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Technical Report

Fixed Radio Systems;
Point-to-point and point-to-multipoint equipment;
Rules for the co-existence of point-to-point and point-to-multipoint systems using different access methods in the same frequency band

Reference

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Transmission and Multiplexing (TM).

Introduction

The main field of application of Point-to-Multipoint (P-MP) systems using the Fixed Service (FS) is to provide access to both public and private networks (PSTN, PDN, etc.). By means of P-MP systems the networks service area may cover scattered subscriber locations. The systems may be applied to build new access networks by means of a multi cellular architecture, covering both suburban, urban and regional areas.

The main field of application of Point-to-Point (P-P) systems using the Fixed Service (FS) is to provide transparent capacity or access to both public and private networks. The system may be applied to build transport networks or to integrate access networks covering both suburban, urban and regional areas.

1 Scope

The present document gives guidance on the compatibility of Point-to-Multipoint digital radio fixed service systems intended to operate in the same frequency band and in near or identical geographical location, using different access methods and characteristics. Furthermore, it outlines the strategy for compatibility between fixed service P-MP systems operation and P-P systems.

The present document defines the methodologies to be used for evaluating the interference between two P-MP systems and between a P-MP system and a P-P radio link. It should be noted that for the evaluation of the degree of co-existence some assumptions shall be taken and some parameters shall be defined.

The document produces a series of considerations regarding the identification of some critical parameters, the constraints which they should satisfy and some mitigation methods that could be applied for a better co-existence.

2 References

For the purposes of this Technical Report (TR), the following references apply:

[1] ETSI EN 302 085: "Fixed Radio Systems; Point-to-Multipoint Antennas; Antennas for point-to-multipoint fixed radio systems in the 3 GHz to 11 GHz band".

[2] ETSI EN 300 833: "Fixed Radio Systems; Point to Point Antennas; Antennas for point-to-point fixed radio systems operating in the frequency band 3 GHz to 60 GHz".

[3] ETSI EN 301 021: "Fixed Radio Systems; Point-to-multipoint equipment; Time Division Multiple Access (TDMA); Point-to-multipoint radio systems in the Frequency Division Duplex (FDD) bands in the range 3 GHz to 11 GHz".

[4] ETSI EN 301 253: "Fixed Radio Systems; Point-to-multipoint equipment; Frequency Hopping Code Division Multiple Access (FH-CDMA); Point-to-multipoint digital radio systems in frequency bands in the range 3 GHz to 11 GHz".

[5] ETSI EN 301 213-3: "Fixed Radio Systems; Point-to-multipoint equipment; Point-to-multipoint digital radio systems in frequency bands in the range 24,25 GHz to 29,5 GHz using different access methods; Part 3: Time Division Multiple Access (TDMA) methods".

[6] ETSI EN 300 431: "Fixed Radio Systems; Point-to-point equipment; Parameters for radio system for the transmission of digital signals operating in the frequency range 24,50 GHz to 29,50 GHz".

[7] ITU-R Recommendation P.837-2: "Characteristics of precipitation for propagation modelling".

[8] ETSI TR 101 854: "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".

[9] ETSI EN 301 127: "Fixed Radio Systems; Point-to-point equipment; High capacity digital radio systems carrying SDH signals (2 x STM-1) in frequency bands with about 30 MHz channel spacing and using Co-Channel Dual Polarized (CCDP) operation".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

Frequency Block: Bandwidth assigned to an operator by a regulatory authority for the operation of a P-MP system within a defined service area

Class A interference: This class (and its sub classes of interference A1, A2, A3 and A4) refer to the interference between two P-MP systems operated by different network operators

Class B interference: This class (and its sub classes of interference B1, B2, B3 and B4) refer to the interference between a P-MP system and a P-P system operated by different network operators

Guard band channel: Unused slice of spectrum between the two closest carriers of different operators

%KO Area: Percentage of a P-MP cell area where interference may afflict or arise from TS, and "Knock Out" the radio receiver(s)

3.2 Symbols

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

C/I	Carrier to Interference ratio
dB	decibel
dBm	decibels relative to one milliwatt
GHz	GigaHertz
kbit/s	kilobits per second
km	kilometre
m	metre
Mbit/s	megabits per second
MHz	MegaHertz

3.3 Abbreviations

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

ATPC	Automatic transmit power control
BER	Bit Error Ratio
CDMA	Code Division Multiple Access
CRS	Central radio station
DL	Downlink
EIRP	Effectively Isotropic Radiated Power
EN	European Standard
FB	Frequency block
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FH-CDMA	Frequency Hopping Code Division Multiple Access
IACI	Intra-Cell interference
IRCI	Inter-Cell interference
ISI	Inter-System Interference
LOS	Line of Sight
NFD	Net Filter Discrimination
P-MP	Point-to-Multipoint system
P-P	Point-to-Point system
RF	Radio Frequency
RTPC	Remote Transmit Power Control
TDD	Time Division Duplex

TDMA	Time Division Multiple Access
TS	Terminal Station
UL	Uplink

4 Executive summary

This clause contains an executive summary on the report contents and, in particular, on the conclusions derived from the report. The summary is introduced by a general overview on P-MP and P-P radio systems considered in the present document. In particular, the TM4 EN's classification of radio equipment and antennas actually standardized is given with particular focus on frequencies and on standardized classes of equipment.

4.1 P-MP systems

4.1.1 P-MP equipment

For P-MP equipments the frequency bands are usually grouped as follows:

- below 1 GHz;
- between 1 GHz and 3 GHz;
- between 3 GHz and 11 GHz;
- between 24,5 GHz and 29,5 GHz;
- between 40,5 GHz and 43,5 GHz.

Each of TM4 EN's standards, related to a specific access method (TDMA, MC-TDMA, FDMA, DS-CDMA, FH-CDMA, DS-CD/TDMA), refer to one of the frequency bands quoted above.

4.1.2 P-MP antenna

The TM4 EN's standards regarding P-MP antennas are usually grouped as follows:

- between 1 GHz and 3 GHz;
- between 3 GHz and 11 GHz;
- between 24 GHz and 30 GHz;
- between 40,5 GHz and 43,5 GHz.

4.2 P-P systems

4.2.1 P-P equipment

TM4 EN's for P-P equipment specify different classes of systems, depending on channel spacing, order of modulation and capacity, in many of the frequency bands between 1 GHz and 60 GHz.

4.2.2 P-P antenna

The TM4 EN's standards regarding P-P antennas are usually grouped as follows:

- between 1 GHz and 3 GHz;
- between 3 GHz and 60 GHz.

4.3 Executive summary

The present document deals with the problem of co-existence between P-MP and P-P equipment, operated by different network operators, using the same frequency band and the same geographical area.

In clause 5 are defined all the possible combinations (classes) of interference between two P-MP systems and between a P-P and a P-MP system. Clauses 6 and 7 contain the methodologies to analyse the different classes of interference identified in the report. Clauses 8 and 9 summarize the conclusions regarding the co-existence of P-MP and P-P systems. These conclusions have been derived from the methodologies in the report, the discussions within the group, people experience and they are supported by some co-existence analysis examples reported in annexes A and B.
The conclusions reached by the present document can be summarized as follows.

In order to accomplish the co-existence of two P-MP systems the following rules apply:

- the two systems should have similar EIRP;
- the use of ATPC on the uplink decreases the level of interference;
- systems with similar channel size co-exists better than systems with different channel size;
- co-existence between P-MP using FDD technique is facilitated by co-siting of CRS's.

In order to accomplish the co-existence between P-MP and P-P systems the following rules apply:

- systems with similar channel size co-exists better than systems with different channel size;
- a minimum distance and angular decoupling between P-P site and CRS should be provided;
- the use of ATPC on the P-MP uplink decrease the level of interference.

In order to accomplish a co-existence analysis as close as possible to reality it is necessary to have EN limits on system parameters as close as possible to actual system parameters such as:

- transmit power;
- receiver threshold;
- interference sensitivity;
- transmitter mask.

In fact, the results of the co-existence analysis carried out in the annex point out a significant difference whether actual parameters or EN limits are used.

In order to accomplish the co-existence analysis it is necessary to have the possibility to evaluate the cross NFD between different systems (even between a P-P and a P-MP system) compliant with different standards. Therefore, it is necessary to have in the EN's the following parameters:

- transmitter mask;
- receiver sensitivity mask.

The first one is directly available as an European Standard while the second is not. The present document suggests to introduce receiver sensitivity masks in the EN's or a way to derive this parameter directly from the EN's.

5 P-MP and P-P deployment scenario

In this clause are reported general considerations upon P-MP and P-P radio networks, on the kind of interference considered in the present document and on propagation conditions. It is also described a quite general set of interference scenarios in order to define the interference classes to be studied in the following clauses.

5.1 P-MP radio networks

P-MP systems will be installed in frequency bands starting from below 1 GHz up to 40 GHz (see clause 4), and in the future even higher. In each frequency band propagation characteristics, available bandwidth dictated by the regulation specific to that band, as well as system characteristics will constrain the P-MP system applications, in terms of capacity transported, cell radius achieved, services transported and even in terms of the cell architecture itself.

In any case the quality of service for a P-MP transport media has often to compete with that of the wired network. This also being valid for both the short term performance and availability objectives as well as for the long term objectives.

The following assumptions should be taken as essential to further evaluation of the compatibility between P-MP systems operation.

1) Within a service area there will be more than one operator who build up their own network infrastructure. Especially in economically interesting regions four or more operators will ask for frequency blocks to operate their own P-MP systems to connect the envisaged user to the network node.
2) The operator will plan and deploy independently the P-MP system.
3) Different Operators provide different services portfolio to their envisaged users and therefore will install different P-MP systems in the same area.
4) The P-MP systems will be of different origin.
5) Various access methods applied by the P-MP systems in accordance with the ESTI standards which are in force or are going to be published or even produced will be used by different operators.
6) The network planning as well as the cell planning will be under the responsibility of each network operator.
7) The regulatory authority will be responsible for the assignment of the necessary frequency block for each operator. In adjacent Frequency Blocks (FB) in the same frequency band the authority has also to guarantee in a reasonable way the envisaged usage by different operators in the same area. That means that each P-MP operator has the possibility to operate and provide the grade of service to his customer as stated in the relevant "network license" given to the operator. However, that does not mean that the regulators guarantees an interference free operation but rather a controlled level of interference with the necessary rules, etiquette and mechanism to settle any sharing problem.
8) It cannot be expected that there shall be no restriction due to compatibility reasons for any operator to install the Terminal Stations (TS) as necessary in respect to his envisaged customer. Restrictions around other operators base stations should be anticipated.

5.2 P-P radio networks

P-P systems will be installed in frequency bands starting from 1 GHz up to 58 GHz (see clause 4), and in the future even higher. In each frequency band propagation characteristics, available bandwidth dictated by the regulation specific to that band, as well as system characteristics will constrain the P-P system applications, in terms of capacity transported, hop length achieved and services transported.

In any case the quality of service for a P-P transport media has to be ensured for both the short term performance and availability objectives as well as for the long term objectives.

The following assumptions should be taken as essential to further evaluation of the compatibility between P-P and P-MP systems operation.

1) Within an urban area there will be more than one operator who build up their own P-MP network and (or) P-P network.
2) The operators will plan and deploy independently their P-MP and (or) P-P systems.
3) The P-MP and P-P systems will be of different origin: in particular P-P will be of different channel spacing, capacity and classes of equipment in accordance with ETSI standard.

4) The regulatory authority will be responsible for the assignment of the necessary frequency block for each operator. In adjacent Frequency Blocks (FB) in the same frequency band the authority has also to guarantee in a reasonable way the envisaged usage by different operators in the same area. That means that each P-P operator has the possibility to operate and provide the quality and availability objectives as stated in the relevant "network license" given to the operator. However, that does not mean that the regulators guarantees an interference free operation but rather a controlled level of interference with the necessary rules, etiquette and mechanism to settle any sharing problem.

5) It cannot be expected that there shall be no restriction due to compatibility reasons for a P-MP operator to install the Terminal Stations (TS) as necessary in respect to his envisaged customer. Restrictions around other P-P stations should be anticipated.

5.3 Interference to be studied

The interference between P-MP systems which is covered in the present document is mainly concentrated on the interference of P-MP systems belonging to cells operated by different network operators serving the same area that is the so called Inter-Cell Interference (IRCI). Nevertheless a lot of information in respect to the interference can be taken from the cell planning strategy necessary for installing a cell architecture of a single operator, the so called Intra-Cell Interference (IACI).

ETSI/TM4 does not preclude the use of P-MP systems using either FDD (Frequency Division Duplex) or TDD (Time Division Duplex), each offering its advantages and disadvantages in different deployment scenarios. FDD systems offer a relatively good solution for compatibility between similar systems, specially when the base stations are located in the same site.

TDD systems are more flexible from the spectrum usage point of view as they require a single frequency channel for the up and down links and they are more flexible in handling asymmetric traffic. So both duplex schemes must be considered in the present document.

The interference between a P-P and a P-MP system which is covered in the present document is mainly concentrated on systems belonging to different operator that are deployed on the same area. Thus, the Inter-System Interference (ISI) is here considered while the interference inside each system (P-MP cells and P-P links) should be considered by operators.

5.4 Propagation considerations

Only Fixed Service P-MP and P-P systems operation (no mobility) are of interest. The characteristics of the propagation, i.e. the channel model which have to be taken into account when the usage of such a systems are considered, depends on the frequency band, the bit rate transported over the air and the channel spacing.

Having in mind the frequency range from 1 GHz up to 43 GHz (for the time being) it is obvious that P-MP systems operation may make use of Line of Sight (LOS) or near LOS propagation conditions. Non LOS may be possible where low capacities e.g. < 2 x 64 kbit/s from the CRS to the TS and vice versa are transmitted in the bands up to 4 GHz. For higher capacities and/or higher frequencies (> 4 GHz) mainly Line of Sight (LOS) propagation conditions are considered for the transport between CRS and TS taking into account the overall grade of service which should in any case be competitive with the wired media network.

Having in mind the frequency range from 1 GHz to 58 GHz (for the time being) it is obvious that P-P systems use a LOS propagation condition. This is the only condition to achieve quality requirements and availability objectives which should in any case be competitive with the wired media network.

If rain induced fading is involved, mainly above 10 GHz with increasing effect by increasing frequency, the additional path loss must be included on useful or interfering links depending on rain correlation.

5.5 Interference scenarios

Considering the actual constraints given by ERC recommendations about spectrum arrangement and the possible systems that could be allocated in the same frequency bands there are the following combinations of possible interference to be analysed.

5.5.1 P-MP FDD/FDD combinations

There are two possible arrangements of two FDD P-MP systems to be considered (see note):

NOTE: Usually, only case 1 occurs within any country because each administration defines which sub band to use for downstream and which to use for upstream. Case 2 may only occur on the boundary of two country that uses different sub band allocations.

1) both systems use the same sub-band for downlink (the path from CRS to TS) and therefore also for uplink (the path from TS to CRS);

2) the two systems use a different sub-band for uplink and downlink,

as depicted in figure 1.

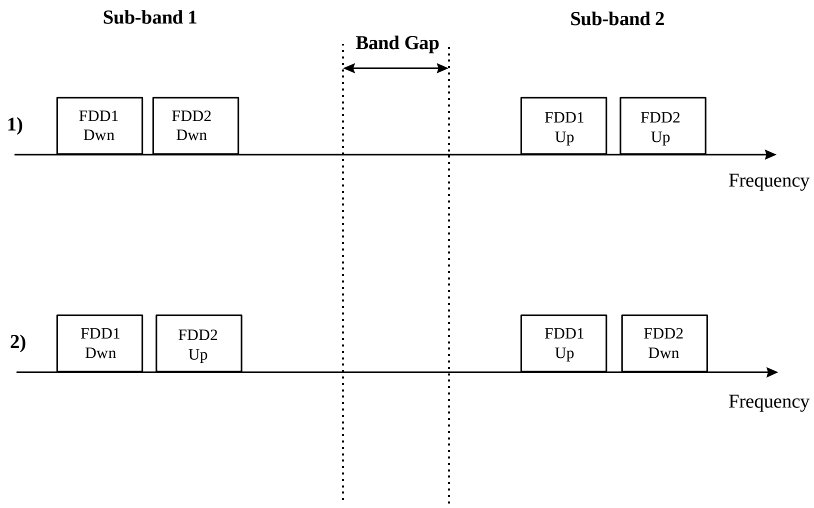

Figure 1: Possible arrangements for two FDD P-MP systems

In order to consider all the possible combinations of interference between two FDD systems it is necessary to define the four following interference classes that can be distinguished for the different pairs of source and destination of interference.

Class A1 (down/down adjacency): the interference source is the CRS of the interferer system and the destination of the interference is the TS of the victim system.

Class A2 (up/up adjacency): the interference source is the TS of the interferer system and the destination of the interference is the CRS of the victim system.

Class A3 (down/up adjacency): the interference source is the CRS of the interferer system and the destination of the interference is the CRS of the victim system.

Class A4 (up/down adjacency): the interference source is the TS of the interferer system and the destination of the interference is the TS of the victim system.

Table 1 summarizes all the cases where some interference may occur. Two different FDD P-MP systems are listed in the table both as potential interferer (in rows) and potential victim (in columns):

- the first (DL in sb1) has downlink (uplink) in sub-band 1 (2);
- the second (DL in sb2) has downlink (uplink) in sub-band 2 (1).

All the potential interference conditions have been listed in table 1, distinguishing between downlink (DL) and uplink (UL). A zero in the table indicates a non-interference situation, while any other reference refers to the classes defined above. We assume that a transmission at one sub-band may cause interference to receivers in the same band, but the duplex spacing is large enough to reject interference from the other sub-band transmission.

Table 1: Potential cases of interference between two FDD P-MP systems

Interferer	Victim	DL in sb1		DL in sb2	
		DL	UL	DL	UL
DL in sb1	DL	A1	0	0	A3
	UL	0	A2	A4	0
DL in sb 2	DL	0	A3	A1	0
	UL	A4	0	0	A2

5.5.2 P-MP FDD/TDD combinations

There are two possible arrangements of a FDD P-MP system and a TDD P-MP system to be considered:

1) the TDD system is allocated near the FDD downlink channel;

2) the TDD system is allocated near the FDD uplink channel,

as depicted in figure 2.

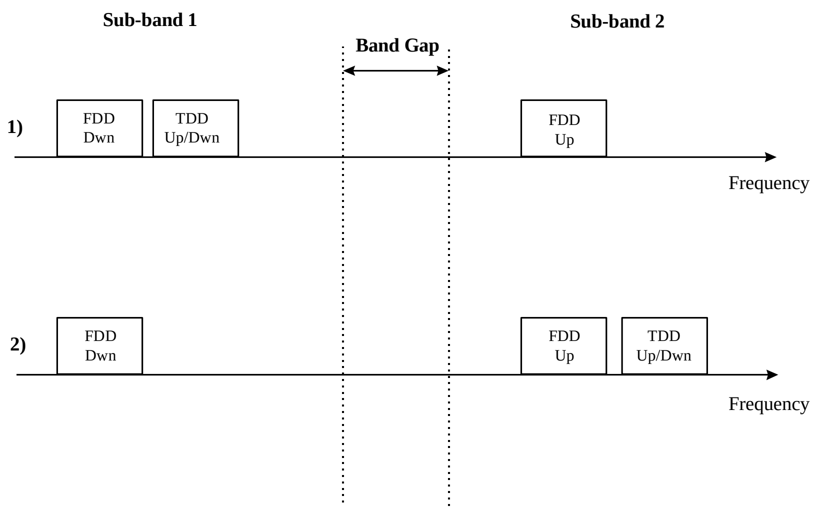

Figure 2: Possible arrangements for a FDD P-MP system and a TDD P-MP system

In this case the same four interference classes shall apply, but the potential cases where interference may occur are listed in table 2, where both FDD and TDD systems are considered as interferer as well as victim. For TDD systems it is indicated the sub-band used. Non zero entries presents the sum of two different interference classes due to the presence of TDD system which uses the same channel for both downlink and uplink.

Table 2: Potential cases of interference between a FDD P-MP system and a TDD P-MP system

		Victim	P-MPTDD		P-MP FDD			
					DL in sb1		DL in sb2	
Interferer			sb1	sb2	DL	UL	DL	UL
P-MP FDD	DL in sb1	DL	A1+A3	0	See table 1			
		UL	0	A2+A4				
	DL in Sb2	DL	0	A1+A3				
		UL	A2+A4	0				
P-MP TDD	sb1		See clause 5.4.3		A1+A4	0	0	A2+A3
	sb2				0	A2+A3	A1+A4	0

5.5.3 P-MP TDD/TDD combinations

There is only one possible arrangement of two TDD P-MP systems given the channel adjacency because each system uses only one channel for both uplink and downlink. Given this situation two cases shall be considered depending on the synchronization (time domain) or not of the two systems.

1) *TDD systems synchronized*: it is the same situation of FDD system due to the correspondence between downlink and uplink of both systems and A1 and A2 interference classes shall be evaluated.

2) *TDD systems not synchronized*: all the possible interference classes (A1, A2, A3 and A4) shall be considered and evaluated.

5.5.4 P-MP/P-P combinations

There are two possible arrangements of a FDD P-MP system and a P-P system to be considered:

1) The P-P channel is allocated near the FDD downlink channel;

2) the P-P channel is allocated near the FDD uplink channel,

as depicted in figure 3.

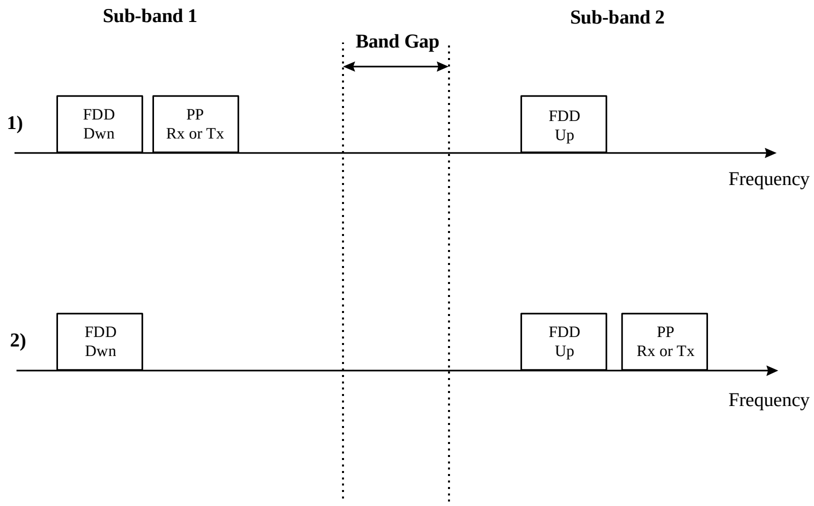

Figure 3: Possible arrangements for a FDD P-MP system and a P-P system

In order to consider all the possible combinations of interference between a P-MP system and a P-P system it is necessary to define the four following interference class that can be distinguished for the different pairs of source and destination of interference.

Class B1 (Down/P-P Rx adjacency): the interference source is the CRS of the P-MP interfering system and the destination of the interference is the receiver of the P-P victim system.

Class B2 (P-P Tx/Up adjacency): the interference source is the transmitter of the P-P interferer system and the destination of the interference is the CRS of the P-MP victim system.

Class B3 (Up/P-P Rx adjacency): the interference source is the TS of the P-MP interfering system and the destination of the interference is the receiver of the P-P victim system.

Class B4 (P-P Tx/Down adjacency): the interference source is the transmitter of the P-P interfering system and the destination of the interference is the TS of the P-MP victim system.

Table 3 summarizes all the cases where some interference may occur. For P-P system is indicated which is the sub-band of its channel that it is used for transmission (when P-P is the interfering) and for receiving (when P-P is the victim).

If a TDD P-MP system has to be considered instead of the FDD P-MP system the same conditions of table 3 apply. The only difference is that always the pair of conditions (B1+B2 or B3+B4) shall be considered due to the TDD P-MP use of the same channel for both downlink and uplink.

Table 3: Potential cases of interference between a FDD P-MP system and a P-P system

<table>
<tr><th colspan="3" rowspan="3">Victim

Interferer</th><th colspan="2">P-P system</th><th colspan="4">P-MP FDD</th></tr>
<tr><td></td><td></td><td colspan="2">DL in sb1</td><td colspan="2">DL in sb2</td></tr>
<tr><td>sb1</td><td>sb2</td><td>DL</td><td>UL</td><td>DL</td><td>UL</td></tr>
<tr><td rowspan="4">P-MP FDD</td><td rowspan="2">DL in sb1</td><td>DL</td><td>B1</td><td>0</td><td colspan="4" rowspan="4">See table 1</td></tr>
<tr><td>UL</td><td>0</td><td>B3</td></tr>
<tr><td rowspan="2">Dl in sb2</td><td>DL</td><td>0</td><td>B1</td></tr>
<tr><td>UL</td><td>B3</td><td>0</td></tr>
<tr><td rowspan="2">P-P system</td><td colspan="2">sb1</td><td colspan="2" rowspan="2">Out of scope</td><td>B4</td><td>0</td><td>0</td><td>B2</td></tr>
<tr><td colspan="2">sb2</td><td>0</td><td>B2</td><td>B4</td><td>0</td></tr>
</table>

6 Interference between Point-to-Multipoint systems: class A interference situations

In this clause is described the frame for the study of compatibility between Point-to Multipoint (P-MP) systems. The compatibility between P-MP systems operation and Point-to-Point (P-P) systems operation will be dealt with in the clause 7 of the present document.

The study focuses on a general analysis that provides a method to analyse the interference all over a defined area for the scenarios described in clause 5. This is the main method to be used to evaluate the effective impact of different interference scenarios.

In addition, a simple equation (that holds for all scenarios) is given to evaluate the minimum distance, between source and victim of interference, necessary to avoid interference even in the worst geometric scenario and propagation condition. This method easily provides a value that can be used for comparison but it does not represent the whole interference analysis.

6.1 Basic assumptions and objectives of the study

In order to evaluate the effects of the interference (classes A1, A2, A3 and A4) of two P-MP systems operating on adjacent channels (using the same polarization) all over the cell area, a simple but general scenario shall be considered. The main assumptions regarding the general scenario are the following.

- For both the useful and the interfering systems only one cell is considered. The two CRS are separated by a generic distance (d) that can be varied to evaluate the amount of interference in different geometric conditions. In particular the analysis will span from zero distance (the complete overlapping of the cells) up to a distance greater than the maximum cell dimension.

- For both the useful and the interfering systems the cell area is covered, in CRS sites, using isotropic antennas with a given antenna gain. By this assumptions (isotropic), the frequency channel adjacency can be considered all over the cell area. Moreover, this (a given antenna gain) allows to consider all interference scenarios, including those with sectored antennas (with different antenna gain), but disregarding the use of sectored antennas as a mitigation technique.

- All radio paths, both useful and interfering path, are in perfect line of sight (LOS). In this way the worst case is considered because the possible interfering attenuation due to a non perfect LOS condition is ignored.

Finally, it must be pointed out that in the following clauses all the link budget equations are expressed in logarithmic units (decibel).

6.2 Analysis methodology

6.2.1 Net filter discrimination

The physical phenomenon that could generate interference among two systems operating on adjacent channels is represented by the portion of the spectrum, emitted by the interfering (I) system, that is in the band of the useful (U) system receiving filter. This situation is depicted in figure 4 where both the receiving filter and the emitted RF spectrum are represented over their respective channels (CH U and CH I). The dark grey area represents the portion of the interfering spectrum that fall in the receiving filter band and generates the unwanted interference.

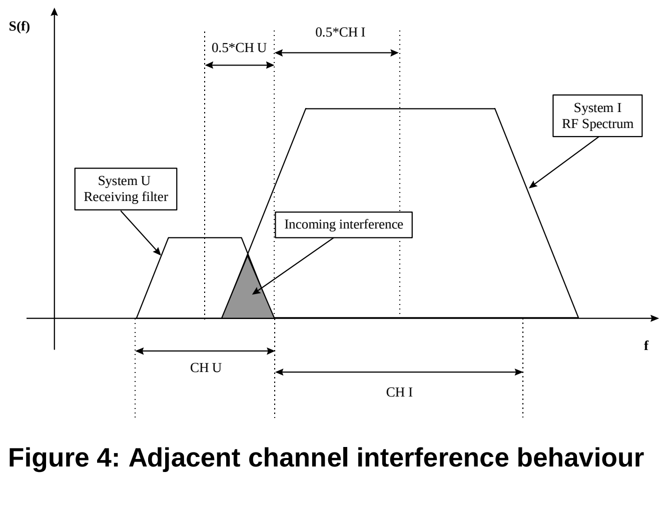

Figure 4: Adjacent channel interference behaviour

The amount of interference can be evaluated by the Net Filter Discrimination (NFD) defined as the ratio between the power transmitted by the interfering system and its portion that could be measured after the receiving filter of the useful system:

$$NFD = \frac{\int_{-\infty}^{+\infty} S_I(f) \cdot df}{\int_{-\infty}^{+\infty} S_I(f) \cdot \left| H_U(f) \right|^2 \cdot df} \tag{1}$$

where $S_I(f)$ is the spectrum of the interfering system and $H_U(f)$ is the transfer function of the useful system receiving filter.

6.2.2 Class A1 analysis

This class regards the interference from the CRS of the interfering system to a TS of the useful system. The generic scenario to be considered is depicted in figure 5, characterized with some other elements for the analysis of interference on downlink, i.e. the link from the useful radio base station (CRSu) to the user represented by his Terminal Station (TS).

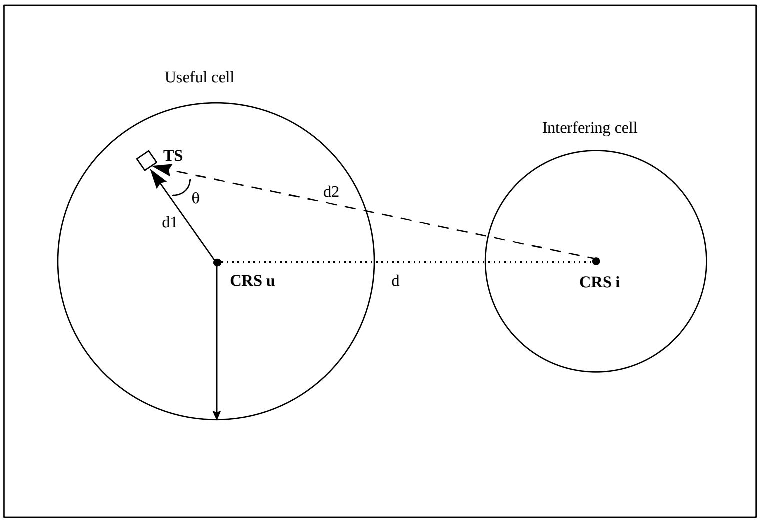

Figure 5: Generic scenario for class A1 interference analysis

Since the distance on the useful link is d_1 the useful signal is

$$P_u = P_u^t + G_u^t + G_{TS} - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d_1}{\lambda} \right) \tag{2}$$

where P_u^t is the nominal power emitted by system U for a single channel, G_u^t is the CRS antenna gain of the useful system and G_{TS} is the antenna gain of terminal station, λ is the carrier wavelength (same units as d_1).

For the sake generality two different gains could be assigned to CRS antennas to consider the effects of the possible use of sectored antennas.

P_u^t, that is the nominal power emitted by system U for a single channel, is different for any access method. For TDMA systems P_u^t is the useful power associated to each time slot and corresponds to the peak power. For CDMA systems P_u^t is the power associated to each code. For FDMA systems P_u^t is the power associated to each sub-carrier.

In the same way the interfering power can be calculated as

$$P_i = P_i^t + G_i^t + G_{TS}(\theta) - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d_2}{\lambda}\right) - NFD \qquad (3)$$

where P_i^t is the total power emitted by the interfering system, G_i^t is the system I CRS antenna gain, $G_{TS}(\theta)$ is the TS gain with an angle separation of θ degrees and NFD is the filter discrimination, calculated by equation (1), of system U against the system I spectrum.

In particular P_i^t is the total power emitted by the interfering system under maximum loading conditions. That is when all time slots are used in TDMA systems, or when all the PN codes are used in CDMA systems, or when all the sub-carriers are used in FDMA systems. Combining previous equations it is possible to calculate the carrier to interference ratio for any user (TS) position in the cell as

$$\frac{C}{I} = (P_u^t - P_i^t) + (G_u^t - G_i^t) + (G_{TS} - G_{TS}(\theta)) - 20 \cdot \log_{10}\left(\frac{d_1}{d_2}\right) + NFD \qquad (4)$$

that depends on systems parameters and on the distance (*d*) among the two system cells.

Another useful equation can be derived by evaluating equation (4) for zero distance among the two cells, i.e. when the CRS are co-sited:

$$\left.\frac{C}{I}\right|_0 = (P_u^t - P_i^t) + (G_u^t - G_i^t) + NFD \qquad (5)$$

because $d_1 = d_2$ and $\theta = 0$. This means that for co-sited CRS the amount of interference over downlink is equal for all the possible user positions and only the intrinsic system parameters are responsible of the result.

6.2.3 Class A2 analysis

This class regards the interference from a TS of the interfering system to the CRS of the useful system. The generic scenario to be considered for uplink analysis is reported in figure 6 where are also indicated, for both cells, the central radio stations (CRSu, CRSi) and the position of terminal stations (TSu, TSi).

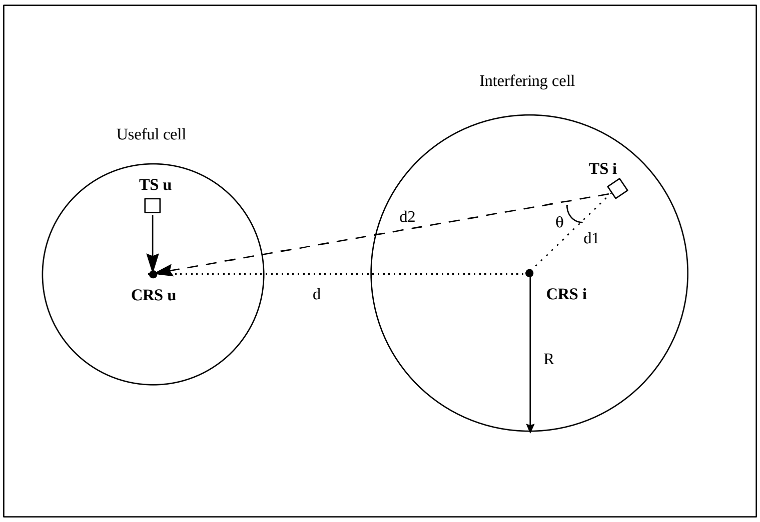

Figure 6: Generic scenario for class A2 interference analysis

To evaluate the available power received by the CRSu from the generic TSu user it must be considered that in P-MP systems a remote transmit power control (RTPC) mechanism is usual implemented to ensure the correct functionality of the system on the uplink. So it can be assumed that the useful received power is

$$P_u = P_u^{th} + M_u \tag{6}$$

where P_u^{th} is the CRS receiver sensitivity (threshold) at the maximum BER admitted and the maximum loading condition, and M_u is a power margin over the threshold. This equation also holds if no RTPC is implemented in order to consider the farthest user in the cell. In the same way works the interfering system in uplink with an RTPC system. So, to ensure a received power on CRSi equal to $P_i^{th} + M_i$, the TSi user must transmit, depending upon its position in the cell (d_1), an amount of power of

$$P_{TSi} = P_i^{th} + M_i - G_i^t - G_{TSi} + 20 \cdot \log_{10}\left(\frac{4\pi \cdot d_1}{\lambda}\right) \tag{7}$$

where $P_i^{th} + M_i$ is the wanted received power, G_i^t the CRSi antennas gain, G_{TSi} the interfering user antenna gain and d_1 is the distance from user to CRSi. If no RTPC is used $P_{TSi} = P_i^t$, that is the upper bound of previous equation. Considering the power (P_{TSi}) transmitted by the interfering user it is possible to evaluate the interfering power that is received by the useful radio base station (CRSu) as

$$I = P_{TSi} + G_u^t + G_{TSi}(\theta) - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d_2}{\lambda}\right) - NFD \tag{8}$$

Combining previous equations the carrier to interference ratio can be obtained, for a given position of the interfering user (TSi) and a given distance *d* among the CRS sites, as

$$\frac{C}{I} = [(P_u^{th} + M_u) - (P_i^{th} + M_i)] + (G_i^t - G_u^t) + (G_{TSi} - G_{TSi}(\theta)) - 20 \cdot \log_{10}\left(\frac{d_1}{d_2}\right) + NFD \tag{9}$$

for an interfering system with RTPC, and

$$\frac{C}{I} = (P_u^{th} + M_u) - P_i^t - G_u^t - G_{TSi}(\theta) + 20 \cdot \log_{10}\left(\frac{4\pi \cdot d_2}{\lambda}\right) + NFD \tag{10}$$

for an interfering system without RTPC. The same considerations of the previous clause apply in this case and it is still useful to evaluate the C/I ratio with the two CRS co-sited, that is

$$\left.\frac{C}{I}\right|_0 = [(P_u^{th} + M_u) - (P_i^{th} + M_i)] + (G_i^t - G_u^t) + NFD \tag{11}$$

for an interfering system with RTPC, and

$$\left.\frac{C}{I}\right|_0 = (P_u^{th} + M_u) - P_i^t - G_u^t - G_{TSi} 20 \cdot \log_{10}\left(\frac{4\pi \cdot d_2}{\lambda}\right) + NFD \tag{12}$$

for an interfering system without RTPC. In the last case the C/I ratio with CRS co-sited is no more a unique value but depends on the distance (d_2) of the interfering TS.

6.2.4 Class A3 analysis

This class regards the interference from the CRS of the interfering system to the CRS of the useful system. The generic scenario to be considered is depicted in figure 7, where the interfering and useful CRS are depicted.

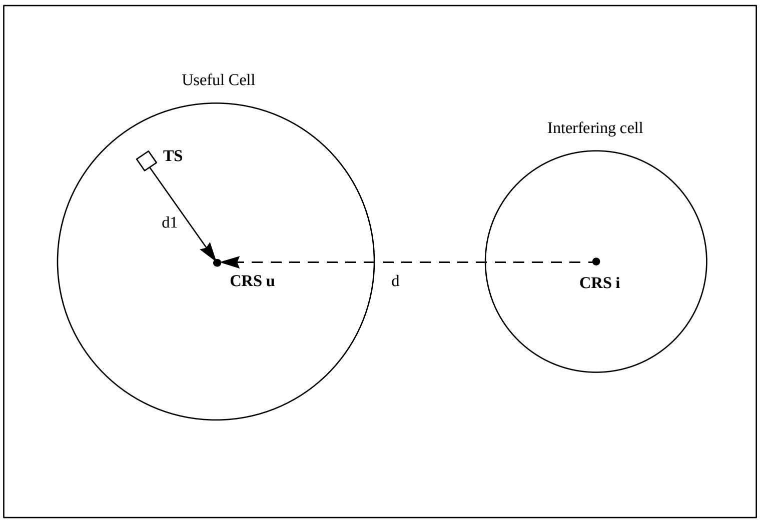

Figure 7: Generic scenario for class A3 interference analysis

The useful signal received by CRSu (transmitted by a TS) is

$$C = P_u^{th} + M_u \tag{13}$$

since a power control mechanism is implemented. The interfering signal, transmitted by the CRSi, is

$$I = P_i^t + G_i^t + G_u^t - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d}{\lambda}\right) - NFD \tag{14}$$

where P_i^t is the total power emitted by the interfering system (see clause 6.2.2), G_i^t and G_u^t the CRS's antenna gain. Combining previous equations it is possible to obtain the carrier to interference ratio

$$\frac{C}{I} = P_u^{th} + M_u - P_i^t - G_i^t - G_u^t + 20 \cdot \log_{10}\left(\frac{4\pi \cdot d}{\lambda}\right) + NFD \tag{15}$$

that depends only on the distance between the two CRS's and does not depend on the position of users inside each cell.

In this case it is necessary to have a minimum distance between the two CRS's in order to obtain the minimum carrier to interference ratio $\left(C/I\right)_{\min}$ allowed by the useful system. This distance can be calculated by the following equation.

$$d \geq \frac{\lambda}{4\pi} 10^{\frac{\left(C/I\right)_{\min} + P_i^t + G_i^t + G_u^t - P_u^{th} - M_u - NFD}{20}} \tag{16}$$

6.2.5 Class A4 analysis

This class regards the interference from a TS of the interfering system to a TS of the useful system. The generic scenario to be considered is depicted in figure 8, where the interfering and useful cells are depicted pointing out the source of interference (TSi) and the victim of interference (TSu).

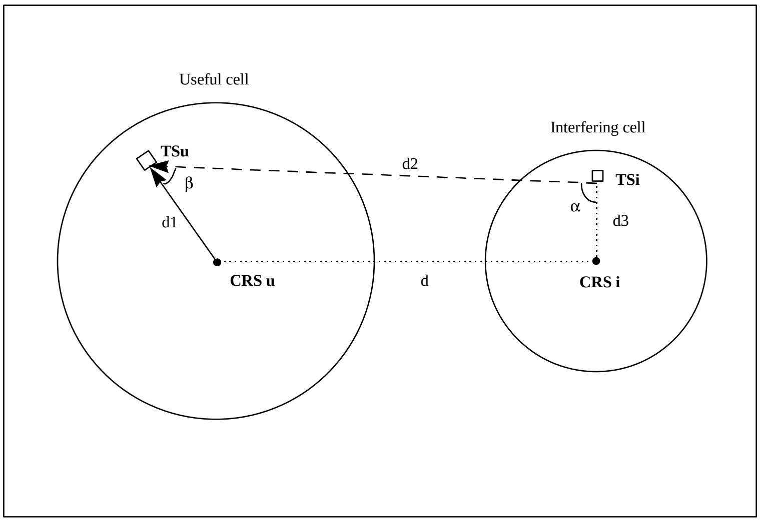

Figure 8: Generic scenario for class A4 interference analysis

The useful power received by TSu is

$$C = P_u^t + G_u^t + G_{TSu} - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d1}{\lambda}\right) \quad (17)$$

where P_u^t is the power emitted by the useful system for a single channel (see sub clause 6.2.2), G_u^t the useful CRS antenna gain and G_{TSu} the TSu antenna gain. The TSi, due to RTPC, transmits a power equal to

$$P_{TSi} = P_i^{th} + M_i - G_{TSi} - G_i^t + 20 \cdot \log_{10}\left(\frac{4\pi \cdot d3}{\lambda}\right) \quad (18)$$

where $P_i^{th} + M_i$ is the CRSi controlled received power, G_{TSi} the TSi antenna gain and G_i^t the CRSi antenna gain. If no RTPC is used then $P_{TSi} = P_i^t$. Thus, the interfering signal generated by TSi and received by TSu is

$$I = P_{TSi} + G_{TSi}(\alpha) + G_{TSu}(\beta) - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d2}{\lambda}\right) - NFD \quad (19)$$

where $G_{TSi}(\alpha)$ and $G_{TSu}(\beta)$ are the antenna gains of the two TS in the direction they see each other (see figure 8). Combining previous equations it is possible to obtain the carrier to interference ratio

$$\frac{C}{I} = P_u^t - P_i^{th} - M_i + G_i^t + G_u^t + G_{TSu} - G_{TSu}(\beta) + G_{TSi} - G_{TSi}(\alpha) - 20 \cdot \log_{10}\left(\frac{d1 \cdot d3}{d2}\right) + NFD \quad (20)$$

for an interfering system with RTPC, and

$$\frac{C}{I} = (P_u^t - P_i^t) + G_u^t + G_{TSu} - G_{TSu}(\beta) - G_{TSi}(\alpha) - 20 \cdot \log_{10}\left(\frac{d1}{d2}\right) + NFD \quad (21)$$

for an interfering system without RTPC. In both cases the C/I depends mainly on the relative position of the terminal stations (source and victim of interference) due to the great decoupling provided by directional antennas of TS's. Equations (20) and (21) can be used to evaluate the interference generated by a single source of interference (TSi) all over a useful cell area. But it is necessary to consider that in a real scenario there are N (number of TSi) possible sources of interference.

6.3 Worst case analysis

Once analysed the effects of interference all over the useful cell area for the four different scenarios it is useful to consider also the worst case of interference in terms of relative position (of source and victim of interference) and propagation conditions. This scenario, valid for all the four interference classes, is depicted in figure 9, where A represents the CRS (or the TS) and A' the TS (or the CRS) of the useful system while B the CRS or the TS of the interfering system. In particular, the correspondence among A, A', B and the proper (useful or interfering) CRS or TS is given in table 4 for the different classes of interference. In each row of table 4 the element A represents the victim of interference while the B element is the source of interference.

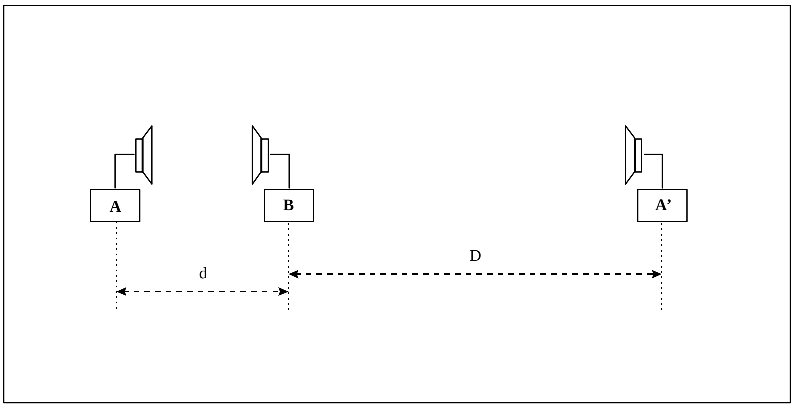

Figure 9: Generic scenario for the worst case analysis

Table 4: Correspondence for element A, A' and B in figure 9

Class	A	A'	B
A1	TSu	CRSu	CRSi
A2	CRSu	TSu	TSi
A3	CRSu	TSu	CRSi
A4	TSu	CRSu	TSi

As depicted in figure 9 the elements A, A' and B are all aligned, that is the worst geometric condition due to the maximum of antenna gain toward the source of interference. Moreover, the source and victim of interference (A and B) are close to each other (distance d) while the other element (B) is far away (distance D>>d).

In this scenario the worst propagation conditions (fading or rain attenuation) can produce a useful signal on A equal to the receiver sensitivity ($C = P_A^{th}$) while the interfering signal, due to small distance, is

$$I = P_B^t + G_B + G_A - 20 \cdot \log_{10}\left(\frac{4\pi d}{\lambda}\right) - NFD \qquad (22)$$

where P_B^t is the total power emitted by B, G_B and G_A the antenna gain of elements B and A. Combining previous equations we obtain the carrier to interference ratio

$$\frac{C}{I} = P_A^{th} - (P_B^t + G_B + G_A) + 20 \cdot \log_{10}\left(\frac{4\pi d}{\lambda}\right) + NFD > \left(\frac{C}{I}\right)_{\min} \qquad (23)$$

that must be grater than the minimum C/I allowed by system A receivers. Thus, it is possible to evaluate the minimum distance d, between A and B, that provide the wanted C/I once given the system parameters:

$$d \geq \frac{\lambda}{4\pi} 10^{\frac{\left(C/I\right)_{\min} + (P_B^t + G_B + G_A) - P_A^{th} - NFD}{20}} \qquad (24)$$

This is a general equation that holds for all the four interference classes analysed in clause 6.2 and the only parameters to be changed are G_B and G_A (antenna gain of CRS or TS) accordingly to table 4. But the distance provided by equation (24) shall be considered in different way for different classes because of the different elements involved. In order to provide a guidance for this considerations in table 5 is show a brief indication on the occurrences of such a worst scenario. In order to obtain a qualitative evaluation of the occurrences it must be considered the extension of interfered area, the extension of the area where interference sources are placed and the probability that the interfering link is in Line Of Sight (LOS).

Table 5: Occurrences of worst case interference scenario

Class	Distance between elements	Interfered area	Area of interference sources	LOS probability	Occurrences of worst case scenario
A1	TS from CRS	small (around CRSi)	1 point (CRSi)	high	few
A2	CRS from TS	1 point (CRSu)	small (around CRSu)	high	few
A3	CRS from CRS	1 point (CRSu)	1 point (CRSi)	very high	1
A4	TS from TS	large (all the cell area)	large (all the cell area)	low	many

Table 5 points out that the occurrences of class A1 and A2 are the same, because the elements involved are a TS and a CRS, and there are few occurrences due to TS of one operator near the CRS of the other operator (overlapping cell problem). Thus, the minimum distance obtained by equation (24) must be respected only by the few TS near the CRS aligned as depicted in figure 9.

Class A3 (only one occurrence) needs a minimum distance between the two CRS's that must be always respected because the CRS's, typically installed on towers are in perfect LOS.

Class A4 (many occurrences) involves two TS's that have a low probability to be place as in figure 9 due to antenna pattern and typical installations that could be obstructed by roofs (non LOS). However this situation must not be ignored due to the large number (one per each TS) of potential victims and sources of interference.

6.4 Required P-MP system parameters

In this clause will be listed the system parameters necessary to accomplish the analysis of different interference classes described in clauses 6.2 and 6.3. A definition and a brief discussion on each parameter is carried out, distinguishing between parameters available and not available from the ETSI standard.

6.4.1 System parameters available from EN's

- *Multiple access method*: depending whether the system uses TDMA or CDMA or FDMA access technique different changes shall be applied to analysis methodology. In particular the changes regard the transmitted power to be considered for useful and interfered system.

- *Frequency bands*: the absolute frequency is very important in order to evaluate minimum distances (see clause 6.3). In general the frequency band of systems influences other parameters, such as antenna gain and antenna pattern.

- *Channel arrangements and duplex technique*: this determines which classes (one or more) of interference shall be considered as described in clause 5.

- *Maximum transmitter output power*: that is the mean transmitter output power that shall not be exceeded.

- *Transmitter mask*: it is the only information available in EN's that can be used to evaluate the net filter discrimination as defined in (1).

- *Receiver sensitivity*: it is the lower received power level that ensures a BER < 10^{-6}. This is an overall parameter that sets the average power over the area occupied by the system, and hence the power leaking out into the victim system.

- C*o-channel sensitivity*: it is the minimum value of the carrier to interference ratio (C/I) that ensures a BER=10^{-6} with a threshold degradation of 1 dB.

6.4.2 Systems parameters not available from EN's

- *Nominal output power*: it is the maximum power generated by the RF power amplifiers of the system and declared by the manufacturer. The nominal output power is usually well short of the specified "Maximum transmitter output power".

- *Actual receiver sensitivity*: the actual receiver sensitivity could be lower than the specified EN's parameter due to the use of better receivers and coding schemes.

- *Actual co-channel sensitivity*: the actual degradation of performances due to interference could be lower than those specified in EN's.

- *Antennas characteristics*: while the radiation patterns are defined in proper EN's it is important to know also the actual antenna gain for both CRS and TS and not only their minimum values.

- *Power control*: also considering the "Typical output power" it is important to know the behaviour of the power control mechanism (ATPC or RTPC) used by the system to carry out a more realistic interference analysis.

- *Radiated power spectral density*: it is the actual emitted spectrum that can be used to evaluate a more realistic NFD value with respect the one evaluated by the "Transmitter mask".

- *Receiving filter characteristic*: at least, the equivalent square root raised cosine parameters (symbol rate and roll-off) can be used to evaluate a more realistic NFD value. Moreover, the complete receiver mask could be provided for a further realistic NFD evaluation.

- *Additional parameters for DS-CDMA systems*: the maximum number of PN codes available is necessary to calculate the useful power associated to each useful signal.

- *Additional parameters for FDMA systems*: the number of sub-carrier, their channel spacing and their relative power are necessary to evaluate both the amount of power leaking out into the other system and the useful power associated to each useful signal.

6.5 Parameters for the evaluation of the degree of interference

Given the previous methodologies for class A interference situations and the considerations regarding the parameters requested for the interference analysis two important classes of parameters must be defined to accomplish a coherent analysis of the degree of co-existence between two P-MP systems. The first class, boundary conditions, includes all the parameters that complete the definition of the scenario and the working conditions to be considered for the co-existence analysis. The second class, evaluation parameters, contains all the parameters necessary to evaluate the degree of co-existence between two systems.

6.5.1 Boundary conditions

6.5.1.1 Frequency band and channel arrangement

The operating frequency band of the systems is the key parameter to define which ETSI standard must be used to pick up system's parameters and to evaluate free space attenuation. The channel arrangement (channel spacing and frequency adjacency between the two systems) must be used to choose which classes (A1, A2, A3 and A4) of interference must be analysed accordingly to clause 5.

6.5.1.2 Receiver sensitivity, degradation and inter-system interference

To carry out the analysis of intra-system interference between two operators also the inter-system interference (due to cellular planning) must be considered. The simplest way to accomplish the analysis is the following. Provided that in ETSI standards the minimum threshold degradation (on receiver sensitivity at BER=10^{-6}) specified is 1 dB, we can associate this degradation to the intra-system interference. Thus, considering the 1 dB degraded receiver sensitivity and the corresponding C/I ratio for the co-existence analysis the rest of degradation (up to 3 dB, as specified in ETSI) can be used by the operator to plan its own cellular network. In other words a minimum portion of degradation is spent for intra-system interference while the rest is given to the operator for inter-system interference.

6.5.1.3 Margin on receiver sensitivity

The link (or fade) margin (M_{th}) on receiver sensitivity is the margin considered during the planning phase of the system development. In the interference analysis there are two ways to consider this parameter.

1) The power margins used in the analysis are equal to those used during the cell planning; this allows to study the interference in normal propagation conditions.

2) The power margin on useful system is zero while the power margin on interfering system equals the one used during cell planning; this allows to study the interference on worst propagation conditions.

6.5.1.4 Cells radius

The cell radius defines the cell area where the interference will be evaluated or the source of interference will be placed. Therefore, the maximum radius, once given the system parameters and a reasonable margin, shall be considered.

6.5.1.5 Antenna pattern and gain

The antenna parameters are very important in the evaluation of the interference. If the actual values of antenna pattern are not available it is possible to use the masks reported in the relevant ETSI standard for P-MP antennas. Indeed, for the antenna gain is necessary to have the actual values.

6.5.2 Evaluation parameters

6.5.2.1 Class A1 evaluation parameters

The simplest evaluation parameter is the minimum distance equation (24) between the useful TS and the interfering CRS in worst propagation conditions. The smaller is the distance the better is the degree of co-existence.

Another evaluation parameter is the difference (Δ[C/I]) between the C/I evaluated for co-sited CRS's equation (5) and the minimum C/I allowed by the useful system. Provided this value it is possible to foresee the co-existence because the distribution of C/I over the cell, when the CRS's are randomly placed, depends only by different propagation attenuations on useful and interfering link. Thus, the greater is Δ[C/I] the better is the degree of co-existence. Table 6 provides a qualitative description on the degree of co-existence for different Δ[C/I] ranges (see note). In this description is assumed that a CRSi placed outside the useful cell do not produce any interference if Δ[C/I] is positive.

NOTE: These ranges are valid for systems operating in low frequency bands (below 10 GHz) and they could be different when considering different frequency band and different rain attenuation.

Table 6: Degree of co-existence vs. Δ[C/I]

Δ[C/I] (dB)	Co-existence
< 0	Impossible on the same area (space separation is requested)
[0, 5]	Possible, but critical, if CRS's are co-sited
[5, 10]	Possible if CRS's are co-sited. Possible, but critical, for distance (d) between CRS's smaller than cell radius (R),that is d<<R
[10, 20]	Possible, but critical, for distance (d) between CRS's up to cell radius (R),in other words the CRS's can be placed everywhere
[20, 30]	Possible for distance (d) between CRS's up to cell radius (R),in other words the CRS's can be placed everywhere
> 30	Full, there is no significant interference

A further evaluation parameter is the percentage of useful cell area (%KO) where the C/I is smaller than the minimum allowed value. In particular, once given the two systems, is useful to evaluate the maximum %KO versus the CRS's distance (d) spanning from 0 to 200 % of cell radius. In this way the maximum percentage of area (and therefore of users) with interference problem can be obtained. Once again the smaller is this value the better is the co-existence.

The %KO evaluation parameter is the most important because allow to evaluate the actual interference problem. It is obvious that a maximum %KO=30 is quite different from %KO=0,1 in terms of number of potential users that cannot be reach. Moreover, when the operator chose the radio as access network it is implicit that a not negligible percentage of users cannot be reached due to environment obstacles. So it is acceptable that another percentage of users cannot be reached due to co-existence issues. This value shall be defined by the regulatory body (and administration) when a given channel is assigned to an operator.

6.5.2.2 Class A2 evaluation parameters

Due to the symmetry (pointed out in clause 6.3) of this class of interference with respect class A1 the same evaluation parameters described in clause 6.5.2.1 hold.

6.5.2.3 Class A3 evaluation parameters

This class considers the interference between the useful and interfering CRS and there is only one parameter to evaluate the degree of co-existence. This is the minimum distance between CRS's provided by equation (16) or (24), depending on the propagation conditions considered.

It must be pointed out that this kind of interference needs a certain distance between CRS's to be considered negligible. That is the opposite of the behaviour of class A1 and A2 where CRS's co-sited, or close to each other, allow a better degree of co-existence.

6.5.2.4 Class A4 evaluation parameters

The simplest evaluation parameter is the minimum distance equation (24) between the useful TS and the interfering TS in worst propagation conditions. As already pointed out in clause 6.3 this parameter is less significant that in classes A1, A2 and A3 because of the low probability to have TS in LOS and the TS antenna directivity. However it must be considered the number of TS, both on useful and interfering cell, to evaluate the overall probability to have interference between TS's.

To help this kind of evaluation can be useful also to evaluate the maximum %KO (as in class A1 and A2) by equations (20) and (21) for different distances between CRS's (spanning from 0 up to 200 % cell radius) and for different interfering TS positions.

7 Interference between P-MP and P-P systems: class B interference situations

In this clause is described the frame for the study of compatibility between Point-to Multipoint (P-MP) and Point to Point (P-P) systems.

The following study provides a method to analyse the interference all over a the P-MP cell area for the scenarios described in clause 5.

7.1 Basic assumptions and objectives of the study

In order to evaluate the effects of the interference (classes B1, B2, B3 and B4) of a P-MP and a P-P system operating on adjacent channels (using the same polarization) all over the cell area, a simple but general scenario shall be considered. The main assumptions regarding the general scenario are the following.

- For the P-MP system only one cell is considered. For the P-P system only one link is considered and, in particular, only the station nearest the P-MP cell area. The CRS of P-MP system and the P-P station are separated by a generic distance (d) that can be varied to evaluate the amount of interference in different geometric conditions.
- For the P-MP system the cell area is covered, in CRS site, using an isotropic antenna with a given antenna gain. By this assumption (isotropic), the frequency channel adjacency can be considered all over the cell area. Moreover, this (a given antenna gain) allows to consider all interference scenarios, including those with sectored antennas (with different antenna gain), but disregarding the use of sectored antennas as a mitigation technique.
- The P-P system uses a directional antenna pointed towards the other station providing an angular decoupling of θ degrees with respect the CRS of P-MP system. This decoupling can be varied to evaluate the amount of interference in different geometric conditions.
- All radio paths, both useful and interfering path, are in perfect line of sight (LOS). In this way the worst case is considered because the possible interfering attenuation due to a non perfect LOS condition is ignored.

In the following clauses all the link budget equations (see note) are expressed in logarithmic units (decibel).

NOTE: Where the output power are intended at the antenna port (cable losses included).

7.2 Analysis methodology

7.2.1 Net filter discrimination

The same evaluation method described in clause 6.2.1 holds.

7.2.2 Class B1 analysis

This class regards the interference from the CRS of the P-MP system to the P-P system. The generic scenario to be considered is depicted in figure 10, where the geometric parameters (d and θ) are shown. The P-P station considered for the interference is P-P, while P-P' is depicted only for a better understanding of the meaning of θ. In fact, P-P' usually is far away from the cell area if P-P is the nearest station.

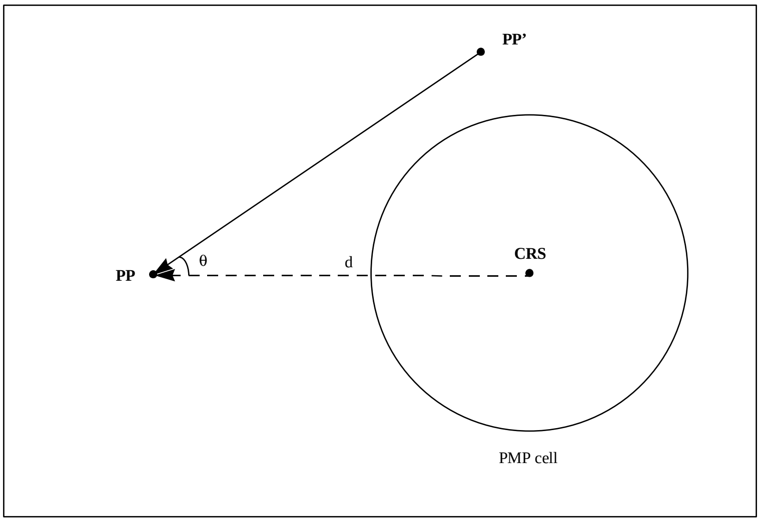

Figure 10: Generic scenario for class B1 interference analysis

The useful signal received by P-P is

$$C = P_{PP}^{th} + M_{PP} \tag{25}$$

where P_{PP}^{th} is the P-P receiver sensitivity (threshold) and M_{PP} is the link margin over the threshold.

The interfering power, generated by CRS, can be calculated as

$$I = P_{PMP}^{t} + G_{CRS} + G_{PP}(\theta) - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d}{\lambda}\right) - NFD \tag{26}$$

where P_{PMP}^{t} is the total power emitted by the P-MP system, G_{CRS} is the CRS antenna gain, $G_{PP}(\theta)$ is the P-P antenna gain at θ degrees, λ is the carrier wavelength (same units as d) and NFD is the filter discrimination of P-P system with respect the P-MP spectrum emission.

In particular P_{PMP}^{t} is the total power emitted by the P-MP system under maximum loading conditions. That is when all time slots are used in TDMA systems, or when all the PN codes are used in CDMA systems, or when all the sub-carriers are used in FDMA systems. Combining previous equations it is possible to calculate the carrier to interference ratio as

$$\frac{C}{I} = (P_{PP}^{th} + M_{PP}) - P_{PMP}^{t} - (G_{CRS} + G_{PP}(\theta)) + 20 \cdot \log_{10}\left(\frac{4\pi \cdot d}{\lambda}\right) + NFD \tag{27}$$

that depends on systems parameters and on the distance (*d*) and decoupling angle (θ) among the CRS and P-P. Therefore, it is possible to evaluate the minimum distance (d) required in order to obtain a C/I ratio greater than the minimum carrier to interference ratio $\left(C/I\right)_{\min}$ allowed by P-P system:

$$d \geq \frac{\lambda}{4\pi} \cdot 10^{\frac{\left(C/I\right)_{\min} + P_{PMP}^{t} + G_{CRS} + G_{PP}(\theta) - (P_{PP}^{th} + M_{PP}) - NFD}{20}} \tag{28}$$

that is a function of the angular decoupling (θ).

7.2.3 Class B2 analysis

This class regards the interference from the P-P system to the CRS of the P-MP system. The generic scenario to be considered is depicted in figure 11, where the geometric parameters (d and θ) are shown.

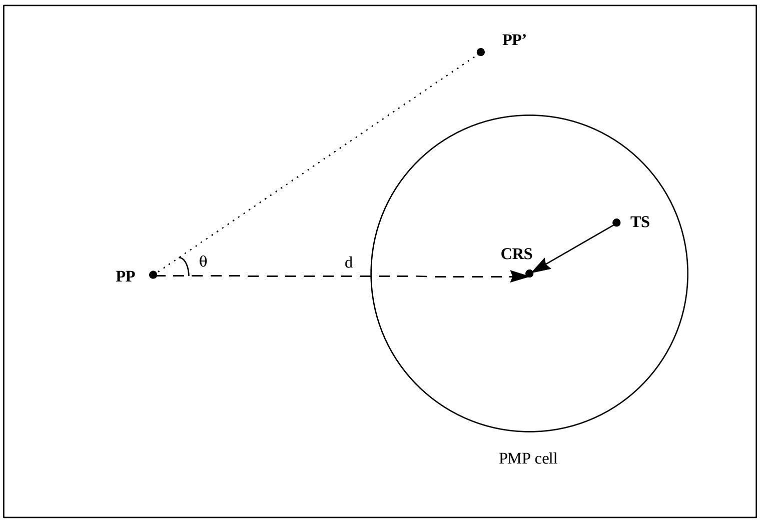

Figure 11: Generic scenario for class B2 interference analysis

The minimum useful signal received by CRS (from farthest TS), independently whether RTPC is implemented or not, is

$$C = P_{PMP}^{th} + M_{PMP} \qquad (29)$$

where the margin can also be null, depending on propagation conditions and on RTPC strategy.

Since the distance between P-P and CRS is *d* the interfering signal is

$$I = P_{PP}^{t} + G_{PP}(\theta) + G_{CRS} - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d}{\lambda}\right) - NFD \qquad (30)$$

where NFD is the CRS receiving filter discrimination with respect the P-P emitted spectrum.

Combining previous equations it is possible to obtain the C/I ratio as

$$\frac{C}{I} = (P_{PMP}^{th} + M_{PMP}) - P_{PP}^{t} - G_{PP}(\theta) - G_{CRS} + 20 \cdot \log_{10}\left(\frac{4\pi \cdot d}{\lambda}\right) + NFD \qquad (31)$$

In this case, as for class B1, it is possible to evaluate the minimum distance (d) required in order to obtain a C/I ratio greater than the minimum carrier to interference ratio $\left(C/I\right)_{\min}$ allowed by P-MP system:

$$d \geq \frac{\lambda}{4\pi} \cdot 10^{\frac{\left(C/I\right)_{\min} + P_{PP}^{t} + G_{CRS} + G_{PP}(\theta) - (P_{PMP}^{th} + M_{PMP}) - NFD}{20}} \qquad (32)$$

that is a function of the angular decoupling (θ).

7.2.4 Class B3 analysis

This class regards the interference from the TS of the P-MP system to the P-P system. The generic scenario to be considered is depicted in figure 12, where, in addition to the general geometric parameters (d and θ), the two decoupling angles (α and β) between TS and P-P are shown.

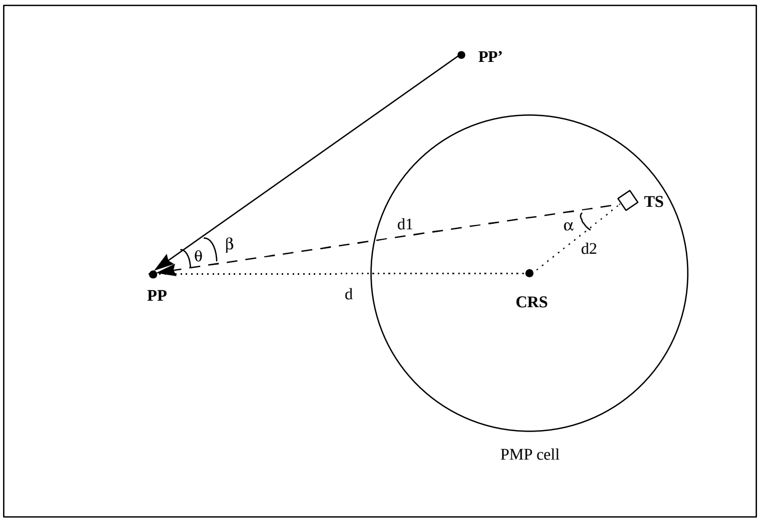

Figure 12: Generic scenario for class B3 interference analysis

The useful signal received by P-P is

$$C = P_{PP}^{th} + M_{PP} \tag{33}$$

as described in clause 7.2.2. If the TS implements a remote transmitter power control (RTPC) its transmitted power is

$$P_{TS} = P_{PMP}^{th} + M_{PMP} - G_{TS} - G_{CRS} + 20 \cdot \log_{10}\left(\frac{4\pi \cdot d2}{\lambda}\right) \tag{34}$$

where $P_{PMP}^{th} + M_{PMP}$ is the wanted received power, G_{TS} is the interfering user antenna gain, G_{CRS} the CRS antenna gain and d_2 is the distance from TS to CRS. If no RTPC is used $P_{TS} = P_{TS}^{t}$, that is an upper bound of previous equation, where P_{TS}^{t} is the TS nominal power emitted for a single channel, that is different for any access method. For TDMA systems P_{TS}^{t} is the useful power associated to each time slot and corresponds to the peak power. For CDMA systems P_{TS}^{t} is the power associated to each code. For FDMA systems P_{TS}^{t} is the power associated to each sub-carrier.

In both cases the interference power on P-P station is

$$I = P_{TS} + G_{TS}(\alpha) + G_{PP}(\beta) - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d1}{\lambda}\right) - NFD \tag{35}$$

where the terms refer to the usual notation, NFD is the P-P receiving filter discrimination with respect the TS emitted spectrum and d_1 is the distance between the TS and P-P. Combining previous equations the carrier to interference ratio can be obtained, for a given geometrical scenario with a particular TS position, as

$$\frac{C}{I} = (P_{PP}^{th} + M_{PP}) - (P_{PMP}^{th} + M_{PMP}) + G_{CRS} + \Delta G_{TS}(\alpha) - G_{PP}(\beta) - 20 \cdot \log_{10}\left(\frac{d2}{d1}\right) + NFD \tag{36}$$

for a P-MP system with RTPC, where $\Delta G_{TS}(\alpha) = G_{TS} - G_{TS}(\alpha)$ is the TS antenna decoupling. If no RTPC is implemented the C/I is

$$\frac{C}{I} = (P_{PP}^{th} + M_{PP}) - P_{TS}^{t} - G_{TS}(\alpha) - G_{PP}(\beta) - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d1}{\lambda}\right) + NFD \qquad (37)$$

In this class of interference it is not useful to evaluate the minimum distance required to avoid interference because the user (sources of interference) are spread all over the cell area. Equations (36) and (37) must be used to evaluate if there are some user that can generate interference, once provided the relative position between CRS and P-P (parameters d and θ).

7.2.5 Class B4 analysis

This class regards the interference from the P-P system to the TS of the P-MP system. The generic scenario to be considered is depicted in figure 13, where, in addition to the general geometric parameters (d and θ), the two decoupling angles (α and β) between TS and P-P are shown.

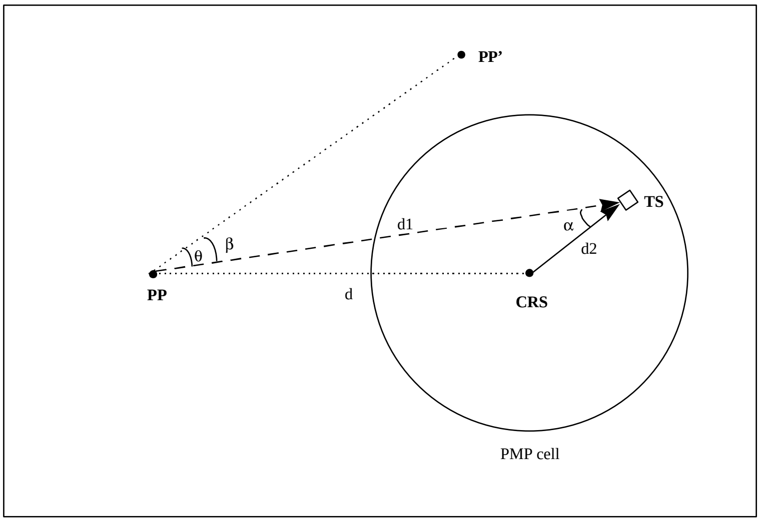

Figure 13: Generic scenario for class B4 interference analysis

Since the distance between CRS and TS is d_2 the useful signal is

$$C = P_{PMP}^{t} + G_{CRS} + G_{TS} - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d2}{\lambda}\right) \qquad (38)$$

where P_{PMP}^{t} is the nominal power emitted for a single channel, that is different for any access method. For TDMA systems P_{TS}^{t} is the useful power associated to each time slot and corresponds to the peak power. For CDMA systems P_{TS}^{t} is the power associated to each code. For FDMA systems P_{TS}^{t} is the power associated to each sub-carrier.

Since the distance between P-P and TS is d_1 the interfering signal is

$$I = P_{PP}^{t} + G_{PP}(\beta) + G_{TS}(\alpha) - 20 \cdot \log_{10}\left(\frac{4\pi \cdot d1}{\lambda}\right) - NFD \qquad (39)$$

where P_{PP}^{t} is the nominal output power of P-P system and NFD the TS receiving filter discrimination with respect the P-P emitted spectrum. Combining previous equations it is possible to obtain the C/I ratio

$$\frac{C}{I} = (P_{PMP}^{t} - P_{PP}^{t}) + G_{CRS} + \Delta G_{TS}(\alpha) - G_{PP}(\beta) - 20 \cdot \log_{10}\left(\frac{d2}{d1}\right) + NFD \qquad (40)$$

that can be used to evaluate which are the TS (over the P-MP cell area) that have a C/I ratio less than the minimum allowed $\left(C/I\right)_{\min}$ by P-MP system. This analysis can be done for every relative position of CRS and P-P.

7.3 Required P-MP system parameters

The required parameters, for the P-MP system, in order to carry out the P-MP/P-P interference analysis are the same reported in clause 6.4.

7.4 Required P-P system parameters

7.4.1 System parameters available from EN's

- *Frequency bands*: the absolute frequency is very important in order to evaluate minimum distances. In general the frequency band of systems influences other parameters, such as antenna gain and antenna pattern.
- *Channel arrangements*: this determines which classes (one or more) of interference shall be considered, as described in clause 5.
- *Maximum transmitter output power*: that is the mean transmitter output power that shall not be exceeded.
- *Transmitter mask*: it is the only information available in EN's that can be used to evaluate the net filter discrimination as defined in (1).
- *Receiver sensitivity*: it is the lower received power level (threshold) that ensures a given BER performance.
- C*o-channel sensitivity*: it is the minimum value of the carrier to interference ratio $\left(C/I\right)_{\min}$ that ensures a given BER performance with a threshold degradation of 1 dB.
- *Antenna characteristic*: the radiation pattern masks included in appropriate EN's must be used to evaluate angular decoupling.

7.4.2 Systems parameters not available from EN's

- *Nominal output power*: it is the maximum power generated by the RF power amplifiers of the system and declared by the manufacturer. The nominal output power is usually well short of the specified "Maximum transmitter output power".
- *Actual receiver sensitivity*: the actual receiver sensitivity could be lower than the specified EN's parameter due to the use of better receivers and coding schemes.
- *Actual co-channel sensitivity*: the actual degradation of performances due to interference could be lower than those specified in EN's.
- *Antennas characteristics*: while the radiation patterns are defined in proper EN's it is important to know also the actual antenna gain for both CRS and TS and not only their minimum values.
- *Power control and link margin*: also considering the "Typical output power" it is important to know the behaviour of the power control mechanism (ATPC or RTPC) used by the system to carry out a more realistic interference analysis.
- *Radiated power spectral density*: it is the actual emitted spectrum that can be used to evaluate a more realistic NFD value with respect the one evaluated by the "Transmitter mask".
- *Receiving filter characteristic*: at least, the equivalent square root raised cosine parameters (symbol rate and roll-off) can be used to evaluate a more realistic NFD value. Moreover, the complete receiver mask could be provided for a more realistic NFD evaluation.

7.5 Parameters for the evaluation of the degree of interference

Given the previous methodologies for class B interference situations and the considerations regarding the parameters requested for the interference analysis two important classes of parameters must be defined to accomplish a coherent analysis of the degree of co-existence between a P-MP and a P-P system. The first class, boundary conditions, include all the parameters that complete the definition of the scenario and the working conditions to be considered for the co-existence analysis. The second class, evaluation parameters, contains all the parameters necessary to evaluate the degree of co-existence between the two systems.

7.5.1 Boundary conditions

7.5.1.1 Frequency band and channel arrangement

The operating frequency band of the systems is the key parameter to define which ETSI standard must be used to pick up system's parameters and to evaluate free space attenuation. The channel arrangement (channel spacing and frequency adjacency between the two systems) must be used to choose which classes (B1, B2, B3 and B4) of interference must be analysed accordingly to clause 5.

7.5.1.2 Receiver sensitivity, degradation and inter-system interference

To carry out the analysis of intra-system interference between P-P and P-MP systems also the inter-system interference (due to cellular planning for P-MP system and link planning for P-P system) must be considered. The simplest way to accomplish the analysis is the following. Provided that in ETSI standards the minimum threshold degradation specified is 1 dB, we can associate this degradation to the intra-system interference. Thus, considering the 1 dB degraded receiver sensitivity, and the corresponding C/I ratio for the co-existence analysis, the rest of degradation (up to 3 dB, as specified in ETSI) can be used by the operator to plan its own cellular network or P-P network. In other words a minimum portion of degradation is spent for intra-system interference while the rest is given to the operator for inter-system interference.

7.5.1.3 Margin on receiver sensitivity

The link (or fade) margin on receiver sensitivity for P-MP system (M_{PMP}) is the margin considered during the planning phase of the system development. In the interference analysis there are two ways to consider this parameter.

1) The power margins used in the analysis are equal to those used during the cell planning; this allows to study the interference in normal propagation conditions.

2) The power margin on P-MP system is zero; this allows to study the interference on worst propagation conditions.

The link (or fade) margin on receiver sensitivity for P-P system (M_{PP}) is the margin on link budget to reach the requested objectives of quality and availability. In the interference analysis there are three ways to consider this parameter.

1) The margin on P-P is zero; this allows to study the interference on worst propagation condition (that is fading or rain attenuation on P-P link).

2) The margin is equal to the link margin: this allows studying the interference on clear sky condition for a system without RTPC.

3) The margin is equal to the link margin decreased by RTPC dynamic: this allows studying the interference on clear sky condition for a system with RTPC.

7.5.1.4 Cell radius

The cell radius of P-MP system defines the cell area where the interference (for a subset of interference classes) will be evaluated or the source of interference will be placed. Therefore, the maximum radius, once given the system parameters and a reasonable margin, shall be considered.

7.5.1.5 Antenna pattern and gain

The antenna parameters are very important in the evaluation of the interference. If the actual values of antenna pattern are not available it is possible to use the masks reported in the relevant ETSI standard for P-MP antennas. Indeed, for the antenna gain is necessary to have the actual values.

7.5.2 Evaluation parameters

7.5.2.1 Class B1 evaluation parameters

In the case of CRS that interferes the P-P system it is possible to evaluate using equation (28) the minimum distances (between CRS and P-P) requested to avoid any interference effect for different angle decoupling. The smaller are the distances the better is the degree of co-existence.

7.5.2.2 Class B2 evaluation parameters

In the case of P-P system that interferes the CRS of P-MP system it is possible to evaluate using equation (32) the minimum distances (between CRS and P-P) requested to avoid any interference effect for different angle decoupling. The smaller are the distances the better is the degree of co-existence.

7.5.2.3 Class B3 evaluation parameters

In the case where the sources of interference (toward P-P system) are the TS of P-MP system equations (36) and (37) provide us which are the TS that, alone, generate a smaller C/I ratio on P-P system, once provided the geometry of P-P and CRS. But this is the actual behaviour if the P-MP system is TDMA or FDMA; while for CDMA systems it must be taken into account that more than one TS transmit at the same time.

However, it is possible to evaluate the percentage of cell area (%KO) where are placed the TS that alone generates a C/I ratio less than $\left(C/I\right)_{\min}$ for a given geometry. Obviously, for a given geometry, the smaller is the percentage the better is the degree of co-existence.

7.5.2.4 Class B4 evaluation parameters

In the case of P-P system that interferes the TS of a P-MP system equation (40) provides which are the TS that are interfered (C/I ratio less than $\left(C/I\right)_{\min}$), for a given geometry of P-P and CRS, in terms of percentage of cell area (%KO). Obviously, for a given geometry, the smaller is the percentage the better is the degree of co-existence.

8 Evaluation of the degree of co-existence for P-MP systems

In this clause some conclusions regarding the rules of co-existence between two P-MP systems are given. These rules or general considerations can be derived by the methodologies described in clause 6. Moreover, some of the rules are well pointed out in the examples of co-existence analysis reported in annex A.

8.1 Considerations related to a specific class of interference

In this clause are reported some qualitative considerations on the degree of co-existence between two systems when one particular kind of interference class (defined in clause 5) is taken into account. In particular, the problems of site sharing (the two systems use the same mast for CRS's), near site placing (the two CRS sites are only few hundred meters far away) and the potential interference area are exploited.

8.1.1 Class A1 considerations

This class regards the interference from the CRS of the interfering system to a TS of the useful system.

It can be easily proved that site sharing is possible and, moreover, that this is the better situation to accomplish the co-existence. This is due to the fact that interfering and useful paths are always the same, thus no unbalance on propagation attenuation influences the C/I ratio. In some cases, with site sharing, the co-existence could be possible without guard bands between the two systems.

Obviously, near site placing is allowed too. This condition may not be so unusual (instead of site sharing) since we are considering systems operating in the same frequency band (similar coverage capacity) and in the same area (same coverage impairments due to buildings or hills).

Vice versa, if there is no site sharing or near site placing, at least one channel of guard band is requested to overcome the overlapping cell problem (the interfered TS is nearer the interfering CRS than the useful CRS). Anyway, a small interfered area around the interfering CRS still remains. This implies that operators of the two systems must observe a minimum of co-existence etiquette to avoid mutual interference without wasting spectrum.

8.1.2 Class A2 considerations

This class regards the interference from a TS of the interfering system to the CRS of the useful system.

Due to the symmetry with class A1 (already pointed out in clause 6) the same considerations of clause 8.1.1 apply also to class A2.

8.1.3 Class A3 considerations

This class regards the interference from the CRS of the interfering system to the CRS of the useful system. In this case a minimum distance between the two CRS's is requested, see equation (16), thus no site sharing is possible.

Moreover, in order to reduce the distance requested to a few hundreds meters (low degree of co-ordination and near site placing) it is always necessary to provide a guard band between systems. Otherwise, the requested degree of co-ordination between the operators could be unacceptable if the required distances are in the same order of magnitude as the cell radius.

8.1.4 Class A4 considerations

This class regards the interference from a TS of the interfering system to a TS of the useful system.

In this case the site sharing is possible but does not relax the problem of co-existence. In order to control the mutual interference between TS's is necessary to provide a useful guard band that reduces the minimum distance of interference equation (24) to a few hundred meters.

Nonetheless, the probability to have interference between TS's is not low or restricted to a particular area due to the high number of possible sources and victims of interference.

In this case operators may expect to face some particular interference situations that change during the deployment of the two networks. For example, when two TS's (one for each operator) must be installed on the same roof.

8.2 General rules to accomplish co-existence

In this clause some general rules (that are not directly associated to a particular class) to accomplish co-existence are given. In particular, one clause regards the rules on system's parameters while the other is related to general deployment rules that could facilitate the co-existence on the same area with the minimum waste of spectrum.

8.2.1 Rules on system's parameters

The following rules can be easily derived by methodologies described in clause 6.

- The greater is the NFD the smaller is the requested guard band. This rule obviously applies to all classes of interference. Thus, the NFD values derived from EN's to evaluate the necessary guard band must be as close as possible to actual system performance. This is a topic issue to avoid wasting of spectrum.
- The EIRP's (Effectively Isotropic Radiated Power) of the two P-MP CRS's, defined as the sum of the nominal output power and CRS antenna gain, should be similar in order to reduce class A1 interference.
- The use of RTPC on TS's reduces the average interference produced for classes A2 and A4. Thus, it reduces the guard band requested.
- When considering equal channel spacing similar receiver sensitivity reduces the requested guard band for class A2. Moreover, this condition lead to have similar cell radius for the two systems because the frequency band is the same and the output power is, more or less, the same. This implies that only one interfering CRS is present on the useful cell area and therefore the interfered area is restricted around this CRS. Vice versa the interfered cell area is the sum of two (or more) of such areas.

8.2.2 Deployment rules

A useful deployment rule to facilitate the co-existence of two FDD P-MP systems operating on the same area it is to assign one of the two paired sub bands (foreseen in many ERC recommendations) for the downlink and the other for uplink.

In this way the only interference classes to be considered are A1 and A2 (see clause 5). As described in clause 8.1 both classes allow site sharing or near site placing (guard band may be avoided) and lead to a restricted and well defined residual interference area when no site sharing is used.

Another useful guideline is to arrange on adjacent channels systems with similar channel spacing because the guard band requested is usually equal to the larger channel spacing. In this way the wasted spectrum is reduced.

When, at least, one of the two P-MP systems uses TDD duplex technique class A3 must be taken into account. Thus, at least, one channel (usually two channels) of guard band should be foreseen in order to grant some sort of near site placing and to reduce the requested co-ordination between operators.

8.3 Parameters not available in EN's

In clause 6 is reported a list of parameters (necessary for the interference analysis) that are labelled as "not available in the EN's", in the sense that only some sort of limits are available in EN's. This labelling reflect the necessity (see annexes A and B) to have tighter values than the limits usually reported in the EN's.

But one of the requested parameters to accomplish the interference analysis is not really defined and it cannot be derived by EN's. This is the NFD, that is the net filter discrimination of a receiver with respect the emitted spectrum of a different system.

In the present document a way to evaluate the NFD is provided and it is based on the equivalent raised cosine filter parameters and on transmitter masks reported in EN's. Obviously, this method can be applied if and only if a particular system is considered and, therefore, the manufacturer can provide the equivalent raised cosine filter parameters.

Since the number of equipment classes and channel arrangements allowed within an EN is huge it is quite impossible to provide the requested NFD limits for all the possible combinations. Moreover, for co-existence purposes it would be necessary to have all the cross NFD's between equipments compliant with different standards that apply in the same frequency band.

Therefore, in order to allow the NFD evaluation the EN's should define the necessary parameters:

- transmitter spectrum mask: already defined in all the EN's but usually far from actual RF emitted spectrum;
- receiver sensitivity mask: not defined in the EN's.

Moreover, these two parameters should be defined in a way that they will result to be similar (if not identical) or scaleable for different equipment classes and channel arrangements. By doing this the co-existence evaluation would be easier and the use of the spectrum more efficient.

It should be noted that a method to derive the P-P receiver parameters necessary for co-existence is contained in ETSI TR 101 854 [8]. It is expected that a similar report will be produced also for P-MP systems.

9 Evaluation of the degree of co-existence for P-MP and P-P systems

In this clause some conclusions regarding the rules of co-existence between P-MP and P-P systems are given. These rules or general considerations can be derived by the methodologies described in clause 7. Moreover, some of the rules are well pointed out in the examples of co-existence analysis reported in annex B.

9.1 Considerations related to a specific class of interference

In this clause are reported some qualitative considerations on the degree of co-existence between a P-MP and a P-P systems when only one kind of interference class (classes B defined in clause 5) is taken into account. In particular, the problems of site sharing (the two systems use the same mast), the distance and angular decoupling, the potential interference area are exploited.

9.1.1 Class B1 considerations

This class regards the interference from the CRS of the P-MP system to the P-P system, thus it involves only two sites and it can be considered as P-P/P-P co-existence (since it requires distance and co-ordination area).

No site sharing is possible and between CRS and P-P sites a minimum distance is required. This distance, once given a frequency decoupling (NFD), is a function of the angular decoupling between P-P link and CRS site. The closer is the link path to CRS the higher is the distance required.

9.1.2 Class B2 considerations

This class regards the interference from the P-P system to the CRS of the P-MP system. Due to the geometric symmetry with class B1 the same considerations of clause 9.1.1 apply also to class B2. Thus, it is necessary a minimum distance between CRS and P-P site to avoid interference.

9.1.3 Class B3 considerations

This class regards the interference from the TS of the P-MP system to the P-P system.

Site sharing is the worst situation (see annex B) and requires the highest frequency separation. In general, even without site sharing, if no sufficient frequency decoupling is provided and if the P-P link crosses the P-MP cell area there is always an area of potential TS interference in correspondence of P-P link. This situation (even if the area is small) cannot be accepted because even if only one TS is within that area it provides a quality degradation or an unavailability period to the P-P link each time it set up a connection.

This fact, in conjunction with higher antenna gain on P-P link with respect the CRS antenna of a P-MP systems, means that to overcome this class of interference is necessary a higher guard band than those required for P-MP to P-MP co-existence.

9.1.4 Class B4 considerations

This class regards the interference from the P-P system to the TS of the P-MP system. Due to the geometric symmetry with class B3 the same considerations of clause 9.1.3 apply also to class B4; i.e. this interference situation requires a wide guard band in order to avoid the interference on P-MP TS placed on the P-P link path.

9.2 General rules to accomplish co-existence

In this clause some general rules (that are not directly associated to a particular class) to accomplish co-existence are given. In particular, one clause regards the rules on system's parameters while the other is related to general deployment rules that could facilitate the co-existence on the same area with the minimum waste of spectrum.

9.2.1 Rules on system's parameters

The following rules can be easily derived by methodologies described in clause 7.

- The greater is the NFD the smaller is the requested guard band or the minimum distance. This rule obviously applies to all classes of interference. Thus, the NFD values (for both P-MP and P-P systems) derived from EN's must be as close as possible to actual system performance. This is a topic issue to avoid wasting of spectrum.
- In order to provide the maximum angular decoupling (classes B1 and B2) P-P antenna patterns should be compliant to higher order classes masks (defined in the relevant ETSI standard EN 302 085[1] or EN 300 833 [2]) if the P-P link will be deployed in an interference congested area. If the P-P link is already deployed the CRS's of P-MP system should be placed far away from the P-P site accordingly to antenna pattern used by P-P link.
- The higher is the capacity (and channel spacing) of the P-P system the more difficult is the co-existence with a P-MP system due to higher C/I ratios requested by P-P and higher guard band required.

9.2.2 Deployment rules

Two different deployment scenarios can be considered: the first when only one P-P site is within the deployment area of P-MP system (urban area), the second when the entire P-P link (both sites) is within the deployment area of P-MP system. The two following rules hold for the two different scenarios.

1) One P-P site: since only one side of the P-P link must be taken into account it can be useful to foresee the channel arrangement of figure 14. In this way only classes B1 and B2 are present, and a reasonable combination of minimum distance, angular decoupling and guard band can overcome the interference.

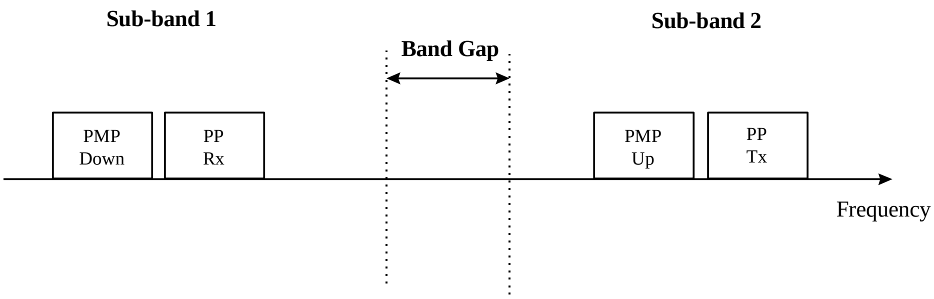

Figure 14: Useful channel arrangement

2) The entire P-P link: in this case all four interference classes are present disregarding any possible channel arrangement (once we considering adjacent channels). Thus, due to classes B3 and B4 a greater guard band is requested to allow the co-existence of a P-P link all over the P-MP deployment area.

9.3 Parameters not available in EN's

The same considerations of clause 8.3 also apply for P-MP and P-P co-existence.

Annex A: Examples of P-MP vs P-MP co-existence analysis

In this clause some examples of co-existence analysis between two P-MP systems with different characteristics (channel spacing, access method, duplex technique, etc.) but operating in the same frequency band are reported.

These examples provide some guidelines on how to use the interference evaluation methodologies, described in clause 6, in order to establish the necessary guard bands, the degree of co-existence and the residual risk of interference.

The examples are carried out both using the actual system parameters of commercial equipment (provided by manufacturers) and their limits reported in the relevant ETSI standard.

The main characteristics of the examples carried out in the following clauses can be summarized as follows.

EXAMPLE 1: Systems operating in the 3,5 GHz band, one using TDMA access method together with FDD duplex technique, the other using FH-CDMA together with TDD duplex technique.

EXAMPLE 2: Systems operating in the 26 GHz band both using TDMA access method and FDD duplex technique.

EXAMPLE 3: Systems operating in the 26 GHz band, one using TDMA access method, the other using FDMA access method and both employing FDD duplex technique.

A.1 Systems in the 3,5 GHz band

In this example we consider two P-MP systems operating in the 3,5 GHz band, one using a TDMA access method (namely TDM) and the other using FH-CDMA access method (namely FHCD). Their actual system parameters together with their relevant ETSI limits are reported in table A.1.

Table A.1: System parameters

	TDM		FHCD	
Parameter	**Actual**	**EN 301 021 [3]**	**Actual**	**EN 301 253 [4]**
Access method	TDMA	TDMA	FH-CDMA	FH-CDMA
Duplex technique	FDD	FDD	TDD	TDD
Channel spacing [MHz]	3,5	3,5	1	1
RF spectrum	Figure A.1	Figure A.1	Figure A.1	Figure A.1
CRS Transmission power [dBm]	28	< 35	25	< 35
TS Transmission power [dBm]	27	< 35	25	< 35
Uplink power control	yes	-	yes	-
Sensitivity [dBm] @ BER=10^{-6}	-92	-83	-90	-90
Power margin [dB] on sensitivity	10	-	10	-
Symbol rate [Mbaud]	2,5	-	0,75	-
Roll-off	0,4	-	0,35	-
CRS antenna gain (see note) [dBi]	15	-	13	-
TS antenna gain [dBi]	15	-	14	-
TS antenna pattern	Figure A.2	Figure A.2	Figure A.2	Figure A.2
C/I limit [dB] @ BER=10^{-6} Sensitivity degradation=1 dB	14	23	15	21
NOTE: CRS antenna gain reported refer to a 90 degree sectored antennas.				

In figure A.1 the RF emitted spectrums of the two systems are reported, normalized with respect the maximum, as a function of the frequency offset from the carrier frequency (*f0*). For both systems the actual RF spectrum (normal lines) and the ETSI spectrum mask (bold lines) are depicted. In this analysis we do not consider spurious emissions limits that are defined beyond 250 % of channel spacing.

Figure A.2 shows the TS antenna patterns (on the azimuth plane) normalized with respect to the maximum gain (reported in table A.1). For the TDM system an actual antenna pattern is used while for the other cases we used the antenna pattern envelope mask of EN 302 085 [1] (P-MP antenna in 3 GHz to 11 GHz) (class 5 in range 1).

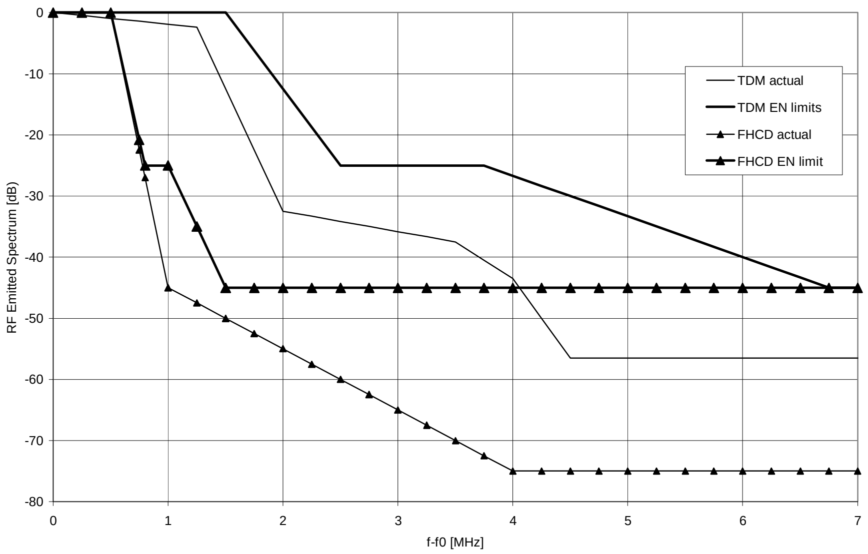

Figure A.1: RF emitted spectrums

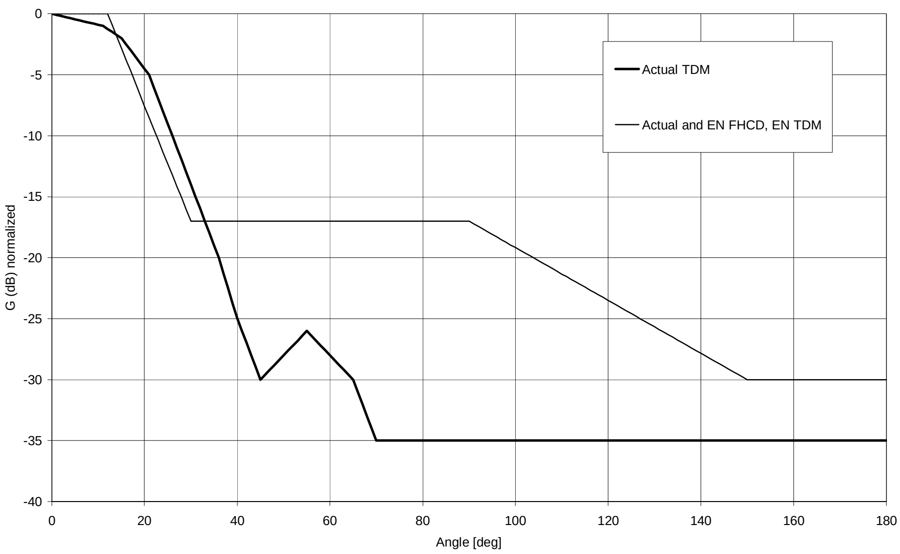

Figure A.2: Antenna pattern envelope on the azimuth plane

Once given all the necessary system parameters the first step to be done is the evaluation of the NFD of one system against the other considering different guard band (GB) between the two systems. In this case we consider three situations: adjacent channels (carriers frequency separation of 2,25 MHz), 1 MHz guard band (carriers frequency separation of 3,25 MHz), which is equal to the FHCD system channel spacing, and 3,5 MHz guard band (carriers frequency separation of 5,75 MHz) which is equal to the TDM channel spacing. Table A.2 shows the NFD evaluated with both actual RF spectrum and ETSI spectrum mask, but using always the equivalent square root raised cosine filter approximation of the receiving filters (symbol rate and roll off). The values in this table should be interpreted as follows. Let's consider the upper left corner value (36,7 dB), this is the NFD of FHCD (victim) receiving filter with respect the (actual) RF spectrum emitted by TDM (source) when the two channel are adjacent (0 MHz guard band).

In general you can see that NFD values of FHCD are lower, with respect TDM, than the opposite due to the fact that TDM has a larger channel spacing than FHCDM.

Table A.2: NFD values (dB)

		NFD [dB]		
Source/victim	RF spectrum	GB=0 MHz	GB=1 MHz	GB=3,5 MHz
TDM/FHCD	Actual	36,7	41,2	61
TDM/FHCD	ETSI	22	31,5	44,5
FHCD/TDM	Actual	33	58	71
FHCD/TDM	ETSI	29,9	41,5	45

Since the FHCD system employs a TDD duplex technique there may be different channel arrangements with respect to the TDM FDD system as described in clause 5. However, in any case there is always the interference class A3 (between CRS's) to be considered. This class of interference imposes a minimum distance between CRS's (see equation (16) in clause 6.2.4) in order to obtain the desired C/I ratio on the useful CRS. The requested distances, evaluated for the same situations of relevant NFD values of table A.2, are reported in table A.3.

Table A.3: Requested distances [km] between CRS's to overcome A3 interference

		Distance [km]		
Source/victim	RF spectrum	GB=0 MHz	GB=1 MHz	GB=3,5 MHz
TDM/FHCD	Actual	11,2	6,7	0,68
TDM/FHCD	ETSI	60,7	20,3	4,5
FHCD/TDM	Actual	13,6	0,76	0,17
FHCD/TDM	ETSI	19,5	5,1	3,4

Table A.3 points out that, at least, a guard band equal to the largest channel (3,5 MHz) is necessary in order to reduce the requested minimum distances to reasonable values (few hundred meters) with respect the cell radius of this kind of systems (typical medium coverage distance of about 15 km). In particular, with actual NFD values, 0,68 km (grey cell in table A.3) are necessary if the FHCD channel is near the TDM downlink channel while only 0,17 km if FHCD channel is near the TDM uplink channel (depending on channel arrangement).

But, if we consider NFD values obtained by ETSI spectrum mask, distances of about 3-4 km are necessary. This requires a high degree of co-ordination between operators that could not be possible in practice. Thus, an additional channel guard band should be provided in order to have distances of few hundred meters (or less).

Let's now consider to have a 3,5 MHz guard band, in order to provide a small requested distance between CRS's, and let's use the actual system parameters to evaluate the effect of classes A1 (CRS on TS) and A2 (TS on CRS) of interference. As described in clause 6, it is useful to first evaluate the C/I ratios available in the particular situation (even if not allowed in this case due to A3 interference) of co-sited CRS. These values are reported in table A.4 for all possible combinations and for similar propagation conditions on useful and interfering link. These values were computed using equation (5) (for the A1 case) and equation (11) (for the A2 case).

Table A.4: C/I ratios for co-sited CRS's (class A1 and A2) using actual parameters

Source/victim	**Interference class**	**C/I [dB]**
TDM/FHCD	A1	56
TDM/FHCD	A2	65
FHCD/TDM	A1	76
FHCD/TDM	A2	67

Obviously, depending on channel arrangement, there will be to consider only two of the four interference of table A.4. However, we can take into account the worst interference situation (TDM on FHCDM, class A1) and suppose a further 10 dB degradation due to different propagation conditions (mainly fading at this frequency). Since the FHCD system requires a 15 dB of minimum C/I we obtain a

$$\Delta[C/I] = 56 - 10 - 15 = 31 \text{ dB} \tag{41}$$

that, accordingly to table 6, provides a good margin (more than 30 dB) to overcome the overlapping cell problem when the CRS are placed in different sites. In other words, the A1 and A2 interference classes in this case will not produce a significant %KO area with interference problem. Applying the methods described in clause 6, a maximum %KO smaller than 0,5 % will always be obtained.

Therefore, using actual parameters, once provided the guard band (3,5 MHz) necessary to ensure a reasonable distance between CRS's the other possible interference classes are negligible. Also class A4 (interference between TS's) can be easily neglected due to high NFD (frequency decoupling) combined with their antenna directivity (space decoupling).

Let's now consider to have the same 3,5 MHz guard band, but we want to evaluate the effects of classes A1 and A2 using the limits on parameters provided by ETSI standard. As done before, it is useful to first evaluate the C/I ratios available in the particular situation (not allowed in this case due to A3 interference) of CRS co-sited. These values are reported in table A.5 for all possible combinations and for similar propagation conditions on useful and interfering link. These values are obtained using NFD values from ETSI limits and considering an equal EIRP (the sum of transmission power and antenna gain) on both systems since only upper limits are provided by ETSI standard. This is the best situation for smaller interference effects. Moreover, it was assumed that both systems use an uplink power control (nevertheless not specified in ETSI standard) in order to reduce the interfering power.

Table A.5: C/I ratios for co-sited CRS's (class A1 and A2) using ETSI limits

Source/victim	Interference class	C/I [dB]
TDM/FHCD	A1	44,5
TDM/FHCD	A2	37,5
FHCD/TDM	A1	45
FHCD/TDM	A2	52

In this case the worst interference situation (TDM on FHCD, class A2) provides a C/I=37,5 dB due to the unbalance on systems sensitivity (-90 dBm against –83 dBm). This value, combined with a 10 dB degradation due to propagation on useful link and the 21 dB requested by ETSI limits, leads to a margin of

$$\Delta[C/I] = 37.5 - 10 - 21 = 6.5 \text{ dB} \tag{42}$$

on C/I ratio. Accordingly to table 6, this value (6,5 dB) is not sufficient to overcome the overlapping cell problem in a strong way as for the previous situation with actual parameters (31 dB). In figure A.3 is depicted the %KO area (considering a 15 km cell radius), as a function of the distance between CRS's, for the 6,5 dB situation (equal EIRP) and for a 3 dB unbalanced situation on EIRP (3 dB EIRP unbalance) due to different CRS antenna gain or power control error.

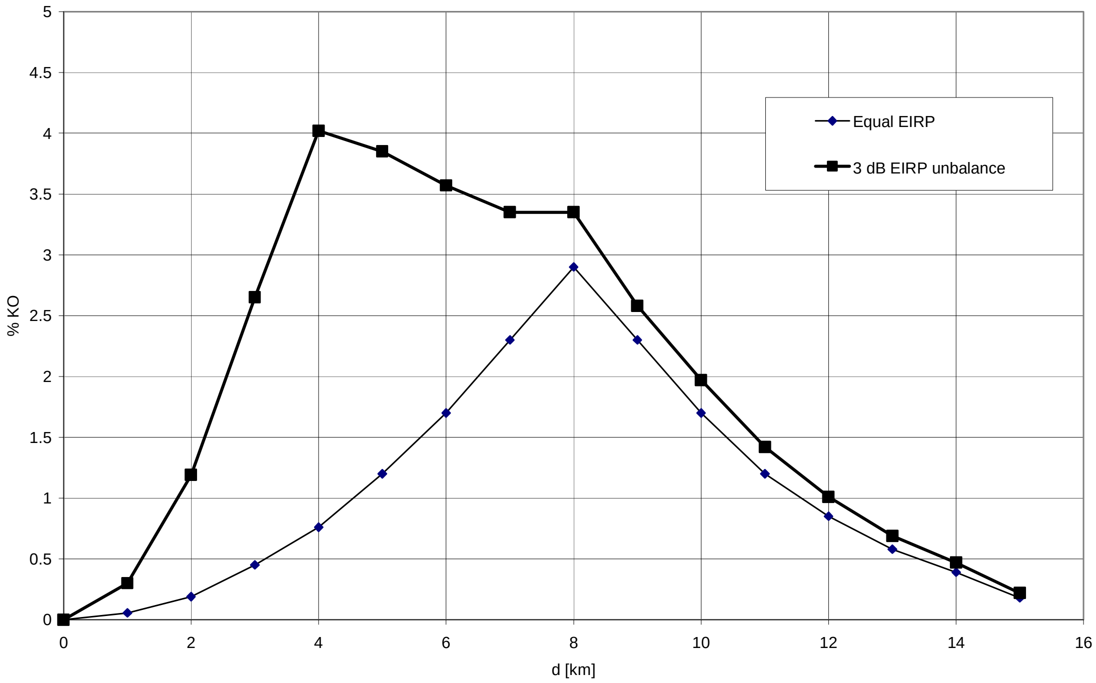

Figure A.3: %KO area for class A2 (TDM on FHCD) with ETSI limits

For both situations figure A.3 points out a maximum %KO of about 3-4 % that cannot be neglected. In fact, the area (%KO) where any TS of the TDM system interferes the CRS of the FHCD is no more a restricted slice around the CRS. Moreover, for the 3 dB EIRP unbalance situation the high values of %KO interests a wider range of distance between CRS's. Thus, the probability to have interference is higher.

In figure A.4 is depicted the C/I ratio, generated by a TDM TS, depending on its position within the TDM cell area (cell radius of 15 km) when the distance between the CRS's is 8 km and with equal EIRP.

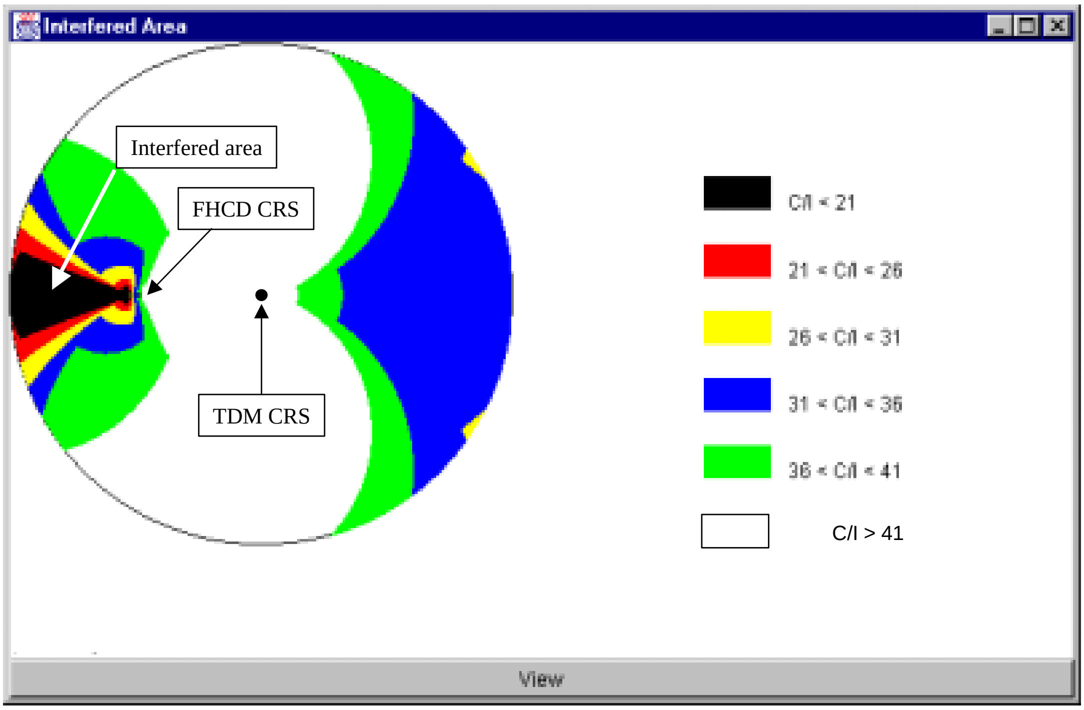

Figure A.4: C/I distribution over the TDM cell area

In figure A.4 the black area corresponds to %KO area where any potential TS could generates (alone) a C/I ratio smaller than 21 dB, that are requested by the FHCD system. As you can see this area is such a sector centred on FHCD CRS that continues beyond cell boundaries.

Therefore, using ETSI limits, a 3,5 MHz guard band is not sufficient in order to grant a good degree of co-existence between two systems (such as those here considered) compliant with the considered classes of ETSI EN 301 021 [3] and EN 301 253 [4]. In fact, distances of 3-4 km between CRS's are requested and classes A1 and A2 residual interfering areas are not negligible. Thus, an additional guard band (for a total of 7 MHz) is requested in order to ensure an independent (for operators) and free-of-interference deployment of the two cellular networks.

This example points out the following general facts.

1) When considering the co-existence of systems with different channel spacing the most critical interference situation is on the system with the smaller channel spacing. This is due to greater RF out of band emissions generated by the system with larger channel spacing (that produces smaller values of NFD).

2) When one system is TDD the more stringent requirements, in terms of frequency separation (requested NFD), are usually on A3 interference between CRS's. Once provided the NFD necessary to reduce distances between CRS's to a few hundred meters, the residual risk of interference between CRS and TS, TS and CRS, TS and TS is usually negligible.

3) When one system is TDD, in order to allow distances between CRS's of few hundred meters (or less), a guard band of one channel spacing (equals to largest channel spacing of two systems involved) is always necessary and two channel spacing could be necessary (in particular, if ETSI limits are used in for co-existence analysis).

4) In some cases the differences between ETSI limits and actual parameters (in particular on NFD evaluation and receiver sensitivity) lead to a quite different evaluation on the requested guard bands.

A.2 Two TDMA systems in the 26 GHz band

In this example we consider two P-MP systems operating in the 26 GHz band both using a TDMA access method (namely TDM1 and TDM2). Their actual system parameters are reported in table A.6. As you can see the two systems are actually the same since they present the same parameters.

Table A.6: System parameters

Parameter	TDM1	TDM2
Access method	TDMA	TDMA
Duplex technique	FDD	FDD
Channel spacing [MHz]	28	28
RF spectrum	-	-
CRS Transmission power [dBm]	24	24
TS Transmission power [dBm]	24	24
Uplink power control	Yes	Yes
Sensitivity [dBm] @ BER=10^{-6}	-77	-77
Power margin [dB] on sensitivity	25	25
Symbol rate [Mbaud]	-	-
Roll-off	-	-
CRS antenna gain (see note) [dBi]	19	19
TS antenna gain [dBi]	34	34
TS antenna pattern	See figure A.5	See figure A.5
C/I limit [dB] @ BER=10^{-6} Sensitivity degradation=1 dB	21	21
NOTE: CRS antenna gain reported refer to a 90 degrees sector antenna.		

The 25 dB power margin on sensitivity (see table A.6) represents the rain margin in a K-climatic zone (as defined in ITU-R Recommendation P.837-2 [7]) for a cell radius of about 4 km. It represents the requested margin in order to overcome the rain attenuation. This is the main difference with respect the previous example in the 3,5 GHz band where the rain has no attenuation effect on radio signal.

Figure A.5 shows the TS antenna patterns (on the azimuth plane).

In this case we don't use the RF spectrum and the equivalent parameters of receiving filters to evaluate the NFD. Since we are considering systems with the same channel spacing it is possible to evaluate (as the difference between co-cannel and adjacent channel interference sensitivity) the requested NFD by the relevant EN 301 213-3 [5]. In this case (system type A of [5]), considering a 1 dB threshold degradation for BER=10^{-6} it is possible to derive an NFD=23 dB when the two channel are adjacent.

When we consider a guard band equal to the systems channel spacing (28 MHz) we use the NFD=54 dB provided by measurement carried out by the manufacturer.

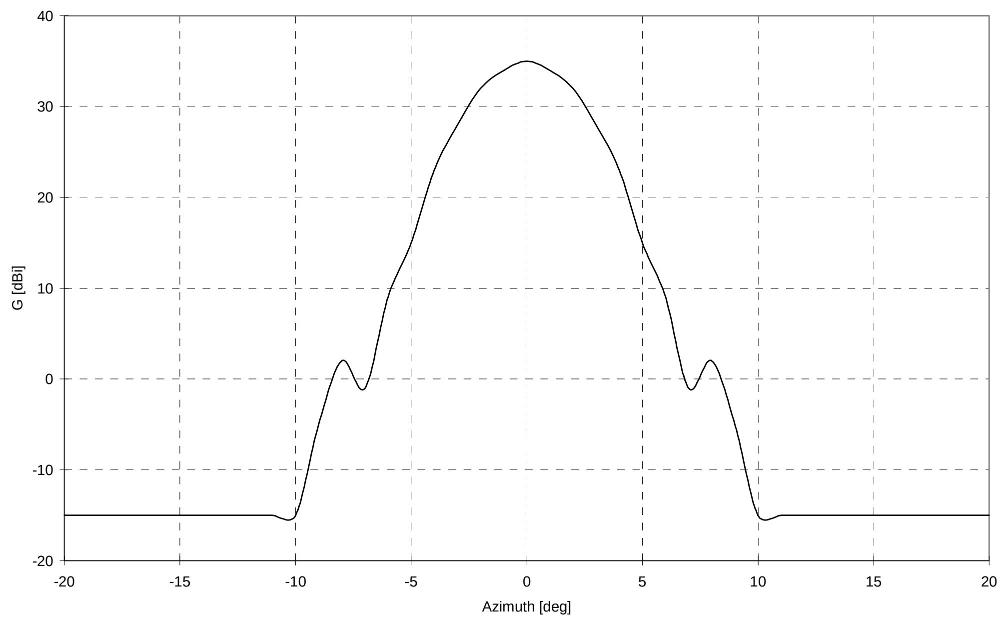

Figure A.5: Antenna pattern envelope on the azimuth plane

Since we are considering two systems that use FDD duplex technique, and assumed that both use the same sub-band for CRS transmission, and consequently for TS transmission (see figure 1 case 1), the only interference classes to be considered are A1 (CRS to TS) and A2 (TS to CRS). Moreover, we can consider only the interference from TDM1 to TDM2 because the vice versa is the same due to fact that the two systems are identical.

The first step to be done is the evaluation the C/I ratios available in the particular situation of co-sited CRS. These values are reported in table A.7 for classes A1, A2 and for the two NFD values considered.

Table A.7: C/I ratios for co-sited CRS's (class A1 and A2) using actual parameters

Guard band [MHz]	NFD	Interference class	**C/I [dB]**
0	23	A1	23
28	54	A1	54
0	23	A2	23
28	54	A2	54

As you can see the C/I ratios equal the NFD values because of the identical systems parameters. This is the most favourable condition for co-existence. In fact, if we suppose the co-sited CRS the C/I achieved with no guard band (23 dB) is sufficient for the 21 dB requested by this system. Therefore, if site sharing is used those two systems can co-exists without any guard band.

The near site placing (CRS's placed within few hundred meters) is quite critical because the 2 dB of margin (23 dB-21 dB) are not sufficient to overcome the little unbalance on free space attenuation. This unbalance is then worsened by the rain un-correlated attenuation on useful and interfering link.

It should be pointed out that a tighter NFD requirement by EN (for example 30 dB) will allow:

- the near site placing (30-21=9 dB are sufficient to overcome little unbalance on propagation);
- the site sharing (and probably even the near site placing) when the two systems parameters are slightly different on transmitted power, antenna gain and receiver sensitivity, e.g. systems by different manufacturer.

On the other hand, if no site sharing (or near site placing) is foreseen by the operators the free space and the un-correlated rain attenuation must be considered. We first consider the class A1 interference (from CRS to TS) and we evaluate the necessary guard band.

In order to simulate the possible rain attenuation on useful link, combined with no attenuation on interfering link, when the overlapping cell problem (interference near – useful far) is considered the useful transmitted power must be decreased by the rain margin (25 dB in table A.6). Then, we can apply the same method described in clause 6 that will provide the %KO area in the worst propagation conditions. The results, for the two possible NFD, are reported in figure A.6.

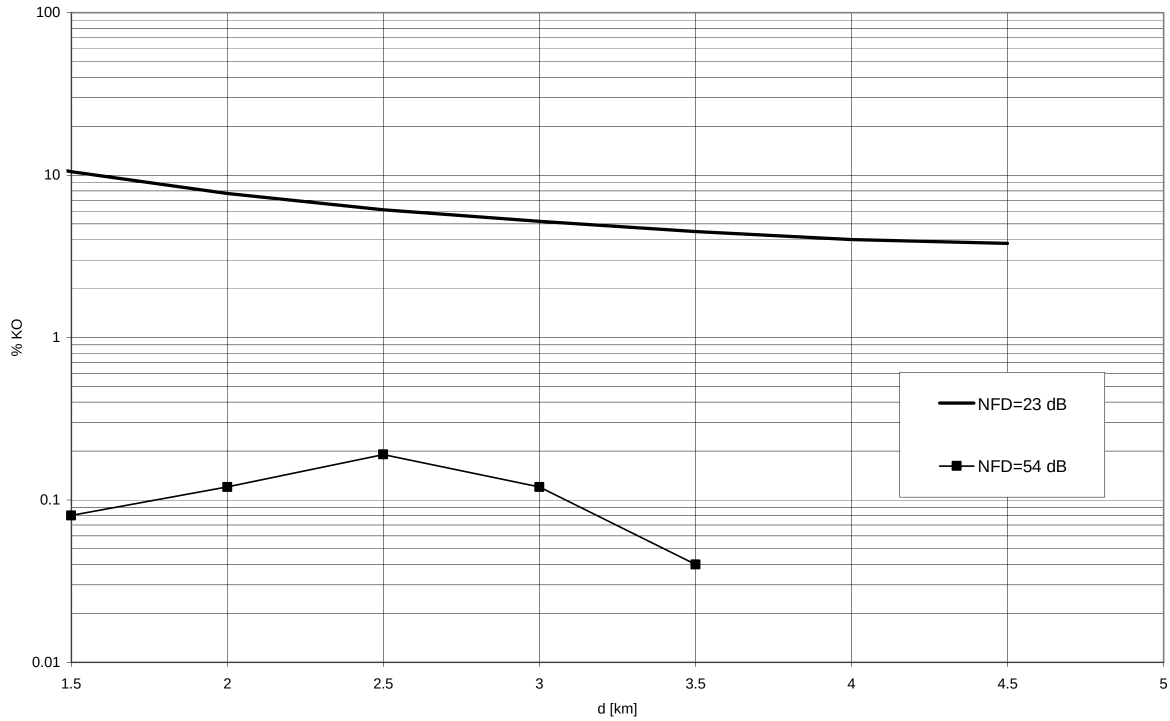

Figure A.6: %KO area for class A1 interference

The distances between CRS's considered in figure A.6 are greater than 1,5 km because for smaller distance the un-correlation on rain attenuation decreases and the 25 dB unbalance on power transmission are no more correct. However, also for distances greater than 1,5 km the %KO is still higher than 3 %. This means that during rainfall a big area (i.e. a big number of TS) will be interfered and many TS will degrade their performances before reaching the rain margin foreseen in the cell planning.

On the contrary, for NFD=54 dB the %KO area is always smaller than 0,2 % with any possible distance between CRS. For example, in figure A.7 is depicted the C/I distribution (over the useful cell area) and the interfered area for CRS distance of 2 km. As you can see, even in worst propagation conditions, the percentage of area with interference problem (black area) is very small and easily negligible. Moreover, in clear sky condition the %KO area is actually zero.

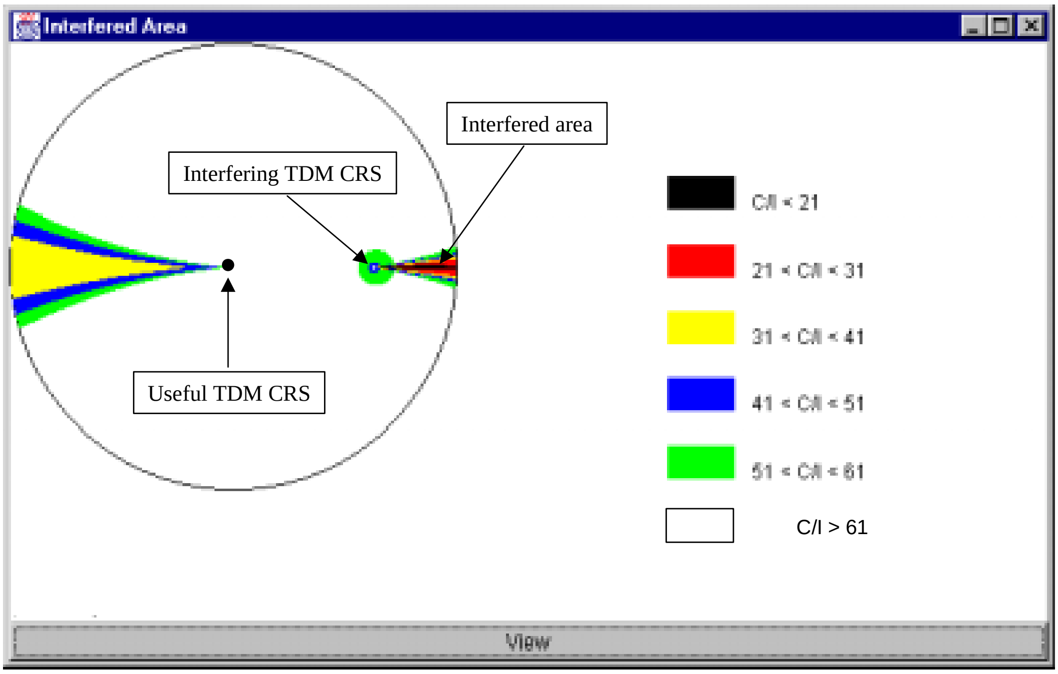

Figure A.7: C/I distribution over the useful TDM cell area for CRS distance of 2 km

The interference class A2 is symmetrical with respect the class A1 already analysed. Thus, the interference problems and the %KO is the same as for A1. The results previously showed apply also for class A2.

This example points out the following general facts.

1) Considering two similar systems (for channel spacing, transmitted power, antenna gain and sensitivity) the site sharing is possible without any guard band, even with NFD requested by EN.

2) The near site placing could be possible, without any guard band and also for non-completely identical systems, if a tighter and reasonable requirement on NFD is imposed.

3) For a completely uncoordinated deployment of the two networks, due to overlapping cell problem and un-correlated rain attenuation, a guard band equal to one channel spacing (28 MHz in this example) is requested.

A.3 Different systems in the 26 GHz band

While in the previous clause the co-existence of two identical systems was considered, now it is useful to analyse the co-existence of two different systems operating in the 26 GHz band. One system is the TDMA system (namely TDM) already considered in clause A.2. The second one is an FDMA system (namely FDM) with the same channel spacing of 28 MHz used by TDM system. The main system parameters of FDM system are listed in table A.8.

Table A.8: FDMA system parameters

Parameter	FDM
Access method	FDMA
Duplex technique	FDD
Channel spacing [MHz]	28
Number of 2 Mb/s sub-carriers	16
RF spectrum	See figure A.9
Total CRS transmission power [dBm]	18
Single carrier transmission power [dBm]	5
Uplink power control	Yes
Sensitivity [dBm] @ BER=10^{-6}	-95
Power margin [dB] on sensitivity	20
Symbol rate [Mbaud]	1,34
Roll-off	0,3
CRS antenna gain (see note) [dBi]	15
TS antenna gain [dBi]	34,5
TS antenna pattern	See figure A.8
C/I limit [dB] @ BER=10^{-6} Sensitivity degradation=1 dB	17,5
NOTE: CRS antenna gain reported refer to a 90 degrees sector antenna.	

The 20 dB power margin on sensitivity (see table A.8) represents the rain margin in a K-climatic zone (as defined in ITU-R Recommendation P.837-2 [7]) for a cell radius of about 3 km. It represents the requested margin in order to overcome the rain attenuation.

A brief description of the FDMA system considered is the following. In the 28 MHz channel there are 16 sub-carriers each transporting a 2 Mb/s to the end user. The power associated to a single sub-carrier is 5 dBm, while the total output power of the CRS is 18 dBm when transmitting all 16 sub-carriers. The symbol rate per sub-carrier is evaluated considering a QPSK modulation with a coding rate ¾, while the roll off factor is evaluated in order to accommodate 16 carriers within the 28 MHz radio channel.

Figure A.8 shows the TS antenna patterns (on the azimuth plane) used by the FDM system (actual antenna pattern mask).

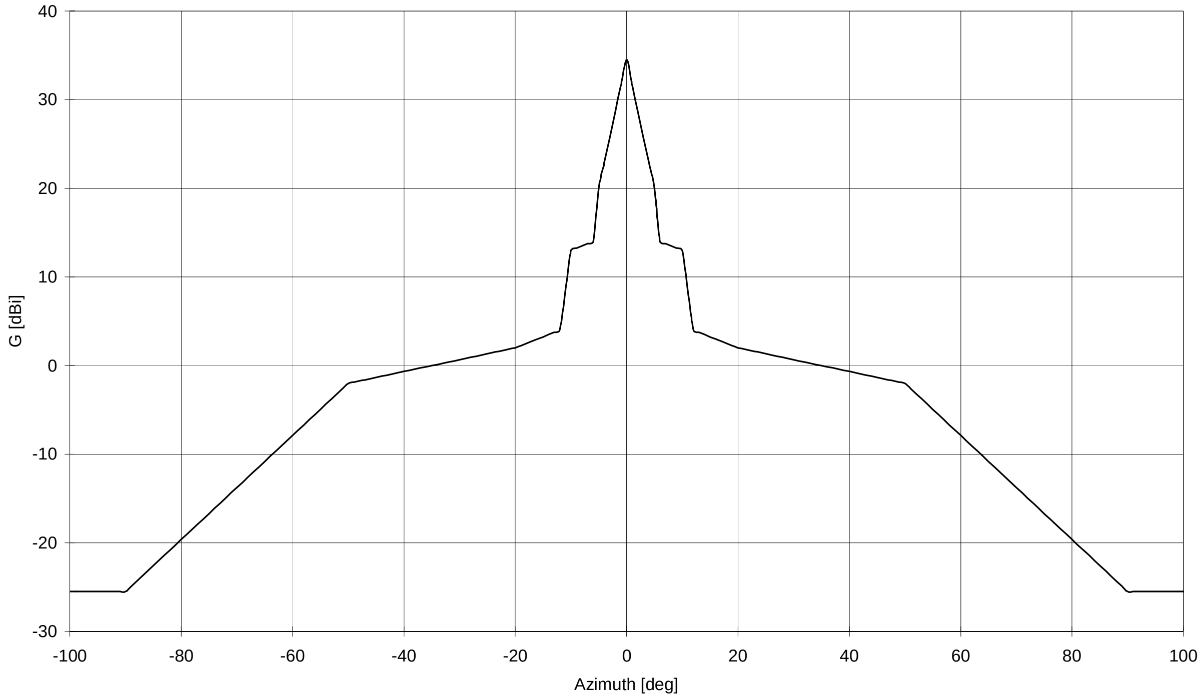

Figure A.8: TS antenna pattern envelope, on the azimuth plane, for FDM system

In order to evaluate the NFD figures the spectrum masks, provided by the manufacturers, of figure A.9 have been used. For the FDMA system the mask represents the emitted spectrum on the CRS when all the 16 sub-carriers are transmitted (full load condition).

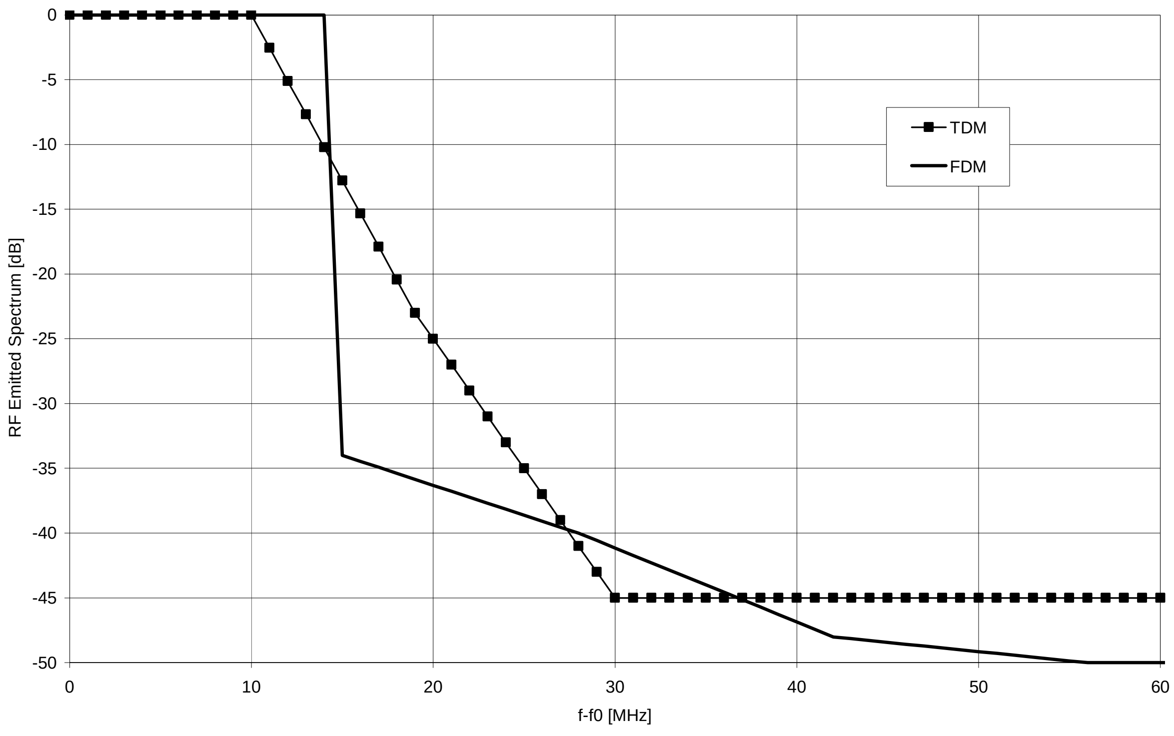

Figure A.9: RF emitted spectrums

As described before for the FDM system also for the TDM system the symbol rate and roll off have been evaluated respectively in 18,75 Mbaud and 0,4. This is necessary in order to estimate the NFD values of TDM when the FDM system is interfering. Table A.9 shows the NFD values calculated with no guard band (GB) and with a 28 MHz guard band. It should be noted that, when considering the interference of TDM system on FDMA system, there are 16 different NFD's to be evaluated, one per each sub-carrier. All these values are listed in table A.9. These values are quite different when no guard band is provided; that is the sub-carrier (1) closer to the interfering TDM channel is the most interfered and it has a small NFD figure. On the contrary, when a 28 MHz guard band is provided all the NFD associated to each sub-carrier are he same due to the fact that these channels are placed on the floor (-45 dB) of the TDM spectrum mask reported in figure A.9.

Table A.9: NFD values (dB)

		NFD [dB]	
Source/victim	**Sub-carrier**	**GB=0 MHz**	**GB=28 MHz**
FDM/TDM	-	41,2	51,3
TDM/FDM	1	21,9	57,5
TDM/FDM	2	26,6	57,5
TDM/FDM	3	31,3	57,5
TDM/FDM	4	35,8	57,5
TDM/FDM	5	39,4	57,5
TDM/FDM	6	42,8	57,5
TDM/FDM	7	46,3	57,5
TDM/FDM	8	49,8	57,5
TDM/FDM	9	53,3	57,5
TDM/FDM	10,11,12,13, 14,15,16	57,5	57,5

Since we are considering two FDD systems we have to evaluate the interference classes A1 and A2 described in clause 6. Table A.10 shows the C/I ratio expected with co-sited CRS's for both classes, both systems and with 0 and 1 channel of guard band. For the FDM system (victim) interference evaluation the smaller NFD value (sub-carrier 1) has been used.

Table A.10: C/I ratios for co-sited CRS's (class A1 and A2)

Source/Victim	**Guard band [MHz]**	Interference class	NFD [dB]	**co-site C/I [dB]**	C/I [dB] limit
FDM/TDM	0	A1	41,2	51,2	21
FDM/TDM	0	A2	41,2	55,2	21
FDM/TDM	28	A1	51,3	61,3	21
FDM/TDM	28	A2	51,3	65,3	21
TDM/FDM	0	A1	22	-1	17,5
TDM/FDM	0	A2	22	8	17,5
TDM/FDM	28	A1	57,5	34,5	17,5
TDM/FDM	28	A2	57,5	43,5	17,5

By comparing the last two columns (co-site C/I and its limit) of table A.10 it must be noted that:

- the TDM system present a high C/I margin (at least 51,2-21≅30 dB) also without any guard band;
- the FDM system present a low C/I margin (only 34,5-17,5≅17,5 dB) even with a 28 MHz guard band.

These facts are related to the different NFD values (in particular for 0 guard band) and to the different thresholds and transmitted powers used by the two systems. In fact, the different channel spacing (28 MHz for TDM and 28/16=1,75 MHz for FDM) leads to different sensitivity (-77 dBm for TDM and –95 dBm for FDM).

Since the 0 guard band co-site C/I for TDM on FDM are smaller than the C/I limit it is obvious that, at least, one channel of guard band is required also for co-site deployment. Therefore, we should better analyse the A1 interference of TDM on FDM that is the worst case (smaller margin) for 1 channel guard band.

Figure A.10 shows the %KO (interfered) area of the useful FDM cell that is afflicted by an unacceptable level of interference. In particular, there are two curves of %KO which refer to normal propagation conditions and worst conditions (25 dB rain attenuation on useful link, no attenuation on interfering link).

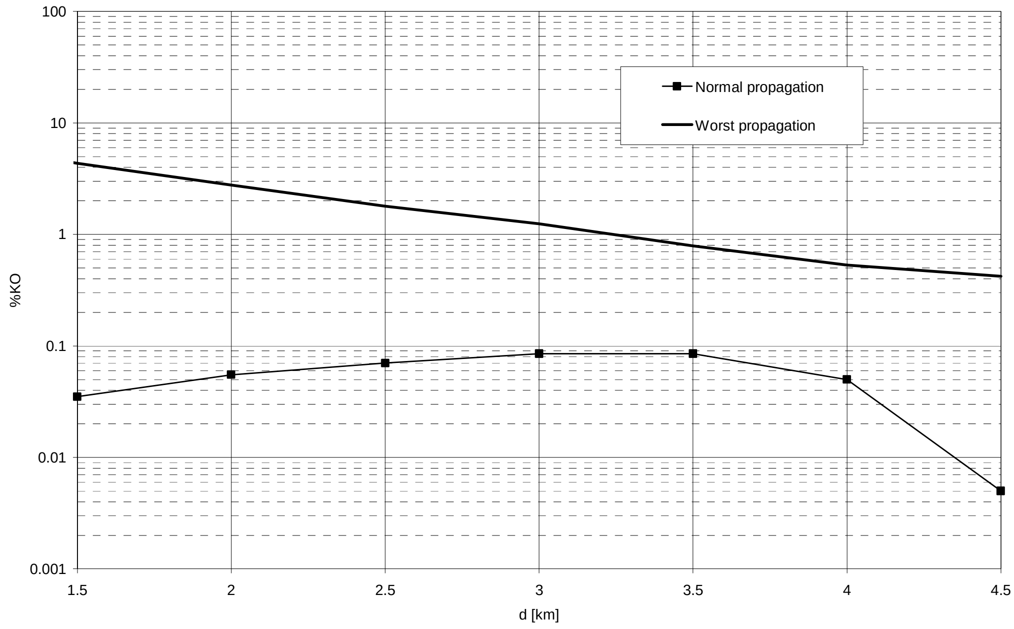

Figure A.10: %KO area for FDM system (class A1, 28 MHz guard band)

Figure A.10 points out that during rain faded conditions there is about 3 % of the whole cell area where the C/I ratio is not sufficient to get the performance objectives. Thus, 1 guard band channel is critical to allow a complete uncoordinated deployment of two networks using the two systems considered. On the contrary, if we consider a near site sharing deployment the rain un-correlation become negligible (a few dB) and the %KO will be similar to the %KO curve related to normal propagation conditions (figure A.10). Thus, a maximum %KO smaller than 0,1 % is achieved and the near site sharing deployment is feasible with one channel of guard band.

This example points out the following general facts:

1) Considering two adjacent systems with strong difference on system parameters, one channel of guard band (equal to the largest channel spacing) is necessary even if the site sharing deployment is foreseen.

2) Also near site sharing is possible with one guard band channel.

3) For a completely uncoordinated deployment a single channel guard band is essential, 2 channel guard band will accommodate the overlapping cell problem, the un-correlated rain attenuation effects and system gain unbalance between two different systems.

Annex B: Examples of P-MP vs P-P co-existence analysis

In this clause an example of co-existence analysis between a P-MP and a P-P system, operating in the same frequency band and in the same area, is given.

This example provides some guidelines on how to use the interference evaluation methodologies, described in clause 7, in order to establish the necessary guard bands, the degree of co-existence and the residual risk of interference.

The example is carried out using actual system parameters of commercial equipment (provided by the manufacturers) and the ETSI limits on parameters reported in the relevant EN standard.

The main characteristics of the examples carried out in the following clause can be summarized as follows.

EXAMPLE 1: Systems operating in the 3,9 GHz band; P-MP is a 3,5 MHz TDMA with FDD duplex technique, P-P is a 30 MHz equipment suitable for SDH STM-1 system capacity.

EXAMPLE 2: Systems operating in the 26 GHz band; P-MP is a 28 MHz TDMA with FDD duplex technique, P-P is a 56 MHz, 16 QAM equipment suitable for SDH STM-1 system capacity.

B.1 Systems in the 3,9 GHz band

In this example we consider a P-MP operating in the 3,9 GHz band using a TDMA access method. Its actual system parameters with their relevant ETSI limits (EN 301 021 [3]) are reported in table B.1.

Table B.1: P-MP system parameters

Parameter	Actual	EN 301 021 [3]
Access method	TDMA	TDMA
Duplex technique	FDD	FDD
Channel spacing [MHz]	3,5	3,5
RF spectrum	Figure B.1	Figure B.1
CRS Transmission power [dBm]	28	< 35
TS Transmission power [dBm]	27	< 35
Uplink power control	Yes	-
Sensitivity [dBm] @ BER=10^{-6}	-92	-83
Power margin [dB] on sensitivity	10	-
Symbol rate [Mbaud]	2,5	-
Roll-off	0,4	-
CRS antenna gain (see note) [dBi]	15	-
TS antenna gain [dBi]	15	-
TS antenna pattern	Figure B.2	Figure B.2
C/I limit [dB] @ BER=10^{-6} Sensitivity degradation=1 dB	14	23
NOTE: CRS antenna gain reported refer to a 90 degrees sectored antennas.		

The P-P system considered in this analysis it's a STM-1 high capacity system employing 128 QAM modulation. Its actual system parameters with their relevant ETSI limits (class 4 equipment in EN 301 127 [9]) are reported in table B.2.

Table B.2: P-P system parameters

Parameter	Actual	EN 301 127 [9]
Duplex technique	FDD	FDD
Channel spacing [MHz]	30	30
RF spectrum	Figure B.1	Figure B.1
Transmission power [dBm]	32	38
Power control	Yes/20 dB ATPC range	-
Sensitivity [dBm] @ BER=10^{-6}	-69	-67
Power margin [dB] on sensitivity	35	-
Symbol rate [Mbaud]	24	-
Roll-off	0,3	-
Antenna gain (see note) [dBi]	40	-
Antenna pattern	Figure B.2	Figure B.2
C/I limit [dB] @ BER=10^{-6} Sensitivity degradation=1 dB	33	35
NOTE: P-P antenna gain reported refer to a 3 m diameter antenna.		

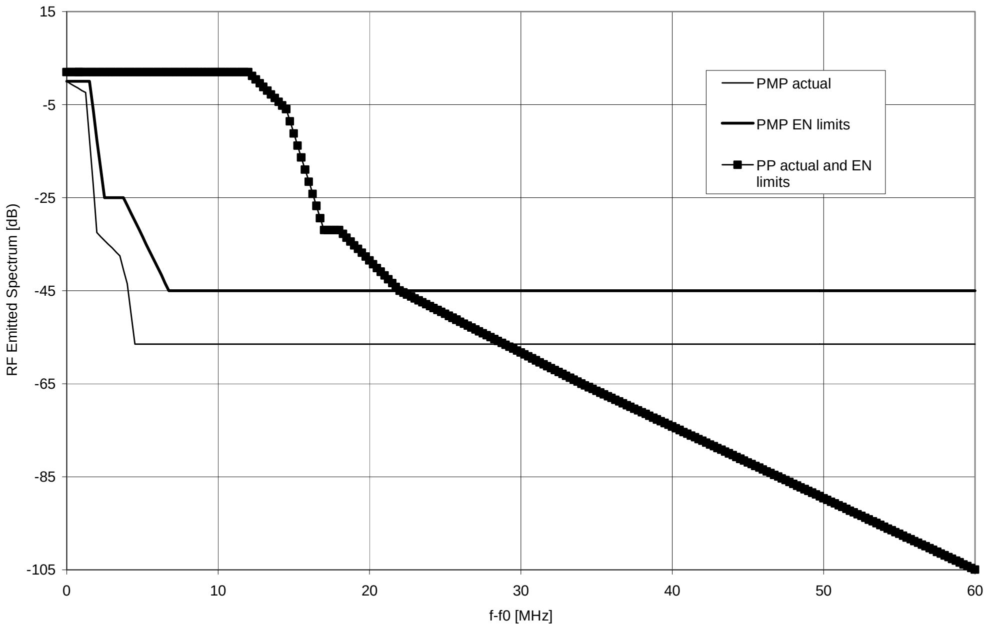

Figure B.1: RF emitted spectrums

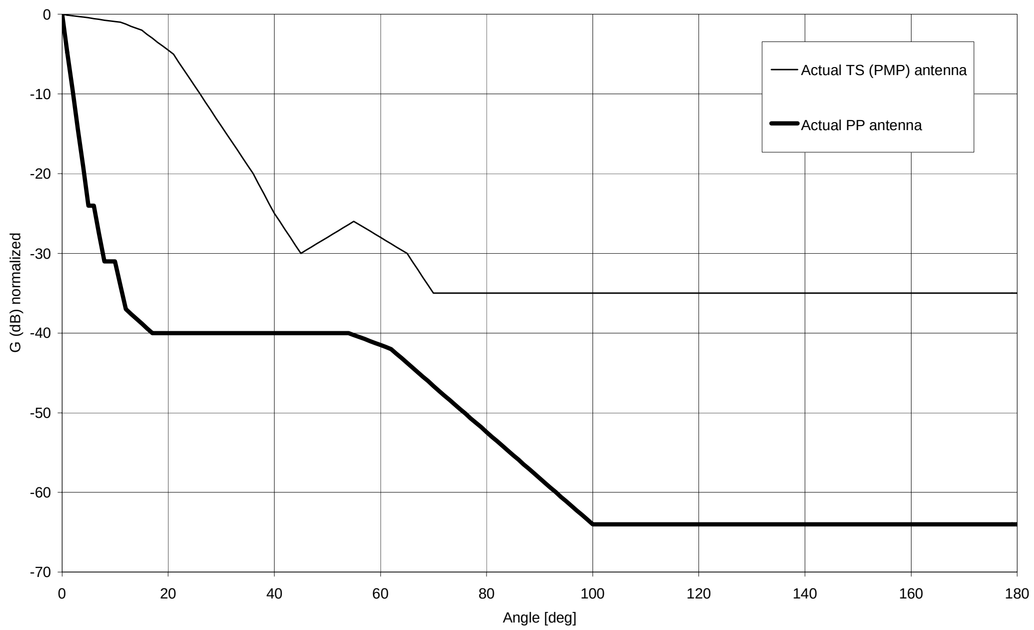

Figure B.2: Antenna pattern envelope on the azimuth plane

Once given all the necessary system parameters the first step to be done is the evaluation of the NFD of one system against the other, considering different guard band (GB) between the two systems. In this case we consider three situations: adjacent channels (0 MHz guard band), 3,5 MHz guard band, which is equal to the P-MP system channel spacing, and 30 MHz guard band which is equal to the P-P channel spacing. Table B.3 shows the NFD evaluated with both actual RF spectrum and ETSI spectrum mask.

Table B.3: NFD values (dB)

		NFD [dB]		
Source/victim	**RF spectrum**	**GB=0 MHz**	**GB=3,5 MHz**	**GB=30 MHz**
P-MP/P-P	Actual	37,8	45,9	(45,9)
P-MP/P-P	ETSI	28	36,4	(36,5)
P-P/P-MP	Actual	-	-	-
P-P/P-MP	ETSI	35,7	50,8	96

Regarding table B.3, the following facts should be noted:

- there is no P-P/P-MP NFD's with actual RF spectrum because the actual P-P RF emitted spectrum is not available;
- but the P-P/P-MP NFD's (with ETSI mask) are greater because of a tighter spectrum mask with respect P-MP;
- the P-MP/P-P NFD's with a 30 MHz guard band (values in round brackets) are not meaningful (they are actually smaller) because of a channel separation greater than 250 % of channel spacing (3,5 MHz), therefore we do not consider the 30 MHz guard band.

Because of the great increase (around 10 dB) of NFD values due to a 3,5 MHz guard band (a small guard band with respect the 30 MHz) we will consider this channel separation for comparison with adjacent channels.

When considering the co-existence between a P-MP and a P-P system there are 4 different classes of interference to be considered, as described in clause 5. The methodologies to analyse the 4 classes are described in clause 7. In order to get a rough idea on the degree of co-existence between the two systems it is useful to evaluate the minimum distance, between CRS (P-MP system) and P-P site, to counteract interference classes B1 and B2. This distance is a function of the angular decoupling between P-P link and CRS, depending on the P-P antenna pattern envelope. Since this pattern (see figure B.2) is flat between 20 and 50 degrees we can evaluate the minimum distance for an angular decoupling of 20 degrees (just outside the keyhole of P-P link).

In table B.4 are shown the minimum distances to counteract classes B1 and B2 for all different system parameters considered and guard band size (adjacent and 3,5 MHz). All the distances are evaluated considering the victim system at the receiver threshold (worst condition).

Table B.4: Minimum distances (km) to counteract classes B1 and B2 interference (with a 20 degrees angular decoupling)

			Distance [km]	
Source/victim	**RF spectrum**	**Interference class**	**GB=0 MHz**	**GB=3,5 MHz**
P-MP/P-P	Actual	B1	1,2	0,5
P-MP/P-P	ETSI	B1	9,7	3,7
P-P/P-MP	Actual	B2	4,5	0,8
P-P/P-MP	ETSI	B2	8,9	1,5

Table B.4 points out the following facts:

- a great difference between figures evaluated with actual parameters and ETSI limits, in particular for the P-MP/P-P case where a difference in NFD values also apply (see table B.3);
- the 3,5 MHz guard band produces a significant reduction of distances (due to increased NFD).

Since we are studying the co-existence of the two systems on the same area we shall consider the situation of *3,5 MHz guard band* with actual system parameters because it needs the minimum guard distance (about 0,8 km).

For this situation it is possible to obtain the complete function of guard distances for classes B1 and B2, as depicted in figures B.3 and B.4. In particular, each figure shows the guard distance for both the worst condition (victim system at the receiver threshold) and the normal condition propagation condition (victim system with a received power above the threshold).

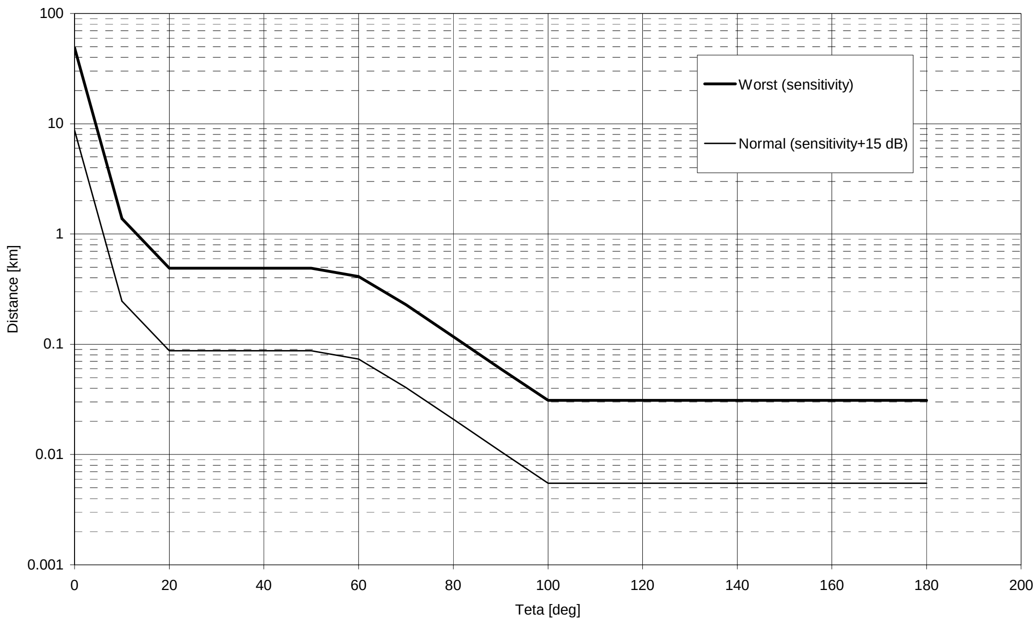

Figure B.3: Minimum distance between P-P and CRS sites in order to avoid class B1 interference

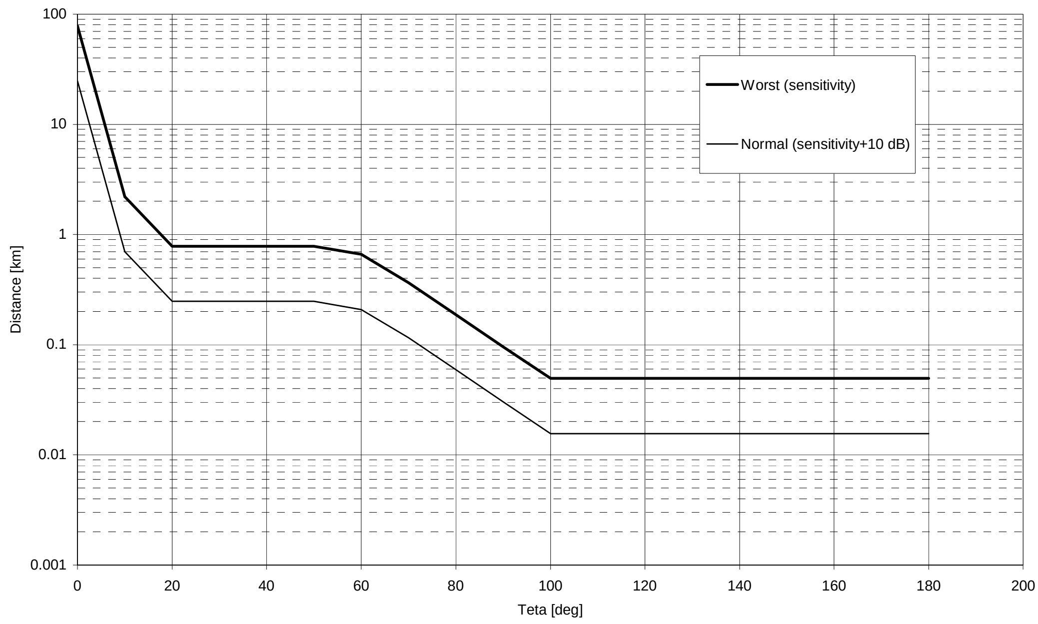

Figure B.4: Minimum distance between P-P and CRS sites in order to avoid class B2 interference

Figures B.3 and B.4 point out that for angular decoupling less than 20 degrees the requested distance increase exponentially, i.e. this situation should be avoided.

Once analysed classes B1 and B2, it is also necessary to analyse the interference from P-MP TS transmitters to P-P receiver (class B3) and from P-P transmitter to P-MP TS downlink receivers (class B4). In these cases it is possible to evaluate the percentage of P-MP cell area where any potential TS is source of interference (class B3) towards P-P system, and where any potential TS is interfered by the P-P system (class B4). The results of the analysis, with a 3,5 MHz guard band channel and in worst propagation conditions (victim system at receiver threshold), are depicted in figures B.5 and B.6 as a function of P-P/CRS sites distance (d) and angular decoupling (teta). For the P-MP system it is assumed a coverage radius of 15 km, which defines the cell area where the interference analysis is carried out.

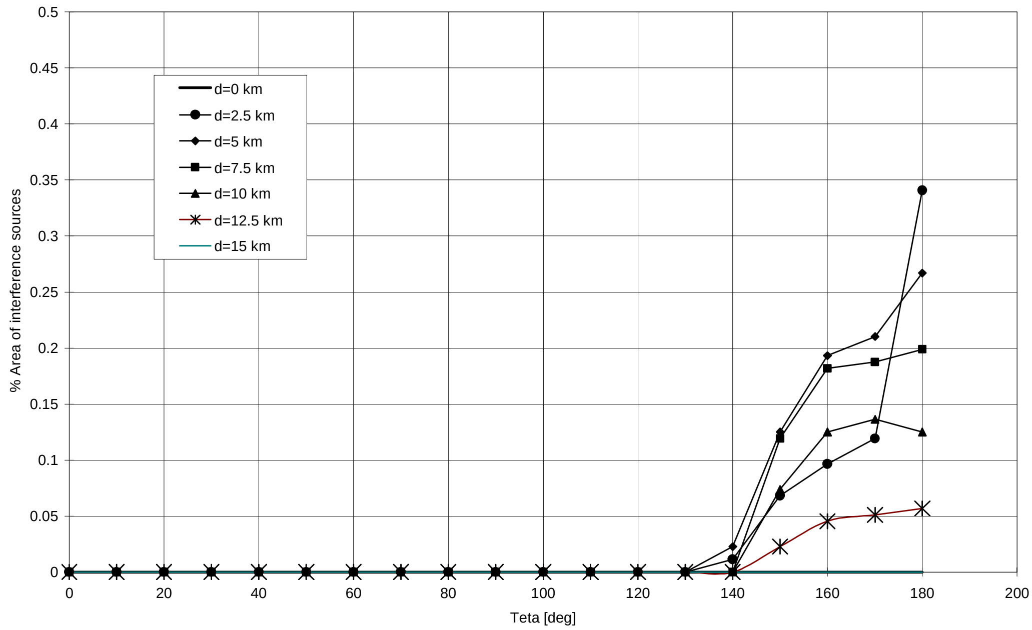

Figure B.5: % of cell area for any potential TS interfering P-P (class B3)

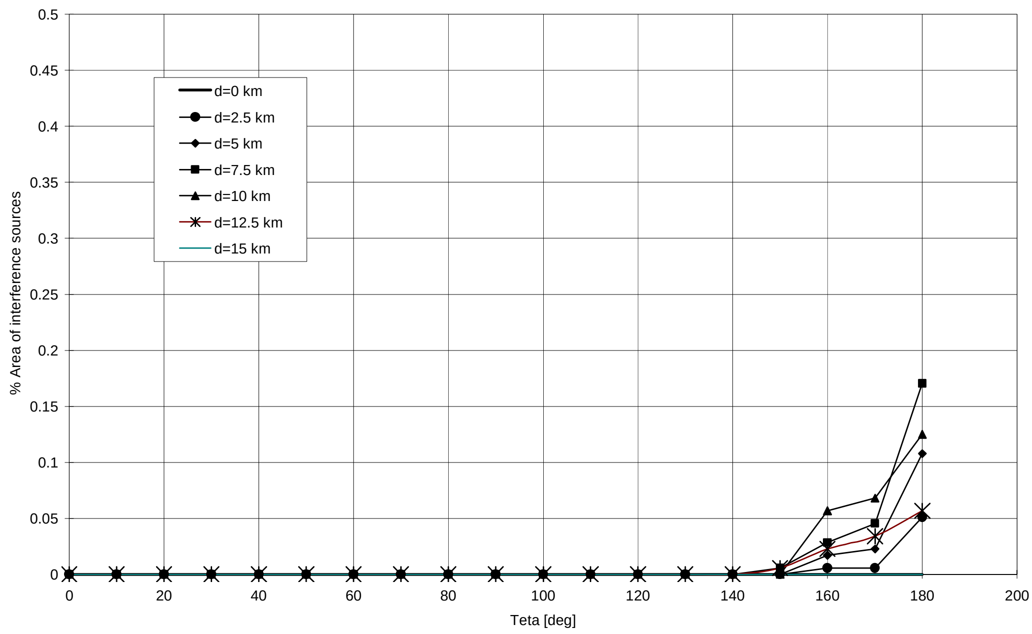

Figure B.6: % of cell area where any potential TS is interfered by P-P (class B4)

Both figures B.5 and B.6 show that the percentage of area of potential source or victim of interference is quite small (less than 0,2-0,3 %) and it is present only for decoupling angles greater than 150 degrees. An example of such a situation is depicted in figure B.7 where the percentage of cell area for any TS interfering P-P (class B3) is shown for a distance (CRS to P-P) of 5 km and a decoupling angle of 160 degrees. The interfering area is the thin black area within the cell along the P-P link. This interference is due to the fact that P-P link has a small decoupling angle with respect the CRS-TS link of the P-MP system. The only way to avoid this interference is to provide a suitable angular decoupling (as for classes B1 and B2) or to keep a small distance between CRS and P-P site (less than 3 km).

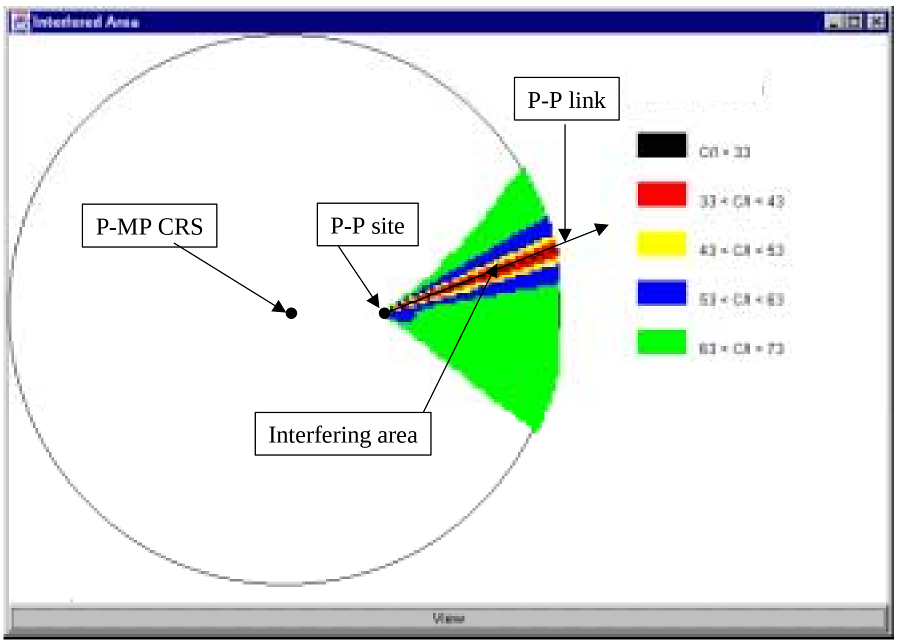

Figure B.7: Cell area of potential sources (TS) of interference (class B3) and their relevant C/I generated on the P-P receiver

This example points out the following general facts.

1) In order to mitigate interference classes B1 and B2 it is always necessary to respect a minimum distance and an angular decoupling (20 degrees in this case, due to P-P antenna pattern) between P-P link and P-P/CRS direction (if P-P link is pointed towards CRS). Moreover, a channel of guard band is useful in order to reduce the minimum distance between P-P and CRS.

2) In order to avoid any possible interference to P-P link (class B3) from the TS it is necessary to respect an additional (with respect point 1) angular decoupling between P-P link and P-P/CRS direction and to provide, at least, one guard band channel. In fact, it is not tolerable to have any area of potential interference within the P-MP cell.

3) The interference of P-P link on P-MP TS (class B4) is similar to class B3, thus it requires the same countermeasures, but it is acceptable to have a small area where a TS can be afflicted by interference during worst propagation conditions. It is the same concept used for P-MP vs. P-MP co-existence, a little percentage of users (TS) located in a well defined area will probably suffer interference problems in worst propagation conditions.

4) In the case here analysed, the good NFD figures and the guard band considered, provide a free of interference (class B3 and B4) scenario if the distance between CRS and P-P site is less than 3 km and even for co-siting. The co-siting could also be used to avoid class B1 and B2 interference by an appropriate site engineering (providing the sufficient vertical separation that can be achieved to allow the necessary decoupling on the vertical axis).

B.2 Systems in the 26 GHz band

In this example only actual system parameters are considered. The P-MP system considered in this analysis is the same TDMA system already used in annex A, whose parameters are listed in table B.5.

Table B.5: P-MP system parameters

Parameter	P-MP
Access method	TDMA
Duplex technique	FDD
Channel spacing [MHz]	28
RF spectrum	See figure B.8
CRS Transmission power [dBm]	24
TS Transmission power [dBm]	24
Uplink power control	Yes
Sensitivity [dBm] @ BER=10^{-6}	-77
Power margin [dB] on sensitivity	25
Symbol rate [Mbaud]	18,75
Roll-off	0,4
CRS antenna gain (see note) [dBi]	19
TS antenna gain [dBi]	34
TS antenna pattern	See figure B.9
C/I limit [dB] @ BER=10^{-6} Sensitivity degradation=1 dB	21
NOTE CRS antenna gain reported refer to a 90 degrees sector antenna.	

The P-P here considered for the analysis is a system compliant with class 4 equipment (16 QAM) defined in EN 300 431 [6]. The main system parameters are listed in table B.6.

Table B.6: P-P system parameters

Parameter	P-P
Duplex technique	FDD
Channel spacing [MHz]	56
RF spectrum	Figure B.8
Transmission power [dBm]	18
Power control	Yes/15 dB ATPC range
Sensitivity [dBm] @ BER=10^{-6}	-77
Power margin [dB] on sensitivity	30
Symbol rate [Mbaud]	42
Roll-off	0,3
Antenna gain (see note) [dBi]	40
Antenna pattern	Figure B.9
C/I limit [dB] @ BER=10^{-6} Sensitivity degradation=1 dB	25
NOTE: P-P antenna gain reported refer to a 0,6 m antenna diameter.	

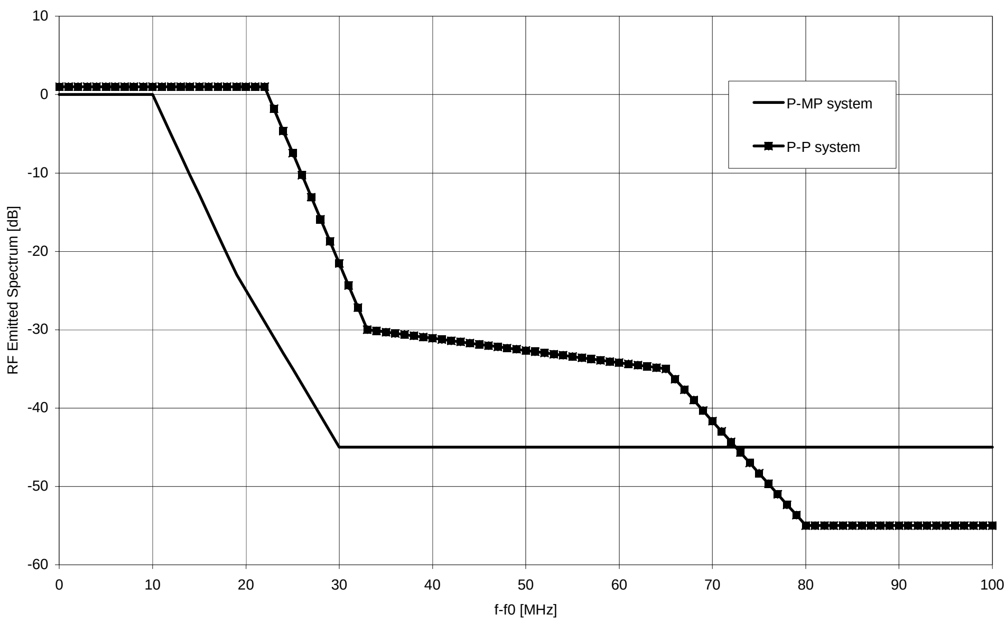

Figure B.8: RF emitted spectrum

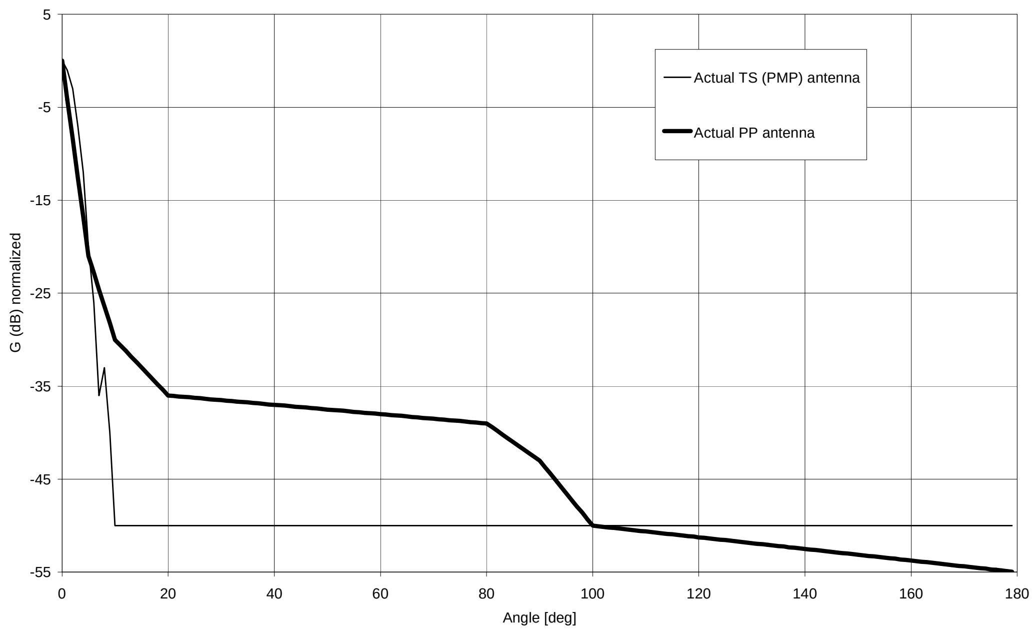

Figure B.9: Antenna pattern envelope on the azimuth plane

Once given all the necessary system parameters the first step to be done is the evaluation of the NFD of one system against the other, considering different guard band (GB) between the two systems. In this case we consider three situations: adjacent channels (0 MHz guard band), 28 MHz guard band which is equal to the P-MP system channel spacing, and 56 MHz guard band which is equal to the P-P channel spacing. Table B.7 shows the NFD values.

Table B.7: NFD values (dB)

	NFD [dB]		
Source/victim	GB=0 MHz	GB=28 MHz	GB=56 MHz
P-MP/P-P	27,6	42,8	43
P-P/P-MP	36	43,8	60

The first step of the analysis is the evaluation of the minimum distance (between CRS and P-P site) in order to counteract classes B1 and B2 of interference (see the previous example).The minimum distance is evaluated for an angular decoupling of 20 degrees. Table B.9 shows the requested distances. Table B.7 shows smaller distances with respect table B.4 (systems in the 3,9 GHz band)). This fact is due to:

- higher frequency band (greater free space attenuation);
- more similar system parameters in terms of channel size, transmit power, sensitivity, etc.

Table B.8: Minimum distances (km) to counteract classes B1 and B2 interference (with a 20 degrees angular decoupling)

		Distance [km]		
Source/victim	**Interference class**	**GB=0 MHz**	**GB=28 MHz**	**GB=56 MHz**
P-MP/P-P	B1	1,1	0,2	0,18
P-P/P-MP	B2	0,13	0,05	0,01

Since the difference between 28 MHz and 56 MHz guard band is negligible in terms of guard distances, we will deeply analyse all the interference classes considering the *28 MHz guard band*.

Figures B.10 and B.11 show the complete function of guard distances for any decoupling angle, and for both worst (receiver at the threshold) and normal propagation conditions (receiver above the threshold). As in the previous example, figures B.10 and B.11 point out that a minimum angular decoupling of about 20 degrees is necessary in order to obtain a reasonable (a few hundred meters or less) distance between P-P and CRS sites. Therefore, it is possible to control classes B1 and B2 of interference if a channel of guard band and a 20 degrees of angular decoupling are provided.

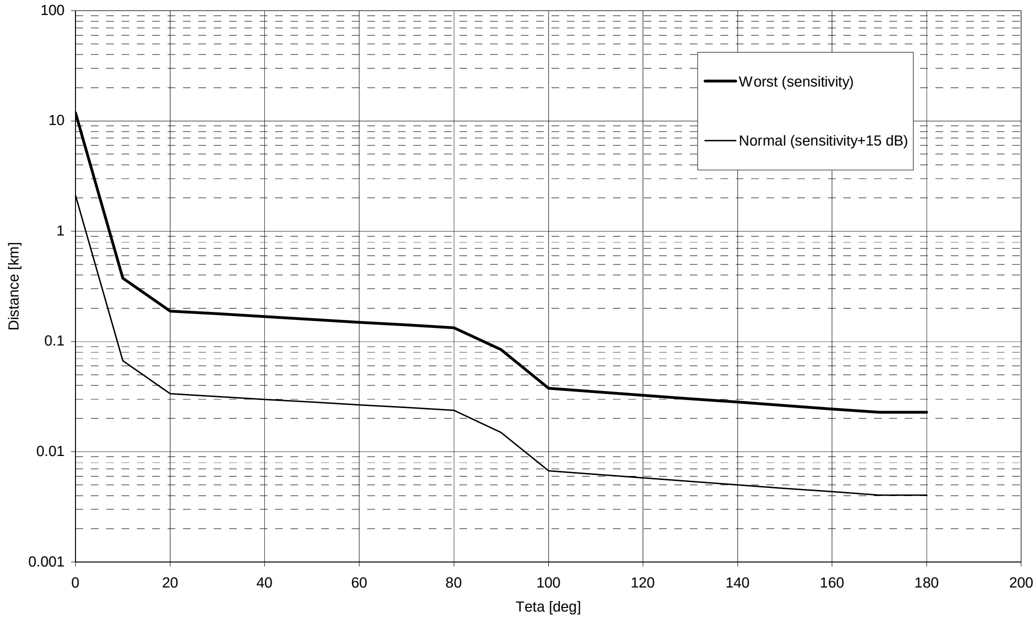

Figure B.10: Minimum distance between P-P and CRS sites in order to avoid class B1 interference

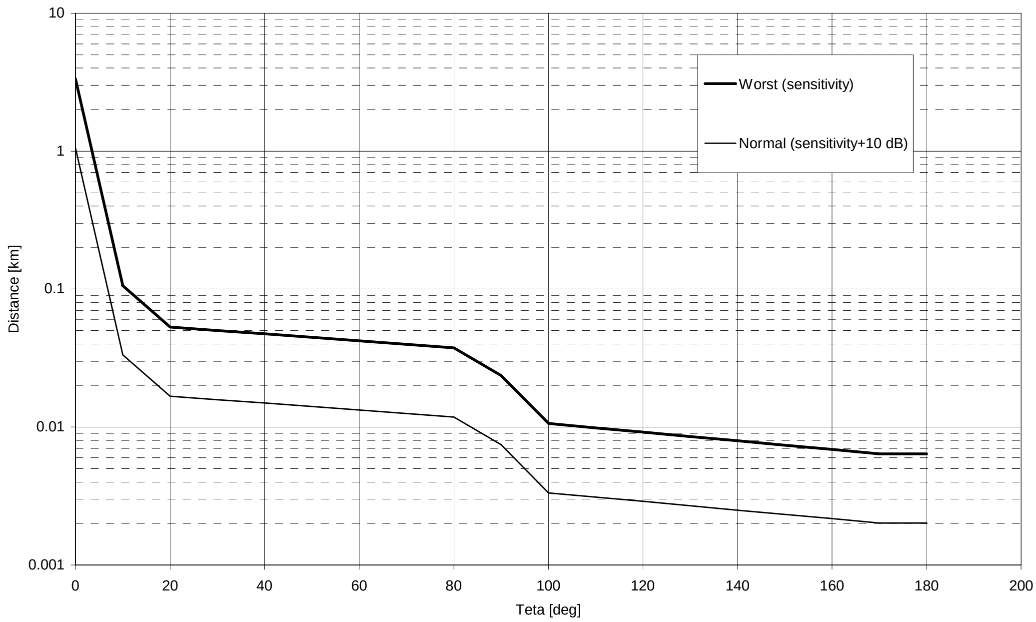

Figure B.11: Minimum distance between P-P and CRS sites in order to avoid class B2 interference

Once analysed classes B1 and B2, it is also necessary to analyse the interference from P-MP TS transmitters to P-P receiver (class B3) and from P-P transmitter to P-MP TS downlink receivers (class B4). The results of the analysis, with a 28 MHz guard band channel and in worst propagation conditions, are depicted in figures B.12 and B.13 in the same way used in previous example (see clause B.1). For these interference analysis a 4 km coverage radius has been assumed for the P-MP system.

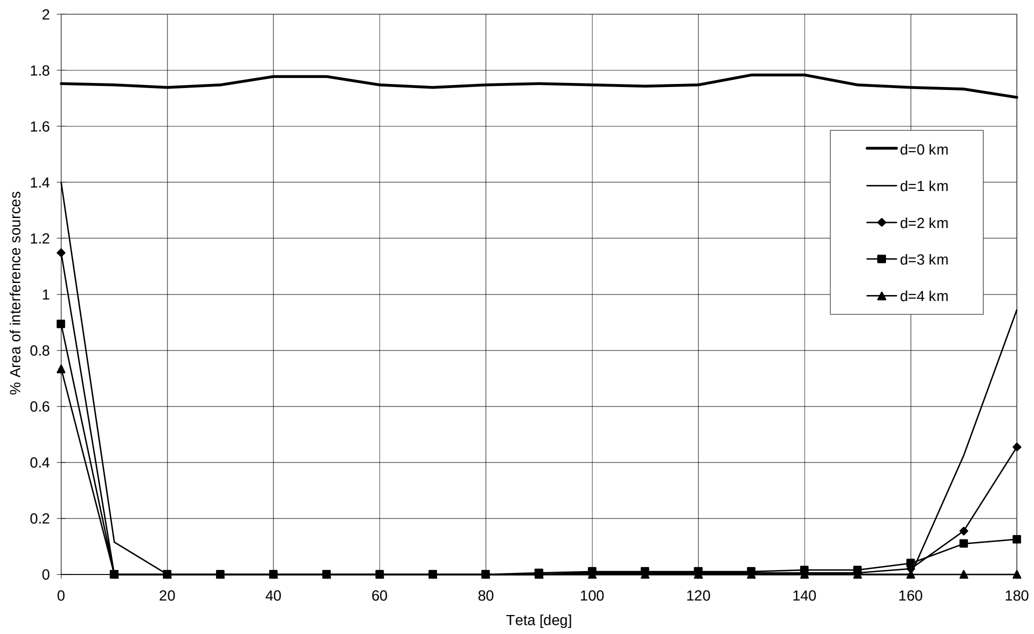

Figure B.12: % of cell area for any potential TS interfering P-P (class B3)

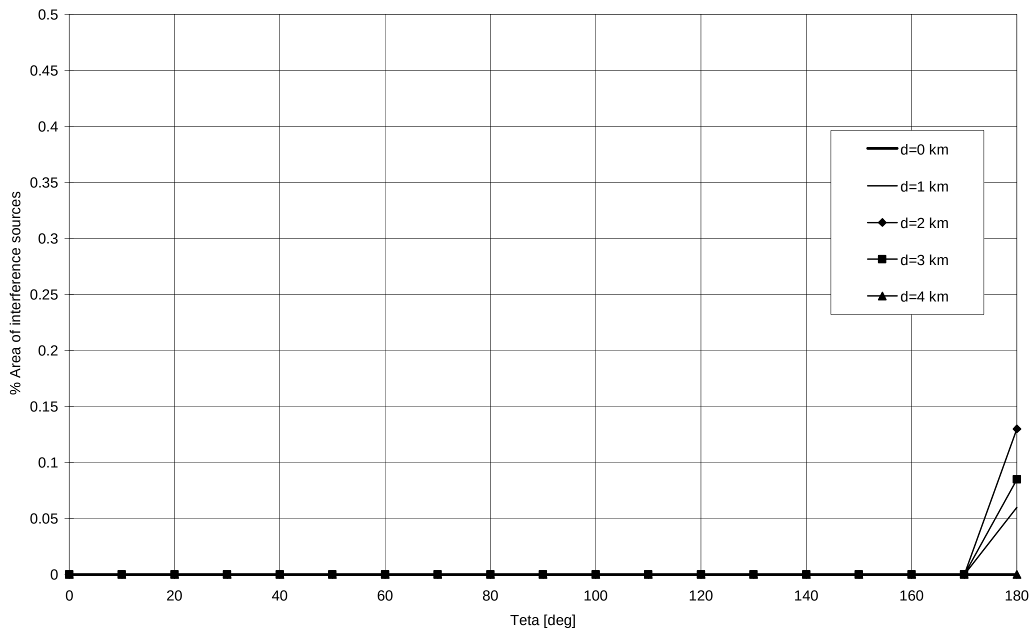

Figure B.13: % of cell area where any potential TS is interfered by P-P (class B4)

While figure B.13 shows a negligible (less than 0,1 %) amount of interference, figure B.12 shows a high percentage of interference (up to 2 %) for co-site scenario (d=0 km). This means that co-site is not allowed by interference classes B3 even if a channel of guard band is provided. In fact, as depicted in figure B.14, the interfering area (black area) for co-siting is quite big, thus the probability of interference (that is the probability of one TS transmitting within the black area) is close to 1.

Also for other distances figure B.12 shows high interference risks. It must be pointed out that class B3 is the most severe interference to be considered. In fact, each time the P-P link is near its sensitivity threshold (worst propagation conditions) if a P-MP TS, located within a particular area in the cell, transmits a signal it will produce a level of interference not allowed by the P-P system, which causes a sequence of errors. Thus, it produces an increase of ES, SES and unavailability that can not be accepted by the P-P operator.

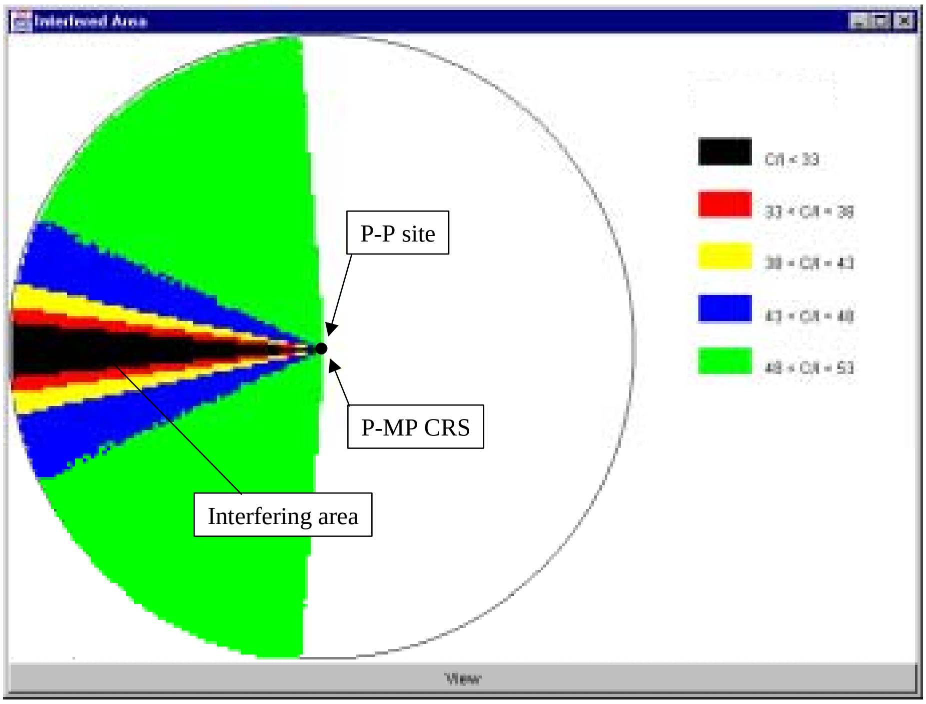

Figure B.14: Cell area of potential sources (TS) of interference (class B3) and their relevant C/I generated on the P-P receiver

This example points out the following general facts:

1) In order to mitigate interference classes B1 and B2 it is always necessary to respect a minimum distance and an angular decoupling between P-P link and P-P/CRS direction (if P-P link is pointed towards CRS). Moreover, a channel of guard band is useful in order to reduce the minimum distance between P-P and CRS.

2) In order to avoid any possible interference to P-P link (class B3) from the TS it is necessary to respect an additional (with respect point 1) angular decoupling between P-P link and P-P/CRS direction even with one guard band channel. In fact, it is not tolerable to have any area of potential interference within the P-MP cell.

3) The interference of P-P link on P-MP TS (class B4) is similar to class B3, thus it requires the same countermeasures, but it is acceptable to have a small area where a TS can be afflicted by interference during worst propagation conditions. It is the same concept used for P-MP vs. P-MP co-existence, a little percentage of users (TS) located in a well defined area will probably suffer interference problems in worst propagation conditions.

4) The co-siting is impossible because of the class B3 interference, that cannot be avoided by an appropriate site engineering.

Bibliography

The following material, though not specifically referenced in the body of the present document (or not publicly available), gives supporting information.

- ETSI ETR 101 274: "Transmission and Multiplexing (TM); Digital Radio Relay Systems (DRRS); Point-to-multipoint DRRS in the access network: Overview of different access techniques".

History

Document history		
V1.1.1	October 2000	Publication