 (sSTM-14) in 3,5 (16 QAM)	14,400 (sSTM-22) in 3,5 (64 QAM)	STM-1 in 27,5 (128 QAM)	STM-1 in 55 (16 QAM)	2 × STM-1 in 56 (128 QAM)	2 in 3,5 (2 State)	2 × 2 in 3,5 (4 State)	8 in 3,5 (16 QAM)	8 in 7 (4 State)
NF (dB)	6	6	6	6	6	6	6	6	6	6
S/N (dB)	13,7 to 19,3	13,7 to 19,3	20,5 to 26	23,6 to 29,4	13,7 to 19,3	23,6 to 31,4	10,5	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2
NOTE: ETSI EN 302 217-2 [i.5] allows for STM-4/4 × STM-1 using two 2 × STM-1 carriers.										
Frequency band	22,0 GHz to 23,6 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	2 × 8 in 7 (16 QAM)	2 × 8 in 14 (4 State)	34 in 14 (16 QAM)	34 in 28 (4 State)	51 in 14 (32 QAM)	51 in 28 (16 QAM)	51 in 56 (4 State)	140/STM-1 in 28 (128 QAM)	140/STM-1 in 56 (16 QAM)	2 × STM-1 in 56 (128 QAM)
NF (dB)	6	6	6	6	6	6	6	6	6	6
S/N (dB)	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	16,4 to 23	13,7 to 19,3	10,5 to 14,2	23,6 to 29,4	13,7 to 19,3	23,6 to 29,4
NOTE: ETSI EN 302 217-2 [i.5] allows for STM-4/4 × STM-1 using two 2 × STM-1 carriers.										

Frequency band	22,0 GHz to 23,6 GHz					24,5 GHz to 26,5 GHz				
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	10 in 3,5 (16 QAM)	10 in 7 (4 State)	100 in 28 (16 QAM)	100 in 28 (64 QAM)	100 in 56 (16 QAM)	2 in 3,5 (4 State)	2 × 2 in 3,5 (4 State)	8 in 3,5 (16 QAM)	8 in 7 (4 State)	2 × 8 in 7 (16 QAM)
NF (dB)	6	6	6	6	6	7	7	7	7	7
S/N (dB)	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	20,5 to 26	13,7 to 19,3	10,5 to 14,2	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3
Frequency band	24,5 GHz to 26,5 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	2 × 8 in 14 (4 State)	34 in 14 (16 QAM)	51 in 14 (32 QAM)	34 in 28 (4 State)	51 in 28 (16 QAM)	140/STM-1 in 28 (128 QAM)	51 in 56 (4 State)	140/STM-1 in 56 (16 QAM)	10 in 3,5 (16 QAM)	10 in 7 (4 State)
NF (dB)	7	7	7	7	7	7	7	7	7	7
S/N (dB)	10,5 to 14,2	13,7 to 19,3	16,4 to 23	10,5 to 14,2	13,7 to 19,3	23,6 to 29,4	10,5 to 14,2	13,7 to 19,3	13,7 to 19,3	10,5 to 14,2
Frequency band	24,5 GHz to 26,5 GHz				27,5 GHz to 29,5 GHz					
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	100 in 28 (16 QAM)	100 in 28 (64 QAM)	100 in 56 (16 QAM)	2 × STM-1 in 56 (128 QAM)	2 in 3,5 (4 State)	2 × 2 in 3,5 (4 State)	8 in 3,5 (16 QAM)	8 in 7 (4 State)	2 × 8 in 7 (16 QAM)	2 × 8 in 14 (4 State)
NF (dB)	7	7	7	7	7	7	7	7	7	7
S/N (dB)	13,7 to 19,3	20,5 to 26	13,7 to 19,3	23,6 to 29,4	10,5 to 14,2	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2
NOTE: ETSI EN 302 217-2 [i.5] allows for STM-4/4 × STM-1 using two 2 × STM-1 carriers.										
Frequency band	27,5 GHz to 29,5 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	34 in 14 (16 QAM)	51 in 14 (32 QAM)	34 in 28 (4 State)	51 in 28 (16 QAM)	140/STM-1 in 28 (128 QAM)	51 in 56 (4 State)	140/STM-1 in 56 (16 QAM)	10 in 3,5 (16 QAM)	10 in 7 (4 State)	100 in 28 (16 QAM)
NF (dB)	7	7	7	7	7	7	7	7	7	7
S/N (dB)	13,7 to 19,3	16,4 to 23	10,5 to 14,2	13,7 to 19,3	23,6 to 29,4	10,5 to 14,2	13,7 to 19,3	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3

Frequency band	27,5 GHz to 29,5 GHz		31,8 GHz to 33,4 GHz							
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	100 in 28 (64 QAM)	100 in 56 (16 QAM)	2 in 3,5 (4 State)	2 × 2 in 3,5 (4 State)	8 in 3,5 (16 QAM)	8 in 7 (4 State)	2 × 8 in 7 (16 QAM)	2 × 8 in 14 (4 State)	34 in 14 (16 QAM)	51 in 14 (32 QAM)
NF (dB)	7	7	7	7	7	7	7	7	7	7
S/N (dB)	20,5 to 26	13,7 to 19,3	10,5 to 14,2	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	16,4 to 23
Frequency band	31,8 GHz to 33,4 GHz						37,0 GHz to 39,5 GHz			
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	34 in 28 (4 State)	51 in 28 (16 QAM)	140/STM-1 in 28 (128 QAM)	51 in 56 (4 State)	140/STM-1 in 56 (16 QAM)	2 × STM-1 in 56 (128 QAM)	2 in 3,5 (4 State)	2 × 2 in 3,5 (4 State)	8 in 3,5 (16 QAM)	8 in 7 (4 State)
NF (dB)	7	7	7	7	7	7	8	8	8	8
S/N (dB)	10,5 to 14,2	13,7 to 19,3	23,6 to 29,4	10,5 to 14,2	13,7 to 19,3	23,6 to 29,4	10,5 to 14,2	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2
Frequency band	37,0 GHz to 39,5 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	2 × 8 in 7 (16 QAM)	2 × 8 in 14 (4 State)	34 in 14 (16 QAM)	51 in 14 (32 QAM)	34 in 28 (4 State)	51 in 28 (16 QAM)	140/STM-1 in 28 (128 QAM)	51 in 56 (4 State)	140/STM-1 in 56 (16 QAM)	2 × STM-1 in 56 (128 QAM)
NF (dB)	8	8	8	8	8	8	8	8	8	8
S/N (dB)	13,7 to 19,3	10,5 to 14,2	13,7 to 19,3	16,4 to 23	10,5 to 14,2	13,7 to 19,3	23,6 to 29,4	10,5 to 14,2	13,7 to 19,3	23,6 to 29,4
NOTE: ETSI EN 302 217-2 [i.5] allows for STM-4/4 × STM-1 using two 2 × STM-1 carriers.										
Frequency band	48,5 GHz to 50,2 GHz								51,4 GHz to 52,6 GHz	
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	2 in 3,5 (4 States)	2 × 2 in 3,5 (4 States)	2 in 7 (2 States)	8 in 7 (4 States)	2 × 2 in 14 (2 States)	2 × 8 in 14 (4 States)	8 in 28 (2 States)	34 in 28 (4 States)	2 in 3,5 (4 States)	2 × 2 in 3,5 (4 States)
NF (dB)	9	9	9	9	9	9	9	9	10	10
S/N (dB)	10,5 to 14,2	10,5 to 14,2	10,5	10,5 to 14,2	10,5	10,5 to 14,2	10,5	10,5 to 14,2	10,5 to 14,2	10,5 to 14,2

Frequency band	51,4 GHz to 52,6 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	8 in 3,5 (16 QAM)	2 in 7 (2 State)	2 × 2 in 7 (2 State)	8 in 7 (4 State)	2 × 8 in 7 (16 QAM)	8 in 14 (2 State)	2 × 8 in 14 (4 State)	34 in 14 (16 QAM)	51 in 14 (32 QAM)	2 × 8 in 28 (2 State)
NF (dB)	10	10	10	10	10	10	10	10	10	10
S/N (dB)	13,7 to 19,3	10,5	10,5	10,5 to 14,2	13,7 to 19,3	10,5	10,5 to 14,2	13,7 to 19,3	16,4 to 23	10,5
Frequency band	51,4 GHz to 52,6 GHz					55,78 GHz to 57,0 GHz				
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	34 in 28 (4 State)	51 in 28 (16 QAM)	34 in 56 (2 State)	51 in 56 (4 State)	140/STM-1 in 56 (16 QAM)	2 in 3,5 (4 State)	2 × 2 in 3,5 (4 State)	8 in 3,5 (16 QAM)	2 in 7 (2 State)	2 × 2 in 7 (2 State)
NF (dB)	10	10	10	10	10	10	10	10	10	10
S/N (dB)	10,5 to 14,2	13,7 to 19,3	10,5	10,5 to 14,2	13,7 to 19,3	10,5 to 14,2	10,5 to 14,2	13,7 to 19,3	10,5	10,5
Frequency band	55,78 GHz to 57,0 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	8 in 7 (4 State)	2 × 8 in 7 (16 QAM)	8 in 14 (2 State)	2 × 8 in 14 (4 State)	34 in 14 (16 QAM)	51 in 14 (32 QAM)	2 × 8 in 28 (2 State)	34 in 28 (4 State)	51 in 28 (16 QAM)	34 in 56 (2 State)
NF (dB)	10	10	10	10	10	10	10	10	10	10
S/N (dB)	10,5 to 14,2	13,7 to 19,3	10,5	10,5 to 14,2	13,7 to 19,3	16,4 to 23	10,5	10,5 to 14,2	13,7 to 19,3	10,5
Frequency band	55,78 GHz to 57,0 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	51 in 56 (4 State)					140/STM-1 in 56 (16 QAM)				
NF (dB)	10					10				
S/N (dB)	10,5 to 14,2					13,7 to 19,3				
Frequency band	71 GHz to 76 GHz / 81 GHz to 86 GHz									
System Option Capacity (Mbit/s) in Bandwidth (MHz) (Modulation scheme)	71 to 1 140 in 62,5 to 2 000 (4 State)		142 to 4 560 in 62,5 to 2 000 (16 QAM)			262 to 8 400 in 62,5 to 2 000 (64 QAM)			350 to 11 200 in 62,5 to 2 000 (256 QAM)	
NF (dB)	13		13			13			13	
S/N (dB)	10,8 to 14,5		13,7 to 19,3			21 to 28,5			28,1 to 30,5	

Annex E: Receiver selectivity (conservative approach)

By analysing the generic spectrum mask, as shown in figure E.1, the portion of transmitted spectrum that is vital to the satisfactory transfer of information can be identified. The receiver needs to meet adjacent channel and "CW interference sensitivity" (blocking) requirements. Therefore, it can be assumed that the overall Rx filter design is such that it meets the 1dB degradation, from the BER of 10^{-6} threshold to a 10^{-5} performance, commonly used as the EN interference criteria for FS systems.

This methodology derives receiver selectivity limits, shown in figure E.1, and follows the relationship:

$$\text{Rx attenuation}_{(\text{asymptotic})} [\text{dB}] = C/I_{(\text{at } 1 \text{ dB } 10^{-6} \text{ co-channel degradation})} - C/I_{(\text{as given by CW interference requirement})} \quad (\text{E.1})$$

The theoretical overall Rx selectivity mask in the shaded area of figure E.1 may be taken as a conservative value for any system. Of course the derivation of NFD levels can be calculated using the manufacturers guaranteed receiver selectivity mask.

NOTE 1: It should be remembered that some systems require separate mask profiles. For example, where a technical standard provides different criteria for innermost channels these masks are not used to define Net Frequency Discrimination.

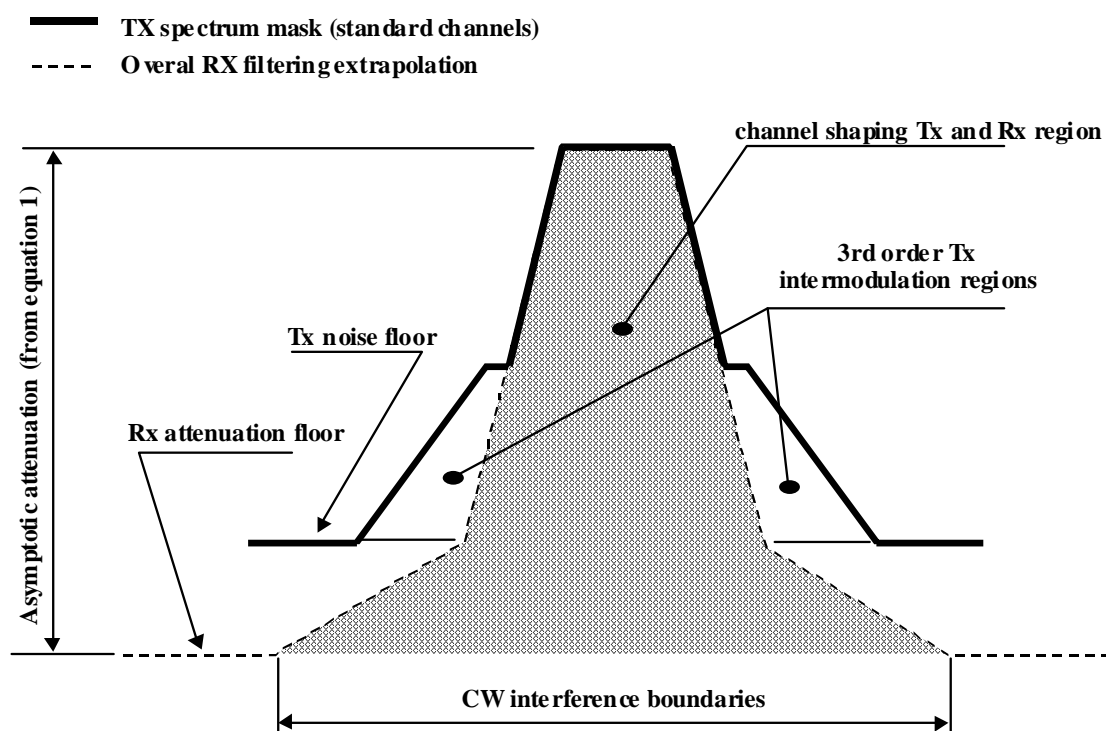


Figure E.1: Deriving the receiver filter selectivity from the transmitter spectrum mask and CW interference sensitivity (blocking) requirement

NOTE 2: It should be noted that this approach is a worst case scenario. It will not fulfill the adjacent channel requirement stated in the corresponding ETSI-standard for like-systems but it can be used for worst-case calculations between unlike-systems or different equipment classes.

Annex F: Receiver selectivity (more realistic approach)

F.0 Introduction

In this annex, a more realistic approach is used. The evaluation is based on Nyquist-filters in the transmit- and in the receiver path.

NOTE: It should be noted that the resulting transmitter-mask and receiver selectivity are theoretical values. Using this approach may still lead to interference between real unlike-systems or equipment classes (because of the use of typical values).

F.1 Gross bit-rate

First the gross bit-rate has to be determined. The gross bit-rate is the payload, multiplied with an overhead-factor. This overhead-factor (typically constant as absolute rate) depends in % on the payload.

This overhead-factor includes all non-payload information. For PDH and SDH fixed hierarchic payload, typical % range is given in table F.1.

Table F.1: overhead (PDH and SDH)

Payload (Mbit/s)	4	8	16	34	51	2 x 34	155 N x 155
Overhead-factor (%)	10... 20	10 ... 20	10 ... 20	10 ... 20	5 ... 20	5 ... 15	5 ... 10

When packet data (Ethernet) payloads are concerned, the minimum payload (RIC, Radio Interface Capacity) is given, in terms of net Ethernet frames capacity plus service and side traffic, for each CS and spectral efficiency class, by ETSI EN 302 217-2 [i.5]; in this case, standing that the gross-rate of the radio interface is constant, the % redundancy over L1/L2 layer payload depends on the assumed Ethernet frame lengths (lower frame lengths result in higher redundancy) and on other radio frames design. Real Ethernet frame streams are not composed by constant frame length; therefore, for an average length of 1 024 bytes/frame, the typical redundancy may range from about 25 % down to 15 % when the CS increases from 7 MHz up to 112 MHz.

Having selected a suitable overhead factor, the total gross bit-rate is calculated as:

$$\text{Gross bit rate GBR} = \text{payload} * \frac{100 + \text{overhead} (\%)}{100} \quad (\text{F.1})$$

F.2 Derivation of transmitter spectrum mask

The second step is to derive a typical transmitter spectrum mask. To derive this mask the following parameters have to be specified:

Channel spacing CS

Gross bit-rate GBR see clause F.1

Modulation scheme N where N = modulation order 2^N , (e.g. 4 for 16 QAM)

Nyquist frequency f_n where $f_n = 0,5 \times \text{Symbol rate} = \frac{\text{Gross bitrate}}{2 * N}$ (F.2)

Cosine roll-off factor r_{of} see also clause F.4

The time signal of the pulse transmission (practical a rectangular random-data source) is transformed in the frequency domain and filtered by a root raised cosine filter. The mathematical formula for the transfer function of the magnitude of $H_{TX}(f)$ and $H_{RX}(f)$ for the theoretical Nyquist channel is defined by the equation:

$H_{Total}(f)^2 = 1$	$f < f_n * (1 - r_{of})$	(F.3)
$H_{Total}(f)^2 = 0.5 * \left(1 + \cos \left(\frac{\pi}{2 * r_{of}} * \left(\frac{f}{f_n} - 1 + r_{of} \right) \right) \right)$	$f_n * (1 - r_{of}) \leq f \leq f_n * (1 + r_{of})$	
$H_{Total}(f)^2 = 0$	$f > f_n * (1 + r_{of})$	

For the transmitter respectively receiver filtering it can be derived:

$H_{Tx}(f) = H_{Rx}(f) = \sqrt{H_{Total}(f)^2} = 1$	$f < f_n * (1 - r_{of})$	(F.4)
$H_{Tx}(f) = H_{Rx}(f) = \sqrt{H_{Total}(f)^2} = \frac{1}{\sqrt{2}} * \sqrt{\left(1 + \cos \left(\frac{\pi}{2 * r_{of}} * \left(\frac{f}{f_n} - 1 + r_{of} \right) \right) \right)}$	$f_n * (1 - r_{of}) \leq f \leq f_n * (1 + r_{of})$	
$H_{Tx}(f) = H_{Rx}(f) = \sqrt{H_{Total}(f)^2} = 0$	$f > f_n * (1 + r_{of})$	

The course of the spectrum follows the pulse response in the frequency domain with a cosine roll-off factor selected to tangent the Tx spectrum mask until the attenuation reaches the starting level of the intermodulation region (see point T1 in figure F.1). This point may be taken from the transmitter spectrum mask of the relevant standard. From this point a straight line is drawn to the point of intersection of the spectrum mask with the mask noise floor (point T2). The mask noise floor is given in any product standard. This diagram should remain always below the spectrum mask in the relevant standard.

Regarding the selection of suitable roll-off factor it should be considered that, while PDH only systems over conventional N x 7 MHz based CS permitted relatively high roll-off (up to about 50 %), SDH applications for same CS require tighter roll-off (e.g. less than 35 %). Finally, packet-based (Ethernet) systems, having no hierarchic rates to respect, tend to squeeze the maximum possible capacity in the CS; therefore, lower roll-off (e.g. about 20 %) are more common.

Figure F.1 shows a typical transmitter spectrum.

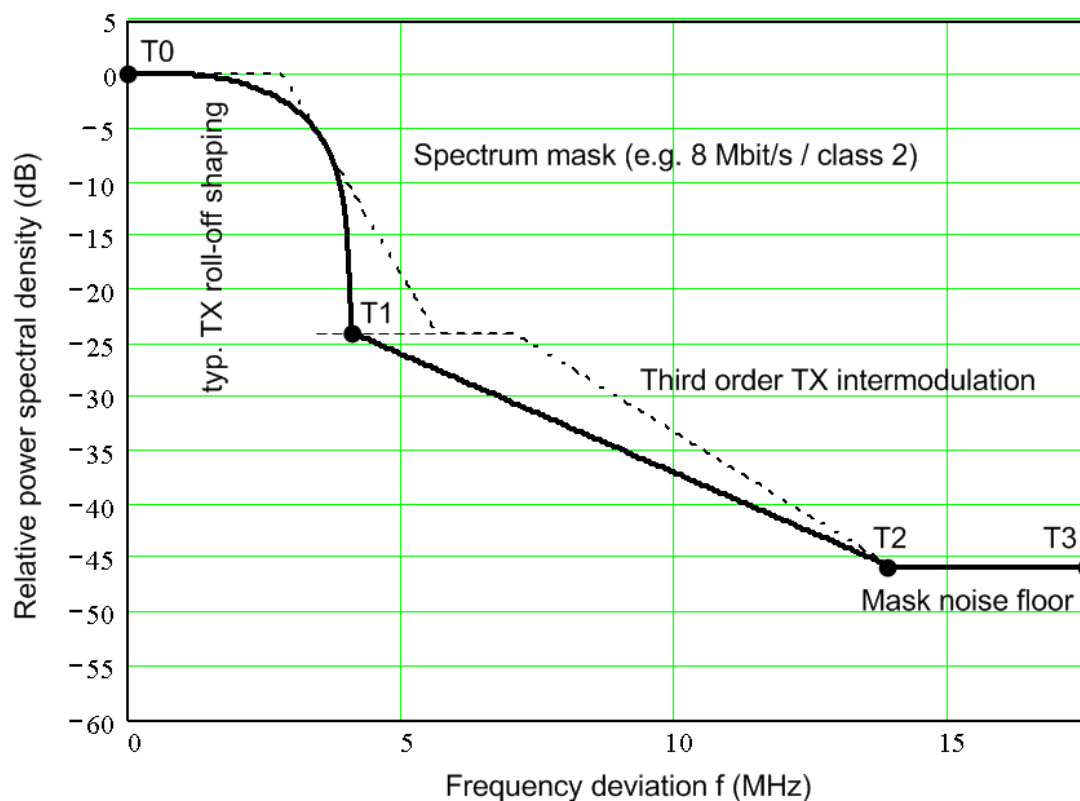


Figure F.1: Typical transmitter spectrum

Table F.2 shows the corner points of figure F.1.

Table F.2: Reference points for the typical transmitter spectrum

Reference points	Frequency deviation [f]	Relative power spectral density [dB]	Course of the spectrum
T0	0	K1 according EN	Square Root Nyquist filtering
T1	Cosine roll-off selected to tangent Tx spectrum mask	Starting level of the intermodulation region	Straight line
T2	Intersection of Tx mask with noise floor	Mask noise floor	Straight line
T3	2,5 x CS	Mask noise floor	

F.3 Derivation of receiver selectivity

For the receiver side the filter is similar. The receiver filter is a combination of a Nyquist filter and 2 straight lines until the limits of 2,5 x channel bandwidth. As figure F.2 shows the receiver selectivity follows the Nyquist filtering until the attenuation achieves half the way between the starting level of Tx intermodulation region and Tx mask floor. From this point a straight line is drawn to the point of intersection of the extension of the first part of Tx-mask with the Rx asymptotic attenuation and from there a horizontal line up to 2,5 x CS. The value of Rx asymptotic attenuation is given by formula (F.5). Values in formula (F.5) should be taken from those given in ETSI EN 302 217-2 [i.5] for the relevant system under analysis.

$$\text{Rx attenuation}_{(\text{asymptotic})} [\text{dB}] = C/I_{(\text{at } 1 \text{ dB } 10^{-6} \text{ co-channel degradation})} - C/I_{(\text{as given by CW interference requirement})} \quad (\text{F.5})$$

For the Rx cosine roll-off factor, the same value as calculated for the transmitter mask is used.

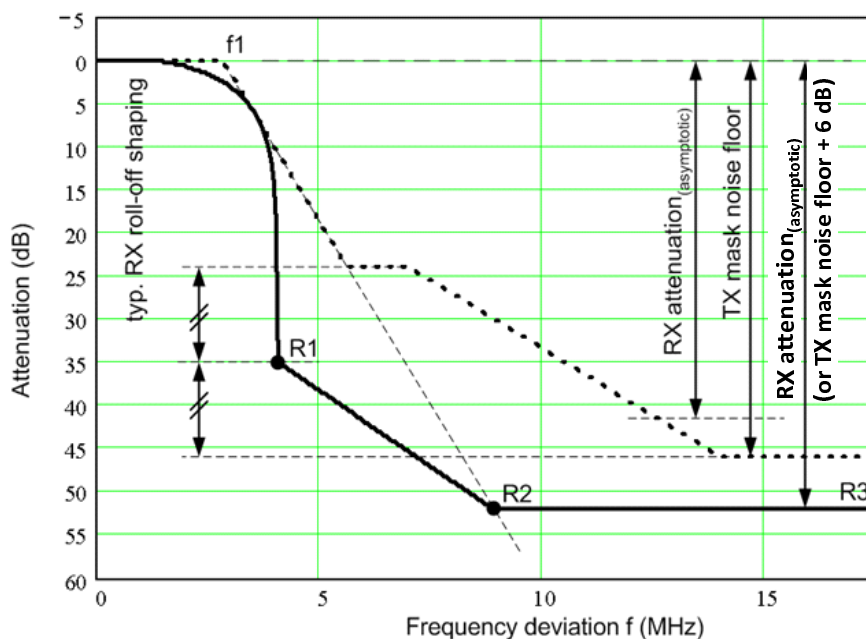


Figure F.2: Typical receiver selectivity

Table F.3 shows the corner points of figure F.2.

It should be noted that, in general, the values given in ETSI EN 302 217-2 [i.5], result in a $Rx\ attenuation_{(asymptotic)}$ larger than the corresponding TX mask noise floor +6 dB.

Table F.3: Reference points for the typical receiver selectivity

Reference points	Frequency deviation [f]	Attenuation of the receiver filter [dB]	Course of the selectivity
R0	0	K1 according EN	Square Root Nyquist filtering
R1	Cosine roll-off selected to tangent Tx spectrum mask	Half the way between starting level of intermodulation region and Tx mask noise floor	Straight line
R2	Intersection point between the line starting at corner point f1 extended to cross the corner point indicating the beginning of the intermodulation region and crossing the $Rx\ attenuation_{(asymptotic)}$ or Tx mask noise floor +6 dB	$Rx\ attenuation_{(asymptotic)}$ Or (Tx mask noise floor +6 dB) whichever is more stringent	Straight line
R3	2,5 x CS	$Rx\ attenuation_{(asymptotic)}$ Or (Tx mask noise floor +6 dB) whichever is more stringent	

F.4 Derivation of cosine roll-off

The net filter discrimination (see clause 4.2.4) for the first adjacent channel, calculated with the parameters above (transmitter spectrum mask and receiver selectivity), has to comply with the requirements of the relevant standard.

If the net filter discrimination for the first adjacent channel does not comply with the requirement in the relevant standard, the cosine roll-off factor of both transmitter spectrum mask and receiver selectivity has to be changed by the same amount until the minimum requirement is met (for like-systems).

If the net filter discrimination for the first adjacent channel is already met with the parameters calculated above then the cosine roll-off factor of the receiver may be increased until the requirement for the first adjacent channel in the relevant standard is met.

The resulting transmitter spectrum mask and receiver selectivity may now be used to calculate net filter discrimination between equipment of different spectrum efficiency classes and systems (unlike-systems).

F.5 Transmitter mask and receiver selectivity of other equipment classes

The following table F.4 shows the similar approach for other system classes.

Table F.4

	Transmitter mask	Receiver selectivity
4-segment spectrum mask	<p>The graph shows a 4-segment transmitter mask. The y-axis is 'Spectral power density (dB)' ranging from -60 to 5. The x-axis is 'Frequency deviation f (MHz)' ranging from 0 to 50. The curve starts at T0 (0, 0), remains flat until T1 (approx. 18, 0), then drops to T2 (30, -55), and remains flat until T3 (50, -55). A dashed line shows a steeper slope between T1 and T2.</p>	<p>The graph shows a 4-segment receiver selectivity curve. The y-axis is 'Attenuation (dB)' ranging from -5 to 80. The x-axis is 'Frequency deviation f (MHz)' ranging from 0 to 50. The curve starts at R0 (0, 0), remains flat until R1 (approx. 18, 0), then drops to R2 (20, 75), and remains flat until R3 (50, 75). A dashed line shows a steeper slope between R1 and R2. A vertical arrow indicates 'RX attenuation (system)'. A horizontal arrow indicates the slope between R1 and R2.</p>
5-segment spectrum mask	See example in clauses F.2 and F.3	
6-segment spectrum mask	<p>The graph shows a 6-segment transmitter mask. The y-axis is 'Spectral power density (dB)' ranging from -60 to 5. The x-axis is 'Frequency deviation f (MHz)' ranging from 0 to 50. The curve starts at T0 (0, 0), remains flat until T1 (approx. 15, 0), then drops to T2 (30, -45), and remains flat until T3 (50, -45). A dashed line shows a steeper slope between T1 and T2.</p>	<p>The graph shows a 6-segment receiver selectivity curve. The y-axis is 'Attenuation (dB)' ranging from -5 to 70. The x-axis is 'Frequency deviation f (MHz)' ranging from 0 to 50. The curve starts at R0 (0, 0), remains flat until R1 (approx. 15, 0), then drops to R2 (20, 65), and remains flat until R3 (50, 65). A dashed line shows a steeper slope between R1 and R2. A vertical arrow indicates 'RX attenuation (system)'. A horizontal arrow indicates the slope between R1 and R2.</p>
7-segment spectrum mask	<p>The graph shows a 7-segment transmitter mask. The y-axis is 'Spectral power density (dB)' ranging from -60 to 5. The x-axis is 'Frequency deviation f (MHz)' ranging from 0 to 50. The curve starts at T0 (0, 0), remains flat until T1 (approx. 12, 0), then drops to T2 (45, -55), and remains flat until T3 (50, -55). A dashed line shows a steeper slope between T1 and T2.</p>	<p>The graph shows a 7-segment receiver selectivity curve. The y-axis is 'Attenuation (dB)' ranging from -5 to 70. The x-axis is 'Frequency deviation f (MHz)' ranging from 0 to 50. The curve starts at R0 (0, 0), remains flat until R1 (approx. 12, 0), then drops to R2 (20, 65), and remains flat until R3 (50, 65). A dashed line shows a steeper slope between R1 and R2. A vertical arrow indicates 'RX attenuation (system)'. A horizontal arrow indicates the slope between R1 and R2.</p>

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