Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Coexistence Recommended Practice – draft amendment version 1**
Date Submitted	**2002-07-11**
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Re:	Amendments to Recommended Practice for Coexistence of Fixed BWA Systems IEEE802.16.2
Abstract	This is the first complete draft amendment to the Recommended Practice for Coexistence of Fixed Broadband Wireless Access Systems
Purpose	First complete draft for consideration of start of WG letter ballot at session # 20
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
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Task Group Editorial Notes

1.This page contains guidance on the editing of the coexistence recommended practice
2 This WORD version of the amended document is to be read in conjunction with the published document IEEE Std 802.16.2-2001.
3. Part 1 of the document is an updated version of the published standard. Not all text or figures have been reproduced here, especially where the original standard has not been modified. Unmodified text is reproduced only to aid reading. The published version takes precedence in the case of any unintended reproduction errors.
4. Changes in Part 1are indicted as editorial instructions for the IEEE editor. All other text, figures and diagrams are unaltered, apart from paragraph numbering which is changed to accommodate the new and edited sections.
5. Part 2 and Part 3 are new and contain the full text, figures and diagrams to be added to the published standard.
6. All editorial instructions for the IEEE editor are highlighted in RED text.
7. The title page and IEEE introductory pages have been omitted from this version of the document.
8. The interpretation of the published standard has been reviewed. The text has been updated accordingly. The text of the interpretation was as follows:

> "Subsection 6.1.3, Out-of-block unwanted emissions of the Recommended Practice for Coexistence of Fixed Broadband Wireless Access Systems relates to out-of-block unwanted emissions. Figure 7 provides an example application of out-of-block unwanted emission limits. The transmitter spectrum shown in the figure is an example of a typical actual spectrum for one possible channel bandwidth. It shows the relationship between the placement of the example carrier and the block edge mask, so as to meet the recommended out-of-blocks limits. It is not an emission mask and there is no intention to imply the use of any particular mask. The system designer is free to choose the levels and placement of carrier frequencies in order to meet the recommended out-of-block emission limits."

9. A draft record of archived documents has been added to the document

10. The introduction and related pages, together with the list of participants are to be added later. These precede the table of contents and the main text.
11. These notes do not form part of the amended document itself.

IEEE Draft Recommended Practice for Local and Metropolitan area networks

Coexistence of Fixed Broadband
Wireless Access Systems

Sponsor
LAN/MAN Standards Committee
Of the
IEEE Computer Society

and the
IEEE Microwave Theory and Techniques Society

Approved [tba]
IEEE – SA Standards Board

Editorial Instructions to page i:
- add new approval date when known
- add MMDS in key words section
- replace original Abstract with the following text:

“**Abstract:** This document amends IEEE recommended practice 802.16.2-2001 by enhancing and updating the published information and by adding guidelines for minimizing interference in fixed broadband wireless access (BWA) systems operating in the frequency range 2 – 11 GHz and by adding guidelines for coexistence with point to point link systems operating in the frequency range 23.5 to 43.5 GHz. It analyzes appropriate additional coexistence scenarios and provides guidance for system design, deployment, coordination and frequency usage.”

Keywords: coexistence, fixed broadband wireless access (BWA), interference, local multipoint distribution service (LMDS), multichannel multipoint distribution service (MMDS), millimeter wave, multipoint, point-to-multipoint, radio, wireless metropolitan area network (WirelessMAN^{TM}) standard

Editorial instructions for pages ii to viii;

- these pages are not yet available - to be added later

Contents

Editorial Instruction:

- Delete the existing Overview and replace with the following text:

“1. Overview of Recommended Practice

This document provides recommended practice for the design and coordinated deployment of fixed Broadband Wireless Access (BWA) systems to control interference and promote coexistence. This Recommended Practice is divided into three parts:-

-Part 1 deals with coexistence of FBWA systems in the frequency range 23.5 –43.5 GHz.

-Part 2 deals with coexistence issues between point-to-point link systems and FBWA systems in the frequency range 23.5 3.5 GHz.

-Part 3 deals with coexistence of FBWA systems in the frequency range 2-11 GHz

References to other standards that are useful in applying this Recommended Practice are provided. Definitions and abbreviations that are either not found in other standards or have been modified for use with this Recommended Practice are provided.

Each part of the recommended practice includes a number of clauses, dealing with the following issues:

1. A scope statement relevant to that part of the Recommended Practice.
2. A summary of fixed BWA coexistence recommendations and guidelines.
3. An overview of the systems for which coexistence criteria are analyzed, including system architecture and medium overview.
4. Equipment design parameters relevant to the simulations and calculations
5. For part 1, recommended tolerance levels for certain receiver parameters, including noise floor degradation and blocking performance, for interference received from other fixed BWA systems as well as from other systems.
6. A methodology to be used in the deployment and coordination of systems
7. Interference and propagation evaluation examples, indicating some of the models, simulations and analyses used in the preparation of this Recommended Practice.
8. Mitigation techniques that could be employed in case of co-channel interference between systems operating in adjacent areas or in case of undesired signals caused by natural phenomena and other unintentional sources.

Appendices to each part provide a summary of all the coexistence simulation methods and results, from which the recommendations and guidelines have been derived. Reference to the input documents containing the full analysis of interference scenarios is also provided in an appendix, in order to provide full traceability to the reader of the basis for this recommended practice.”

Editorial Instruction:

-delete the existing Scope and replace with the following text:

"1.1. Scope of Recommended Practice

The intent of this document is to define a set of consistent design and deployment recommendations that promote coexistence for fixed BWA systems and for point-to-point systems that share the same bands. The recommendations have been developed and substantiated by analyses and simulations specific to the deployment and propagation environment appropriate to terrestrial fixed BWA intersystem interference experienced between operators licensed for fixed BWA and operators of point-to-point link systems sharing the same bands. These recommendations, if followed by manufacturers and operators, will facilitate a wide range of equipment to coexist in a shared environment with acceptable mutual interference.

The scope of this Recommended Practice includes the examination of interference between systems deployed across geographic boundaries in the same frequency blocks and systems deployed in the same geographic area in adjacent frequency blocks. This document emphasizes coexistence practices for multipoint systems with a variety of architectures and for point-to-point systems, where these share the same frequency bands as the multipoint systems. This Recommended Practice does not cover coexistence issues due to intra -system frequency reuse within the operator's authorized band, and it does not consider the impact of interference created by fixed BWA systems on satellite or other non - BWA systems.

This document is not intended to be a replacement for applicable regulations, which would take precedence."

2. Normative References

This Recommended Practice shall be used in conjunction with the following:

ETSI EN 301 390 V1.1.1. (2000-12), Fixed Radio Systems; Point-to-Point and Point-to-Multipoint Systems; Spurious Emissions and Receiver Immunity at Equipment/Antenna Port of Digital Fixed Radio Systems. 1

IEEE P802.16/D3, Draft Standard for Local and Metropolitan Area Networks; Part 16: Standard Air Interface for Fixed Broadband Wireless Access Systems.

Recommendation ITU-R F.1509: Technical and Operational Requirements that Facilitate Sharing between Point-to-Multipoint Systems in the Fixed Service and the Inter-Satellite service in the band 25.25 - 27.5 GHz. 3

ETSI TS 101 999 V1.1.1 (2002-04), Broadband Radio Access Networks (BRAN); HIPERACCESS; PHY protocol specification.

ETSI TS 102 000 V1.1.1 (2002-06), Broadband Radio Access Networks (BRAN); HIPERACCESS; DLC protocol specification.

ETSI TS 102 003 V1.1.1 (2002-03), Broadband Radio Access Networks (BRAN); HIPERACCESS; System Overview.

Industry Canada SRSP.303-4: Technical Requirements for Fixed Wireless Access Systems Operating in the Band 3400-3700 MHz.

Industry Canada RSS-192: Radio Standards Specification “Fixed Wireless Access Systems in the Band 3400-3700 MHz”.

RA 390: Inter-operator co-existence and co-ordination guidelines for Broadband Fixed Wireless Access (BFWA) systems operating in the band 27.5 – 29.5 GHz.

ETSI TR 101 853 V1.1.1 (2000-10), Fixed Radio Systems; Point-to-point and point-to-multipoint equipment; Rules for the coexistence of point-to-point and point-to-multipoint systems using different access methods in the same frequency band.

ITU Recommendation P 525: “Calculation of free space attenuation”.

ITU Recommendation P 526: “Propagation by diffraction”.

ITU Recommendation P 530: “Propagation data and prediction methods required for the design of terrestrial line-of-sight systems”.

ITU Recommendation P 452: Prediction procedures for the evaluation of microwave interference, between stations on the surface of the earth at frequencies above about 0.7 GHz.

ITU Recommendation P.676-4: "Attenuation by atmospheric gases".

3.Definitions and Abbreviations

3.1 Definitions

3.1.1 authorized band: The range of frequencies over which an operator is permitted to operate radio transmitters and receivers.

3.1.2 automatic transmit power control (ATPC): A technique used in BWA systems to adaptively adjust the transmit power of a transmitter to maintain the received signal level within some desired range.

3.1.3 base station (BS): A generalized equipment set providing connectivity, management, and control of the subscriber station.

3.1.4 broadband: Having instantaneous bandwidths greater than around 1 MHz and supporting data rates greater than about 1.5 Mbit/s.

3.1.5 broadband wireless access (BWA): Wireless access in which the connection(s) capabilities are broad- band.

3.1.6 cross-polar discrimination (XPD): The XPD of an antenna for a given direction is the difference in dB between the peak co-polarized gain of the antenna and the cross-polarized gain of the antenna in the given direction.

3.1.7 digital modulation: Digital modulation is the process of varying one or more parameters of a carrier wave (e.g., frequency, phase, amplitude, or combinations thereof) as a function of two or more finite and discrete states of a signal.

3.1.8 downlink: The direction from a base station to the subscriber station.

3.1.9 DS-3: A North American Common Carrier Multiplex level having a line rate of 44.736 Mbit/s.

3.1.10 fixed wireless access: Wireless access application in which the location of the SS and the BS are fixed in location.

3.1.11 frequency block: A contiguous portion of spectrum within a sub-band or frequency band, typically assigned to a single operator.

NOTE: A collection of frequency blocks may form a sub-band and/or a frequency band.

3.1.12 frequency division duplex (FDD): A duplex scheme in which uplink and downlink transmissions use different frequencies but are typically simultaneous.

3.1.13 Frequency Range 1: For purposes of this document, Frequency Range 1 refers to 10 - 23.5 GHz.

3.1.14 Frequency Range 2: For purposes of this document, Frequency Range 2 refers to 23.5 –4 3.5 GHz.

3.1.15 Frequency Range 3: For purposes of this document, Frequency Range 3 refers to 43.5 - 66 GHz.

3.1.16 frequency re-use: A technique for employing a set of frequencies in multiple, closely-spaced cells and/or sectors for the purpose of increasing network traffic capacity.

3.1.17 harmonized transmissions: The use, by multiple operators, of a compatible transmission plan so that the base stations from different operators can share an antenna site and minimize interference. For FDD systems, this implies that each operator's base station transmits in the same frequency sub-block (typically on a different channel) and that their terminals transmit in the corresponding paired sub-block. For TDD systems, harmonization implies frame, slot, and uplink/downlink synchronization.

3.1.18 intercell link: Intercell links interconnect two or more BS units, typically using wireless, fiber, or copper facilities.

3.1.19 mesh: A wireless network topology, known also as multipoint-to-multipoint, in which a number of subscriber stations within a geographic area are interconnected and can act as repeater stations. This allows a variety of routes between the core network and any subscriber station. Mesh systems do not have base stations in the conventional point-to-multipoint sense.

3.1.20 multicarrier system: A system using two or more carriers to provide service from a single transmitter.

3.1.21 multipoint (MP): A generic term for point-to-multipoint and multipoint-to-multipoint and variations or hybrids of these. Multipoint is a wireless topology in which a system provides service to multiple, 3.1.23 OC-3: One hierarchical level in the Synchronous Optical Network transmission standard. The line rate for this level is 155.52 Mbit/s.

Editorial instructions:
-Delete existing definition 3.1.24
-Add new definitions for "block bandwidth" and "channel bandwidth"
-Renumber subsequent definitions to maintain sequence

Old text to be deleted as follows:

"3.1.24 occupied bandwidth (B_O): For a single carrier, B_O is the width of a frequency band such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5% of the total mean power radiated by a given emission. This implies that 99% of the total mean emitted power is within this band, and hence this bandwidth is also known as the 99% bandwidth. When a multicarrier transmission uses a common amplifier stage, the occupied bandwidth of this composite transmission is defined by the following relationship:

$B_{OM} = 1/2\ B_{OU} + 1/2\ B_{OL} + (F_{OU} - F_{OL})$

where:

B_{OM} = Occupied bandwidth of the multicarrier system
B_{OU} = Single-carrier Occupied Bandwidth of the lowermost sub-carrier
F_{OU} = Center frequency of the uppermost sub-carrier
F_{OL} = Center frequency of the lowermost sub-carrier

NOTE 1: This multicarrier definition will give a bandwidth which is slightly wider han the multicarrier 99% power bandwidth. For example, for six identical, adjacent carriers, B O will contain 99.5% of the first carrier, 99.5% of the last carrier and 100% of the four middle carriers and therefore 99.8333% of total mean power.

New text to be added as follows:

"3.1.24 block bandwidth **(*B*):** Block bandwidth *B* is defined to be the contiguous authorized bandwidth available to an operator.

3.1.25 Channel bandwidth **(B_o):** For single carriers, channel bandwidth B_o is defined to be the bandwidth assigned to individual carriers within a block. The channel bandwidth may differ for different carriers within a block. The occupied bandwidth of a carrier within a channel may be less than or equal to the bandwidth of a channel.

When a multicarrier transmission uses a common amplifier stage the channel bandwidth of this composite transmission is defined to be the sum of the channel bandwidths of all of the composite carriers.

NOTE 1: This definition applies to most analog and simple digital emissions (QAM, QPSK, etc.), but its applicability to other more complex modulation structures (e.g., OFDM, CDMA) is still to be determined."

3.1.26 out-of-block emissions (OOB emissions): Emissions from the edge of the authorized bandwidth up to 200% of the occupied bandwidth from the edge of the authorized bandwidth. These emissions occur both above and below the authorized bandwidth.

3.1.27 point-to-multipoint (PMP): In wireless systems, a topology wherein a base station simultaneously services multiple, geographically separated subscriber stations and each subscriber station is permanently associated with only one base station.

3.1.28 point-to-point: A topology in which a radio link is maintained between two stations.

3.1.29 power flux density (pfd): The radiated power flux per unit area.

3.1.30 power spectral flux density (psfd): The radiated power flux per unit bandwidth per unit area.

3.1.31 radiation pattern envelope (RPE): The RPE is a graph that represents the maximum sidelobe levels of an antenna over the specified band.

3.1.32 repeater station (RS): A station other than the BS that includes radio communication equipment facing two or more separate directions. Traffic received from one direction may be partly or wholly retransmitted in another direction. Traffic may also terminate and originate at the repeater station.

3.1.33 service area: A geographic area in which an operator is authorized to transmit.

3.1.34 spectrum disaggregation: Segregation of spectrum to permit several operators access to subportions of a licensee's authorized band.

3.1.35 spurious emissions: Emissions greater than 200% of the occupied bandwidth from the edge of the authorized bandwidth. While this definition is specific to this Recommended Practice, International Telecommunications Union (ITU) Radio Regulation S.145 defines spurious emission as follows: Emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

3.1.36 subscriber station (SS): A generalized equipment set providing connectivity between subscriber equipment and a base station.

3.1.37 synchronized transmissions: Harmonized time-division duplex (TDD) transmissions.

3.1.38 terminal equipment: Terminal equipment encompasses a wide variety of apparatus at customer premises, providing end user services and connecting to subscriber station equipment (SS) via one or more interfaces.

3.1.39 time-division duplex (TDD): A duplex scheme where uplink and downlink transmissions occur at different times but may share the same frequency.

3.1.40 uplink: The direction from a subscriber station to the base station.

3.1.41 unwanted emissions: Out-of-band emissions, spurious emissions, and harmonics.

3.1.42 virtual block edge: A reference frequency used as a block edge frequency for testing of unwanted emissions so as to avoid effects of radio frequency (RF) block filters.

3.1.43 wireless access: End-user radio connection(s) to core networks.

Editorial instruction:

Add the following:

3.1.44 narrowband: The bit rate does not exceed 64 kbit/s.

3.1.45 wideband: The bit rate is above 64 kbit/s and does not exceed the primary rate, also know as "broadband".

3.1.46 % KO area: Percentage area of a P-MP cell area where interference may afflict or arise from TS and "Knock Out" the radio receiver(s).

3.1.47 guard band channel: Unused slice of spectrum between the two closest channels of different operators.

3.1.48 Frequency Range 1: For the purposes of this document, Frequency Range 1 refers to 2-11 GHz.

3.1.49 Net Filter Discrimination: The ratio between the power transmitted by the interfering system and the portion that could be measured after the receiving filter of the useful system.

3.1.50 Rayleigh fading: Is caused by the reception of a large number of reflected waves. Due to wave cancellation effects, the instantaneous received power seen by the antenna becomes a random variable.

3.1.51 Rician distribution: The model behind Rician fading is similar to that for Rayleigh fading, except that in Rician fading a strong dominant component is present. This dominant component can for instance be the line-of-sight wave

3.1.52 ortho mode transducer: Is a waveguide port that allows the reception of two simultaneous polarisation signals with high cross polarisation (isolation) and minimal transmission loss.

3.1.53 Line Of Sight: Where the signal path is >60% clear of obstructions within the Fresnal Zone.

3.1.54 Obscure (or Near Non) Line Of Sight: Where the signal path is >40% but <60% clear of obstructions within the Fresnal Zone.

3.1.55 Non Line Of Sight: Where the signal path is <40% clear of obstructions within the Fresnal Zone.

3.2 Abbreviations

AdjCh	adjacent channel
ATPC	automatic transmit power control
AZ	azimuth
BER	bit error ratio
BFWA	broadband fixed wireless access
B_O	occupied bandwidth
BRAN	broadband radio access networks (an ETSI Project)
BS	base station
BW	bandwidth
BWA	broadband wireless access
CDF	cumulative distribution function
CDMA	code division multiple access
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications (European Conference of Postal and Telecommunication Administrations)
C/I	carrier-to-interference ratio
C/N	carrier-to-noise ratio
C/(N+I)	carrier-to-noise and interference ratio
CoCh	co-channel
CS	central station (used in Annexes only); or channel separation (in 6.1.3 only)
CW	continuous wave
dBc	decibels relative to the carrier level
dBi	gain relative to a hypothetical isotropic antenna
DRS	data relay satellite
DS-3	44.736 Mbit/s line rate
D/U	desired carrier-to-undesired carrier ratio
EL	elevation
EIRP	effective isotropic radiated power
EN	European norm
ERC	European Radiocommunications Committee
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission (USA)
FDD	frequency division duplex
FDMA	frequency division multiple access
FSPL	free space path loss
FWA	fixed wireless access
GSO	geostationary orbit
IA	Interference area
IC	Industry Canada
ICL	interference coupling loss
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers, Inc.
I/N	interference-to-thermal noise ratio
ISOP	interference scenario occurrence probability
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union Œ Radiocommunication Sector
LMCS	local multipoint communication system
LMDS	local multipoint distribution service
LOS	line of sight
MAN	metropolitan area network
MCL	minimum coupling loss
MMDS	multichannel multipoint distribution system
MP	multipoint
MP-MP	multipoint-to-multipoint
MWS	multimedia wireless systems
NFD	net filter discrimination
NLOS	non line of sight
OC-3	155.52 Mbit/s line rate
OFDM	orthogonal frequency division multiplexing
OFDMA	orthogonal frequency division multiple access
OLOS	obstructed line of sight
OOB	out-of-block
PCS	personal communication service
pfd	power flux density
PMP	point-to-multipoint
psd	power spectral density
psfd	power spectral flux density
PTP	point-to-point
QAM	quadrature amplitude modulation
QPSK	quadrature phase shift keying
RA	Radiocommunications Agency
RABC	Radio Advisory Board of Canada
RF	radio frequency
RPE	radiation pattern envelope
RS	repeater station
RSS	Radio Standards Specifications
Rx	receive
SRSP	Standard Radio Systems Plan
SS	subscriber station
TDD	time division duplex
TDMA	time division multiple access
TS	terminal station
Tx	transmit
XPD	cross-polar discrimination

Editorial instructions

-Add new section title for Part 1, as follows

“Part 1 Coexistence of Fixed Broadband Wireless Access Systems operating in the Frequency Range 23.5 – 43.5 GHz”

Editorial instruction: as follows;-

-Insert new scope section, as follows:

“1-1.Scope of part 1

Part 1 of this Recommended Practice defines a set of consistent design and deployment recommendations that promote coexistence for fixed BWA systems that share the same bands. The recommendations have been developed and substantiated by appropriate analyses and simulations. The recommendations, if followed by manufacturers and operators, will facilitate a wide range of equipment to coexist in a shared environment with acceptable mutual interference.

The frequency range considered in Part 1 is 23.5 – 43.5 GHz

The scope of this Part 1 of the Recommended Practice includes the examination of interference between systems deployed across geographic boundaries in the same frequency blocks and systems deployed in the same geographic area in adjacent frequency blocks.

This document is not intended to be a replacement for applicable regulations, which would take precedence.”

1-2. Summary of fixed BWA coexistence recommendations and guidelines

1-2.1 Document philosophy

Radio waves permeate through legislated (and even national) boundaries and emissions spill outside spectrum allocations. Coexistence issues between multiple operators are therefore inevitable. The resolution of coexistence issues is an important factor for the fixed BWA industry. The Recommendations in 1-2.2 are provided for consideration by operators, manufacturers, and administrations to promote coexistence. Practical implementation within the scope of the current recommendations will assume that some portion of the frequency spectrum (at the edge of the authorized bandwidth) may be unusable. Furthermore, some locations within the service area may not be usable for deployment. Coexistence will rely heavily on the good-faith collaboration between spectrum holders to find and implement economical solutions. The document analyzes coexistence using two scenarios:

-A co-channel (CoCh) scenario in which two operators are in either adjacent territories or territories within radio line of sight of each other and have the same spectrum allocation, and

-An adjacent Channel (AdjCh) scenario in which the licensed territories of two operators overlap and they are assigned adjacent spectrum allocations.

Coexistence issues may arise simultaneously from both scenarios as well as from these scenarios involving multiple operators. As a starting point for the consideration of tolerable levels of interference into fixed BWA systems, ITU-R Recommendation F.758-2 [B16] details two generally accepted values for the interference-to-thermal noise ratio (I/N) for long-term interference into fixed service receivers. When considering interference from other services, it identifies an I/N value of -6dB or -10dB matched to specific requirements of individual systems. This approach provides a method for defining a tolerable limit that is independent of most characteristics of the victim receiver, apart from noise figure, and has been adopted for this Recommended Practice. The acceptability of any I/N value needs to be evaluated against the statistical nature of the interference environment. In arriving at the Recommendations in this document this evaluation has been carried out for an I/N value of -6 dB.

Clause 9 provides interference mitigation measures that can be utilized to solve coexistence problems. Because of the wide variation in subscriber station and base station distribution, radio emitter/receiver parameters, localized rain patterns, and the statistics of overlapping emissions in frequency and time, it is impossible to prescribe in this document which of the mitigation measures are appropriate to resolving a particular coexistence problem. In the application of these mitigation measures, identification of individual terminals or groups of terminals for modification is preferable to the imposition of pervasive restrictions.

Implementing the measures suggested in Recommendations 1-8 and 1-9 in 1-2.2 using the suggested equipment parameters in Clause 6 will, besides improving the coexistence conditions, have a generally positive effect on

intrasystem performance. Similarly, simulations performed in the preparation of this Recommended Practice suggest that most of the measures undertaken by an operator to promote intrasystem performance
will also promote coexistence. It is outside the scope of this document to make recommendations that touch on intrasystem matters such as frequency plans, frequency reuse patterns, etc.

1-2.2. Recommendations

Editorial instructions:
-Renumber recommendations 1-1, 1-2 etc
-Update references in text of recommendations as shown
-Delete recommendation 9 entirely
-Renumber subsequent references to maintain sequence
-Delete text in brackets [ ]in recommendation 1-6

1-2.2.1Recommendation 1-1

Adopt a criterion of 6 dB below receiver thermal noise (i.e., I/N = -6 dB) in the victim receiver as an acceptable level of interference from a transmission of an operator in a neighboring area. The document recommends this value in recognition of the fact that it is not practical to insist upon an iinterference-free environment. Having once adopted this value, the following are some important consequences: -Each operator accepts a 1 dB degradation [the difference in dB between C/N and C/(N + I)] in receiver sensitivity. In some regard, an I/N of Œ6 dB becomes the fundamental criterion for coexistence. The very nature of the MP system is that receivers must accept interference from intrasystem transmitters. Although a good practice would be to reduce the intrasystem interference level to be well below the thermal noise level (see Recommendation 1-6 in 4.2.6?), this is not always feasible. The actual level of external interference could be higher than the limit stated above and still be not controlling, or comparable to the operator’s intrasystem interference. Thus, there is some degree of interference allocation that could be used to alleviate the coexistence problem.

- Depending upon the particular deployment environment, an operator’s receiver may have interference contributions from multiple CoCh and AdjCh operators. Each operator should include design margin capable of simultaneously accepting the compound effect of interference from all other relevant operators. The design margin should be included preemptively at initial deployment, even if the operator in question is the first to deploy in a region and is not experiencing interference.

All parties should recognize that, in predicting signal levels that result in the -6 dB interference value, it is difficult to be precise in including the aggregating effect of multiple terminals, the effect of uncorrelated rain, etc. Therefore, all parties should be prepared to investigate claims of interference even if the particular assessment method used to substantiate the -6 dB value predicts that there should not be any interference.

1-2.2.2 Recommendation 1-2

Each operator should take the initiative to collaborate with other known operators prior to initial deployment and prior to every relevant system modification. This recommendation should be followed even if an operator is the first to deploy in a region. To encourage this behavior for co-channel interference, this document introduces the concept of using power spectral flux density values to “trigger” different levels of initiatives taken by an operator to give notification to other operators. The specific trigger values and their application to the two deployment scenarios are discussed in Recommendation 1-5 (4.2.5) and Recommendation 1-6 (4.2.6) and in Clause 7

1-2.2.3 Recommendation 1-3

In the resolution of coexistence issues, in principle, incumbents and first movers should coordinate with operators who deploy at a later time. In resolving coexistence issues, it is legitimate to weigh the capital investment an incumbent operator has made in his or her system. It is also legitimate to weigh the capital investment required by an incumbent operator for a change due to coexistence versus the capital investment costs that the new operator will incur.The logic behind this Recommendation is that some coexistence problems cannot be resolved simply by modifying the system of a new entrant into a region. Rather, they require the willingness of an incumbent to make modifications as well. It is recognized that this Recommendation is especially challenging in the AdjCh scenario where overlapping territories imply that the incumbent and the late-comer may be competing for the same clients. The reality of some spectrum allocations are such that AdjCh operators will be allocated side-by-side frequency channels. As is seen below, this is an especially difficult coexistence
problem to resolve without co-location of the operator's cell sites.

1-2.2.4 Recommendation 1-4

No coordination is needed in a given direction if the transmitter is greater than 60 km from either the service area boundary or the neighbor's boundary (if known) in that direction. Based on typical fixed BWA equipment parameters and an allowance for potential LOS interference couplings, subsequent analysis indicates that a 60 km boundary distance is sufficient to preclude the need for coordination. At lesser distances, coordination may be required, but this is subject to a detailed examination of the specific transmission path details that may provide for interference link excess loss or blockage. This coordination criteria is viewed to be necessary and appropriate for both systems that conform to this Recommended Practice and those that do not.

Editorial instruction:
-Delete this text from Recommendation 1-5 "…In cases of significant deployment of point-to-point systems alongside point-to-multipoint systems where protection of the point-to-point systems is mandated, tighter psfd trigger levels may be appropriate For example, -125 (dBW/m^2)/MHz at 38 GHz band is applied by some administrations to protect point-to-point links."

1-2.2.5 Recommendation 1-5

(This Recommendation applies to co-channel cases only.) Recommendation 1-2 above introduced the concept of using power spectral flux density "triggers" as a stimulus for an operator to take certain initiatives to collaborate with his or her neighbor. It is recommended that regulators specify the applicable trigger values for each frequency band, failing which the following values may be adopted: The coordination trigger values (see Annex B) of -114 (dBW/m^2)/MHz (24, 26, and 28 GHz bands) and -111 (dBW/m^2)/MHz (38 and 42 GHz bands) are employed in the initiative procedure described in Recommendation 1-6 (1-2.2.6). The evaluation point for the trigger exceedance may be at either the victim operator's licensed area boundary, the interfering operator's boundary, or at a defined point in between depending to some extent on the specific geographic circumstances of the BWA licensing. These values were derived as that power spectral flux density values which, if present at a typical point-to-multipoint base station antenna and typical receiver, would result in approximately the -6 dB interference value cited in Recommendation 1. It should be emphasized that the trigger values are useful only as thresholds for taking certain actions with other operators; they do not make an absolute statement as to whether there is, or is not, interference potential. [In cases of significant deployment of point-to-point systems alongside point-to-multipoint systems where protection of the point-to-point systems is mandated, tighter psfd trigger levels may be appropriate For example, -125 (dBW/m^2)/MHz at 38 GHz band is applied by some administrations to protect point-to-point links.]

1-2.2.6 Recommendation 1-6

(This Recommendation applies to co-channel cases only.)
The "triggers" of Recommendation 1-5 [and Recommendation 6] should be applied prior to deployment and prior to each relevant system modification. Should the trigger values be exceeded, the operator should try to modify the deployment to meet the trigger or, failing this, the operator should coordinate with the affected operator. Three existing coordination procedures are described in D, E, and F.

1-2.2.7 Recommendation 1-7

For same area/adjacent channel interference cases, analysis and simulation indicate that deployment may require an equivalent guard frequency between systems operating in close proximity and in adjacent frequency blocks. It is convenient to think of the "guard frequency" in terms of "equivalent channels" related to the systems operating at the edges of the neighboring frequency blocks. The amount of guard frequencylg depends on a variety of factors such as "out of block" emission levels and in some cases is linked to the probability of interference in given deployment scenarios. Clause 8 provides insight into some methods that can be employed to assess these situations, while Clause 9 describes some possible interference mitigation techniques. These mitigation techniques include frequency guard bands, recognition of cross-polarization differences, antenna angular discrimination, spatial location differences, and frequency assignment substitution. In most co-polarized cases, where the transmissions in each block are employing the same channel bandwidth, the guard frequency should be equal to one equivalent channel. Where the transmissions in neighboring blocks employ significantly different channel bandwidths, it is likely that a guard frequency equal to one equivalent channel of the widest bandwidth system will be adequate. However, analysis suggests that, under certain deployment circumstances, this may not offer sufficient protection and that a guard frequency equal to one channel at the edge of each operator's block may be required. Where administrations do not set aside guard channels, the affected operators would need to reach agreement on how the guard channel is apportioned between them. It is possible that, with careful and intelligent frequency planning, coordination, and/or use of orthogonal polarization or other mitigation techniques, all or partial use of this guard channel may be achieved. However, in order to minimize interference conflicts and at the same time maximize spectrum utilization, cooperative deployment between operators will be essential. This recommendation strongly proposes this.

1-2.2.8 Recommendation 1-8

Utilize antennas for the base station and subscriber stations at least as good as the Class 1 antennas described in 6.2. The coexistence simulations which led to the Recommendations contained herein revealed that a majority of coexistence problems are the result of main-beam interference. The sidelobe levels of the base station antennas are of a significant but secondary influence. The sidelobe levels of the subscriber antenna are of tertiary importance. In the context of coexistence, therefore, antennas such as those presented in 6.2 are sufficient. It should be emphasized that utilizing antennas with sidelobe (and polarization) performance better than the minimum will not degrade the coexistence performance and, in fact, is an effective mitigation technique for specific instances. In many cases, intrasystem considerations may place higher demands on antenna performance than those required for intersystem coordination.

[Recommendation 9

Utilize an emission mask at least as good as that described in 6.1.3. The utility of emission masks for controlling adjacent channel coexistence issues is strongly dependent upon the separation of the two emitters in space and in frequency. In case of large spatial separation between emitters, the opportunity exists for an interfering emitter to be much closer to a receiver than the desired emitter. This unfavorable range differential can overwhelm even the best emission mask. Likewise, emission masks are most effective when at least one guard channel exists between allocations. The emission mask presented in 6.1.3 is most appropriate for the case in which a guard channel separates allocations and emitters are modestly separated. For cases with no guard band, it is recommended that co-location of harmonized base station emitters be considered before trying to improve emission masks.]

1-2.2.9 Recommendation 1-9

Limit maximum EIRP in accordance with recommendations in 6.1.1 and use SS power control in accordance with recommendations in 6.1.1.5. The interests of coexistence are served by reducing the amount of EIRP emitted by base, SS, and repeater stations. The proposed maximum EIRP spectral density values are significantly less than allowed by some regulatory agencies but should be an appropriate balance between constructing robust fixed BWA systems and promoting coexistence.

1-2.2.10 Recommendation 1-10

In conducting analyses to predict power spectral flux density and for coordination purposes, the following should be considered:

a) Calculations of path loss to a point on the border should consider:
1) Clear air (no rain) plus relevant atmospheric absorption
2) Intervening terrain blockage

b) For the purpose of calculating psfd trigger compliance level, the psfd level at the service area boundary should be the maximum value which occurs at some elevation point up to 500 m above local terrain elevation. Equations (B.2) and (B.3) in Annex B should be used to calculate the psfd limits.

c) Actual electrical parameters (e.g., EIRP, antenna patterns, etc.) should be used.

d) Clear sky propagation (maximum path length) conditions should be assumed. Where possible, use established ITU-R Recommendations relating to propagation (e.g., Recommendation ITU-R P.452 [B20]).

1-2.3 Suggested guidelines for geographical and frequency spacing

This subclause and Clause 8 indicate some of the models, simulations, and analysis used in the preparation of this Recommended Practice. While a variety of tools may be used, the scenarios studied below should be considered when coordination is required. Guidelines for geographical and frequency spacing of fixed BWA systems that would otherwise mutually interfere are given in 8.1 for each of a number of interfering mechanisms. This subclause summarizes the overall guidelines, taking into account all the identified interference mechanisms. The two main deployment scenarios are as follows:

- Co-channel systems that are geographically spaced
- Systems that overlap in coverage and (in general) require different frequencies of operation

Editorial instruction
-delete colon after “Table 1”

The most severe of the several mechanisms that apply to each case determines the guideline spacing, as shown in Table 1.1

The guidelines are not meant to replace the coordination process described in Clause 7. However, in many (probably most) cases, these guidelines will provide satisfactory psfd levels at system boundaries. The information is therefore valuable as a first step in planning the deployment of systems.

1-3 System overview

BWA generally refers to fixed radio systems used primarily to convey broadband services between users’ premises and core networks. The term “broadband” is usually taken to mean the capability to deliver significant bandwidth to each user. In ITU terminology, and in this document, broadband transmission refers to transmission rate of greater than around 1.5 Mbit/s, though many BWA networks support significantly

Table 1.1: Summary of the guidelines for geographical and frequency spacing

Dominant interference path(note 1)	**Scenario**	**Spacing at which interference is below target level (generally 6 dB below receiver noise floor)**
PMP BS to PMP BS	Adjacent area, same channel	60 km (note 5)
Mesh SSs to PMP BS	Adjacent area, same channel	12 km (note 2)
PMP BS to PMP BS	Same area, adjacent channel	1 guard channel (notes 3 and 5)
Mesh SSs to PMP SS	Same area, adjacent channel	1 guard channel (note 4)

NOTES
1 -The dominant interference path is that which requires the highest guideline geographical or frequency spacing.
2 -The 12 km value is based on a BS at a typical 50 m height. For other values, the results change to some extent, but are always well below the 60 km value calculated for the PMP - PMP case.
3 -The single guard channel spacing is based on both interfering and victim systems using the same channel size. Where the transmissions in neighboring blocks employ significantly different channel bandwidths then it is likely that a guard frequency equal to one equivalent channel of the widest bandwidth system will be adequate. However, analysis suggests that, under certain deployment circumstances, this may not offer sufficient protection and that a guard frequency equal to one channel at the edge of each operator's block may be required.
4 -The single guard channel spacing for mesh to PMP is based on both interfering and victim systems using the same channel size. This may be reduced in some circumstances. Where the transmissions in neighboring blocks employ significantly different channel bandwidths, it is likely that a guard frequency equal to one equivalent channel of the widest bandwidth system will be adequate. However, analysis suggests that under certain deployment circumstances this may not offer sufficient protection and that a guard frequency equal to one channel at the edge of each operator's block may be required.
5 -In a case of harmonized FDD band plans and/or frequency reassignable TDD systems, the BS-to-BS case ceases to be dominant.

higher data rates. The networks operate transparently, so users are not aware that services are delivered by radio. A typical fixed BWA network supports connection to many user premises within a radio coverage area. It provides a pool of bandwidth, shared automatically among the users. Demand from different users is often statistically of low correlation, allowing the network to deliver significant bandwidth-on-demand to many users with a high level of spectrum efficiency. Significant frequency reuse is employed.

The range of applications is very wide and evolving quickly. It includes voice, data, and entertainment services of many kinds. Each subscriber may require a different mix of services; this mix is likely to change rapidly as connections are established and terminated. Traffic flow may be unidirectional, asymmetrical, or symmetrical, again changing with time. In some territories, systems delivering these services are referred to as multimedia wireless systems (MWS) in order to reflect the convergence between traditional telecommunications services and entertainment services.

These radio systems compete with other wired and wireless delivery means for the “first mile” connection to services. Use of radio or wireless techniques result in a number of benefits, including rapid deployment and relatively low “up-front” costs.

1-3.1 System architecture

Editing instructions:
-Change “IEEE….is developing” to “IEEE……has developed a standard for PMP systems operating in frequency range 1”
-Change “is being developed” to “has been developed”
-Delete “7” after “BRAN”
- Delete penultimate sentence

Fixed BWA systems often employ multipoint architectures. The term multipoint includes point-to-multipoint (PMP) and multipoint-to-multipoint (MP-MP). The IEEE 802.16 Working Group on Broadband Wireless Access (see Clause 2) has developed a standard for PMP systems operating in frequency range 1 with base stations and subscriber stations communicating over a fully specified air interface. A similar PMP standard has been developed is being developed within the “HIPERACCESS” topic within ETSI Project BRAN [7] [Coexistence specifications for MWS (which includes the requirements for HIPERACCESS) are being prepared by the ETSI TM4 committeee 3.]. In addition, a number of proprietary fixed BWA systems exist for which the air interface is not standardized.

1-3.1.1 PMP Systems

PMP systems comprise base stations, subscriber stations and, in some cases, repeaters. Base stations use relatively wide-beam antennas, divided into one or several sectors providing up to 360-degrees coverage with one or more antennas. To achieve complete coverage of an area, more than one base station may be required. The connection between BSs is not part of the fixed BWA network itself, being achieved by use of radio links, fiber optic cable, or equivalent means.

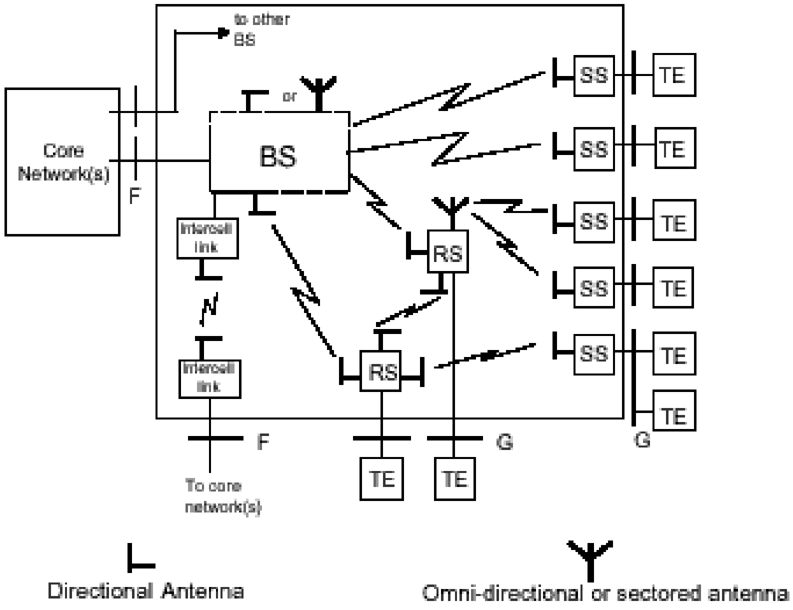
Links between BSs may sometimes use part of the same frequency allocation as the fixed BWA itself. Routing to the appropriate BS is a function of the core network. Subscriber stations use directional antennas, facing a BS and sharing use of the radio channel. This may be achieved by various access methods, including frequency division, time division, or code division.

1-3.1.2 MP systems (Mesh)

Multipoint-to-multipoint (MP-MP) systems have the same functionality as PMP systems. Base stations provide connections to core networks on one side and radio connection to other stations on the other. A subscriber station may be a radio terminal or (more typically) a repeater with local traffic access. Traffic may pass via one or more repeaters to reach a subscriber. Antennas are generally narrow-beam directional types, with means for remote alignment.

1-3.2 System components

Fixed broadband wireless access systems typically include base stations (BS), subscriber stations (SS), subscriber terminal equipment, core network equipment, intercell links, repeaters, and possibly other equipment. [1]A reference fixed BWA system diagram is provided in Figure 1. This diagram indicates the relationship between various components of a BWA system. BWA systems may be much simpler and contain only some elements of the network shown in Figure 1.[5] A fixed BWA system contains at least one BS and a number of SS units. In the figure, the wireless links are shown as zigzag lines connecting system elements. Intercell links may use wireless, fiber, or copper facilities to interconnect two or more BS units. Intercell links may, in some cases, use in-band point to point (PTP) radios that provide a wireless backhaul capability between base stations at rates ranging from DS-3 to OC-3. Such PTP links may operate under the auspices of the PMP license.



Editorial Instructions:

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-Delete source statement [SOURCE: ETSI 301 390 v1.1.1 (2000 – 12)] and move to after figs 8 and 9
-Delete figure 1 caption [**Figure 1 – Interference Sources to a fixed BWA BS]** and replace with "Figure 1.1; Reference Diagram for Fixed BWA Systems"

Antennas with a variety of radiation patterns may be employed. In general, a subscriber station utilizes a highly directional antenna. Some systems deploy repeaters. In a PMP system, repeaters are generally used to improve coverage to locations where the BS(s) have no line of sight within their normal coverage area(s), or alternatively to extend coverage of a particular BS beyond its normal transmission range. A repeater relays information from a BS to one or a group of SSs. It may also provide a connection for a local subscriber station. A repeater may operate on the same downlink frequencies as those frequencies that it uses, facing the BS, or it may use different frequencies (i.e., demodulate and remodulate the traffic on different channels). In MP-MP systems, most stations are repeaters that also provide connections for local subscribers.

The boundary of the fixed BWA network is at the interface points F and G of Figure 1. The F interfaces are points of connection to core networks and are generally standardized. The G interfaces, between subscriber stations and terminal equipment, may be either standardized or proprietary.

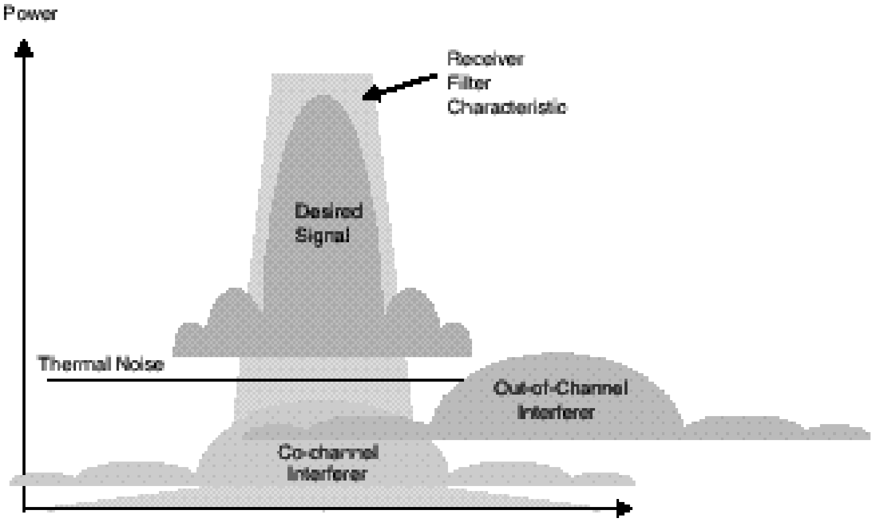
1-3.3 Medium Overview

Electromagnetic propagation over Frequency Ranges 1-3 (10-66 GHz) is relatively nondispersive, with occasional but increasingly severe rain attenuation as frequency increases. Absorption of emissions by terrain and human-generated structures is severe, leading to the normal requirement for optical line-of-sight between transmit and receive antennas for satisfactory performance. Radio systems in this frequency regime are typically thermal or interference noise-limited (as opposed to multipath-limited) and have operational ranges of a few kilometers due to the large free-space loss and the sizable link margin which has to be reserved for rain loss. At the same time, the desire to deliver sizable amounts of capacity promotes the use of higher-order modulation schemes with the attendant need for large C/I for satisfactory operation. Consequently, the radio systems are vulnerable to interference from emissions well beyond their operational range. This is compounded by the fact that the rain cells producing the most severe rain losses are not uniformly distributed over the operational area This creates the potential for scenarios in which the desired signal is severely attenuated but the interfering signal is not.

1-3.3.1 Interference Scenarios

1-3.3.1.1 Forms of Interference

Interference can be classified into two broad categories: co-channel interference and out-of-channel interference. These manifest themselves as shown in Figure 1.2. [6]



SOURCE: ETSI EN 301 390 V1.1.1. (2000-12), Fixed Radio Systems; Point-to-Point and Point-to-Multipoint Systems; Spurious Emissions and Receiver Immunity at Equipment/Antenna Port of Digital Fixed Radio Systems.

Figure 1.2- Forms of Interference

Editorial Instruction

-Delete ETSI acknowledgement (SOURCE:…….) as this diagram is an IEEE contribution, and not from the referenced ETSI standard.

Figure 2 illustrates the power spectrum of the desired signal and co-channel interference in a simplified example. Note that the channel bandwidth of the co-channel interferer may be wider or narrower than the desired signal. In the case of a wider co-channel interferer (as shown), only a portion of its power will fall within the receive filter bandwidth. In this case, the interference can be estimated by calculating the power arriving at the receive antenna and then multiplying by a factor equal to the ratio of the filter's bandwidth to the interferer's bandwidth.

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An out-of-channel interferer is also shown. Here, two sets of parameters determine the total level of interference as follows:

A portion of the interferer's spectral sidelobes or transmitter output noise floor falls co-channel to the desired signal; i.e., within the receiver filter's passband. This can be treated as co-channel interference. It cannot be removed at the receiver; its level is determined at the interfering transmitter. By characterizing the power spectral density of sidelobes and output noise floor with respect to the main lobe of a signal, this form of interference can be approximately computed in a manner similar to the co-channel interference calculation, with an additional attenuation factor due to the suppression of this spectral energy with respect to the main lobe of the interfering signal. The main lobe of the interferer is not completely suppressed by the receiver filter of the victim receiver. No filter is ideal, and residual power, passing through the stopband of the filter, can be treated as additive to the co-channel interference present. The level of this form of interference is determined by the performance of the victim receiver in rejecting out-of-channel signals, sometimes referred to as "blocking" performance. This form of interference can be simply estimated in a manner similar to the co-channel interference calculation, with an additional attenuation factor due to the relative rejection of the filter's stopband at the frequency of the interfering signal.

Quantitative input on equipment parameters is required to determine which of the two forms of interference from an out-of-channel interferer will dominate.

1-3.3.1.2 Acceptable level of interference

A fundamental property of any millimeter-wave fixed BWA system is its link budget, in which the range of the system is computed for a given availability, with given rain fading. During the designed worst-case rain fade, the level of the desired received signal will fall until it just equals the receiver thermal noise, kTBF, (where k is Boltzmann's constant, T is the temperature, B is the receiver bandwidth, and F is the receiver noise), plus the specified signal-to-noise ratio of the receiver. A way to account for interference is to determine C/(N + I), the ratio of carrier level to the sum of noise and interference. For example, consider a receiver with 6 dB noise figure. The receiver thermal noise is -138 dBW/MHz. Interference of -138 dBW/MHz would double the total noise, or degrade the link budget by 3 dB. Interference of -144 dBW/MHz, 6 dB below the receiver thermal noise, would increase the total noise by 1 dB to -137 dBW/MHz, degrading the link budget by 1 dB.

For a given receiver noise figure and antenna gain in a given direction, the link budget degradation can be related to a received power flux density tolerance. In turn, this tolerance can be turned into separation distances for various scenarios.

1-3.3.1.3 Interference paths

1-3.3.1.3.1 Victim BS

Figure 1.3 shows main sources of interference where the victim receiver is a fixed BWA base station, with a sectoral-coverage antenna.

The victim BS is shown as a black triangle on the left, with its radiation pattern represented as ellipses. The desired SS transmitter is shown on lower right of figure. In the worst case, the desired signal travels through localized rain cell, and is received at minimum signal strength. Thus, interference levels close to the thermal noise floor are significant.

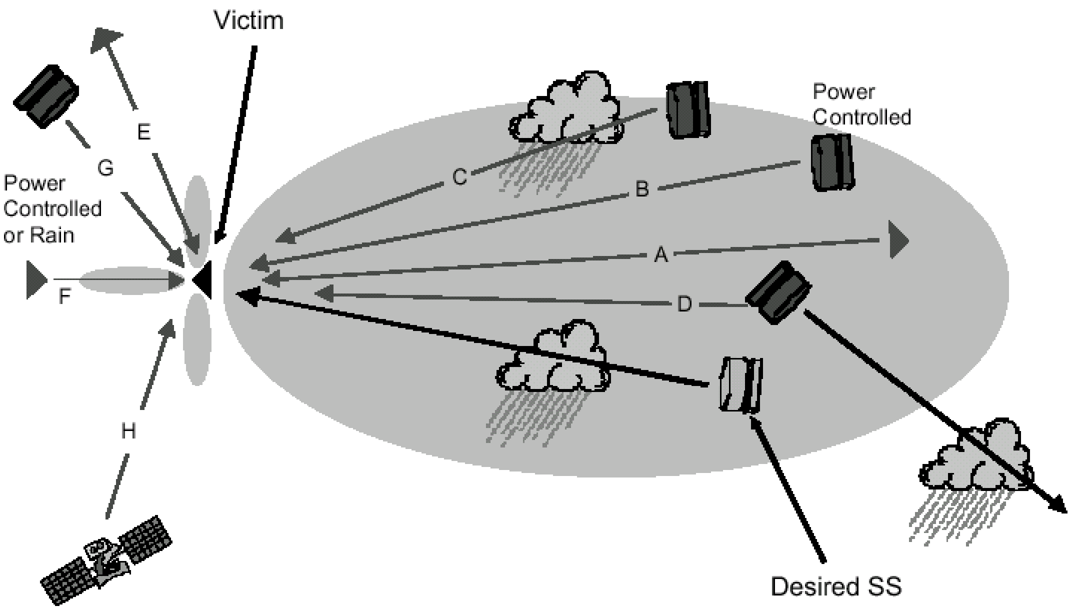


Figure 1.3 – Interference sources to a fixed BWA BS

The letters in Figure 1.3 illustrate several cases of interference to a base station.

Case A shows BS-to-BS interference in which each BS antenna is in the main beam of the other. This case could occur commonly, as sector coverage angles tend to be wide_up to 90º. In fact, a victim BS could tend to see the aggregate power of several BSs. In addition, BS antennas tend to be elevated, with a high probability of a line-of-sight path to each other. As rain cells can be very localized, it is quite conceivable that the interferer travels on a path relatively unattenuated by rain, while the desired signal is heavily attenuated. BS-to-BS interference can be reduced by ensuring that there is no co-channel BS transmission on frequencies being used for reception at other BSs. This is possible with FDD through cooperative band planning, whereby vendors agree to use a common sub-band for BS transmissions and another common subband for BS reception.

Case B shows SS-to-BS interference in which each antenna is in the main beam of the other. As SS antenna gain is much higher than the BS antenna gain, this might appear to be the worst possible case. However, fixed BWA PMP systems can safely be assumed to employ uplink adaptive power control at subscriber stations (Power control is required to equalize the received signal strength arriving at a BS from near and far SSs on adjacent channels. Note that active control of downlink power from BS transmitters is usually not employed, as the BS signal is received by a variety of SSs, both near and far, and power control would tend to create an imbalance in the level of signals seen from adjacent sectors.) Assuming that the subscriber station in Case B sees clear air, it can be assumed to have turned its power down, roughly in proportion to the degree of fade margin of its link. Note, however, that power control is imperfect, so the degree of turndown may be less than the fade margin. The turn-down compensates for the fact that the SS antenna has such high gain, so the net effect is that Case B may not be more severe than Case A. In addition, the narrow beamwidth of a SS antenna ensures that Case B is much less common an occurrence than Case A. However, Case B interference cannot be eliminated by band planning. Case B also covers interference generated by terrestrial point-to-point transmitters.

Case C is similar to Case B, except the interferer is assumed to see a rain cell and therefore does not turn down its power. However, as the interferer's beamwidth is narrow, the interference must also travel through this rain cell on the way to the victim receiver; hence, the net result is roughly the same as Case B. Because power control tracks out the effect of rain, interference analysis can be simplified: we need consider either Case B or Case C but not both. Thus Case B is more conservative with imperfect power control; i.e., the turn-down will tend to be less than the fade margin, so the net received power at the victim receiver is several dB higher than Case C.

Case D is similar to Case C, except the interference is stray radiation from a sidelobe or backlobe of the SS antenna. In the worst case, the SS antenna sees rain towards its intended receiver and therefore does not turn down its power. Modeling of this case requires assumptions of the sidelobe and backlobe suppression of typical SS antennas. These assumptions need to take into account scattering from obstacles in the mainlobe path appearing as sidelobe emissions in real-world installations of SS antennas; an antenna pattern measured in a chamber is one thing while the effective pattern installed on a rooftop is another. If effective sidelobe and backlobe suppression exceeds the power turn down assumption for clear skies, then Case B dominates and Case D need not be considered. The only exception is where Case D models a source of interference that is not a fixed BWA system but a point-to-point transmitter or a satellite uplink. In these cases, the transmit parameters may be so different from a fixed BWA subscriber station that the interference could be significant.

Case E is another case of BS-to-BS interference. In this case, the interfering BS's main beam is in the victim's sidelobe or backlobe. In a related scenario, (not shown), the interfering BS's sidelobe is in the victim's main lobe. As fixed BWA systems tend to employ intensive frequency reuse, it is likely that Case A concerns will dominate over Case E.

Case F covers BS-to-BS backlobe-to-backlobe or sidelobe-to-sidelobe. The low gains involved here ensure that this is a problem only for co-deployment of systems on the same rooftop. Like all sources of BS-to-BS interference, this can be virtually eliminated in FDD via a coordinated band plan.

Case G covers interference from an SS antenna to the victim BS's sidelobe or backlobe. Referring to the commentary concerning Cases B and C, we need only consider the clear air case and assume the interferer has turned down its power. As BS antennas see wide fields of view, Case B is expected to dominate and Case G need not be considered.

Finally, **Case H** covers interference from a satellite downlink or stratospheric downlink. This case is not included in this Recommended Practice.With the above simplifying assumptions, the dominant sources of interference which require detailed modeling are shown in Figure 4. Case A will tend to dominate unless there is a harmonized band plan for the use of FDD. It will be of concern for unsynchronized TDD or unharmonized FDD. Case B is always a concern. Case D is probably of less concern than Case B when the interferer is a fixed BWA system, but could be significant if the interferer is a higher-power point-to-point transmitter or satellite uplink. Case F is a concern only for co-sited BSs and can be largely mitigated by the use of a harmonized band plan with FDD.

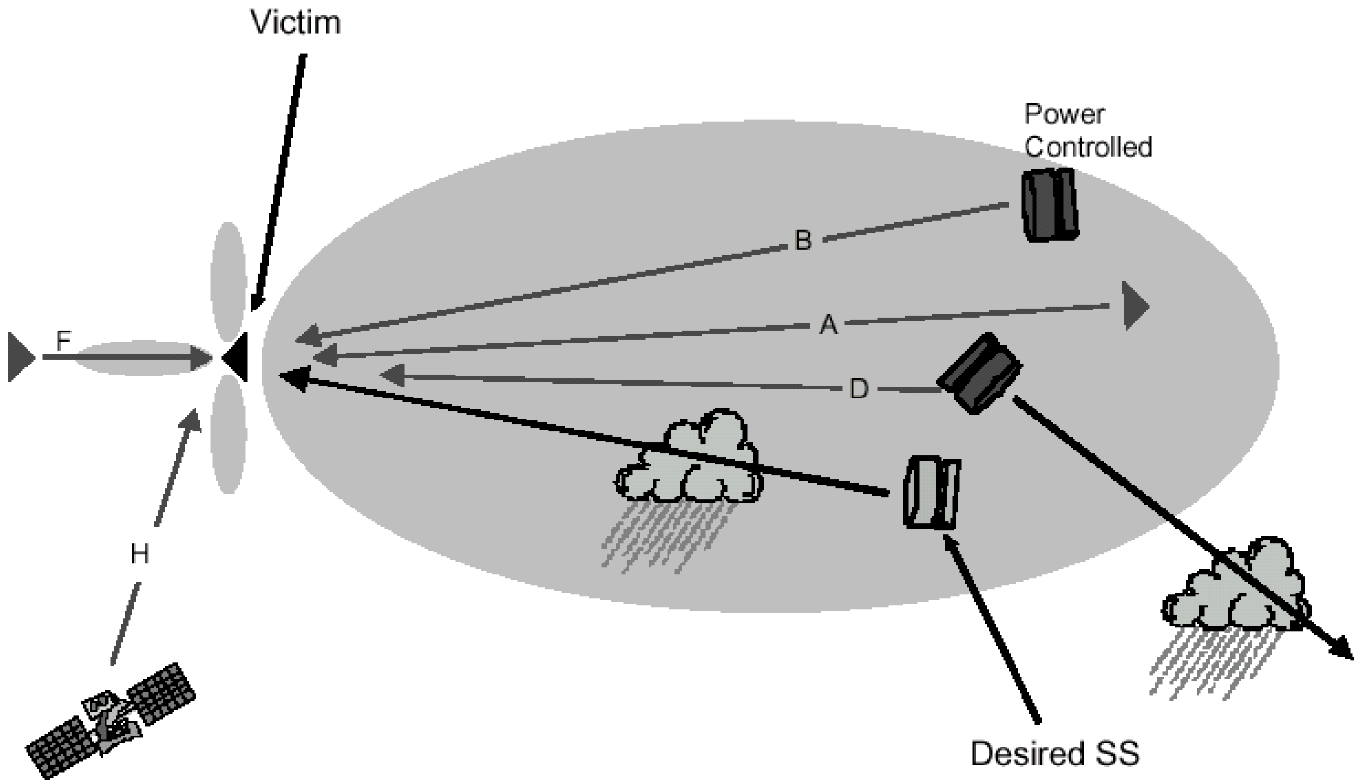


Figure 1.4 Simplified model for interference to a fixed BWA BS

1-3.3.1.3.2 Victim subscriber station

Figure 1.5 shows the main sources of interference to a subscriber station having a narrow beamwidth antenna.

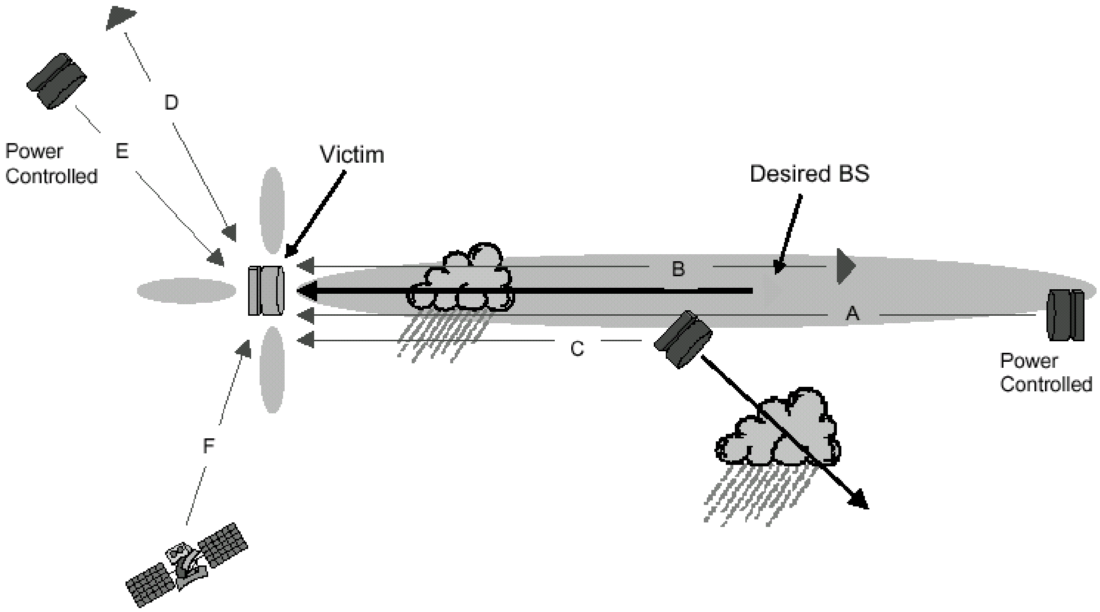


Figure 1.5 Interference sources to affixed BWA subscriber station

The victim subscriber station is shown along with its radiation pattern (ellipses). The BS and several interferers are also shown. The victim SS cases are fundamentally different from the victim BS cases because the antenna pattern is very narrow. If the desired signal is assumed to be attenuated due to a rain cell, then interference arriving in the main lobe must also be assumed to be attenuated. The letters in Figure 5 illustrate several cases of interference to a subscriber station:

Case A covers SS-to-SS interference where the beams are colinear (which is relatively rare). In these cases, the interferer is generally far away from the victim; therefore, it may be assumed that the rain cell attenuating the interference as it arrives at the victim is not in the path from the interferer to its own BS. In this case, the interferer sees clear air and turns down its power.

Case B covers BS-to-SS interference.

Case C covers the case of a narrow-beam transmitter (fixed BWA or point-to-point) or satellite uplink at full power, due to rain in its path, but radiating from its sidelobe towards the victim. This case is more likely to occur than Case A because it could occur with any orientation of the interferer.

Case D covers BS-to-SS interference picked up by a sidelobe or backlobe of the victim. This case could be common because BSs radiate over wide areas, and this case could occur for any orientation of the victim.

Case E covers SS-to-SS interference picked up by a sidelobe or backlobe of the victim. Similar to reasoning in the victim BS cases B and C, the worst case can be assumed to be clear-air in the backlobe with the interferer having turned its power down.

Case F covers interference from a satellite downlink or stratospheric downlink. This case is not included in this Recommended Practice.

1-4 Equipment design parameters

This clause provides recommendations for equipment design parameters which significantly affect interference levels and hence coexistence. Recommendations are made for the following fixed BWA equipwment: base station equipment, subscriber station equipment, repeaters and intercell links (including PTP equipment). Recommendations are for both transmitter and receiver portions of the equipment design. The recommended limits are applicable over the full range of environmental conditions for which the equipment is designed to operate, including temperature, humidity, input voltage, etc.

NOTE-The following design parameters apply to Frequency Range 2 (23.5-43.5 GHz), unless otherwise indicated.

1-4.1 Transmitter design parameters

This subclause provides recommendations for the design of both subscriber and base station transmitters to be deployed in fixed broadband wireless access systems. Recommendations are also made for repeaters and intercell links.

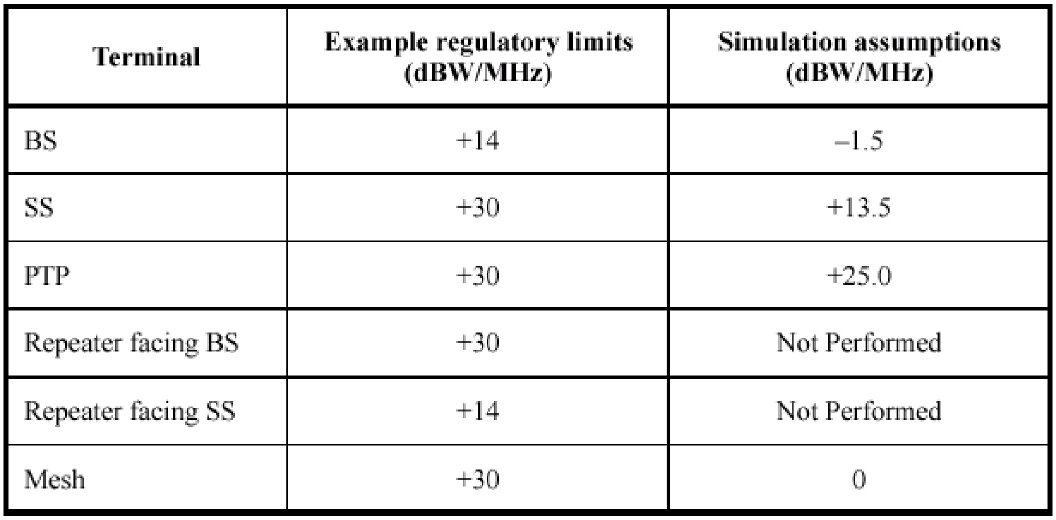
1-4.1.1 Maximum EIRP spectral density limits

The degree of coexistence between systems depends on the emission levels of the various transmitters. Thus, it is important to recommend an upper limit on transmitted power, or, more accurately, a limit for the equivalent isotropically radiated power (EIRP). Since point-to-multipoint systems span very broad frequency bands and utilize many different channel bandwidths, a better measure of EIRP for coexistence purposes is in terms of power spectral density (psd) expressed in dBW/MHz rather than simply power in dBW.

The following paragraphs provide recommended EIRP spectral density limits. These limits apply to the mean EIRP spectral density produced over any continuous burst of transmission. (Any pulsed transmission duty factor does not apply.) The spectral density should be assessed with an integration bandwidth of 1 MHz; i.e., these limits apply over any 1 MHz bandwidth.

In preparing this Recommended Practice, emission limits from current (July 2000) US FCC (Part 101 section 101.113), Industry Canada (SRSP 324.25 12, SRSP 325.35 13, and SRSP 338.6 14), and ITU-R regulations and recommendations (ITU-R F.1509, 15, 17, and 18) were reviewed. Table 2 depicts some example regulatory EIRP spectral density limits.

Table 1.2 – Comparison of typical regulatory and coexistence simulation eirp spectral densities



Terminal	Example regulatory limits (dBW/MHz)	Simulation assumptions (dBW/MHz)
BS	+14	–1.5
SS	+30	+13.5
PTP	+30	+25.0
Repeater facing BS	+30	Not Performed
Repeater facing SS	+14	Not Performed
Mesh	+30	0

Although it is possible that the regulatory limits may be approached in the future, these emission limits are significantly higher (e.g., 15 dB) than supported by most currently available equipment. They are also significantly higher than those utilized by the coexistence simulations, which considered reasonable cell sizes, link budgets and availabilities and were the basis for the recommendations contained in this Recommended Practice. Table 2 compares regulatory limits to those used in simulations. Typical parameters used for the BS and in coexistence simulations for this Recommended Practice are as follows:

Tx Power: +24 dBm (-6 dBW)
SS Antenna Gain: +34 dBi
BS Antenna Gain: +19 dBi
Carrier Bandwidth: 28 MHz (+14.47 dB-MHz)

It is recommended that any regulatory limits be viewed by the reader as future potential capabilities and that, where possible, actual deployments should use much lower EIRP spectral density values as suggested in 6.1.1.1 through 6.1.1.4. If systems are deployed using the maximum regulatory limits, they should receive a detailed interference assessment unless they are deployed in isolated locations, remote from adjacent operators. The assessment is needed to check consistency with the one guard channel recommendation for the same area/adjacent channel case (see Recommendation 7 in 4.2.7).

1-4.1.1.1 Base station (BS)

A BS conforming to the recommendations of this Recommended Practice should not produce an EIRP power spectral density exceeding +14 dBW/MHz. However, it is strongly recommended that a maximum EIRP power spectral density of 0 dBW/MHz be used in order to comply with the one guard channel recommendation for the same area/adjacent channel case (see Recommendation 7 in 4.2.7). The spectral density should be assessed with an integration bandwidth of 1 MHz; i.e., these limits apply over any 1 MHz bandwidth.

For the specific subband 25.25-25.75 GHz, the recommended BS EIRP spectral limits as stated in ITU-R F.1509 should be observed.

1-4.1.1.2 ***Subscriber station (SS)***

A SS conforming to the recommendations of this Recommended Practice should not produce an EIRP spectral density exceeding +30 dBW/MHz. However, it is strongly recommended that a maximum EIRP power spectral density of +15 dBW/MHz be used in order to comply with the one guard channel recommendation for the same area/adjacent channel case (see Recommendation 7 in 4.2.7). Note the stated limits apply to the SS operating under faded conditions (rain attenuation). Power control is recommended for unfaded conditions, as described in 6.1.1.5.

NOTE- For the specific sub-band 25.25-25.75 GHz, the recommended SS EIRP limits as stated in ITU-R F.1509 should be observed and are summarized as follows:

Transmitter of an SS in a fixed BWA system or transmitters of point-to-point fixed stations: Where practicable, the EIRP spectral density for each transmitter of an SS of a fixed BWA system, or transmitters of point-to-point fixed stations in the direction of any geostationary (GSO) data relay satellite (DRS) orbit location specified in ITU-R Recommendation ITU-R SA.1276, should not exceed +24 dBW in any 1 MHz.

1-4.1.1.3 ***Repeater station***

Several types of repeaters are possible (see 5.2). From the point of view of EIRP spectral density limits, two recommendations are given, according to the direction faced by the repeater and type of antenna used. The first recommended limit applies to situations where a repeater uses a sectored or omni-directional antenna, typically facing a number of SSs. The second case applies where a repeater uses a highly directional antenna, typically facing a BS or single SS.

Fixed BWA repeater stations systems deploying directional antennas and conforming to the equipment requirements of this Recommended Practice should not produce an EIRP spectral density exceeding +30 dBW/MHz. However, it is strongly recommended that a maximum EIRP power spectral density of +15 dBW/MHz be used in order to comply with the one guard channel recommendation for the same area/adjacent channel case (see Recommendation 7 in 4.2.7).

Fixed BWA repeater stations deploying omni-directional or sectored antennas and conforming to the equipment requirements of this Recommended Practice should not produce an EIRP spectral density exceeding +14 dBW/MHz. However, it is strongly recommended that a maximum EIRP power spectral density of 0 dBW/MHz be used in order to comply with the one guard channel recommendation for the same area/adjacent channel case (see Recommendation 7 in 4.2.7).

1-4.1.1.4 ***In-band intercell links***

An operator may employ point to point links that use adjacent channel or co-channel frequencies and that are in the same geographical area as a point to multipoint system. If the recommendations for SS EIRP in 6.1.1.2 and unwanted emissions in 6.1.3 are applied to these links, then they can operate within the coexistence framework described in this document. If not, then re-evaluation of the coexistence recommendations is recommended.

1-4.1.1.5 Uplink power control

A SS conforming to the equipment design parameters recommended by this Recommended Practice should employ uplink power control with at least 15 dB of dynamic range. Simulation results described in other sections of this document demonstrate that such a range is necessary in order to facilitate coexistence.

1-4.1.1.6 Downlink power control

This Recommended Practice assumes that no active downlink power control is employed. However, it is recommended that the minimum power necessary to maintain the links be employed. In all cases, the recommended limits given in 6.1.1 should be met.

1-4.1.2 Frequency tolerance or stability

The system should operate within a frequency stability of +/- 10 parts per million.

NOTE- This specification is only for the purposes of complying with coexistence requirements. The stability requirements contained in the air interface specifications may be more stringent, particularly for the base station. In addition, it is highly recommended that the SS transmit frequency be controlled by using a signal from the downlink signal(s).

1-4.1.3 Out-of-block unwanted emissions

Editorial instructions
-Delete old text in 6.1.3
-Replace with new text below
-Delete figures 6 and 7

Old text and diagrams to be deleted:
“Unwanted emissions produced by an operator’s equipment and occurring totally within an operator’s authorized band are relevant only for that operator and are not covered in this Recommended Practice. Unwanted emissions from an operator into adjacent bands should be constrained to avoid giving unacceptable interference to users of adjacent spectrum. Recommended emission limits are given below. As indicated in Figure 6, single-carrier or multicarrier transmissions whose occupied bandwidth is totally within the authorized band will nevertheless emit some power into adjacent bands. These unwanted emissions include out-of-band (OOB) emissions (within 200% of the emission occupied bandwidth (Bo) of the authorized band edge) and spurious emissions (beyond this 200% point).

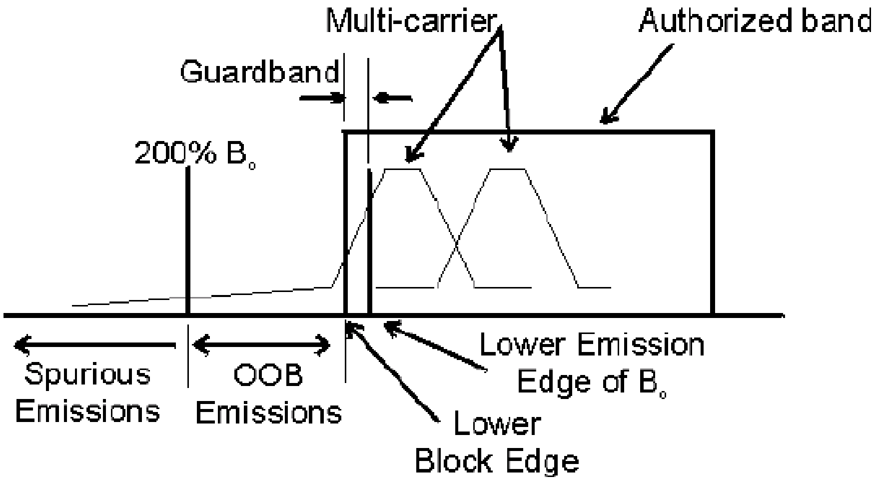


Figure 6 -Unwanted emissions

The spectral density of unwanted emissions at the input to the antenna port should be attenuated by at least A(dB) below the total mean output power P mean as follows:

1) For a single-carrier transmitter (see A.1.2, single-carrier test):

In any 1.0 MHz reference bandwidth outside the authorized band and removed from the authorized band edge frequency by up to and including +200% of the occupied bandwidth (i.e., 2 B o), A = 11 + 40 f offset /B o + 10 log 10 (B o) (dB), where B o is in MHz and f offset is the frequency offset (in MHz) from the authorized band edge. Attenuation greater than 50 + 10 log 10 (B o) (dB) is not required. An absolute transmit level below Œ70 dBW/MHz is not required.

2) For a multicarrier transmitter or multitransmitters (excluding OFDM) sharing a common final stage amplifier (see A.1.3):

Each of the carriers individually should pass the single-carrier limit above and in addition the following limits apply:

The mask is to be the same as in 1), using the occupied bandwidth defined for multicarrier transmitters in 3.1. The total mean power is to be the sum of the individual carrier/transmitter powers.

NOTE- When several transmitters share a passive antenna, each transmitter should satisfy the individual mask; the multi-carrier mask should not be applied in this case.

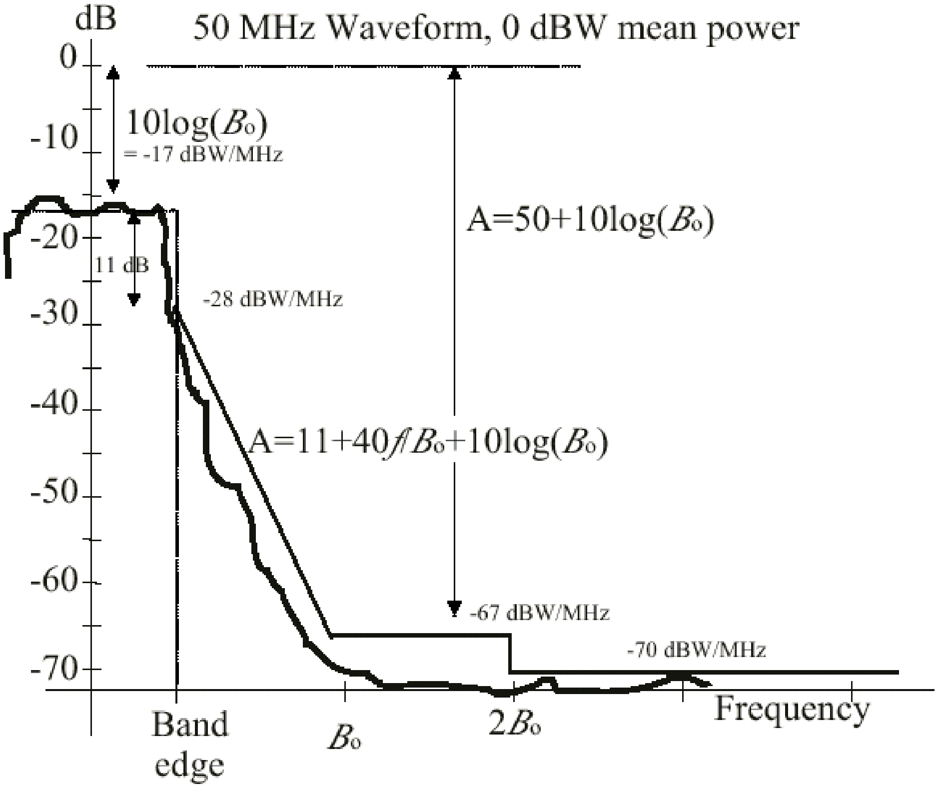
3) In any 1.0 MHz band removed from the identified edge frequency by more than +200% of the occupied bandwidth:

Emissions should not exceed an absolute level of -70 dBW/MHz.

Figure 7 provides an example of how the unwanted emission mask would be applied to a hypothetical 50 MHz single carrier, located at the edge of the authorized band with a mean power of 0 dBW.

- The in-band spectral density will be 0 - log 10 (50) = -17 dBW/MHz.
- The first section of the equation "A = 11 + 40f offset /B o + 10log 10 (Bo)" starts 11 dB below this in-band spectral density and falls linearly with offset frequency from the band edge
  - In this example, the attenuation A reaches a value of -67 dB shortly before a 50 MHz offset and at that point the attenuation floor of if A = 50 + 10log 10 (B o)ll starts and continues at this value until a "2B o" offset. In this example, the second adjacent channel attenuation is thus -50 dBc.
- Beyond the ih2B o lh frequency offset, the spurious emission absolute limit of -70 dBW/MHz starts and continues out indefinitely.

In other examples (e.g., in the above example, if the mean power was -10 dBW), the absolute emission limit of -70 dBW/MHz may be reached before the attenuation floor of "A = 50 + 10log 10 (Bo)" is reached. In this case, the absolute emission limit takes precedence.



New text to be inserted:

"Unwanted emissions produced by an operator's equipment and occurring totally within an operator's authorized block bandwidth are relevant only for that operator and are not considered in this Recommended

Practice. Unwanted emissions from an operator that fall into adjacent bands are subject to the constraints set by regulatory authorities. These emission limits may or may not be sufficient to ensure that unacceptable levels of interference are avoided to users of adjacent spectrum.

It is appropriate to define acceptable coexistence criteria in terms of an interference coupling level (ICL). ICL is the combination of net filter discrimination (NFD) and further isolation obtained by use of system interference mitigation techniques. NFD is represented by the transmission cascade of the out-of-band (OOB) emissions from the interference source and the filter selectivity of the victim receiver. By itself, isolation obtained through NFD is not necessarily sufficient to ensure that acceptable interference coexistence criteria are achieved.

It is possible to identify ICL limits that define the necessary limits for acceptable coexistence. An example of the identification of such requirements may be found in ETSI report [ref.] Generally speaking, ICL requirements are controlled by the carriers that are located closest to the block edge. Establishment of necessary ICL limits can involve a number of interference mitigation techniques, employed singly or jointly. These include:

1) Employing alternative polarization assignments for carriers located at block edge.
2) Reducing the EIRP of carriers located on block edge.
3) Establishing BS separation distance limits (BS to BS couplings).
4) Reducing channel bandwidth assignments ($B_{o)}$ for carriers in proximity to block edge.
5) Developing a full or partial guard band by not assigning carriers right up to block edge

By employing a combination of the above techniques, it may be possible to operate without the need for a specific guard band. An operator may then be able to maximize use of spectrum within the assigned frequency block."

1-4.1.3.1 Unwanted emission levels specified in ETSI standards

In regions where they apply, the ETSI limits of EN 301 390 should be followed.

Within +/-250% of the channel, a specific spectrum mask applies. This should be taken from the appropriate standard documented by ETSI.

According to ETSI 301 390 section 4.1.3, the following requirements should be used in Europe:

The CEPT/ERC Recommendation 74-01 [B1] applies for spurious emissions in the frequency range 9 kHz to 21.2 GHz and above 43.5 GHz.

For spurious emissions falling in the range 21.2 GHz to 43.5 GHz, the tighter limits shown in Figure 8 and Figure 9 shall apply to both base and subscriber stations. In this frequency range, where the -40 dBm limit shown in Figure 8 and Figure 9 applies, allowance is given for no more than 10 discrete (CW) spurious emissions which are each permitted to exceed the limit up to -30 dBm.

In the same figures, for comparison, the less stringent limits from CEPT/ERC Recommendation 74-01 [B1] are also shown.

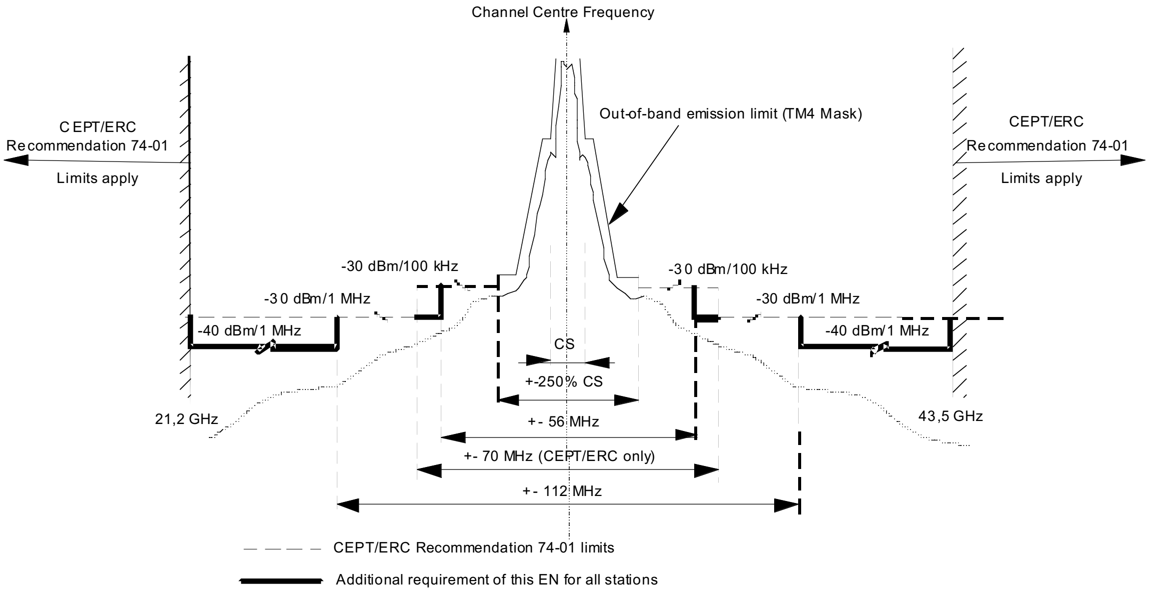
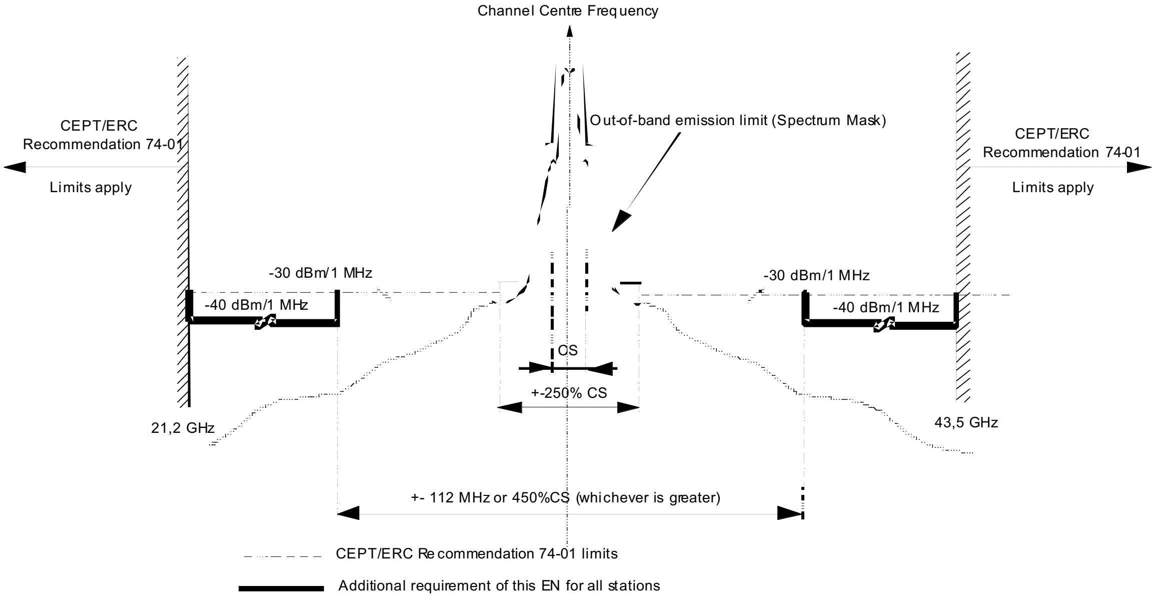


Figure 1.8 – Systems for channel separation 1<CS*≤10 MHz

Editorial Instructions:
Add ETSI acknowledgement “SOURCE: ETSI EN 301 390 v1.1.1 (2000-12), Fixed Radio Systems; Point- to-Point and Point- to- Multipoint Systems; Spurious Emissions and Receiver Immunity at Equipment / Antenna Port of Digital Fixed radio Systems.”



Editorial Instructions:
Delete figure 9 caption and replace with “Figure 1.9-Systems for channel separation CS*>10MHz”
Add ETSI acknowledgement “SOURCE: ETSI EN 301 390 v1.1.1 (2000-12), Fixed Radio Systems; Point- to- Point and Point- to- Multipoint Systems; Spurious Emissions and Receiver Immunity at Equipment / Antenna Port of Digital Fixed radio Systems.”

1-4.2 Antenna parameters

The following antenna parameters apply to Frequency Range 2 (23.5-43.5 GHz), unless otherwise indicated.

In considering coexistence, the operator needs to consider the antenna radiation pattern in the azimuth (AZ) and elevation (EL) planes relative to the required coverage footprint. For purposes of consistency and ease of implementation, the ability to select either horizontal or vertical polarization without the need for concern for differences in the RPEs is considered very important. Hence, the AZ and EL RPEs are independent of polarization. The polarization discrimination is specified in the tabular and graphical form below.

1-4.2.1 Polarization

Two linear polarization orientations, horizontal and vertical, are recommended. The required polarization purity is captured in the specification of antenna cross-polar discrimination (XPD) in 6.2.2. Also, the radiation pattern envelopes (RPEs) of this recommendation are independent of polarization.

1-4.2.2 Base station antenna

1-4.2.2.1 Electrical classes

The performance of BS antennas is here divided into two electrical classes. Class 1 represents the minimum recommended performance. Class 2 antennas have enhanced RPEs and represent more favorable coexistence performance.

a) Electrical Class 1

Electrical Class 1 antennas, which are characterized by moderate sidelobe performance, are recommended for operation in environments in which interference levels are typical.

b) Electrical Class 2

Electrical Class 2 antennas are meant for operation in environments in which interference levels could be potentially significant and cause problems under certain conditions.In such environments, Class 2 antenna with higher levels of discrimination in side lobes and back lobes may be deployed to provide acceptable per-formance of the system and mitigate intersystem interference.

1-4.2.2.1.1 Azimuth radiation pattern envelopes

This subclause describes radiation pattern envelopes (RPEs) for the two Electrical Classes of antenna. The radiation pattern envelope is specified in terms of a variable _ that is half the azimuth -3 dB beamwidth of the antenna. Sector sizes for these RPE tables range from 15° to 120°
.

Figure 10 and Figure 11 illustrate the azimuth co-polar and cross-polar RPEs for the two electrical classes of antenna. Some specific data points are provided in Table 3 and Table 4; between these pint, linear interpolation is used.

Note: Unaltered figures and tables omitted
[Figure 10 omitted] renumber as fig1.10

[Figure 11 omitted] renumber as fig. 1.11

[Table 3 BS RPE in the azimuth plane Electrical Class 1, omitted] renumber as table 1.3

[Table 4 BS RPE in the azimuth plane Electrical Class 2, omitted] renumber as table 1.4

1-4.2.2.1.2 Elevation radiation pattern envelopes

The elevation RPEs should be specified both above and below the local horizon to provide isolation, improve coexistence, and ensure efficient use of radiated power. The pattern below the horizon should be specified as a minimum in order to reduce coverage nulls that would require an increase in radiated power by the SS antenna. The elevation RPE below the horizon is specified in terms of Beta, where 2 Beta is the 3 dB beamwidth in the elevation plane.

This specification follows accepted practices for the specification of elevation radiation pattern envelopes that provide for the 0° angle to be directed at the local horizon, the 90° angle directed overhead, and the -90° angle directed downward.

It may be necessary in practical deployments to use electrical or mechanical tilt, or a combination of both, to achieve the required cell coverage, taking into account the surrounding terrain, for example.

Figure 1.12, Figure 1.13, and Figure 1.14 illustrate the elevation RPEs for Classes 1 and 2. Some specific data points are provided in Table 1.5, Table1.6, and Table 1.7; between these points, linear interpolation is used.

[Figure 12 omitted] renumber as fig. 1.12
r
[Figure 13 -BS co-polarized minimum below the horizon, omitted] renumber as fig. 1.13

[Figure 14, omitted] renumber as fig. 1.14

[Table 5, omitted] renumber as Table 1.5

[Table 6, omitted] renumber as Table 1.6

[Table 7, omitted] renumber as Table 1.7

1-4.2.3 Subscriber station

Fixed BWA systems employ SS antennas that are highly directional, narrow-beam antennas. Although it is not as important for coexistence as the BS RPE, the RPE of the SS antenna is a factor in determining intersystem interference.

The performance of SS antennas is here divided into three electrical classes. Class 1 is defined with moderate sidelobe characteristics and represents the minimum recommended performance. Class 2 and Class 3 antennas have enhanced RPEs and represent increasingly favorable coexistence performance.

1-4.2.3.1 Radiation pattern envelope

Figure 1.15, Figure 1.16, and Figure 1.17 show the RPEs of co-polar and cross-polar patterns for Classes 1, 2, and 3. Some specific data points are provided in Table 1.8, Table 1.9, and Table 1.10; between these pint, linear interpolation is used.The required side lobe level and front-to-back ratio of the SS antenna depends on the coexistence scenario, C/I requirements of the radios, rain region, and f BS antenna pattern. It is recommended here that all of the above-mentioned parameters be taken into consideration in choosing the right class of antenna. In Table 1.8, Table 1.9, and Table 1.10, 2 Beta is the 3 dB (or half-power) beamwidth of the antenna. It is also assumed that the same RPE should apply to both E-plane and H-plane. There is, however, no requirement on the symmetry of the antenna patterns as long as they meet the following RPEs.

[Figures 15, 16,17, omitted] renumber as Figures 1.15, 1.16, 1.17

[Tables 8,9,10, omitted] renumber as Tables 1.8, 1.9, 1.10

1-4.2.4 Mechanical characteristics

This subclause discusses the recommended minimum requirements regarding antenna mechanical requirements for typical environments. However, for harsher environments, such as hurricane-prone areas, more robust antenna systems may be required.

1-4.2.4.1 Wind and ice loading

Wind loading, as specified in this document for the BS, results in mechanical deformation or misalignment that would cause the radiated pattern to be altered and, hence, affect the coexistence characteristics. Antennas should meet the system operational requirements when subjected to the expected wind and ice loading in the geographical installation area. The angular deviation of the antenna main beam axis during specified operational conditions should not be more than 0.5º. The antenna can exceed this deviation during survival conditions, but it should return to its original pointing direction after the adverse condition ceases. In any case, the minimum design operational wind load should be 112 km/hr, and the minimum design survival wind load should be 160 km/hr. These minimum specified loads may be increased substantially in many geographical areas. If potential ice buildup is a factor, the ice thickness should be considered radial, with the density assumed to be 705 kg/m 3 . Consideration of ice buildup on the radome face depends on the material of the radome and whether a heater is utilized. Radome ice should be considered on a case-by-case basis

1-4.2.4.2 Water tightness

Water tightness is important in eliminating unwanted attenuation that might be nonuniform over the antenna aperture. This could change the pattern and nonuniformly reduce the distance over which the BS would operate. In this regard, the antenna should be designed to ensure that water ingress is negligible.

1-4.2.4.3 Temperature and humidity

The antennas should not suffer performance degradation when subjected to temperature or humidity extremes, as this could potentially cause interference. Therefore, antennas should be designed to operate within the recommendation of this document over the full temperature and humidity range for which the system is intended to be deployed.

1-4.2.4.4 ***Radomes and heaters***

Editorial instructions;
-delete “métiers”
-replace with “met with”

If radomes are used, all recommended antenna limits included in this Recommended Practice should be [métiers] the radomes installed. This includes radome heaters where required.

1-4.2.4.5 ***Labeling***

With respect to coexistence, labeling aids in installing the correct antenna with the correct radiation characteristics. Antennas should be clearly identified with a weatherproof and permanent label(s) showing the antenna type, antenna frequency range, antenna polarization, and serial number(s). It should be noted that integrated antennas may share a common label with the outdoor equipment.

1-4.2.4.6 ***Mechanical adjustment assembly***

The sector antennas described in this specification typically have a wide azimuth pattern and a narrow elevation pattern. The mechanical tilting assembly should accommodate adjustments in elevation and azimuth, consistent with the overall system design requirements.

1-4.2.4.7 ***Vibration***

Due to narrow azimuth and elevation beamwidth, the SS antennas should be highly stable and undergo little mechanical deformation due to wind and other sources of vibrations.

1-4.3 Receiver design parameters

This subclause provides recommendations for the design of both subscriber and base station receivers, which are to be deployed in fixed broadband wireless access systems. The parameters for which recommendations are made are those that affect performance in the presence of interference from other fixed BWA systems.

1-4.3.1 Co-channel interference tolerance

The simulations performed in support of the recommendations included in this Recommended Practice assume an interference signal level not exceeding 6 dB below the receiver noise floor causing a noise floor degradation of 1 dB. This was chosen as an acceptable degradation level upon which to operate a fixed BWA system while allowing interference levels to be specified in an acceptable manner. The following subclauses recommend minimum design standards to allow for interference. These simulations do not account for an operator's specific equipment and frequency band. Operators should adjust the results to account for their own system parameters.

1-4.3.1.1 ***Base station***

The base station receiver might be subjected to adjacent channel interference and co-channel interference from other fixed BWA systems operating in close proximity to the reference system. Therefore, the base station receivers should be designed with proper selectivity and tolerance to interference.

1-4.3.1.2 ***Subscriber station***

The SS receiver might be subjected to adjacent channel interference and co-channel interference from other fixed BWA systems operating in the close proximity to the reference system. Therefore, the receivers intended for SS terminal applications should be designed with the proper selectivity and tolerance to interference.

1-4.3.1.3 ***Link availability in a joint C/N + C/I transmission environment***

From the simulation results described in other sections of this document, it has been found that some single interference coupling is usually dominant when worst case interference levels are examined. Such worst caseimpairments are expected to be rare as they require a boresight alignment between interference and victim antennas.

The simulation results indicate that the proposed receiver interference tolerance of a 1 dB threshold impairment is sufficient in terms of establishing acceptable coordination design objectives. However, the possibility still remains that multiple interferers can exist and may add to the threshold impairment. The following example examines the significance of these interference sources.

The system design model is based on the "typical" parameters for fixed BWA at 26 GHz as identified in 6.1.1. A 4-QAM modulation system is assumed with an excess bandwidth of 15% and a receiver noise figure of 6 dB. Availability objectives of 99.995% for a BER = 10 -6 , based on a threshold C/N = 13 dB, translate to a maximum cell radius of R = 3.6 km in ITU-R rain region K with a corresponding interference-free fade margin of 26 dB. Worst case H-POL transmission has been assumed.

For I/N = -6 dB, C/I = 19 dB and the effective receiver threshold is impaired by approximately 1 dB such that the limiting C/N is now 14 dB. A 3 dB impairment to threshold (C/I = 16 dB) would move the C/Nrequirement to 16 dB. Figure 18 illustrates the reduction in availability as C/I increases, referenced to R fixed
at 3.6 km. It is apparent that link availability degrades modestly as C/I increases. At C/I = 16 dB, availability has degraded to only 99.9925%.

[Figure 18, omitted] renumber as Fig. 1.18

Figure 1.19 indicates the necessary reduction in cell radius R that would be required to maintain availability at 99.995%. At C/I = 16 dB, R is reduced to 3.25 km, a reduction of 10%. Consequently, if system operation in a strong interference environment is anticipated, a system design with modestly reduced cell dimensions may be prudent.

It is thus concluded that the selected I/N = -6 dB is a conservative metric for specification of interference criteria.

[Figure 19, omitted] renumber as Fig. 1.19

1-4.3.2 Adjacent channel desired to undesired signal level tolerance

Where coordination between operators cannot be guaranteed, it is recommended that an operational receiver be capable of withstanding the exposure of relatively high power adjacent channel carriers. The recommended numerical values below are based on the emission mask in 6.1.3, QPSK modulation and, single-carrier operation. Coordination between operators will reduce the likelihood of this kind of interference.

This recommendation has a direct impact on coexistence referenced to the estimation of guard band requirements discussed extensively elsewhere in this Recommended Practice. The coexistence criteria assume that adjacent channel carrier interference, as defined by net filter discrimination (NFD), establishes the requirements and that interfering signals have not degraded the NFD. Thus, the following tests can be only indirectly related to the emission level masks and the guard band criteria recommended elsewhere in this Recommended Practice.

A possible test can be defined in terms of a desired carrier (D) to undesired carrier (U) ratio, D/U. The D carrier emissions should correspond to the signal characteristics normally expected to be present at the victim receiver input port.

1-4.3.2.1 Base station and subscriber station D/U tolerance

This test should be performed with both desired and undesired signals having the same modulation characteristics and equal transmission bandwidths. With both the desired D and undesired U signals coupled to the input of the victim D receiver, set the input level of the desired signal such that it is 3 dB above the nominally specified BER performance threshold.

1-4.3.2.2 First adjacent channel D/U

Set the undesired carrier frequency so that it corresponds to a one channel bandwidth frequency offset and at a D/U = -5 dB.

The measured BER performance of the D receiver should not exceed that specified for nominal threshold performance.

1-4.3.3 Second adjacent channel D/U

Set the undesired carrier frequency so that it corresponds to a two channel bandwidth frequency offset and at a D/U = -35 dB.

The measured BER performance of the D receiver should not exceed that specified for nominal threshold performance.

Examples of suitable test methods can be found, such as those in ETSI conformance testing procedures (see A.3).

Where coordination between operators cannot be guaranteed, it is recommended that an operational receiver be capable of withstanding the exposure of relatively high power adjacent channel carriers.

1-5 Deployment and coordination

This clause provides a recommended structure process to be used to coordinate deployment of fixed BWA systems in order to minimize interference problems.

NOTE- National regulation and/or international agreements may impose tighter limits than the following and shall take precedence in this case.

This methodology will facilitate identification of potential interference issues and, if the appropriate recommendations are followed, will minimize the impact in many cases, but compliance with this process will not guarantee the absence of interference problems.

NOTE- In the following, “coordination” implies, as a minimum, a simple assessment showing the likelihood of interference. It may imply a detailed negotiation between operators to mitigate problem areas for the benefit of both systems.

1-5.1 Co frequency, adjacent area

1-5.1.1 Methodology

Coordination is recommended between licensed service areas where both systems are operating co-channel, i.e., over the same fixed BWA frequencies, and where the service areas are in close proximity, e.g., the shortest distance between the respective service boundaries is less than 60 km. [7] The rationale for 60 km is given in 7.1.2. The operators are encouraged to arrive at mutually acceptable sharing agreements that would allow for the provision of service by each licensee within its service area to the maximum extent possible. Under the circumstances where a sharing agreement between operators does not exist or has not been concluded, and where service areas are in close proximity, a coordination process should be employed. In addition to the procedure described below, two alternative coordination procedures are described in Annex E (based on a different I/N) and Annex F (based on a two-tier psfd approach).

Fixed BWA operators should calculate the power spectral flux density (psfd) at their own service area boundary. Power spectral flux density should be calculated using good engineering practices, taking into account such factors as propagation loss, atmospheric loss, antenna directivity toward the service area boundary, and the curvature of Earth. The psfd level at the service area boundary should be the maximum value for elevation point up to 500 m above local terrain elevation. No aggregation is needed because principal interference processes are direct main beam to main beam coupling. Refer to 7.1.2 for a rationale behind the psfd levels presented in this process. The limits here refer to an operator's own service boundary, since that is known to the operator and will frequently be the same as the adjacent operator's service boundary. In cases where the two boundaries are separate (e.g., by a large lake), dialog between operators, as part of the coordination process, should investigate relaxing the limits by applying the limits at the adjacent service boundary. In cases where there is an intervening land mass (with no licensed operator) separating the two service areas, a similar relaxation could be applied. However, in this case, caution is needed since both existing operators may have to re-engineer their systems if service later begins in this intervening land mass. Deployment of facilities which generate a psfd, averaged over any 1 MHz at their own service area boundary, less than or equal to that stated in Table 11, should not be subject to any coordination requirements.

[table 11, omitted] renumber as table 1.11

1-5.1.2 Coordination trigger

As described above, distance is suggested as the first trigger mechanism for coordination between adjacent licensed operators. If the boundaries of two service areas are within 60 km of each other, then the coordination process is recommended.

footnote 7 : In case of sites of very high elevation relative to local terrain, BWA service areas beyond 60 km may be affected. The operator should coordinate with the affected licensee(s).

The rationale for 60 km is based upon several considerations, including radio horizon calculations, propagation effects, and power flux density levels. The latter is discussed in 7.3.

The radio horizon, defined as the maximum line-of-sight distance between two radios, is defined (see Figure 20) as follows:

[formula (1), omitted]

where

Rh = radio horizon (km)
h1 = height of Radio 1 above clutter (m)
h2 = height of Radio 2 above clutter (m)

[Figure 20, omitted] renumber as Fig. 1.20

Table 1.12 presents the horizon range for different radio heights above average clutter. Note that if the antenna is erected on a mountain (or building), then the "height of radio above clutter" will probably also include the height of the mountain (or building).

[Table 12 -Horizon range for different radio heights AGL (in kilometers), omitted] renumber as table 1.12

The worst-case interference scenario involves two base stations, as these are typically located on relatively high buildings or infrastructures and hence have greater radio horizon distances than subscriber stations. A typical height for a base station is 65 m above ground level, or 55 m above clutter, assuming an average clutter height of 10 m over the whole path length. This produces a radio horizon of 60 km. There will be cases where the base station equipment may be located on higher buildings, which would produce a greater radio horizon. However, these base stations tend to tilt their antennas downward. This effectively reduces the amount of power directed towards the adjacent base station and therefore reduces the interference. The following subclauses examine power levels in further detail.

1-5.2 Same area/adjacent frequency

As stated in Recommendation 1-1 to 1-7, deployments will usually need one guard channel between nearby transmitters. Where administrations do not set aside guard channels, the affected operators would need to reach agreement on how the guard channel is apportioned between them. Where channel sizes are different, the guard channel should be equal to that of the wider channel system. This document does not consider the case where an operator deploys multiple channel sizes within his or her allocation.

1-5.3 Use of power spectral flux density (psfd) as a coexistence metric

This subclause addresses the maximum power flux density that can be tolerated as a result of co-channel interference originating from an adjacent licensed operator. For the purposes of the Recommendations in this document, the amount of interference generally considered acceptable or tolerable is a level which produces a degradation of 1 dB to the system's C/N This degradation is usually taken into consideration during the original link budget exercise. For the noise floor to increase by 1 dB, the interference power level must be 6 dB below the receiver's thermal noise floor.

In Annex B, a typical psfd calculation is shown at frequencies of 28 and 38 GHz. The psfd limit can be applied in different ways that affect the probability of interference. Two examples are given in Annex A and Annex F. The 38 GHz band has been used extensively for individual point-to-point radio links for a number of years in many countries. More recently, the band has also been used to provide point-to-point links in support of fixed broadband wireless access systems. Thus, it is important that these point-to-point radio receivers be afforded an equal opportunity to coexist with point-to-multipoint equipment in a shared frequency environment. Where there is significant deployment of point-to-point links as well as point-to-multipoint systems and protection of point-to-multipoint systems is mandated, tighter psfd trigger levels may be appropriate [e.g., -125 (dBW/m2)/MHz at 38 GHz band is applied by some administrations to protect point-to-point links].

1-5.3 Deployment procedure

Operators should develop a "turn-on" procedure for use during transmitter activation, the objectives being the avoidance of inadvertent interference generation. The "turn-on" operator is highly encouraged to communicate with other known operators who may be affected. It is expected that operators will independently develop their ihturn-onlt procedures but it is outside the scope of this document to provide specifics.

1-6 Interference and propagation evaluation/examples of coexistence in a PMP environment

1-6.1 Guidelines for geographical and frequency spacing between fixed BWA systems

The following subclauses indicate some of the models, simulations, and analysis used in the preparation of this Recommended Practice. While a variety of tools can be used, it is suggested that the scenarios studied below be considered when coordination is required.

1-6.1.1 Summary

This subclause provides guidelines for geographical and frequency spacings of fixed BWA systems that would otherwise mutually interfere. The guidelines are not meant to replace the coordination process described in Clause 7. However, in many (probably most) cases, by following these guidelines, satisfactory psfd levels will be achieved at system boundaries. The information is therefore valuable as a first step in planning the deployment of systems. The actual psfd levels can then be calculated or measured, as appropriate, and any adjustments to system layout can then be made. These adjustments should be relatively small, except in unusual cases.

1-6.1.2 Interference mechanisms

Various interference mechanisms can reduce the performance of fixed BWA systems. Although intrasystem interference is often a significant source of performance degradation, it is not considered in this analysis. Its reduction to acceptable levels requires careful system design and deployment, but these are under the control of the operator, who may decide what constitutes an acceptable maximum level. Thus, only intersystem interference mechanisms, where interoperator coordination may be appropriate, are considered here. In each frequency band assigned for fixed BWA use, different types of systems may be deployed, some conforming to IEEE 802.16 standards and some designed to other specifications. Therefore, we consider a wide range of possibilities in determining the likely interference levels and methods for reduction to acceptable levels.
The following are the two main scenarios, each with several variants:

- Co-channel systems that are geographically spaced
- Systems that overlap in coverage and (in general) require different frequencies of operation

The various potential BS-SS-RS interference paths need to be considered to determine how much interference will occur. Between any two systems, several interference mechanisms may be operating simultaneously (see 5.3). The geographical or frequency spacing (or both) necessary to reduce interference to acceptable levels is then determined by the most severe mechanism that occurs. A number of techniques have been used to estimate intersystem interference. They are as follows:

- Worst case analysis
- Interference Area method
- Monte Carlo simulations

Each of these is described below. The most appropriate method depends on the interference mechanism. In each case, geographical or frequency spacing between systems has been varied in the calculations until the interference is below an acceptable threshold. These values are shown in the tables of results as guidelines for nominal geographical or frequency spacing.

1-6.1.3 Worst-case analysis

Some interference mechanisms arise from a single dominant source and affect each victim in a similar way. A relatively simple calculation of the worst-case interference can then be made, using realistic values for system parameters and ignoring additional radio path terrain losses. An example is the interference from a single dominant BS into the victim BS of an adjacent system.

1-6.1.4 Simulations

There are many cases where a simple worst-case analysis is of limited use. Where there are many possible interference paths between a particular type of interferer and the associated victim stations, the worst case could be very severe, but may also be very improbable. Planning on the basis of the worst case would then be unrealistic. An example is the interference between subscriber stations of different operators in the same geographical area. Most interference will be negligible, but a certain small proportion of cases could have very high interference levels. Monte Carlo simulations provide a means of assessing the probability of occurrence of a range of interference levels at victim stations. The recommended geographical or frequency spacing is then a compromise in which an acceptably small proportion of cases suffer interference above the recommended limit. For example, 1% of randomly positioned SSs might suffer interference above the desired level. A model of an interference scenario is created using realistic parameters in which the placement of fixed BWA stations (usually the SSs) can be randomly varied. Other randomly varied parameters, such as buildings and terrain factors, may be included. The simulation is run many times and the results plotted as a probability distribution.

1-6.1.5 Interference area (IA) method

In some scenarios, it can be shown that specific parts of the coverage area will suffer high levels of interference while other areas are not affected. The interference area (IA) is the proportion of the sector coverage area where interference is above the target threshold. This is equivalent to the probability that a randomly positioned station (within the nominal coverage area) will experience interference above the threshold. In several scenarios, the interference area value is a small percentage and the locations are predictable. Although high levels of interference do occur, they are sufficiently localized to be acceptable.

The interference area may be determined by running a simulation program in which victim or interfering stations are randomly positioned. For each case in which the desired interference limit is reached or exceeded, a point is marked on a diagram. After a large number of trials, the interference area value can be calculated and is easily identified on the diagram. Figure C.5 provides an example.

1-6.1.6 ISOP (Interference scenario occurrence probability)

Although not used in this document, the concept of ISOP may be interesting in some cases. The ISOP analysis is an extension of the IA method in which a calculation is made of the probability that at least one victim SS will be inside the IA. The probability may be averaged across a wide range of different frequency and polarization assignment cases and therefore may not be representative of a specific deployment.

Further information on both the ISOP method and the IA method can be found in ERC Report 099 [B2].

1-6.1.7 Simulations and calculations

Table 1.13 summarizes the simulations and calculations undertaken for this Recommended Practice. The most appropriate method has been selected, dependent on the scenario and interference path.

[Table 13, omitted] renumber as table 1.13

1-6.1.8 Variables

In the simulations, a number of parameters have been varied in order to test the sensitivity of the results to critical aspects of system design. In particular, antennas with various RPEs have been evaluated. In particular, simulations have been completed using data for antennas with a range of RPEs. While many of the simulation results show improvement with the use of antennas with enhanced RPEs, the relative value of the performance improvement was found to be modest for all of the antennas considered. On this basis, a good practice is to choose the best antenna possible, consistent with system economics.

In some configurations, the intrasystem interference considerations will dominate the decision on antenna RPEs. Effective frequency reuse between cells will demand the use of antennas whose intrasystem requirements can provide satisfactory intersystem interference levels.

1-6.1.9 Results of the analysis

Simulations have been undertaken for many of the interference mechanisms described below. A summary of each method and its results is given in Annex 1-C.

1-6.1.10 Co-channel case

1-6.1.10.1 BS-to-BS co-polar, single, and multiple interferes

This scenario only occurs where the victim BS receiver is co-channel to the interfering BS transmitter. The BS-to-BS interference is not necessarily the worst case, but when interference occurs, it affects a large number of users at the same time. Mitigation, by moving or repointing the BS or by changing frequency, can be very disruptive to a system. Therefore, a relatively iesafele value should be applied to co- channel, co-polar geographical spacing. Shorter distances are possible, but will increase the probability of interference. Therefore it is recommended that these be verified by more detailed analysis.

Occasionally, the normal recommended geographical spacing will not be sufficient, due to adverse terrain conditions. Where one station is on a local high point much higher than the mean level of the surroundingterrain, it is recommended that a specific calculation or measurement be made of the interference level and the necessary geographical spacing derived from this.

The results for this case are derived from worst-case analysis (for a single interferer and a typical set of system parameters) and from simulation. This analysis has used parameters that are typical of fixed BWA systems.

For systems with multiple BSs, typical frequency reuse arrangements can lead to multiple sources of interference on a given channel/polarization. The level of interference can therefore be higher than that for asingle interferer.

1-6.1.10.2 ***SS-to-BS, co-channel case***

In this case, single and multiple SSs need to be considered. Depending on the system design, the number of SSs which transmit at any one time may be low (or only one) from a given cell sector. However, interference can often arise from several cells, especially when rain fading occurs selectively (i.e., where a localized storm cell attenuates some radio paths but not others).

In the case of mesh systems, there may be several interferers on a given channel, although only a small number will transmit simultaneously and very few will be visible at a particular BS simulation. Monte Carlo modeling may be useful to analyze this case of multiple interferers.

1-6.1.10.3 ***SS-to-SS, co-channel case***

Interference between SSs in adjacent areas has, in general, a low probability of occurrence. In PMP systems, it usually occurs in specific areas. Its level could be low or high, depending on circumstances. If co-channel PMP cells are at or beyond the minimum recommended iesafeln distance, SS interference has a low probability, but in a few cases (in localized interfered areas) could be at a higher level than that experienced by a BS due to the higher antenna gain of the subscriber station.

For the mesh to PMP case, the results are similar to PMP to PMP, except that interference is generally lower, due to the use of lower gain mesh SS antennas.

1-6.1.11 Overlapping area case

In the overlapping area case, significant spatial separation between interferer and victim cannot be assumed and coexistence relies upon the following:

- Frequency separation between interferer and victim
- Frequency discrimination of the transmitter and receiver

The worst-case scenarios that can be envisaged, if used to derive the protection criteria, would result in excessive frequency separations between systems operating in adjacent frequency blocks. In effect, excessive guard bands, with the consequential loss of valuable spectrum, would result. This can be avoided through the use of statistical methods to assess the impact of guard bands on a deployment as a whole. The calculations can be repeated many times to build up a reliable picture.

1-6.1.11.1 ***BS-to-BS interference***

In PMP systems without harmonization, BS-to-BS interference is evaluated by use of a simulation program. It is clear that an interfering BS could be relatively close to a victim BS, but the level of interference depends on the relative locations of the BSs of the two systems, which affects the antenna pointing direction. Analysis shows that a single guard channel between systems will, in general, be a good guideline for uncoordinated deployment when the systems employ similar channel spacings. Where channel spacings are considerably different, one equivalent guard channel may be necessary at the edge of each operator’s block.

1-6.1.11.2 ***SS-to-BS interference***

In PMP systems, SS-to-BS interference may be evaluated by use of a simulation program. It is clear that an interfering SS could be relatively close to a victim BS, but the level of interference depends on the relative locations of the BSs of the two systems (which affects the antenna pointing direction), on the use of automatic transmit power control (ATPC), and on possible differential rain fading. Analysis of this case, in C.3 and C.13, shows that a single guard channel between systems will in general be a good guideline for uncoordinated deployment. Where channel spacings are considerably different, one equivalent guard channel may be necessary at the edge of each operator’s block.

Where the interferer is a mesh system, the antenna pointing directions are more random and possible multiple interferers have to be considered. An analysis of this situation, in C.12, shows that the same one channel guard band is a good guideline for uncoordinated deployment.

1-6.1.11.3 ***SS-to-SS, same area case***

This problem may be analyzed by use of Monte Carlo modeling. In general, the probability of interference occurring is low but, when it does occur, the level can be high. Unlike the BS-to-SS case, the high levels of interference are not in predictable parts of the cell(s). Mitigation is by use of guard bands, improved antennas and (in mesh systems) by rerouting so as to avoid the worst pointing directions of antennas. An analysis of this case can be found in C.5 for the PMP case and in C.12 and C.13 for the mesh-PMP case. The case without harmonization is analyzed. The analysis shows that a single guard channel between systems will in general be a good guideline for uncoordinated deployment. Where channel spacings are considerably different, one equivalent guard channel may be necessary at the edge of each operator’s block.

1-7 Mitigation techniques

1-7.1 General

This subclause describes some of the mitigation techniques that could be employed in case of co-channel interference between systems operating in adjacent areas. As each situation is unique, no single technique can be effective for all cases. In certain circumstances, the application of more than one mitigation technique may be more effective.

In general, analyses to evaluate the potential for interference and any possible mitigation solution should be performed prior to system implementation. Coordination with adjacent operators could significantly lower the potential for interference. Best results may be obtained if full cooperation and common deployment planning is achieved.

1-7.2 Frequency band plans

By retaining spare frequencies for use only when interference is detected, some potential co-channel and adjacent channel problems can be eliminated.

A similar frequency plan for the uplink and downlink could help to reduce interference for FDD systems. The most problematic interference occurs between base stations, primarily because base stations are typically located on high buildings or other structures and therefore tend to have good clear line of sight (LOS) with neighboring base stations. Base stations typically operate over 360°, and base stations are always transmitting.

Harmonized base stations that transmit in the same subband do not interfere with each other when located in adjacent areas and enable site sharing when located in the same area.

Frequency exclusion provides another, albeit very undesirable, approach for avoiding interference. This involves dividing or segregating the spectrum so that neighboring licensees operate in exclusive frequencies, thus avoiding any possibility for interference. This should be considered an absolute last resort, where all other remedial opportunities have been completely exhausted between the licensed operators.

When tackling coexistence between systems operating in adjacent frequency blocks in the same or overlapping areas, similar equipment channelization schemes at the block edges help to facilitate coexistence between interfering subscriber stations and victim base stations. The effect is to reduce the guard band required between the frequency blocks due to the similarity of the interferer and victim system characteristics. Additionally, similar characteristics could lead to similar cell coverage areas. This may help to minimize the potential for numerous overlapping cells.

1-7.3 Service area demarcation

If regulators define a service area demarcation boundary in an area of low service demand or in areas that provide natural terrain blockage or separation, then interference across the boundary will tend to be reduced.

1-7.4 Separation distance/power

One of the most effective mitigation techniques that can be employed is to increase the distance between the interfering transmitter and the victim receiver, thus lowering the interfering effect to an acceptable level. If the distance between the interferer and the victim cannot be increased, then the transmitter power can be lowered to achieve the same effect. However, these options are not always viable due to local terrain, intended coverage, network design, or other factors.

Another possible, but less desirable, option is to increase the transmit power levels of the SSs within a cell or sector in a given service area to improve the signal to interference level into the base station receiver. Operating the SSs “hot” at all times may help to address the adjacent area interference. However, it may introduce other interference scenarios that are equally undesirable, so caution should be exercised if this approach is taken.

When tackling coexistence between systems operating in adjacent frequency blocks in the same or overlapping areas, similar operating psd levels help to facilitate coexistence between interfering base stations and victim subscriber stations.

1-7.5 Co-siting of base stations

Careful planning is required for co-sited antennas. When tackling coexistence between FDD systems operating in adjacent frequency blocks in the same or overlapping areas with defined uplink and downlink frequency bands, co-siting of base station transmitters help to facilitate coexistence

Editorial instructions:

- delete following paragraph (this topic is now covered in detail in Part 2)

[Coexistence with PTP systems

In order to facilitate coexistence between PMP systems and PTP systems operating in adjacent frequency blocks in the same area, a minimum separation and angular decoupling is needed between the PTP site and any base station site. To provide the maximum decoupling, the best possible PTP antenna RPE performance is preferable.]

1-7.7 Antennas

1-7.7.1 Antenna-to-antenna isolation

In practice, sector antennas that are directed to the same sector may be co-located. Careful planning is required in this case. Such co-location involves two primary configurations, depending on whether the antennas are mounted on the same mounting structure Antenna-to-antenna isolation is dependent on factors like site location, mounting configurations, and other system level issues. Even with seemingly uncontrollable factors, there is a need for isolation between the antennas directed to the same sector. For guidance, the antenna-to-antenna isolation for antennas pointed to the same sector with sector sizes of 90o and less should be 60 dB to 100 dB.

1-7.7.2 Orientation

In certain system deployments, sectorized antenna are used. A slight change in antenna orientation by the interfering transmitter or victim receiver can help to minimize interference. This technique is especially effective in the case of interference arising from main-beam coupling. However, as with separation distance, although to a lesser degree, this mitigation technique may not be practical in certain deployment scenarios.

1-7.7.3 Tilting

Like changing the main-beam orientation, the downtilt of either the transmitting antenna or receiving antenna can also minimize the interfering effect. A small change in downtilt could significantly change the coverage of a transmitter, thereby reducing interference to the victim receiver. However, in some systems the downtilt range could be quite limited due to technical or economic reasons. This could render this technique impractical.

1-7.7.4 Directivity

In problematic areas near the service area boundaries where interference is of concern, consideration can be given to using high-performance antenna with high directivity as opposed to a broader range sectorized antenna or omni-directional antenna.

Another possible option is to place the base station at the edge of the service area or boundary and deploy sectors facing away from the adjacent licensed area. Interference is then avoided through the front to back lobe isolation of the base station antennas. This can exceed 30 dB, to accommodate QPSK and 16-QAM modulation.

1-7.7.5 Antenna heights

In circumstances where adjacent licensed base stations are relatively close to each other, another possible technique to avoid interference is to place the base station antenna at lower heights to indirectly create LOS blockages to neighboring base stations. This solution will be impractical in many cases, as it will significantly reduce coverage area. However, under certain conditions, it may be the best option available for addressing the interference issue.

1-7.7.6 Future schemes

In the future, alternative schemes may be available. For example, such as adaptive arrays or beam-steering antennas can focus a narrow beam towards individual users throughout the service area in real-time to avoid or minimize coupling with interfering signals. Beam shaping arrays, which create a null in the main beam towards the interfering source, represent another possible approach towards addressing interference.

1-7.7.7 Polarization

Cross polarization can be effective in mitigating interference between adjacent systems. A typical cross-polarization isolation of 25Œ30 dB can be achieved with most antennas today. This is sufficient to counter co-channel interference for QPSK and 16-QAM modulation schemes. As with other mitigation techniques, cross polarization is most effective when coordination is carried out prior to implementation of networks to accommodate all possible affected systems.

1-7.8 Blockage

Natural shielding, such as high ground terrain between boundaries, should be used to mitigate interference where possible. When natural shielding is not available, the use of artificial shielding, such as screens, can be considered.

1-7.9 Signal processing

Using more robust modulation and enhanced signal processing techniques may help in deployment scenarios where the potential for interference is high.

1-7.10 Receiver sensitivity degradation tolerance

Receiver sensitivity determines the minimum detectable signal and is a key factor in any link design. However, as the level of receiver noise floor increases, the sensitivity degrades. This, in turn, causes reduction in cell coverage, degradation in link availability, and loss of revenues. The factors contributing to the increase in noise power divide into two groups: internal and external. The internal factors include, but are not limited to, the noise generated by various components within the receiver, intermodulation noise, and intra-network co-channel and adjacent-channel interference. The external factor is internetwork interference. The amount of degradation in receiver sensitivity is directly proportional to the total noise power added to the thermal noise, □ I, consisting of intranetwork and internetwork components.

[formula (2), omitted]

In order to reduce the inter-network contribution to □ I, it is recommended that the effect of any fixed BWA network on any other coexisting BWA network should not degrade the receiver sensitivity of that fixed BWA network by more than 1 dB. This is the level that triggers the coordination process described in 7.1.

1-7.11 Subscriber Tx lock to prevent transmissions when no received signal present

In the absence of a correctly received downlink signal, the SS transmitter should be disabled. This is intended to prevent unwanted transmission from creating interference that would prevent normal system operation due to antenna misalignment. The SS should continuously monitor the received downlink signal and, if a loss of received signal is detected, no further transmissions should be allowed until the received signal is restored. If the received signal is lost while the unit is transmitting, the unit is permitted to complete the current transmission. This gives the SS a mechanism to notify the base station of the system fault.

1-7.11.1 Fail-safe

It is recommended that the subscriber and base station equipment have the ability to detect and react to failures, either software or hardware, in a manner to prevent unwanted emissions and interference. The following is an example list of items the equipment should monitor:

- Tx phase-locked loop lock status
- Power Amplifier drain voltage/current
- Main power supply
- Microprocessor watchdog

The implementation of monitoring, preventative, and/or corrective actions is considered vendor-specific. The intent is to prevent transmissions that may result in system interference due to individual SS failures.

Annex 1-A

(informative)

Test and measurement/hardware parameter summary

The text in A.1 and A.2 is based on the test and measurement procedures recommended in Canadian standards RSS-191 [B11].

1.A.1 Testing of unwanted emissions

Some transmitters may be frequency agile to cover several authorized bands and may deploy a band edge RF filter only at the extremities. The option for spectrum segregation implies that operator segregation edge frequencies may also occur within an authorized band. Thus unwanted emissions at authorized band edges or at segregation band edges well inside the agility range of the transceiver may not benefit from the band edge RF filter and may be more severe (or "worst-case") compared to emissions at the extreme upper or lower edges.

To facilitate assessing emissions at a generic mid-band segregation or authorized band edge, a virtual block edge is defined and testing (the results are assumed to be valid across the complete operational band) should be implemented at this virtual block edge. Unwanted emissions should be measured at the output of the final amplifier stage or referenced to that point. In addition to active amplifiers, the final amplifier stage may contain filters, isolators, diplexers, ortho-mode transducer, etc. as needed to meet emission requirements.

1.A.1.1 Methodology

Single-carrier and multicarrier requirements are described below. If multicarrier operations are intended, then both requirements should be met. "Multicarrier" refers to multiple independent signals (QAM, QPSK, etc.) and does not refer to techniques such as OFDM.

Single-carrier and multicarrier tests should be carried out relative to a virtual block edge (defined in Table A.1). The virtual block edge is located within the assigned band (see Figure A.1). When a transmitter is designed to only operate in part of a band (e.g. because of frequency division duplexing), the virtual block edge should be inside the designed band of operation. The occupied bandwidth of the carrier(s) should be closer to the center of the block than the virtual block edge. The virtual block edge is only to be used for testing and does not impact an actual implementation in any way. One virtual block edge (at frequency f vl) should be inside the lower edge of the designed or assigned band and the other virtual block edge (at frequency f vu) should be inside the upper edge of the designed or assigned band.

[Table A.1 -Minimum separation between actual and virtual band edge for different bands; omitted] renumber as table 1-A.1

[Figure A1; omitted] renumber as figure 1-A.1

Unwanted emissions should be measured when the transmitter is operating at the manufacturer's rated power and modulated with signals representative of those encountered in a real system operation. Unwanted emissions should be measured at the output of the final amplifier stage or referenced to that point. The measurement can be done at the transmitter™s antenna connector as long as there is no frequency combiner in the equipment under test. It is important however that the point of measurement for this test be the same as the one used for the output power test. The point of measurement and the occupied bandwidth (B o) should be stated in the test report. Single-carrier and multicarrier requirements are described below. If multicarrier operations are intended, then both requirements should be met. "Multicarrier" refers to multiple independent signals (QAM, QPSK, etc.) and does not refer to techniques such as OFDM.

The purpose of specifying the tests relative to the virtual block edges is to avoid the attenuating effects of any RF filters that may be included in the transmitter design, so that the spectrum mask limits of 6.1.3 are applicable to any channel block.

Note that although testing is specified relative to the virtual block edges, the transmitter is expected to perform similarly for all frequencies within the designed band. Therefore, to reduce the number of test runs, the Lower Virtual Block Edge can be in one assigned band and the upper virtual block edge can be in another assigned band.

The search for unwanted emissions should be from the lowest frequency internally generated or used in the device (local oscillator, intermediate or carrier frequency), or from 30 MHz, whichever is the lowest frequency, to the fifth harmonic of the highest frequency generated or used, without exceeding 40 GHz.

1.A.1.2 Single-carrier test

For testing nearest the lower virtual block edge, set the carrier frequency f L closest to the lower virtual block edge, taking into account any guardband used in the design of the equipment, record the carrier frequency f L , the virtual block edge frequency f VL , the guardband (f LG) and plot the RF spectrum. Likewise, perform the highest frequency test with the carrier frequency, f U, nearest the upper virtual block edge. Record the carrier frequency, the virtual block edge frequency (f VU), the guardband (f UG) and the RF spectrum plot. The guardband is the frequency separation between the virtual block edge and the edge (99%) of the occupied emission.

The user manual should contain instructions, such as details on the minimum guardband sizes required to ensure that the radios remain compliant to the certification process.

It is to be noted that the regulations may permit licensees to have more than one frequency block for their systems. Equipment intended to have an occupied bandwidth wider than one frequency block per carrier should be tested using such a wideband test signal for the 6.1.3 requirement.

1.A.1.3 Multi-carrier test

This test is applicable for multicarrier modulation (not OFDM). It applies equally to multitransmitters into a common power amplifier. Note that the multicarrier transmitter should be subjected to the single-carrier testing, described above, in addition to the tests specified below.

For multi-carrier testing, the single-carrier test method of A.1.2 is to be used except that the single carrier is replaced by a multicarrier modulated signal that is representative of an actual transmitter. The number of carriers should be representative of the maximum number expected from the transmitter, and be grouped side by side nearest the lower virtual block edge, with lower guardband, f LG , if required by the design of the equipment. Likewise test nearest the upper virtual block edge. Record their spectrum plots, the number of carriers used and the guardband sizes (f LG, f UG), the carrier frequencies and the virtual block edge frequencies.

Notwithstanding the requirements in Table A.1, any equipment which uses the complete block or multipleblocks for a single licensee can include the attenuating effect of any RF filters in the transmitter design within the multicarrier test, in which case the virtual and actual block edge frequencies will be the same.

The user manual should contain instructions, such as details on the minimum guardband sizes required and the maximum number of carriers or multi-transmitters permitted, to ensure that the radios remain compliant to the testing process.

1.A.2 Measuring frequency stability

As discussed in 6.1.2, the RF carrier frequency should not depart from the reference frequency (reference frequency is the frequency at 20 C and rated supply voltage) in excess of +10 parts per million. The RF frequency of the transmitter should be measured as follows:

a) At temperatures over which the system is designed to operate and at the manufacturer’s rated supply voltage. The frequency stability can be tested to a lesser temperature range provided that the transmitter is automatically inhibited from operating outside the lesser temperature range. If automatic inhibition of operation is not provided the manufacturer’s lesser temperature range intended for the equipment is allowed provided that it is specified in the user manual.

At 85% and at 115% of rated supply voltage, with temperature at +20 C.

In lieu of meeting the above stability value, the test report may show that the frequency stability is sufficient to ensure that the occupied bandwidth emission mask stays within the licensee’s frequency band, when tested to the temperature and supply voltage variations specified above. The emission tests should be performed using the outermost assignable frequencies that should be stated in the test report.

1.A.3 European conformance test standards

ETSI has published a standard, in a number of parts, that deals in detail with the conformance testing procedures for Fixed Wireless Access equipment. EN 301 126-2-1 to EN 301 126-2-1-5, titled “Fixed Radio Systems; Conformance testing” has the following subparts:

- Part 2-1: Point-to-Multipoint equipment; definitions and general requirements
- Part 2-2: Point-to-Multipoint equipment; Test procedures for FDMA systems

- Part 2-3: Point-to-Multipoint equipment; Test procedures for TDMA systems
- Part 2-4: Point-to-Multipoint equipment; Test procedures for FH-CDMA systems
- Part 2-5: Point-to-Multipoint equipment; Test procedures for DS-CDMA systems

Additionally drafting activity on a Part 2-6, catering for Multicarrier TDMA equipment, is complete. Copies of the published standards are available for download from the ETSI Web Site.

Annex 1-B

(informative)

Power spectral flux density (psfd) calculations

Assuming a typical receiver noise figure of 6 dB, then the thermal noise power spectral density of the receiver is calculated as follows:

[formula (B.1); omitted] renumber as 1-B.1

where

No = Receiver thermal noise power spectral density (dBW/MHz)
kTo = Equipartition Law (-144 dBW/MHz)
N F = Receiver noise figure (6 dB)

At 6 dB below No , the interference power level (I tol) into the receiver is -144 dBW/MHz (-138 - 6).

The spectral power flux density (psfd) at the antenna aperture is calculated as follows:

[formula (B.2); omitted] renumber as 1-B.2

where

Pr = interference power level into receiver (-144 dBW/MHz);
Ae = effective antenna aperture;
Lambda = wavelength; and
G = antenna gain.

1-B.1 20-30 GHz

Assuming an operating frequency of 28 GHz (lambda= 0.011 m) and a typical base station antenna gain of 20 dBi, then the tolerable interference level is given as follows:

$$P_{sfdBS} = -144 - 10\text{Log}(0.011^2) - 20 + 10\text{ Log}(4\pi) = -144 + 39 - 20 + 11$$
$$= -114\ (\text{dBW/m}^2)/\text{MHz}$$

Note that the base station receiver is considered only in this analysis (not the subscriber station). This is primarily due to the fact that BSs are typically located on high buildings/structures with omni-directional coverage which tend to increase their probability of achieving line of sight (LOS) to adjacent licensed area transmitters. SSs, on the other hand, tend to be situated at lower altitudes which reduces the probability of LOS (due to obstacles/clutter) to adjacent area systems. Furthermore, SSs have highly directional antennas (narrow beamwidths) which further reduces the probability that they will align with an interference source from an adjacent area.

A sample calculation is given below to determine te feasibility of meeting the psfd limit between a BS transmitter and BS victim receiver. The formula for psfd is as follows:

Editorial instruction:
- in formula B3 change "10log(R)." to "20log(R)….."

[formula B3; omitted] renumber as 1-B.3

where

PTx = transmitter power (-25 dBW/MHz)
GTx = transmitter antenna gain in the direction of the victim receiver (18 dBi)
R = range (60 000 m)
A losses = atmospheric losses, ~0.1 dB/km

The values given in brackets represent typical fixed BWA parameters.

Using the radio horizon range of 60 km from above, the psfd at the victim base station receiver antenna is:

$$\text{psfd}_{\text{victim}} = -25 + 18 - 10\log(4\pi) - 20\log(60\,000) - 60*0.1 = -120\ (\text{dBW/m2})/\text{MHz}$$

The -120 (dBW/m^2)/MHz value is lower than the -114 (dBW/m^2)/MHz tolerable level, therefore, the 60 km range is considered reasonable as a first level trigger point. Note that the above psfd calculation assumes free space propagation and clear line of sight, i.e., complete first Fresnel zone clearance.

1-B.2 38-43.5 GHz

Equation (1-B.2) shows a dependency of the psfd on the wavelength lambda. Thus the psfd limit of -114 (dBW/m^2)/MHz needs correction to the 38-43.5 GHz band. At 40 GHz, lambda = 0.075 m and substituting into Equation (1-B.2) (retaining other assumptions) gives -111 (dBW/m^2)/MHz.

Annex 1-C

(informative)

Description of calculations and simulation methods

For the simulations described in C.1 to C.3, typical fixed BWA 26 GHz transmission parameters, as identified in 6.1.1, were employed. For ITU rain region K, these result in a maximum cell radius of R = 3.6 km and a corresponding rain fade margin of 25 dB. A clear sky cell edge ATPC of 15-20 dB was employed for the TS 8 -to-BS interference analysis. As subsequently identified, unwanted emissions were specified to be Œ20 dBc at a first adjacent carrier flanking and Œ49 dBc at a second adjacent carrier flanking. These values correspond to a numerical integration of the power within the adjacent channel bandwidth based on the ETSI Type B emissions mask specified in [B4]. For simulations that take the impact of correlated/uncorrelated rain fading into consideration, the diameter of a rain cell was specified to be 2.4 km. This is in accordance with the rain cell model described in ITU-R recommendation P.452-2 [B20]. This model assumes a rain cell to be circular with a uniform rain rate within its diameter. Using this model, the relative rain loss of both a victim and an interference transmission vector can be estimated. The simulations described in C.4 to C.8 employed comparable transmission criteria to that described above, with the exception that the emissions coupling from a second adjacent carrier was -54 dBc.

Both ETSI point-to-multipoint antenna RPE masks [B5], [B6] and the RPE masks defined in 6.2 were employed in the simulations.

1-C.1 Subscriber to hub (TS to CS), adjacent area, same frequency

These simulations examine interference sensitivity across a service area or business trading area boundary. They examine the interference sensitivity between co-channel interference situations assuming an uncoordinated alignment of interference and victim sectors. Interference impairment is appropriately expressed in terms of power spectral flux density (psfd) defined in terms of (dBW/m2)/MHz.

The simulation estimates consider only a clear sky environment, as this is the trigger threshold on which operator coordination is recommended. The recommended boundary psfd trigger level for operator coordination is -114 (dBW/m2)/MHz.

1-C.1.1 Simulation model (TS to CS)

Figure C.1 illustrates the simulation model. Two co-channel sectors are exposed to each other across a boundary.

As is typical with cellular system engineering analysis, TS locations are located on the periphery of the sectors. The distance between the CS locations is D and the distance from an interference TS to the victim CS is R i . Randomly selected angle locations are set for the interference TS interference positions and each establish some angle relative to their boresight position and the victim CS. This establishes the TS antenna angular discrimination to be expected from a specific interference link.

As the operator assignments for sector location are assumed to be uncoordinated, the victim link CS boresight angle is set at some value □ and the interference CS boresight is set at some value _. Angle _ establishes the RPE antenna discrimination to be expected from the victim CS link.

footnote 8; Since some of the annexes come from outside sources, different terminology from that used in the main text may be found. Terminal station (TS) is equivalent to subscriber station (SS), central station (CS) and hub are both equivalent to base station (BS).

[Figure C1, omitted] renumber as figure 1-C.1

To complete a simulation, both CS boresight angles are independently incremented in 5º spin intervals. For each spin, the worst C/I estimate is computed from the 20 interference locations and entered into a database. For each CS spin, the locations of the interference TS positions are modified by changing the random number seed. A simulation, parameterized against D, thus consists of 5184 interference level estimates. These values are sorted to provide a cumulative distribution function (CDF) estimate of psfd versus D.

1-C.1.2 Simulation results

The main conclusions from this analysis are as follows.

Typically, the simulation results indicate that at CS separation distances of less than 40 km, 7-10% of deployments will require coordination. Beyond 40 km, there were no exposures that exceeded the -114 (dBW/m2)/MHz psfd trigger threshold. These simulations assumed an LOS coupling mechanism of the interference signal vectors. When a distance proportional random blockage algorithm (80% at 60 km) was added to the simulations, the psfd coordination requirement reduced to 2-4% of the interference exposures at less than a CS separation distance of 40 km. These prior conclusions are of course conditioned on the transmission parameters employed in the simulations. Increased transmit EIRP would have a direct effect on the coordination distance requirements.

The simulation results indicate that, in general, interference coordination requirements have a low sensitivity to antenna sidelobe RPE beyond the main lobe. One exception was found to be the ETSI CS1 antenna. ETSI CS1 antennas (sectored hub antennas) show much more rapid increase of psfd values above the threshold than other types. These antennas should therefore be used with care and antennas with better sidelobe performance are generally preferred.

While antennas with excellent sidelobe suppression were not identified as an absolute requirement for this coexistence scenario, they may be a requirement for control of an operator’s intrasystem interference control. However, the specification of these requirements is outside the scope of this document.

1-C.2 Hub to subscriber (CS to TS), same area, adjacent frequency

These simulations address the case of multiple operators deployed in a given geographical area that are employing adjacent frequencies. In this case, the most serious conflicts occur when two operators have adjacent carriers of the same polarization. Dependent on an operator’s ability to establish reserve carrier assignments there may or may not be a guard band(s). Hence, the NFD protection ratio may be either 20 dB (adjacent channel operation) or 49 dB (one guard channel). The simulations assume that both operators employ the same carrier bandwidth (assumed as 28 MHz for the analysis). Also assumed is that both operators employ a comparable set of transmission parameters.

1-C.2.1 Simulation model (CS to TS)

Figure C.2 illustrates the simulation model. The interference CS is placed in the victim sector at some parameterized distance S between the hub centers.

[figure C2, omitted] renumber as figure 1-C.2

Relative angular position of the interference CS is set random for each rotational spin of sector alignments. As the interference CS is always deemed to be within the victim sector, only the sector alignment of the interference CS needs to be varied. Spin increments were taken at 5°.

A rain cell of radius R c = 1.2 km is positioned in the sector at some parameterized distance D rc . To ensure that at least one victim link experiences the full rain attenuation loss, D rc is restricted to be within the range of 1.2 km to 2.4 km. A worst-case value for D rc would tend to be 1.2 km. At this distance, the rain cell just touches the victim sector, thus maximizing the number of TS locations that experience significant rain loss.

For each rotational spin of the interference CS, the angular position of the rain cell is randomized. Angular rotation is restricted to be within +/Œ45°, thus ensuring that the full diameter of the rain cell is always within the victim sector.

Twenty victim subscribers are selected for each rotational spin. For each spin, the rain loss of interference and victim vectors is computed, based on the transmission geometry that establishes the distance within the rain cell that the interference vector experiences rain attenuation. Victim signal levels are computed based on the transmission parameters, link distance, and rain loss. Interference signal levels are similarly computed but with the inclusion of antenna angular discrimination, relative frequency polarization, and NFD. A single interference computation accounts for the contribution of each of the four CS sectors and each spin represents 20 independent C/I estimates. Thus, a simulation is represented by 1440 C/I estimates. These are sorted and employed to develop a CDF for C/I at given values for S and Drc .

1-C.2.2 Simulation results

Editorial instruction
-delete “ at end of last sentence in para 2

The simulation results for a first adjacent flanking (zero guard band) were unsatisfactory. Under clear sky conditions, the C/I impairment was found to be distance dependant and ranged from 2% to 10% at a C/I = 19 dB. At a C/I = 25 dB, the impairment range extended from 3% to 30%. The impairment was identified to be distance dependent, with the worst cases occurring at small CSŒCS separation distances. The minimum separation distance examined was 0.3 km while the maximum was 2 km. Under rain fading conditions, the simulation results became significantly more severe. Here, the simulations identified that in excess of 20% of the exposures would experience a C/I < 19 dB and that in excess of 30% of the exposures would experience a C/I < 25 dB. Worst-case interference estimates were found to occur at CS separation distances of the order of 0.6R. This is consistent with the simulation conclusions described in C.4.

As expected, the inclusion of a one-carrier bandwidth guard band demonstrates a significant improvement in terms of the probability of C/I impairment. Under rain faded conditions, worst case C/I < 19 dB exposures are less than 2% and for a C/I < 25 dB are less than 4%. As with the simulation results described in C.1 above, the C/I performance was found to be relatively insensitive to antenna RPE outside the main lobe.[”]

1-C.3 Subscriber-to-hub (TS-to-CS), same area/adjacent frequency

These simulations also address the case of multiple operators deployed in the same geographical area that employ adjacent carrier frequencies. However, in this case there are now two sets of TS carriers that need to be considered and both uplink groups apply adaptive transmit power control (ATPC), dependent on the relative values of link distance and rain attenuation. In the CS-to-TS analysis, both victim and interference CS transmitters operate without power control. Consequently, transmit EIRP was balanced. However in this case there could be a significant EIRP differential, dependant on distance and rain loss differential.

The simulation analysis assumes that both operators employ equal bandwidth transmissions. Both operators' transmissions are assumed to be co-polarized. The NFD selected for a simulation is in accordance with the carrier separation specified for the simulation.

1-C.3.1 Simulation model (TS-to-CS)

The layout model is as shown in Figure C.3 where it may be noted that the two sets of subscriber stations likely experience different magnitudes of rain attenuation. Consequently, their ATPC and EIRP will differ as a function of their distance from their serving TS and the adjustment for rain attenuation. It is now convenient to consider the victim CS to be as illustrated in Figure C.4. The rain loss of each of the 20 interference TS links is computed based on their exposure distance within the rain cell. The Tx power of each interference TS is then ATPC adjusted to ensure that its combined distance and rain loss signal level suppression is such that it meets margin objectives. The signal level of each interference path into the victim CS is then computed based on the transmission criteria of the link.

To simplify the complexity of the analysis, it is assumed that victim TS locations are also area proportionally located. Hence, 50% of the victim subscribers are at a distance > than 0.75R from the victim CS. An average victim rain loss is then computed by sampling the intersection of the victim hub with the rain cell across 5º increments. Victim link rain loss is then set at this average and victim link transmission distance is referenced to 0.75R. Victim link ATPC is then set accordingly.

This methodology ensures a 50% TS estimate accuracy for victim link rain loss. However, if the rain loss never exceeds the margin requirement, then all victim link received signals are at the margin requirement. This is the case for many simulation configurations and is guaranteed for clear sky conditions. In such cases, all victim TS signal vectors arrive at the victim CS at the margin Rx signal level.

[figure C3, omitted] renumber as figure 1-C.3

1-C.3.2 Simulation results

As with the CS-to-TS case discussed above, interference levels were found to be unsatisfactory in the absence of a guard band. C/I impairment probability was found to be comparable to the results identified in C.2 for both clear sky and rain faded system scenarios. Similar to the preceding discussions, antenna RPE characteristics outside the main lobe did not introduce a significant change in performance estimation results. All of the preceding excludes consideration of the ETSI CS1 antenna mask as it was not considered subsequent to simulation results described in C.1.

[figure C4, omitted] renumber as figure 1-C.4

1-C.4 Hub to subscriber (CS to TS), same area, adjacent channel, interference

This simulation derives the interference area (IA) for systems operating in the same area. It applies to FDD and TDD systems. The IA is the proportion of the sector area where interference is above the target threshold, equivalent to the probability that a TS placed at random will experience interference above the threshold. Analysis shows that the worst case is where the interfering CS is spaced approximately 0.6 times the cell diagonal away from the serving CS and when a rain cell in the most adverse position reduces the wanted signal. This is illustrated in Figure C.5.

[Figure C5, omitted] renumber as figure 1-C.5

1-C.4.1 Simulation method

A large number of random TS positions are generated within the cell area. For each position, the wanted and unwanted carrier levels are computed, based on angles, distances, antenna patterns and gains and the appropriate NFD. The TS positions where the C/I is below the required target are counted and plotted. The simulation has been repeated using different antenna patterns to determine the importance (or otherwise) of using highly specified antennas.

1-C.4.2. Simulation results

For a single channel guard band, in all cases the IA is relatively small and its location is predictable. Typically, it occurs in the ihshadowl, of the interfering CS and is a narrow area following the cell diagonal and ending at or inside the cell boundary. The exact shape depends on the choice of TS antenna (smaller with a better antenna). For the parameters chosen, the IA was in the range 0.5% to 2%. Within the IA, the interference level can vary from a level that degrades performance to one that is unworkable. In the absence of rain fading, the IA is significantly reduced.

1-C.5 Subscriber-to-subscriber (TS-to-TS), same area, adjacent channel, TDD

This simulation computes the C/I ratio at a victim TS, the interference arising from another TS in a cell, which overlaps the coverage of the wanted cell. The interfering and victim antennas are directional. Wanted and interfering cells may partly or wholly overlap. The geometry is shown in Figure C.6.

[figure C6, omitted] renumber as figure 1-C.6

1-C.5.1 Simulation method

The overlap parameter r is set at a value between zero (cell sectors just touching) and 2.5. At a value of 2, the victim and interfering CS locations are the same. The simulation places a number of terminals randomly inside each cell. The program then computes whether or not there is mutual visibility between all pairs of terminals. Mutual visibility is decided on the basis of a simple iirectangularl_ antenna RPE. Where there is mutual visibility, the C/I ratio at the victim station is computed, allowing for uplink power control. The results are added to the statistics and the simulation repeated a large number of times. Different values of rare used to determine the probability of conflict (mutual interference) for various values of overlap of the cells. The cumulative probability distribution of C/I values is then plotted for different values of r.

1-C.5.2 Simulation results

The C/I ratio probability distribution curves, adjusted for system factors including the NFD for one guard channel between systems, show the following results:

- For small overlap values, the C/I ratio can be low, but the probability is also very low.
- The maximum probability of conflict occurs at an overlap value of r = 2, where the probability rises to approaching 10%. However, the C/I ratio is then at an acceptable level.
- Rain fading has a neutral or beneficial effect. Subscriber to subscriber (TS to TS), co-channel, adjacent area (TDD).

1-C.6 Subscriber to subscriber (TS to TS), co-channel, adjacent area (TDD)

This simulation computes the C/I ratio at a victim TS, the interference arising from another TS in a cell in an adjacent area. The interfering and victim antennas are directional. Wanted and interfering cells may partly or wholly overlap. The geometry is similar to that shown in Figure C.6 for the TS to TS same area case, but with larger values of cell offset.

1-C.6.1 Simulation method

The same Monte Carlo method is used as for the TS-to-TS same area case, with larger cell offset values and with no NFD (i.e., the victim is co-channel to the interferer). Atmospheric attenuation is ignored in the calculations.

1-C.6.2 Simulation results

The C/I probability curves show that at overlap values of as little as r = 5, the C/I values reach acceptable levels and the probability of the highest values is still very low. This corresponds to a distance, which is lower than that required to reduce CS-CS or CS-TS interference to an acceptable level.

It is concluded that TS-to-TS interference is not the limiting case for adjacent area co-channel operation.

1-C.7 Subscriber-to-hub (TS-to-CS), co- channel, adjacent area

This simulation applies both to the FDD and TDD case. It is based on the same Monte Carlo method as that used for the adjacent channel simulations. The path geometry is shown in Figure C.7.

figure C7, omitted] renumber as figure 1-C.7

1-C.7.1 Simulation method

The IA is constructed in a similar way to the hub to sub same area case. In this case, it is the interfering TS that lies in the IA, the victim being the distant BS. Atmospheric attenuation and uplink ATPC are taken into account. Additionally, the effect of using different TS antennas is calculated. The TS antenna patterns considered were drawn from the standard EN 301 215-2 [B6] and from the work of ETSI WP-TM4 detailed in Annex D. Charts are also constructed of the probability of interference against the cell offset value.

1-C.7.2 Simulation results

With the parameters chosen, the interference probability and the interference area fall to negligible values when the offset (distance between hubs of the victim and interfering cells) reaches approximately 35 km. This “worst case” result does not depend on the antenna RPE.

At lower values of offset, the IA can be rather large. It drops sharply as the worst case limit is approached. It is concluded that for TS-to-CS co-channel operation an offset of approximately 35 km is a good guideline for uncoordinated deployment.

1-C.8 Hub-to-hub (CS-to-CS), co-channel, multiple interferers

This simulation considers the case of multiple CS interferers in a multi-cell deployment, interfering with a victim CS (or other station) in a neighboring LMDS system deployment (Figure C.8). The victim station is assumed to be on a high site, so that path obstruction due to intervening terrain is unlikely to occur. This is a low probability situation, but where it occurs, it is important to note the likely value of interference that could be received.

The original simulations also studied the case of multiple TS interferers.

The calculations determine the psfd at the boundary of the victim system deployment and so can be applied to any type of victim station that has a wide enough antenna beam pattern to encompass all the interferers.

[Figure C.8 -Simulation Geometry, omitted]renumber as figure 1-C.8

1-C.8.1 Simulation method

The interfering system deployment (A) contains a number of BS sites that may be co-channel to the victim station in (B). Calculation shows that up to 70 BS sites could be involved. The victim station is 60 km from the boundary of the deployment (A) and on a high site 500 m above local ground level. Earth curvature is taken into account, but no additional building or ground obstruction is considered.

The simulation places the 70 interfering stations randomly over the area of (A) and pointing in random directions. Realistic antenna RPEs and transmitter EIRPs are used. The sum of the power from all interferers that are not over the horizon is taken into account in calculating the psfd along the 60 km locus and the results plotted as cumulative probability distributions.

1-C.8.2 Simulation results

The multiple BSs produce unacceptable psfd levels at 60 km, when there is no additional path loss due to buildings or terrain. With typical system parameters, the nominal psfd value of -114 (dBW/m^2)/MHz (derived in Annex B of this document) is exceeded by 7-12 dB.

Thus, in the case where terrain is unfavorable, additional measures may be needed to reduce the interference to acceptable levels. This situation is likely to be atypical and in most circumstances buildings, trees and terrain will reduce the interference considerably.

Mesh to PMP CS, co-channel, adjacent area

This simulation models a high-density mesh network interfering with a PMP CS sector (hub sector) placed in the most severe position and pointed directly at the mesh. In a mesh network, there are potentially multiple interferers on each channel, so that the signal from all possible contributing stations adds together at the victim station. The geometry is shown in Figure C.9.

[Figure C.9 -Mesh to PMP CS, co-channel, adjacent area, omitted]

Simulation method

The main attributes of the model are as follows:

- Monte Carlo simulation with realistic MP-MP system parameters.
- Line-of-sight propagation probabilities calculated from Rayleigh roof height distribution function [B24].
- Interfering power summed at PMP base or subscriber using full 3-D geometry to compute distances and angles between lines of sight and antenna bore-sights.
- Effect of automatic power control granularity (ATPC) included.
- PMP RPEs for 24-28 GHz band to EN 301 215-2 V1.1.1 [B6] with BS elevation profile ignored for realistic worst case.

- MP-MP antenna RPE model for 24Œ28 GHz band simulates an illuminated aperture with side-lobes to EN 301 215 V1.1.1.
- Atmospheric attenuation to ITU-R P.676-3 [B21]. Cloud and fog to ITU-R P.840-2 23. Rain attenuation to ITU-R P.838 [B22].
- Dry, storm, and frontal weather patterns considered.

The interference target maximum level in the model is -144 dBW/MHz measured at the victim receiver input. A large number of trial runs of the simulator tool (typically 10 000) are used to generate a histogram of interfering signal against probability of occurrence. The deduced minimum spacing is based on the worst-case value of interference. In practice this has a very low probability so that the results indicated below are conservative.

Simulation results

The results show that the required spacing between the mesh edge and the nearest hub location depends on antenna heights of the hub and the mesh stations, but is not significantly affected by antenna RPE. For typical system parameters, quite modest geographical spacing is possible. For example, a hub 50 m above ground level will require a geographical spacing of only 12 km from the mesh edge (service area boundary of the mesh, assuming it is populated right up to the boundary). Most trial configurations gave much better results (lower interference) so that by careful deployment, lower spacing is practical.

Rain fading was found to have negligible effect on the results, either for the case of the storm cell or a general rain front (rain to one side of a line and dry on the other).

The guideline for PMP to PMP network separation 35 km will be conservative for a mesh deployment. A reduced spacing will be possible without coordination and a further reduction will be possible by coordinating with neighboring operators.

Mesh to PMP TS, co-channel, adjacent area

This simulation is similar to that for the mesh to PMP CS case. It models a high-density mesh network interfering with a PMP TS associated with a nearby CS sector (hub sector). The TS is pointed towards its serving CS (hub). As with the CS case, there are potentially multiple interferers on each channel, so that the signal from all possible contributing stations adds together at the victim station. The geometry is the same as that shown in Figure C.9.

Simulation method

The method is identical to that for the CS case, except that the antenna RPE for the PMP TS is different (TS antenna RPE from EN 301 215-2 V1.1.1 [B6]) and the TS always points towards its own hub (CS). The height of the TS antenna is varied to test sensitivity. Many trial runs (typically 10 000 for each set of parameters) are executed to produce a histogram as in the CS case.

Simulation results

For all practical hub (CS) locations, TS heights, and locations in the PMP cell, it was found that interference levels were lower than those received by the corresponding hub (CS). Thus, the controlling factor is the mesh to hub spacing. At the 12 km spacing determined for mesh to 50 m high hub, all TS interference is below the target level of -144 dBW/ MHz, for any randomly selected mesh configuration.

Antenna RPE within the mesh was found to be noncritical.

Rain fading (storm cell or rain front) had negligible effect on the results.

Mesh to PMP CS, same area, adjacent frequency

This simulation uses a slightly modified model to that for the adjacent area case. The same full 3-D geometry is used in computations, except that the victim hub or TS is now inside the area occupied by the high-density mesh network. Again, there are potentially multiple interferers on each channel, so that the signal from all possible contributing stations adds together at the victim station.

Simulation method

Again a Monte Carlo simulation method is used, in which a large number of trial runs are computed using realistic system parameters and varying the locations of the radio stations for each run. The results are presented in statistical form. The same CS antenna pattern is used as for the adjacent area case. The orientation of the antenna in this case is not so important as it lies inside the mesh network. Full 3-D geometry is taken into account. The results are computed with various values of NFD appropriate to adjacent channel operation and for frequency spacings of one or more guard channels. Dry conditions, storm cells, and rain fronts are considered in the calculations.

Simulation results

The results are available in chart form, showing the probability that the total interference exceeds a given value. The target value for relatively interference-free operation is again taken as -144 dBW/MHz measured at the victim receiver input.

For adjacent channel operation (no guard channel), the probability of exceeding the target interference level is around 35%. This is too high for uncoordinated operation, although it indicates that with careful deployment adjacent channel operation may sometimes be possible.

With one guard between the systems, the probability of exceeding the threshold falls to a negligible level (less than 0.02%). Thus, it can be concluded that, in respect of CS interference, a single guard channel is a suitable guideline for planning deployment of systems, without coordination.

Mesh to PMP TS, same area, adjacent frequency

This case is very similar to the same area CS case. The system geometry is nearly identical, except for the typical antenna heights used for the PMP TS. The same full 3-D geometry is used in computations, except that the victim hub or TS is now inside the area occupied by the high-density mesh network. Again, there are potentially multiple interferers on each channel, so that the signal from all possible contributing stations adds together at the victim station.

Simulation method

Again a Monte Carlo simulation method is used, in which a large number of trial runs are computed using realistic system parameters and varying the locations of the radio stations for each run. The results are presented in statistical form. The same TS antenna pattern is used as for the adjacent area case. The orientation of the antenna in this case is not so important as it lies inside the mesh network. Full 3-D geometry is taken into account. The results are computed with various values of NFD appropriate to adjacent channel operation and for frequency spacing of one or more guard channels. Dry conditions, storm cells and rain fronts are considered in the calculations.

Simulation results

The results are available in chart form, showing the probability that the total interference exceeds a given value. The target value for relatively interference-free operation is again taken as -144 dBW/MHz measured at the victim receiver input.

For adjacent channel operation (no guard channel), the probability of exceeding the target interference level is around 12%. As with the CS case, this is too high for uncoordinated operation, although it indicates that with careful deployment adjacent channel operation may sometimes be possible.

With one guard between the systems, the probability of exceeding the threshold falls to a very low level (less than 0.35%). Thus, it can be concluded that, in respect of TS interference, a single guard channel is a suitable guideline for planning deployment of systems, without coordination.

The interference mechanism is also very similar to that for the TS-to-TS case of PMP networks, so that a result showing that a single guard channel is a satisfactory planning guideline is not unexpected.

General scenario, same area, adjacent frequency

This simulation tests a general case of PMP and mesh systems in the same area, in adjacent frequency bands. It analyzes the cases of PMP CS to PMP CS, PMP TS to PMP TS, high-density mesh to PMP CS and high-density mesh to another mesh.

Results from worst-case calculations for example systems operating in the adjacent frequency/same area scenario show that under certain conditions a NFD of 97 dB could be required to ensure interference-free operation in an adjacent channel. In practice this is unrealizable. Therefore a small risk of interference needs to be tolerated along with some frequency separation. In order to assess the level of risk of interference with certain assumed frequency separations, Monte Carlo style analyses were carried out. Operator deployments were considered with systems that employed identical channelization schemes and system deployments with different channelization schemes.

Simulation method

A Monte Carlo style analysis was carried out whereby the interfering stations were randomly distributed around the victim station for numerous trials. An exclusion distance between the victim and interferer of 50 m was chosen (in order to avoid possibility of co-siting the two). The victim is pointing in the same direction throughout the simulation in order to randomize the directivity between victim and potential interferers.

Interference was calculated for each trial and interference probability density function and cumulative distribution function (CDF) generated.

PMP Base stations are assumed to be transmitting at full power throughout the modeling. ATPC is deployed for both PMP and mesh subscribers to counteract rain fading and different distances. In the first set of trials, it is assumed that the interferer and victim operate with the same channel spacing. In the second set of trials, it was assumed that the interferer channelization is four times the victim channelization scheme. In the case where equal channelization is employed, a guard band of half the channel spacing is assumed at the edge of each operator’s frequency band. In the case of unequal channelization schemes, the interferer channelization was four times the victim channelization. In this scenario, the following two cases were investigated:

- A guard band at the edge of each operator’s block equal to half their respective channelization scheme
- A guard band at the edge of each operator’s block equal to one channel of their respective channelization scheme

In assessing the off-frequency interference levels, the transmitter emission masks of Figure C.10 were assumed, based upon EN301-213 [B4] (112 MHz systems) although modified for ultimate attenuation.

[Figure C10; Transmitter masks based on EN 301 213 spectrum masks and -70 dBc floor, omitted]

The interference limit of -146 dBW/MHz is consistent with an I/N = -10 dB based on the parameters in Annex E.

Two interferer densities were assumed of 0.01 per km 2 for PMP networks and 0.45 per km 2 for high-density (HD) mesh networks. It can be seen that only in the case of a high-density mesh network interfering with another mesh network subscriber station is the interference limit exceeded in more than 1% of trials.

Simulation results

Table C.1 summarizes the simulation results.

[Insert Table C.1; Simulation Results]

It is concluded that where networks are operating with identical channel spacings, a guard band per operator of one half the channel spacing is likely to be sufficient for reliable coexistence in the same geographic area.

To ensure substantially interference-free coexistence between two networks where there is a significant difference in the channel spacings deployed, a guard band equal to a single channel spacing will need to be accommodated within each operator's band.

Annex 1-D

(informative)

Work of other bodies

ETSI WP-TM4

ETSI Working Party TM4 is developing a technical report for publication titled “Rules for Coexistence of PTP and PMP systems using different access methods in the same frequency band” [B8]. This report covers the coexistence of Point-to-Multi-point FWA systems with other FWA systems and with Point- to-Point systems deployed in the same frequency band and in the same (or near) geographical area. It examines the interference scenarios and methodologies for evaluating interference, identifies critical parameters required for standards, and looks at mitigation methods.

Certain key assumptions are made regarding the deployment of PMP systems, reflecting the expectation that a number of operators with frequency block assignments deploying a range of equipment utilizing different multiple access methods and duplexing methods are possible. It is recognized that as a result of facilitating coexistence between the operators, some deployment constraints may result.

Editorial instruction:
-add following new sentence:

“In Part 2 of this recommended practice, use has been made of the ETSI report [B8] in developing coexistence guidelines for point to point and fixed BWA systems.”

Interference classes

Based upon typical fixed service frequency plans a set of interference classes are identified. These are summarized in Table D.1.

[table D1: Interference classes, omitted]

Having identified the interference classes with typical frequency plans in mind, the range of interference scenarios are examined against a number of system possibilities to determine which interference classes are appropriate for further study. For example in the case of two PMP TDD systems deployed by adjacent operators all classes A1 to A4 above can be seen to be possible to a greater or lesser extent. For PMP FDD systems, specific cases only of classes A1 to A4 are appropriate. For example, if subbands are defined within the frequency band plan for uplink and downlink transmission directions then only classes A1 and A2 are appropriate. In the case of PMP and PTP deployment, classes B1 to B4 above all apply to some extent.

Deployment scenario assumptions

In order to evaluate the degree of coexistence between PMP systems, the following assumptions are made:

- One cell from each of the two systems is considered, with a generic distance between hubs.
- The whole cell area is covered with the frequency channel adjacent to the frequency block (channel) assigned to another operator.
- All radio paths are in perfect LOS.

Methodology

Using these assumptions all the potential interference scenarios are evaluated, disregarding the potential mitigation due to sector antenna, the usage of other frequency/polarization channels and cell pattern deployment. Expressions for the potential interference are developed using the concept of net filter discrimination (NFD) in order to estimate the amount of interference (coming from the interfering channel) falling within the receiver filter of the useful system.

These expressions can then be used for each class of interference to assess the following “measures of coexistence:”

- Class A1: the percentage of cell area (%KO) where the interference generated from the interferer CS towards the victim TS produces a C/I smaller than a given C/I threshold.
- Class A2: the percentage of cell area (%KO) where the interference generated from an interferer TS towards the useful CS produces a C/I smaller than a given threshold.
- Class A3: the minimum distance between the two CS’s (interferer and victim) in order to achieve the C/I threshold.
- Class A4: the percentage of cell area (%KO) where the interference generated by an interferer TS towards the victim TSs produces a C/I smaller than a given threshold.

The methodology and the interference parameters summarized above enable evaluation of the coexistence (interference) problems from both the analytical perspective (one simple equation) and the numerical point of view (complete evaluation of C/I over the cell area, using a software tool).

Resultant considerations

In carrying out this evaluation a number of considerations have come to light associated with the interference classes identified above. These are summarized as follows:

a) Class A1 and A2:

1) Site sharing improves coexistence possibilities.
2) Site sharing helps to reduce the guard band requirements (possibly zero).
3) Near site sharing helps also.
4) With no site sharing, at least one channel equivalent guard band required between adjacent operator assignments.
5) Similar EIRPs at the central station reduces interference.

b) Class A3:

1) Site sharing is not possible, therefore minimum separation required.
2) Separation distance can be minimized with a guard band.

c) Class A4:

1) Exacerbated by a large number of terminal stations.
2) Guard band is required.

Additionally it is noted that use of ATPC, equal channelization schemes, and similar receiver performance reduces the guard band requirements. Defined uplink and downlink frequency subband planning reduces the number of interference scenarios for FDD PMP systems.

d) Classes B1 and B2:

1) Site sharing is not possible, therefore minimum distance and angular decoupling is required.
2) Distance and angular separation can be minimized with a guard band.

e) Classes B3 and B4:

1) Site sharing is not possible.
2) Geometrical decoupling is impossible to achieve due to the spread of TS over the PMP deployment area.
3) High frequency separation is required, usually more than one channel equivalent guard band.

Worked examples

Finally, the report provides a number of worked examples for systems in lower frequency bands and in the 26 GHz band. These examples include FDD systems employing TDMA and FDMA methods and the lower frequency example examines the impact of utilizing “standard” performance characteristics versus “actual” or typical characteristics. The results show a range of possibilities ranging from zero guard band for near identical systems with good cooperation between operators to the need for two equivalent channel guard bands where nonidentical systems are deployed and poor cooperation exists between operators.

Industry Canada (IC)

Industry Canada, in consultation with manufacturers and service providers, has conducted studies dealing with coordination between fixed broadband wireless access operators. Technical standards including maximum allowable EIRP, out-of block emission limits and coordination process have been established. Moreover, a US/Canadian bilateral arrangement is already in place for the 24/38 GHz band to facilitate frequency sharing along the border.

Editorial instruction:

- delete URL and replace with “http://strategis.ic.gc.ca/SSG/sf01347e.html#Standards”

The documents ([B10], [B11], [B12], [B13], and [B14]) dealing with the above technical standards, referred to as Standards Radio System Plan (SRSP), Radio Standards Specification (RSS) for the 24 GHz, 28 GHz, and 38 GHz, and US/Canadian Bilateral Arrangement for the 24/38 GHz bands, can be found at [http://strategis.ic.gc.ca/spectrum.]

Radio Advisory Board of Canada (RABC)

The Radio Advisory Board of Canada (RABC) has also conducted technical studies dealing with operator-to-operator coordination issues. A paper was issued as an input to the Industry Canada regulation.

This paper entitled “RABC Pub. 99-2: RABC Study Leading to a Coordination Process for Systems in the 24, 28 and 38 GHz Bands” [B25] recommends a coordination process using distance as first trigger and two psfd levels that trigger different actions by the operators. [9]

If the boundary of two service areas is within 60 km of each other, then the coordination process is invoked. Two psfd levels are proposed for coordination. The first one, Level A, represents a minimal interference scenario where either licensed operator does not require coordination. A second, Level B, typically 20 dB higher than A, represents a trigger for two possible categories: if the interference is above A but below B, then coordination is required with existing systems only. If the interference is greater than Level B, then coordination is required for both existing and planned systems. Table D.2 below summarizes psfd Levels A and B for the three frequency bands.

[Table D.2; Proposed psfd levels in the 24, 28 and 38 GHz bands, omitted]

The much lower psfd levels at 38 GHz are to ensure protection to point-to-point systems allowed in this band in Canada. The coordination procedure is graphically summarized in Figure D.1.

Editorial instruction
-change “otawa”to “ottawa” in URL

The paper can be found at http://www.rabc.ottawa.on.ca/english/pubs.cfm and shows how the values were derived.

footnote 9; Courtesy Radio Advisory Board of Canada

[Figure D1; Coordination process recommended in RABC paper, omitted]

Radiocommunications Agency (UK-RA)

The UK-RA has commissioned technical studies dealing with BFWA interoperator coexistence at 28 and 42 GHz. A report titled "BFWA coexistence at 28 and 42 GHz" and a companion extended study are publicly available from the RA web site under the Business Unit/Research-Extra-Mural R&D project section http://www.radio.gov.uk/busunit/research/extramen.htm. The work studied the issues from the point of view of a regulator wishing to put into place coexistence guidelines for BFWA operators to be licensed in the UK. It addresses both interference scenarios and provides recommendations for psfd trigger levels and guard frequencies based upon tolerable I/N of -10 dB and -6 dB.

Editorial instruction:
-add the following text:

"The RA website can be found at http://www.radio.gov.uk"

The reader may also wish to refer to the following document for more information on regional or national regulation or standards:

- UK Radiocommunications Agency Document RA 390 - Inter-operator Co-existence and Co-ordination Guidelines for BFWA Systems Operating in the Band 27.5 - 29.5GHz

CEPT/ERC

The European CEPT has carried out work within its Spectrum Engineering Working Group concerning the coexistence of FWA cells in the 26/28 GHz bands. The completed report, ERC Report 099 [B2], is available from the European Radiocommunication Office at http://www.ero.dk. The report considers both interference scenarios and concludes with recommendations regarding guard frequencies and separation distances. The concepts of interference scenario occurrence probability (ISOP) and interfered area (IA) feature extensively in the analyses documented.

Annex 1-E

(informative)

UK Radiocommunications Agency coordination process

Introduction

An approach has been proposed to derive guidelines in the UK for BFWA interoperator coordination between licensed areas that abut. It reduces the area in which an operator needs to take some coordination action, allowing him to deploy in an unconstrained manner in greater parts of his or her licensed area than suggested by the recommendations in this Recommended Practice (see 4.2.1 through 4.2.11). This approach increases the risk of unacceptable interference near the boundary and shares the burden of coordination between the operators across the licensed area boundary. Additionally the deploying operator needs only consider the interference impact of certain stations on a station-by-station basis.

This is achieved by defining a boundary psfd trigger level applied on a single interferer basis in conjunction with a coordination zone along the licensed area boundaries, shared equally between the operators. The single interferer trigger limit has been tested in a Monte Carlo style simulation in order to test its adequacy and assess the likelihood of harmful interference into a neighboring licensed area.

Coordination triggers

In effect, the coordination distance, which is based on EIRP and an interference threshold at the victim of I/N = -10 dB, forms the first trigger for coordination action followed, if required, by calculation of boundary psfd. If the boundary psfd exceeds the threshold then some further action is required to either re-engineer the interfering station or to enter into a negotiation with the neighboring operator.

The baseline coordination distance from the licensed area boundary is effectively half the minimum separation distance derived from a worst-case minimum coupling loss (MCL) calculation between typical interferer and victim systems detailed below.

The boundary psfd trigger is based upon the acceptable I/N at the typical victim receiver, but reflected back to the boundary based on half the calculated MCL coordination distance. Therefore, the licensed area boundary psfd trigger is somewhat higher than the psfd at a victim receiver based on the acceptable I/N. Consequently, a higher level of interference potential exists over parts of the neighboring licensed area, but the acceptability of this situation can be assessed by examining the probability of harmful interference.

Application of the coordination distance and psfd triggers

An operator calculates the required EIRP dependant coordination distance based on maintaining the psfd boundary requirement using a free-space, LOS calculation. If his or her intended deployment falls outside the required coordination zone, then he or she needs take no further action. If his or her intended deployment falls within the coordination zone, then he or she needs to carry out a more complex calculation of the resulting psfd at (or beyond) the licensed area boundary. This should take into account all relevant propagation factors, terrain, and clutter to establish whether his or her deployment will result in a psfd greater than the limit. For assessing subscriber station interference, attention needs to be paid to the possibility of uncorrelated rain fading in certain directions.

If the psfd threshold is exceeded then he or she should take steps to reduce the EIRP in the direction of the boundary by either repointing or introducing further blockage. Alternatively, depending on the demography of the adjacent licensed area there might be the possibility of negotiation with the adjacent operator to agree a new ievirtuall_ license area boundary for the purposes of coexistence.

Trigger values

Using the methods detailed above and based upon the parameter values below, the following example psfd levels have been derived for application at the licensed area boundary in the frequency bands identified:

28 GHz Band; -102.5 (dBW/m^2)/MHz
40 GHz Band; -98.5 (dBW/m^2)/MHz

These are associated with the following coordination distance requirements based on the typical EIRPs detailed below such that any deployment within this distance of the boundary requires a check of the resultant boundary psfd. They are dependant upon the type of station:

For PMP hub (base station)
28 GHz Band; 27.5 km
40 GHz Band; 18 km

For subscriber stations
28 GHz Band; 16 km
40 GHz Band; 10 km

Statistical modelling of multiple interferer scenarios has shown that when allowance is made for the limited probability of a line of sight path between interferers and victim, and of the deployment of down tilted base station antennas in PMP networks, application of these limits can ensure substantially interference free coexistence between adjacent service areas.

Worst-case interferer calculations

Base station to base station

The basic link budget equation is as follows:

[formula, omitted]

where:

P rec is the interference power at the receiver input.
FSPL is the free space path loss = 20 log (4piR min /).
L atmos is the atmospheric loss (0.16R min dB at 42 GHz or 0.12R min dB at 28 GHz).
G rec is the receiver antenna gain in the direction of the interferer.
R min is the minimum separation distance.

To meet the interference criterion for each band (I/N = -10 dB):

R min = 36 km for 40.5 GHz, therefore coordination distance = 18 km.
R min = 55 km for 27.5 GHz, therefore coordination distance = 27.5 km.

Antenna aperture:

A e = G rec + 10log(lambda ^2 /4pi)
= -35.24 dBm 2 at 27.5 GHz and a 15 dBi antenna gain.
= -38.60 dBm 2 at 40.5 GHz and a 15 dBi antenna gain.

Power spectral flux density:

psfd = Prec – Ae

Prec at 18 km for 40.5 GHz = -137.1 dBW/MHz
Prec at 27.5 km for 27.5 GHz = -137.7 dBW/MHz

Therefore boundary psfd:

For 27.5 GHz = -102.5 (dBW/m2)/MHz
For 40.5 GHz = -98.5 (dBW/m2)/MHz

Subscriber station interference

A maximum cell size R max , needs to be determined based upon the assumed parameter values. From the maximum base station EIRP, subscriber station antenna gain and nominal subscriber receiver operating level a maximum path attenuation can be calculated.

Maximum path attenuation (FSPL + Atmospheric Loss + Rain Fade) = 153 dB.

Therefore maximum cell size:

R max = 2.6 km for 40.5 GHz
R max = 4.1 km for 27.5 GHz

It is assumed that worst case interference occurs when the subscriber station is at the cell edge and looking towards a serving base station at the boundary and beyond to a victim base station located within the neighboring network by the coordination distance.

Therefore worst case distance:

For 40.5 GHz = 20.6 km
For 27.5 GHz = 31.6 km

Max EIRP = 11.5 dBW/MHz, assuming the path in the cell is subject to rain fading. The effective EIRP at the victim is assumed to be reduced by the cell radius multiplied by the rain attenuation figures assumed for the frequency band under consideration.

Interfering power:

[formula, omitted]

Therefore, the interfering power at the victim base station is as follows:

-147.4 dBW/MHz at 27.5 GHz
-146.3 dBW/MHz at 40.5 GHz

These two figures are both marginally below the interference limit assumed for each frequency band. Allowing for the effective EIRP after rain fading, coordination distances can be calculated.
Coordination distance:

13 km at 27.5 GHz
8 km at 40.5 GHz

However, it is possible that a combination of nondirect alignment close to bore-sight and of rain fading not affecting the interference path could cause higher EIRP in the direction of the boundary.

Assuming a maximum EIRP from the subscriber station and a 10 off-boresight angle towards the boundary, then by reference to the assumed antenna pattern, the maximum EIRP towards the boundary could be Œ5.5 dBW/MHz.

Therefore, coordination distance:

16 km at 27.5 GHz
10 km at 40.5 GHz

Parameter values used for trigger derivation and simulations

For the purposes of the calculating appropriate coordination zones, psfd trigger levels, and Monte Carlo testing, the following system, deployment, and propagation parameter values were assumed:

Assumed parameters for interference analysis:

Nominal channel bandwidth: 28 MHz
Base station EIRP: 15 dBW = 0.5 dB W/MHz
Base station antenna gain: 15 dBi
Base station antenna radiation pattern: EN 301 215 class CS2
Base Station antenna downtilt: 9 degrees
Subscriber station EIRP: 26 dBW = 11.5 dBW/MHz
Subscriber station ATPC assumed: Rx input level maintained at 5 dB above the
threshold for BER = 10 -6 .
Subscriber station antenna gain: 32 dBi (PMP); 26 dBi (mesh)
Subscriber station antenna 3 dB beam width: 4 degrees (PMP); 9 degrees (mesh)
Subscriber station antenna radiation pattern: EN 301 215 class TS1
Subscriber station receiver threshold (10 -6 BER): -111 dBW (QPSK) = -125.5 dBW/MHz
Nominal operating level (threshold +5 dB): -106 dBW
Receiver noise figure: 8 dB (42 GHz) 7 dB (28 GHz)
Interference limit (kTBF - 10 dB): -146 dBW/MHz (42 GHz)
-147 dBW/MHz (28 GHz)
Atmospheric attenuation: 0.16 dB/km at 42 GHz
0.12 dB/km at 28 GHz
Rain attenuation: 7.2 dB/km at 42 GHz
4.6 dB/km at 28 GHz

Annex 1-F

(informative)

Industry Canada coordination process

In Canada, a dual power flux density (pfd) level coordination process is used to facilitate coordination of fixed broadband wireless access systems (BWA) operating in the 24/28/38 GHz bands. The Canadian dual pfd metric is identical in principle and value with the dual psfd metric utilized in Recommendation 5 of 4.2 and the discussion in 7.3 because the Canadian psfd metric is always measured in a bandwidth of 1 MHz. The dual pfd coordination process was developed to allow for flexible deployment of fixed BWA systems without unnecessary constraints. In addition, the dual pfd process would be used only in cases where mutual sharing arrangements between fixed BWA operators do not exist. The following is an excerpt 10 of the coordination process being used in Canada for the 24 GHz range as shown in the document Standards Radio System Plan 324.25 (SRSP 324.25) [B12]. (This document, along with the SRSP for the 28 GHz band (SRSP 325.35) [B13], SRSP for the 38 GHz band (SRSP 338.6) [B14], as well as related Radio Standards Systems Plan (RSS 191) [B11] can be found at http://strategis.ic.gc.ca/spectrum).

6. Intersystem coordination

6.1 International coordination

Editorial instruction
-in 6.1.1 change “38.6-0.0 GHz” to “38.6-40.0 GHz”

6.1.1 Usage of the band 24.25-25.25 GHz near the Canada/U.S. border is subject to the provisions of the Interim Arrangement Concerning the Sharing Between Canada and the United States of America on Broadband Wireless Systems in the Frequency Bands 24.25-24.45 GHz, 25.05-25.25 GHz, and [38.6-0.0 GHz.] (Refer to Section 3 of this document.)

6.2 Domestic Coordination

6.2.1 Domestic coordination is required between licensed service areas 11 where the shortest distance between the respective service area boundaries is less than 60 km 12 . The operators are encouraged to arrive at mutually acceptable sharing agreements that would allow for the provision of service of each licensee within its service area to the maximum extent possible.

6.2.2 When a sharing agreement does not exist or has not been concluded between operators whose service areas are less than 60 km apart, the following coordination process shall be employed:

6.2.2.1 Operators are required to calculate the power flux density (pfd) at the service area boundary of the neighboring service area(s) for the transmitting facilities. Power flux density is calculated using accepted engineering practices, taking into account such factors as propagation loss, atmospheric loss, antenna directivity toward the service area boundary, and curvature of the Earth. The pfd level at the service area boundary shall be the maximum value for elevation points up to 500 m above local terrain elevation. (See Appendix C for a sample calculation of a pfd level.)

footnote 10; The text is subject to change without notice. Readers should consult Industry Canada for the most current standards.

footnote 11; Appendix A is provided as a guide to determine which service areas should be considered for coordination

footnote 12; In the event an operator uses sites of very high elevations relative to local terrain that could produce interference to service areas beyond 60 km, the operator shall coordinate with the affected licensee(s).

6.2.2.2 Deployment of facilities that generate a pfd less than or equal to -114 dBW/m2 in any 1 MHz (pfd A) at the other service area boundaries is not subject to any coordination requirements.

6.2.2.3 Deployment of facilities that generate a pfd greater than pfd A (-114 dBW/m2 in any 1MHz), but less than or equal to Œ94 dBW/m 2 in any 1 MHz (pfd B) at the other service area boundaries, is subject to successful coordination between the affected licensees in accordance with the following coordination process:

6.2.2.3.1 The operator must notify the respective licensee(s) of their intention to deploy the facility(ies) and submit the information necessary to conduct an interference analysis.

6.2.2.3.2 The recipient of the notification must respond within 30 calendar days to indicate any objection to the deployment. Objection may be based on harmful interference to existing systems 13 only.

6.2.2.3.3 If there is no objection raised, the deployment may proceed.

6.2.2.3.4 If an objection is raised, the respective licensees must work in collaboration to reach a suitable agreement before the deployment of facilities. It is expected that the time frame to develop such an agreement should not exceed 30 calendar days.

6.2.2.3.5 Proposed facilities must be deployed within 120 calendar days of the conclusion of coordination, otherwise coordination must be reinitiated as per section 6.2.2.

6.2.2.4 Deployment of facilities that generate a pfd greater than Œ94 BW/m 2 in any 1 MHz (pfd B) at the other service area boundaries is subject to successful coordination between the affected licensees.

6.2.2.5 The above process is described graphically in Appendix B of this document.

6.2.3 In any event, licensees are expected to take full advantage of interference mitigation techniques such as antenna discrimination, polarization, frequency offset, shielding, site selection, and/or power control to facilitate the coordination of systems.

6.2.4 All results of analysis on pfd and agreements made between licensees must be retained by the licensees and made available to the Department on request.

6.2.5 If a licence is transferred, the sharing agreement(s) developed between the former licensees shall remain in effect until superseded by a new agreement between the licensees.

6.2.6 In the event a satisfactory agreement or successful coordination between the licensees is not reached, the Department should be informed. In these cases, the Department may impose appropriate technical limitations to facilitate reasonable implementation of systems.

6.2.7 Licensees shall ensure that the pfd at the boundary of unlicensed neighboring service areas does not exceed pfd B.

6.2.8 While coordination between adjacent block licensees operating in the same vicinity may not be required in most cases, licensees may agree to coordinate certain installations to avoid interference

footnote 13; Existing systems include systems that are operational prior to receipt of the notification, or systems that have previously been coordinated

Appendix A (not reproduced)

Appendix B

The process to determine whether coordination is required for cases where a sharing agreement between the licensees has not been concluded. The proposed coordination process is shown in Figure F.1

[Figure F.1; Proposed coordination process, omitted]

Editorial instructions:
Add new annex 1-G to Part 1, as follows:

"Annex 1-G

(Informative)

Interference Coupling Level (ICL)

1-G.1 Description

In order for different BWA systems to co-exist isolation is required between an interfering transmitter and victim receiver. For the parameters used in this Recommended Practice the amount of isolation required can be easily evaluated being the difference between an interfering transmitter EIRP and the victim receiver interference threshold (translated to eirp in front of the receiving antenna).

Isolation Required = EIRP_{TX} - EIRP_{RX} (dB)

Where EIRP_{RX} is the Receiver interference threshold translated into EIRP in front of the receive antenna.

Assuming:
Receiver interference threshold = -144dBW/MHz
Transmitter EIRP = -3dBW/MHz
Antenna gain = 21dBi
Frequency = 28GHz

Then EIRP_{RX} = -144dBW/MHz – 21dBi = -163dBW/MHz

$\therefore$Isolation Required = -3 +163 = 160dB

The required loss to ensure that the I/N = -6dB criteria is not exceeded is 160dB in this example.

This loss can be accounted for by a number of factors but key contributors are physical separation, introducing free space loss, and frequency separation, introducing NFD between an offset transmitter and receiver. Other factors can be important depending on the specifics of the deployment including polarisation discrimination, physical blocking etc…

1-G.2 Net Filter Discrimination (NFD)

This parameter is a key contributor to the isolation required for adequate coexistence that is under the control of the designer.

An example plot of NFD against frequency offset is shown below for an interferer and victim operating in 28MHz channels. At one channel (28MHz) offset (adjacent channel) the NFD is around –29dB. At two channels offset (second adjacent channel) the NFD is around –49dB.

Being a function of both the transmitter emission characteristic and the victim receive filtering, the profile of the plot and hence the NFD values are clearly influenced by design parameters that affect these characteristics. Transmitter emission shaping and excess bandwidth roll off factors play a large part in determining the overall NFD response.

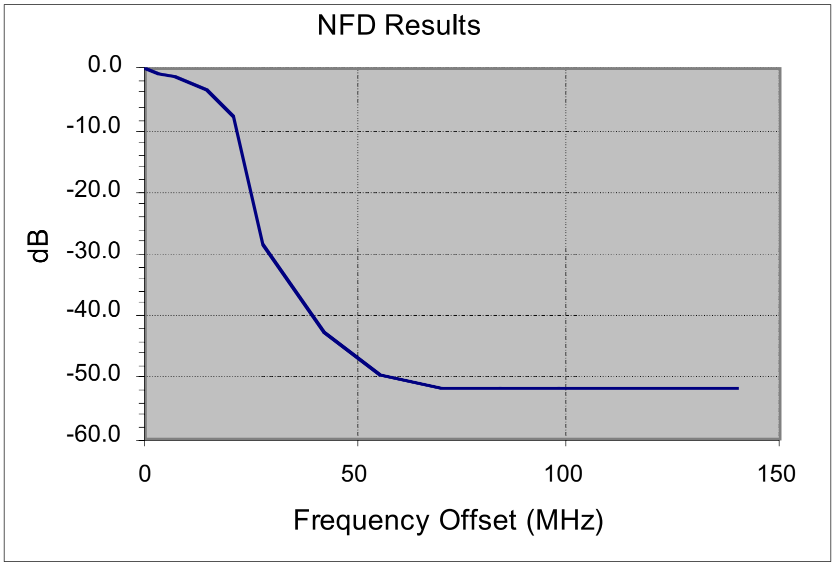


Figure G.1- Example NFD plot

NFD and attenuation due to physical distance separation can be traded off against each other to some extent depending on the deployment scenario in order to achieve the target isolation figure.

1-G.3 Isolation

The following table illustrates the possible trade off mentioned above to achieve a constant isolation requirement of 160dB (in this example) without use of specific mitigation techniques other than physical separation or frequency offset. Assuming a nominal single guard channel the NFD values chosen are appropriate to frequency offsets around 56MHz:

Example NFD at 56MHz offset (dB)	**Single Guard Channel (Fixed), Separation required (m)**	**Separation Distance Fixed (250m), Estimated frequency separation required (MHz)[2]**

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[2] A frequency separation of 56MHz equates to the single guard channel scenario.

45	482	75
50	271	62.5
52	215	55
55	152	40

Table 1-G.1- Separation Distances / Frequency Spacing against NFD values

These considerations should be supplemented by statistical analysis where appropriate.”

Editorial instruction: Add complete new section (part 2) as follows:

Part 2- Coexistence of Fixed Broadband Wireless Access Systems operating in the Frequency Range 23.5 – 43.5 GHz with point- to- point links, sharing the same frequency band.

2-1 Overview of Part 2

Part 2 of this document defines a set of consistent deployment recommendations that promote coexistence between fixed BWA systems and point-to-point systems that share the same bands. The analysis covers frequency range 2 (23.5-43.5 GHz). Each scenario considers the case where one component is a single individually planned “static” PP link or a system comprising multiple PP links within a frequency block and that may be operating dynamically, and the other component is a fixed P-MP BWA system, which may be the victim or the interferer.

The recommendations have been developed and substantiated by appropriate analysis and simulations relevant to system interference experienced between operators licensed for fixed BWA and operators of point-to-point link systems sharing the same bands. These recommendations, if followed by manufacturers and operators, will facilitate a wide range of equipment to coexist in a shared environment with acceptable mutual interference.

The scope of this Recommended Practice includes the examination of interference between systems deployed across geographic boundaries in the same frequency blocks and systems deployed in the same geographic area in adjacent frequency blocks.

This Recommended Practice does not cover coexistence issues due to intra -system frequency reuse within the operator’s authorized band, and it does not consider the impact of interference created by fixed BWA systems on satellite systems.

This document is not intended to be a replacement for applicable regulations, which would take precedence

2-2 Recommendations and Guidelines, including indicative geographical and physical spacing between systems.

2-2.1 Recommendations

Recommendations 1-1,1-2,1-3,1-10,1-11 detailed in Part 1 apply equally to Part 2. Additionally the following new Recommendations apply to this Part 2.

2-2.1.1 Recommendation 2-1

No coordination is needed if a P-P station pointing towards a service area boundary is located greater than 80 km from either the service area boundary or the neighbor’s boundary (if known) in the direction of the link. Based on typical fixed BWA and P-P system equipment parameters and an allowance for potential LOS interference couplings, subsequent analysis indicates that a 80 km boundary distance is sufficient to preclude the need for coordination. At lesser distances, the requirement for coordination should be subject to a detailed examination of the specific transmission path details that may provide for interference link excess loss or blockage. This coordination criteria is viewed to be necessary and appropriate for both systems that conform to this Recommended Practice and those that do not.

2-2.1.2 Recommendation 2-2

This Recommendation applies to co-channel cases only. Recommendation 1-2 introduced the concept of using power spectral flux density "triggers" as a stimulus for an operator to take certain initiatives to collaborate with his or her neighbor. It is recommended that regulators specify the applicable trigger values for each frequency band. As a guide, the following values may be considered: Co-ordination trigger values of -114 (dBW/m^2)/MHz (24, 26, and 28 GHz bands) and -111 (dBW/m^2)/MHz (38 and 42 GHz bands) as detailed in Part 1 can still be considered valid. To some extent, the choice depends on the importance an administration may place on protecting P-P systems, balanced against imposing additional constraint on Multipoint system deployment. As an example. a co-ordination trigger value of -125 (dBW/m^2)/MHz to protect P-P links in the 38 GHz band, is employed by one administration in the initiative procedure described in [ ]

The evaluation point for the trigger exceedance may be at either the victim operator's licensed area boundary, the interfering operator's boundary, or at a defined point in between depending to some extent on the specific geographic circumstances of the BWA licensing. It should be emphasized that the trigger values are useful only as thresholds for taking certain actions with other operators; they do not make an absolute statement as to whether there is, or is not, interference potential.

In common with Recommendation 1-6, these "triggers" should be applied prior to deployment and prior to each relevant system modification. Should the trigger values be exceeded, the operator should try to modify the deployment to meet the trigger or, failing this, the operator should coordinate with the affected operator.

2-2.1.3 Recommendation 2-3

For same area/adjacent channel interference cases, analysis and simulation indicate that operation of individually planned "static" P-P links within the same geographical region in adjacent frequencies will always have considerable constraints on antenna pointing, if damaging interference is to be avoided. Although careful "worst-case" co-ordination is always recommended, at least a single guard channel should be considered, in order to reduce the co-ordination issues to manageable avoidance of main beam couplings between PP stations and P-MP BS or SS.

However, where multiple PP links operate dynamically within a frequency block assignment, further analysis suggests that frequency separation alone, equivalent to two channels of operation, can be recommended and is sufficient to facilitate adequate coexistence.

The ability to co-exist depends upon the amount of guard frequency, distance separation, physical blockage, "out-of -block" emission levels, antenna decoupling and in the case of links operating dynamically, is linked to the probability of interference in given deployment scenarios.

2-2.1.4 Recommendation 2-4

Part 1 Recommendations 1-8 and 1-9 highlight the importance of good antenna pattern and emission mask characteristics for facilitating best coexistence. These considerations are equally important for the scenarios considered in this Part 2. Suitable P-P antenna RPEs are described in this Part 2.

2-2.1.5 Recommendation 2-5

When assigning both PMP frequency blocks and channels or blocks for individually planned "static" PP links, in the same frequency band, it will be useful to maximize the frequency separation possibilities and begin assignments from opposite ends of the band]

2-2.1.6 Recommendation 2-6

Keep deployment height to the minimum necessary for the type of service and application. Local features can provide useful obstacles to help mitigate against interference into adjacent operator installations.

2-2.1.7 Recommendation 2-7

In order to improve NFD values at the frequency block edge, it is recommended to start populating the block starting from the middle and expanding towards the ends. Where different channel sizes are used within a block, it is recommended to assign the smaller bandwidth channels adjacent to the edges of the block.

2-2.2 Suggested guidelines for geographical and frequency spacing

This subclause summarizes the models, simulations and analysis used in Part 2 of this Recommended Practice and provides guidelines for the most severe of the mechanisms identified. The complete set of interference mechanisms is described in Annex 2B,

Guidelines for geographical and frequency spacing between fixed BWA systems and point to point links that would otherwise mutually interfere are given in [8.1] for each of a number of interfering mechanisms. The two main deployment scenarios are as follows:

- Co-channel systems that are geographically spaced
- Systems that overlap in coverage and (in general) require different frequencies of operation

The most severe of the several mechanisms that apply to each case determines the guideline spacing, as shown in Table 2.1. The information is intended to provide a first step in planning the deployment of systems.

Table 2.1 Dominant interference mechanisms between FBWA and Point to Point Systems

Dominant Interference Path (Note 1)	**Scenario**	**Spacing at which interference is below target level (generally 6dB below receiver noise floor)**
PMP SS to PP link station (If the SS antennas are low, the BS case may become dominant, in which case over the horizon spacing is still required)	Adjacent area, same channel	Over the horizon (typically >60km) or combination of large antenna pointing offset and geographical spacing.
PP link station to PMP SS (If the SS antennas are low, the BS case may become dominant)	Adjacent area, same channel	50-80km for typical PP link parameters. If the BS case becomes dominant, lower spacing may be feasible.
PMP BS to PP link station	Same area, adjacent channel	Single guard channel (note 2) plus restrictions on pointing directions.
PP link station to PMP BS	Same area, adjacent channel	Single guard channel (note 2) plus restrictions on pointing directions.
PMP BS to multi PP link system	Adjacent area, same channel	80km for typical system parameters
multi PP link system to PMP BS	Adjacent area, same channel	20-24km for typical system parameters
PMP BS to multi PP link system	Same area, adjacent channel	Two guard channels
multi PP link system to PMP BS	Same area, adjacent channel	Single guard channel

Notes

1- the dominant interference path is that which requires the highest value for the guideline geographical or frequency spacing

2- the guard channel size assumes that the interferer and victim use the same channel size. If they are not equal, then the guard channel should be the wider of the channel sizes of the two systems.

2-3 System overview (interferer and victim systems)

In all cases, a Fixed BWA system is present and may be the victim or interferer. The other system is a point- to- point link or an arrangement of several point- to- point links. There are two main licensing scenarios for the point- to- point link component, each of which is described below.

Fixed BWA systems are described in Part 1 of this Recommended Practice. They are generally of point to multipoint architecture, or sometimes multipoint to multipoint. Although information on base station (BS) locations may be readily available, subscriber stations (SS) are added and removed regularly and information on their locations is not usually available to third parties.

Point- to- point links are simple, generally line of sight, direct connections by radio, using narrow beam antennas. Once installed, they usually have a long lifetime without any changes being made to operating frequencies or other characteristics. They are used for backhaul, inter- cell links and for transmission of telecommunications and entertainment services between fixed points.

Occasionally, systems may comprise a set of point- to- point links, planned and deployed by an operator from a frequency block assignment. They may be used for various applications. In this case, the links may be less permanent than many of the individual links described above. The configuration may vary as the operator’s client base evolves.

2-3.1 Interference scenario 1:multiple point to point links in a frequency block

In some territories, point- to- point links may share frequency bands with MP systems. In this scenario, the links are permitted to operate within a frequency block, and the operator assigns specific frequencies. The system operator decides the link frequencies within the block, determines the antenna characteristics and manages coexistence issues. The regulatory authority does not have responsibility for resolving interference issues, except possibly at block boundaries.

Because the point- to- point link arrangements can change over time, an analysis of interference is best carried out using Monte Carlo simulation techniques, to provide general guidelines for frequency and geographical spacing. The guidelines should be chosen so that the probability of interference above some chosen threshold is acceptably low.

2-3.2 Interference scenario 2: individually licensed links

In territories where point- to- point links share frequency bands with MP systems, the links are commonly individually licensed. In this scenario, the national regulator assigns the link frequencies, determines the antenna characteristics and manages coexistence issues. The operator of the PP link is not free to alter link frequencies or other characteristics without agreement of the regulator. The links are often given a “protected” status over the other services sharing the band, so that he onus is on the operator of the FBWA system to avoid generating unacceptable interference.

Because links are generally protected in this scenario, a worst - case analysis rather than a statistical approach is appropriate. The guidelines should be set so as to avoid all cases of unacceptable interference to (but not necessarily from) the point- to- point link.

2-3.3 System parameters assumed in the simulations

The following tables of parameters for point to point systems were developed as a starting point for simulations and other calculations used in the interference studies.

Table 2.2- Characteristics of multi-link point to point systems used in the simulations

Characteristic (point to point systems)	**Examples**
Layout of system(s) including diagrams	Quasi – random layout of links Consider multiple star/hub configurations
Link lengths	50 to 5000m at 25 GHz 50 to 3000m at 38 GHz
Density of terminal stations	Up to 5/ sq km
Distribution of terminal stations in relation to link length	Uniform (all link lengths have same probability)
Frequency of operation (for each variant to be studied)	Circa 25GHz, circa 38GHz
Duplex method	FDD
Access method	N/A
Receiver parameters	
Channel bandwidth	12.5, 14, 25, 28, 50, 56 MHz Start analysis by assuming 25/28 MHz
filter response	Root Nyquist, 25% roll-off
Noise floor	TBA (6dB noise figure at 25 GHz, 9dB at 38 GHz)
acceptable level for co-channel interference	I/N = -6dB (aggregate of all interferers)
Transmitter parameters	
Channel bandwidth	12.5, 14, 25, 28, 50, 56 MHz Start by assuming 25/28 MHz
emission mask	Depends on modulation – to be specified Assume ETSI or FCC (further discussion required)
maximum power	1W
Typical power	To meet link budget

use of ATPC, steps and range	Uplink and downlink, 2dB steps, 40dB range
Tx-Rx parameters	NFD (net filter discrimination; ETSI data used)
Antenna characteristics (station at point of connection to backhaul or core network)	Composite RPE 1 ft antenna as in 2.3.4. Gain 40-42dBi.
Antenna characteristics (subscriber station)	Composite RPE 1 ft antenna as in 2.3.4 . Gain 40-42dBi.
Antenna characteristics (repeater station)	Same as other antennas
Backhaul links	In – band, separate assignments

Table 2.3: Characteristics of discrete point to point links used in the simulations
(where assignments for point to point systems are made
in the same frequency bands as FWA systems)

Characteristic (point to point systems)	**Examples**
Layout of system(s) including diagrams	Individual, planned link, coordinated by regulatory body
Link lengths	50 to 5000m at 25 GHz 50 to 3000m at 38 GHz
Density of terminal stations	N/A
Distribution of terminal stations in relation to link length	N/A
Frequency of operation (for each variant to be studied)	25GHz, 38GHz
Duplex method	FDD
Access method	N/A
Receiver parameters	
Channel bandwidth	12.5, 14, 25, 28, 50, 56 MHz Start analysis by assuming 25/28 MHz MHz
Filter response	Root Nyquist, 25% roll-off
Noise floor	(6dB noise figure at 25 GHz, 9dB at 38 GHz)
acceptable level for co-channel interference	I/N = -6dB (aggregate of all interferers)
Transmitter parameters	
Channel bandwidth	12.5, 14, 25, 28, 50, 56 MHz Start by assuming 25/28 MHz MHz
emission mask	Depends on modulation – to be specified Assume ETSI or FCC (further discussion required)
maximum power	1W
Typical power	To achieve link budget
use of ATPC, steps and range	Uplink and downlink, 2dB steps, 40dB range
Tx-Rx parameters	NFD (net filter discrimination; ETSI data used)
Antenna characteristics (station at point of connection to backhaul or core network)	Composite RPE 1ft and 2ft antenna(s) as in 2.3.4 Gain = 40-42dBi

Antenna characteristics (subscriber station)	Composite RPE 1ft and 2ft antenna(s) as in 2.3.4 Gain = 40-42 dBi
Antenna characteristics (repeater station)	N/A
Backhaul links	In – band, separate assignments

2-3.4 Antenna parameters

For each interference scenario, two types of antenna are involved. One type is associated with a FBWA system (which may be the interfering or victim system) and the other type is associated with a point to point link or set of point to point links. Antennas for these two types of systems have different characteristics, described below.

2-3.4.1 Typical BFWA system antenna parameters

Typical antenna parameters for FBWA systems in frequency range 2 (23.5-43.5 GHz) are described in Part 1 of this recommended practice. The minimum recommended performance of such antennas is also described. These characteristics have been used for the FBWA component of the analysis in the simulation work carried out in Part 2 of the recommended practice.

2-3.4.2 Typical point to point link antenna characteristics

Research into typical antennas for links operating around 25GHz and around 38GHz has been used to compile a set of “composite” antenna characteristics for point to point links. Whilst these are not intended as a basis for antenna design, they are considered to be adequate to meet reasonable interference objectives and practically feasible (i.e. it could be expected that a number of manufacturers could supply antennas meeting these criteria).

These “composite” antenna RPEs have therefore been used for the point to point link component of the analysis in the simulation work carried out in Part 2 of the recommended practice. Each antenna is specified by creating a radiation pattern envelope (RPE) for each co-polarization and cross-polarization. The RPE is a mask created with a series of straight lines that represents the side lobes of the antenna in dB relative to the main beam at all azimuth angles for either a co-polarized or cross-polarized signal

Using these generic composite envelopes in interference studies ensures that antennas are readily available from more than one manufacturer. The results of the simulations may indicate an antenna with a better RPE is needed. If so, better antennas are available, but may be more costly.

2-3.4.3 Construction of a Composite RPE

The tabular data for each antenna RPE was obtained from each manufacturer’s published RPE. To construct the generic RPE, the RPE of each manufacturer was plotted on the same axes. A composite mask was then drawn over the worst of the set of curves. This was done for two common sizes of high performance antennas in each band. Figure 1 illustrates the construction of a composite co-polarized mask for a 38GHz 1 foot diameter antenna using data from 4 different manufacturers. Both the horizontal and vertical polarizations are plotted for each antenna. The same procedure is also applied to the cross-polarized RPE shown in Figure 2.

The same procedure was applied to 2 foot diameter 38GHz models using data from 4 manufacturers. For the 1 foot diameter and 2 foot diameter 26GHz models, the data of 3 manufacturers were used for each composite RPE.

The actual composite plots for these 6 models are not shown. However, the composite RPE of each is shown later in this document compared to selected standards. Tables of break points for each composite RPE are shown below each plot. The tables associated with the standards have been omitted in this document.

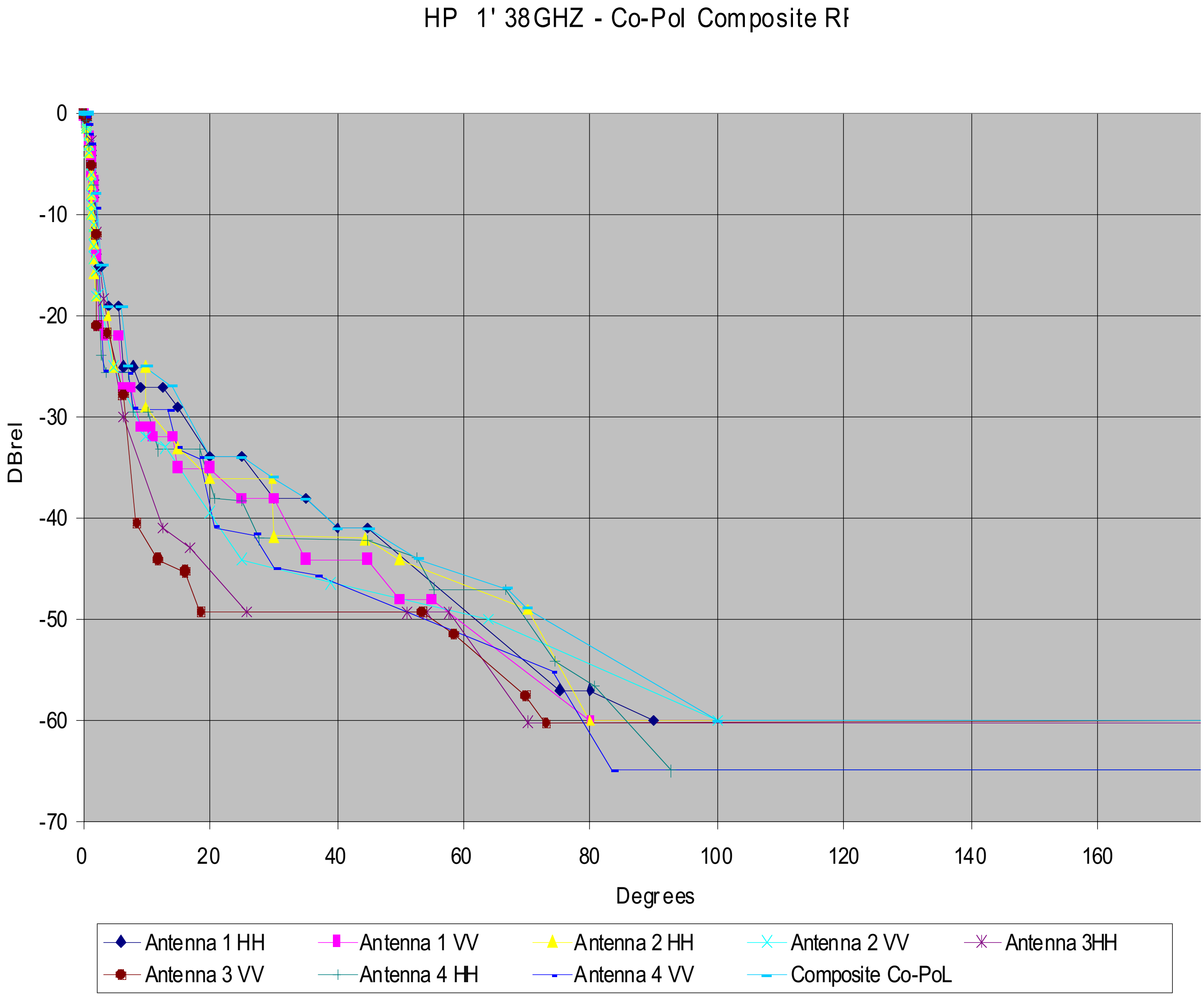


Figure 2.1 Construction of a Composite Co-Pol RPE

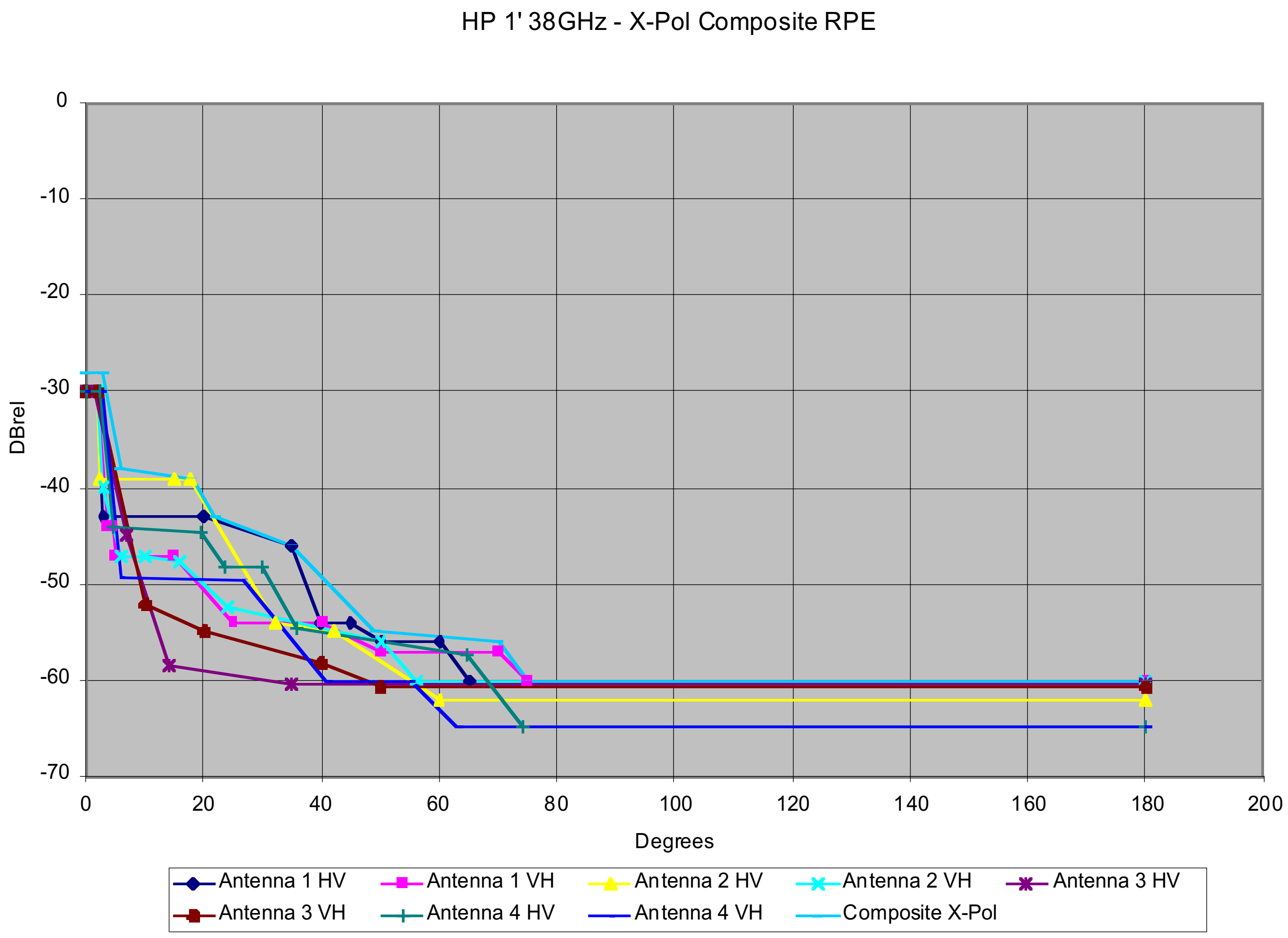


Figure 2.2 Construction of a X-Pol Composite RPE

2-3.5 Comparison of the Composite RPE to Standards

Each composite RPE was compared to a selected number of standards which included ETSI 300 833 class 2, FCC Standard A, and the IEEE 802.16 subscriber classes. Figures 3-10 illustrate those comparisons. In a few cases the composite RPE was slightly worse than ETSI 300 833 class 2. In those cases a modified composite RPE was generated that satisfies the ETSI specification. The rationale for those modifications is that point-to-point links generally require antennas that at least satisfy ETSI 300 833 class 2. The modifications are so slight that they do not significantly affect the availability of antennas that can meet the modified composite RPE.

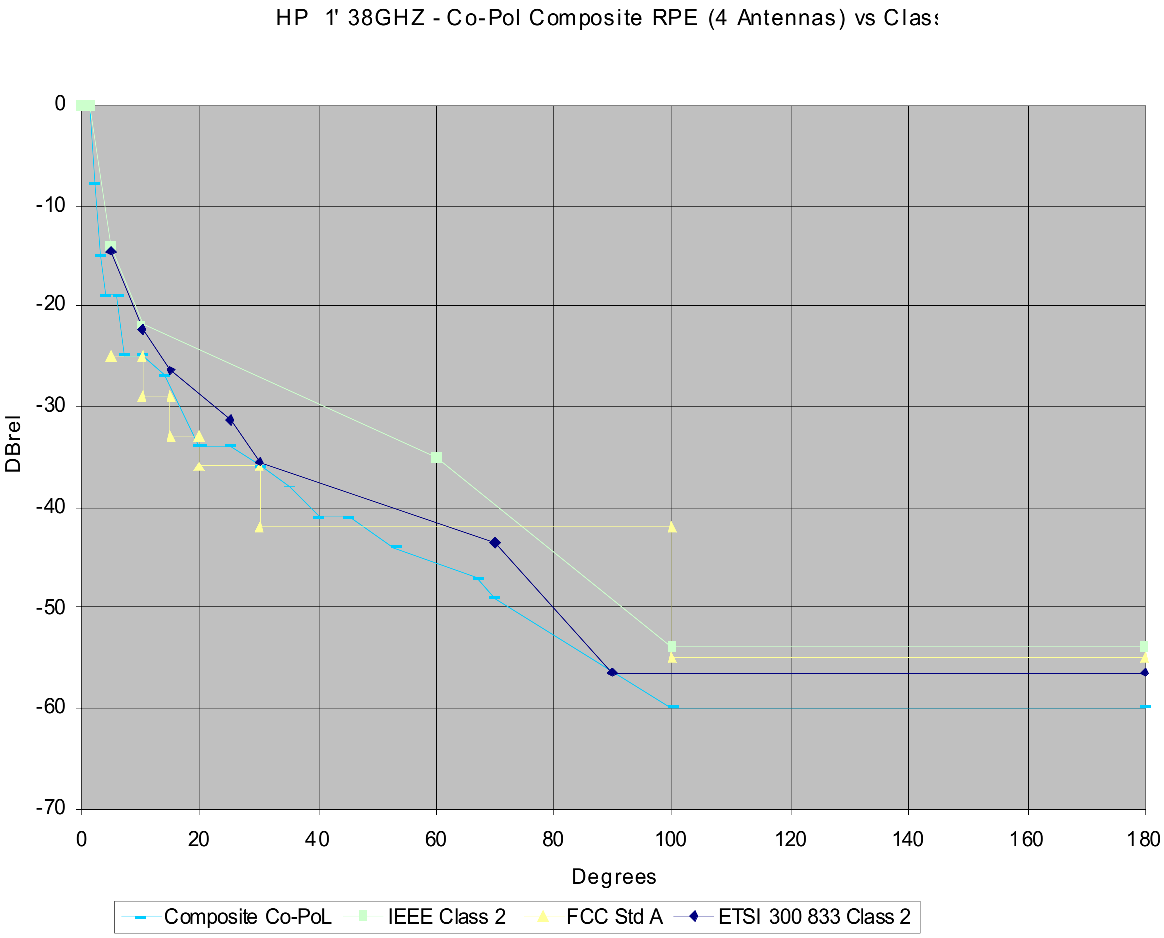


Figure 2.3 Comparison of Co-Pol Composite of HP 1' 38GHz Antennas with Selected Standards

Table 2.4- Breakpoints of Co-Pol Composite of HP 1' 38GHz Antennas

ANGLE (degrees)	0	1	2	3	4	6	7	10	14	20	25	30	35	40	45	53	67	70	100	180
dBrel	0	0	-8	-15	-19	-19	-25	-25	-27	-34	-34	-36	-38	-41	-41	-44	-47	-49	-60	-60

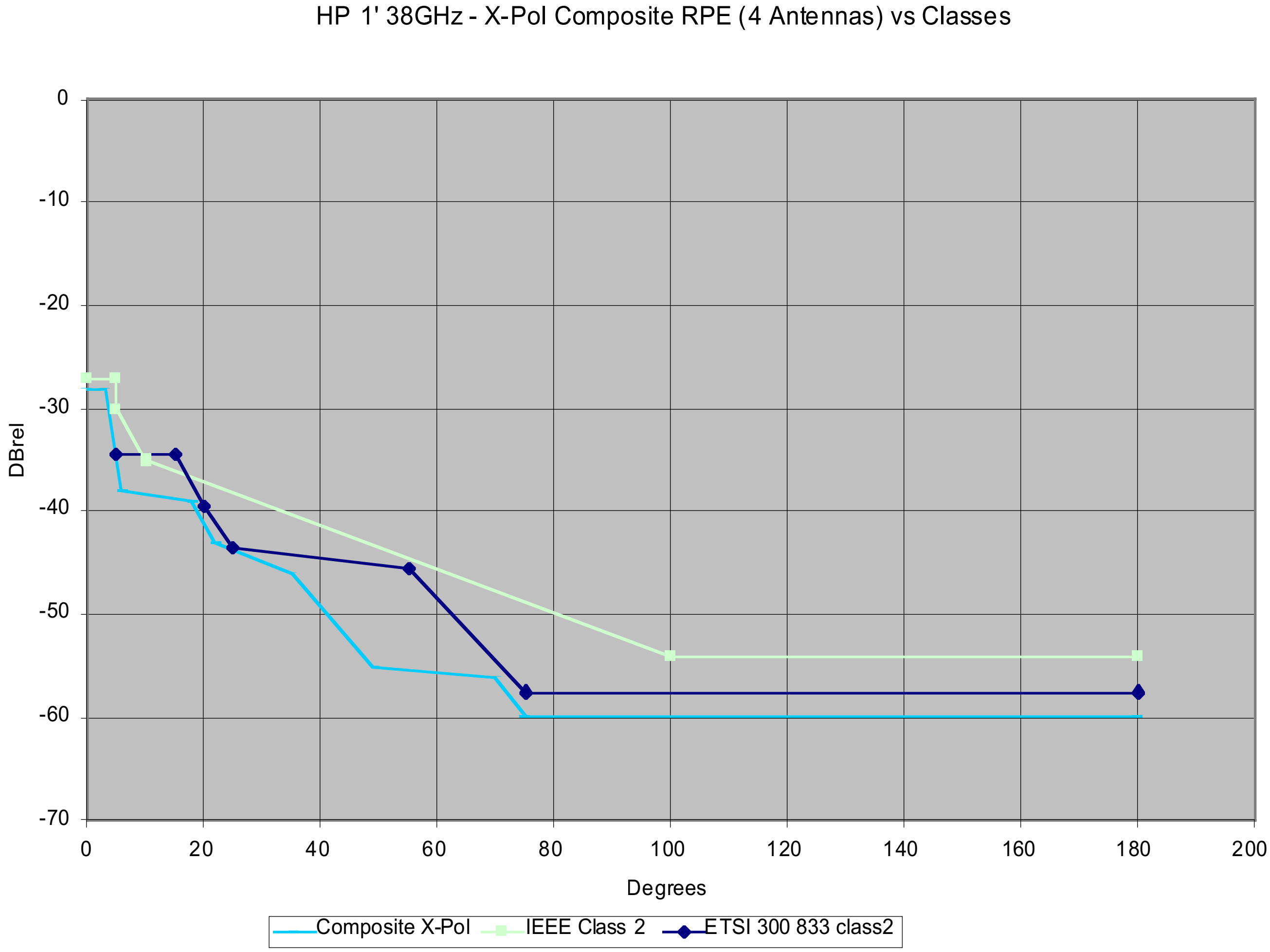


Figure 2.4 -Comparison of X-Pol Composite of HP 1’ 38GHz Antennas with Selected Standards

Table 2.5- Breakpoints of X-Pol Composite of HP 1’ 38GHz Antennas

Angle (degrees)	0	3	6	18	22	35	49	70	75	180
dBrel	-28	-28	-38	-39	-43	-46	-55	-56	-60	-60

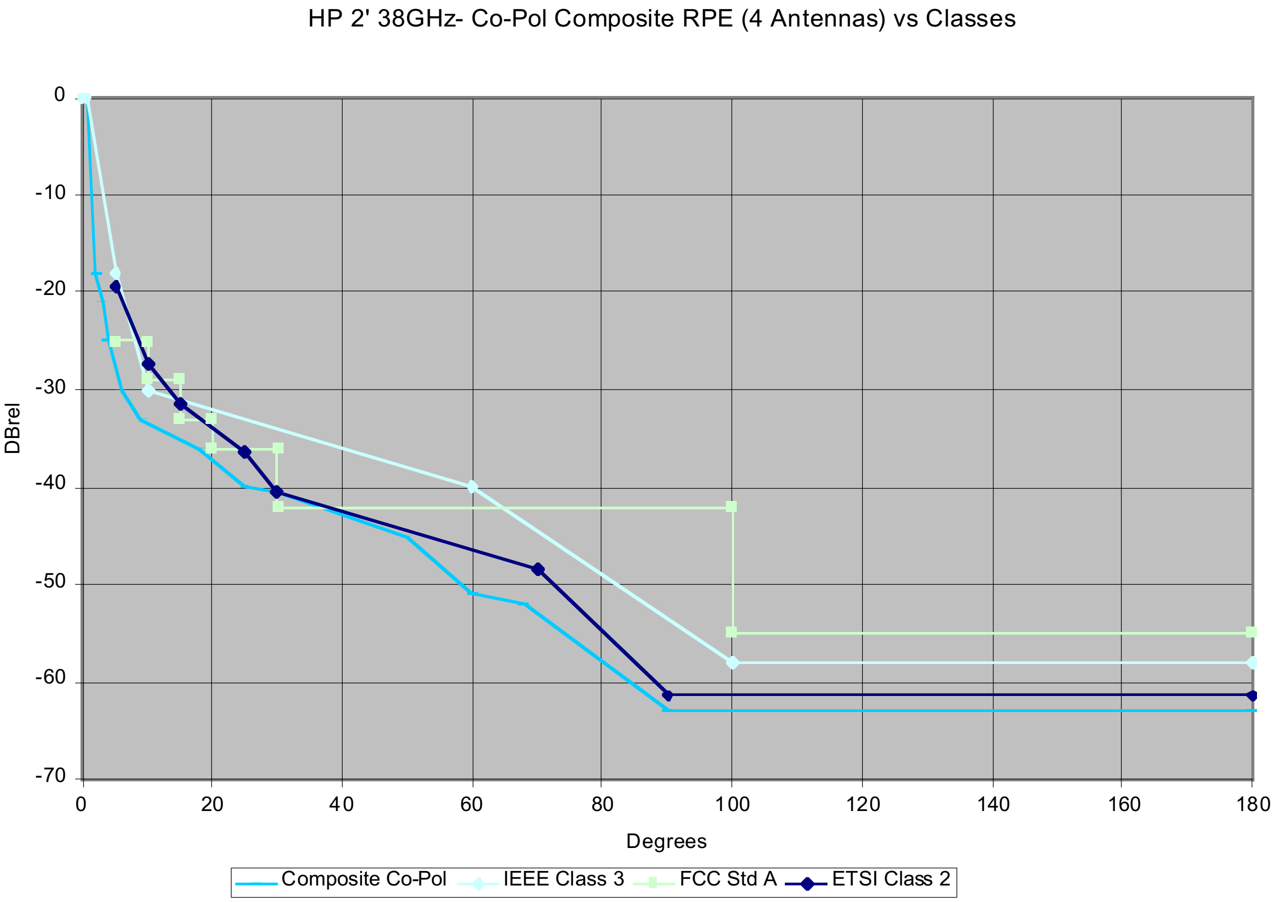


Figure 2.5-Comparison of Co-Pol Composite of HP 2’ 38GHz Antennas with Selected Standards

Table 2.6- Breakpoints of Co-Pol Composite of HP 2’ 38GHz Antennas

Angle (degrees)	0	0.7	2	3	4	6	9	18	25	30	50	60	68	90	180
dBrel	0	0	-18	-21	-25	-30	-33	-36	-40	-40.5	-45	-51	-52	-63	-63

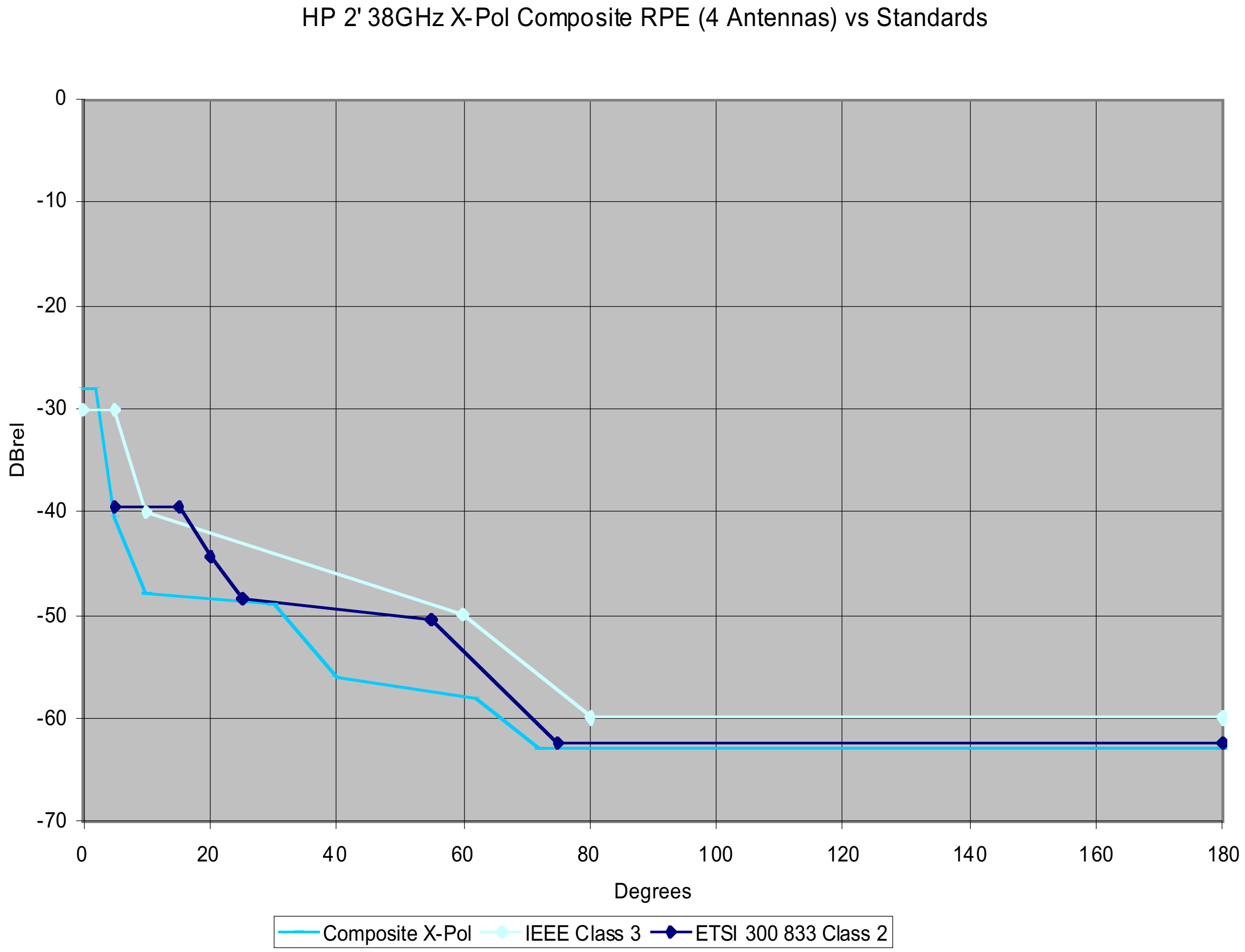


Figure 2.6-Comparison of X-Pol Composite of HP 2’ 38GHz Antennas with Selected Standards

Table 2.7 Breakpoints of X-Pol Composite of HP 2’ 38GHz Antennas

Angle (degrees)	0	2	5	10	30	40	62	72	180
dBrel	-28	-28	-40.5	-48	-49	-56	-58	-63	-63

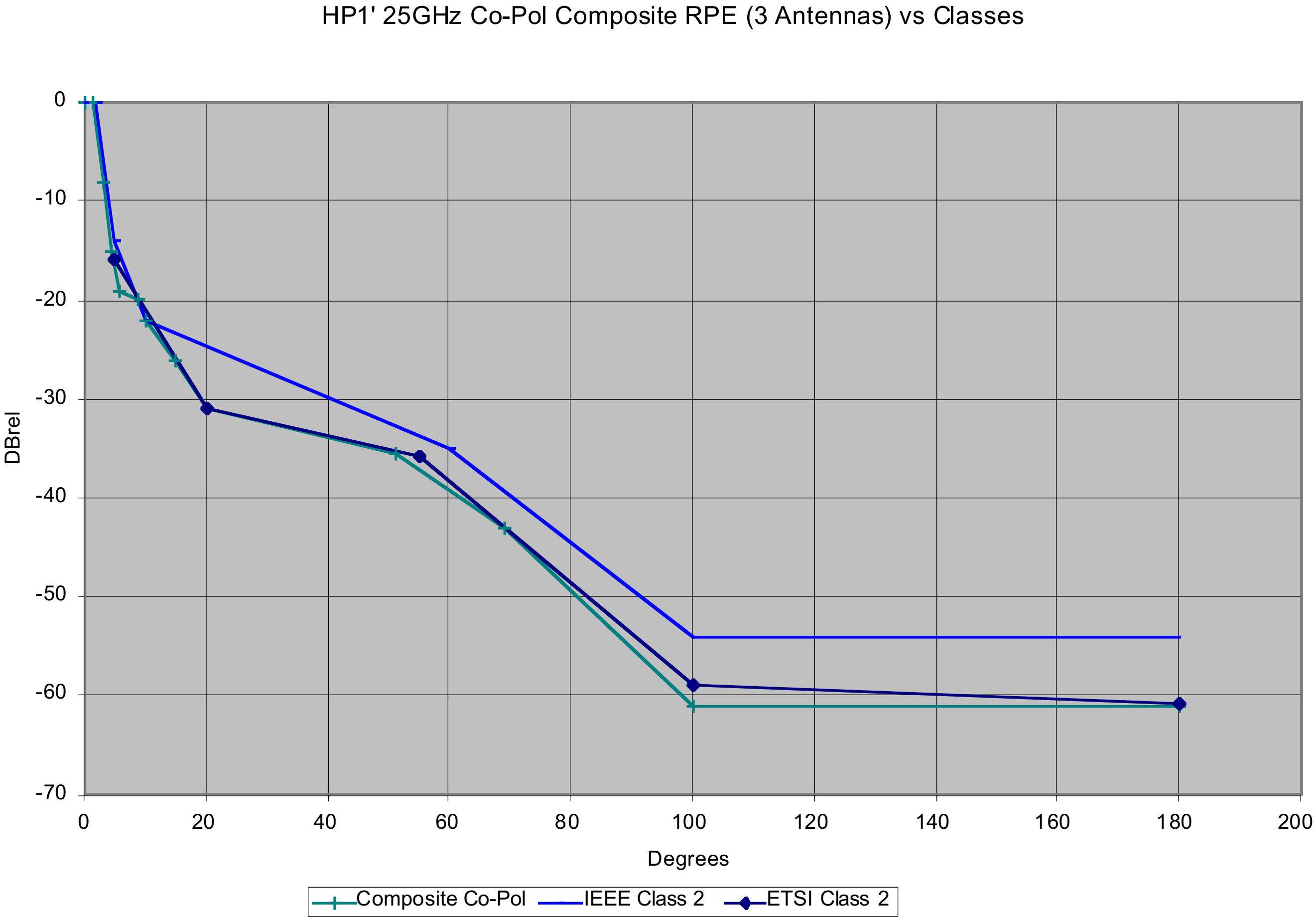


Figure 2.7-Comparison of Co-Pol Composite of HP 1' 25GHz Antennas with Selected Standards

Table 2.8- Breakpoints of Co-Pol Composite of HP 1' 25GHz Antennas

Angle (degrees)	0	1.5	3	4.5	5.8	9	10	15	20	51	69	100	180
dBrel	0	0	-8	-15	-19	-20	-22	-26	-31	-35.5	-43	-61	-61

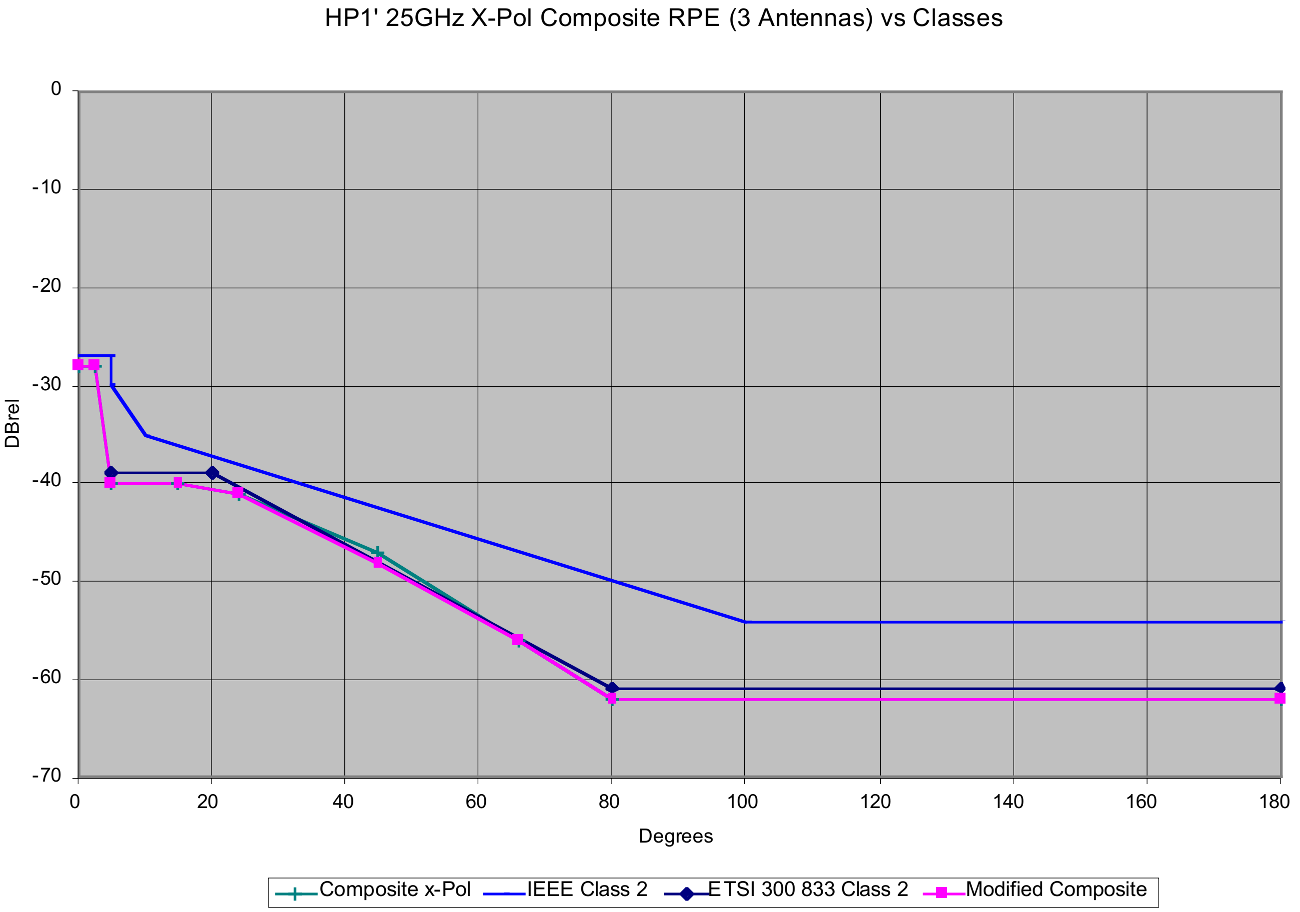


Figure 2.8-Comparison of X-Pol Composite of HP 1' 25GHz Antennas with Selected Standards

Table 2.9- Breakpoints of X-Pol Composite of HP 1' 25GHz Antennas

Angle (degrees)	0	2.5	5	15	24	45	66	80	180
Dbrel	-28	-28	-40	-40	-41	-48	-56	-62	-62

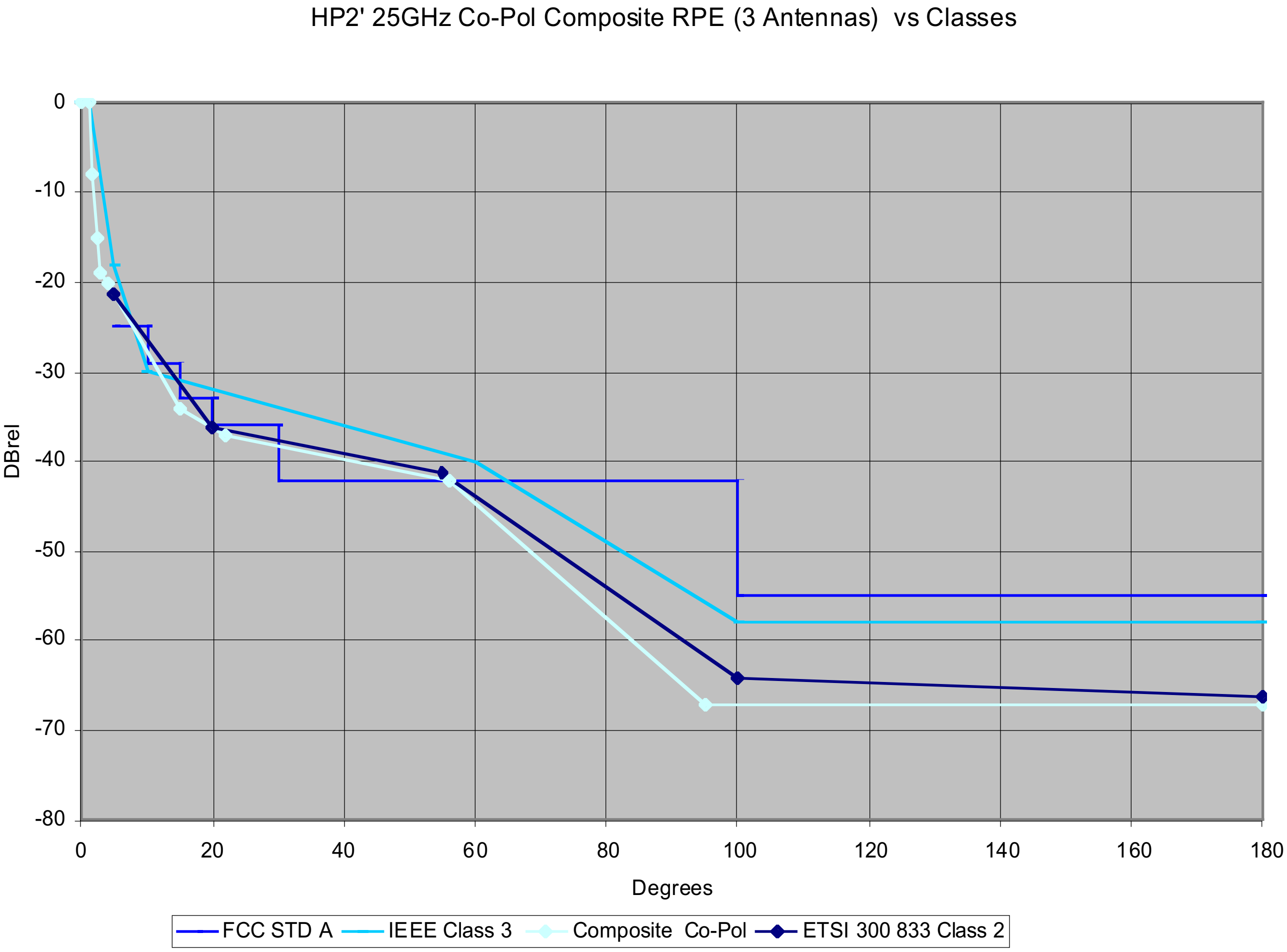


Figure 2.9-Comparison of Co-Pol Composite of HP 2' 25GHz Antennas with Selected Standards

Table 2.10- Breakpoints of Co-Pol Composite of HP 2' 25GHz Antennas

Angle (degrees)	0	1	1.5	2.25	3	4	15	22	56	95	180
Dbrel	0	0	-8	-15	-19	-20	-34	-37	-42	-67	-67

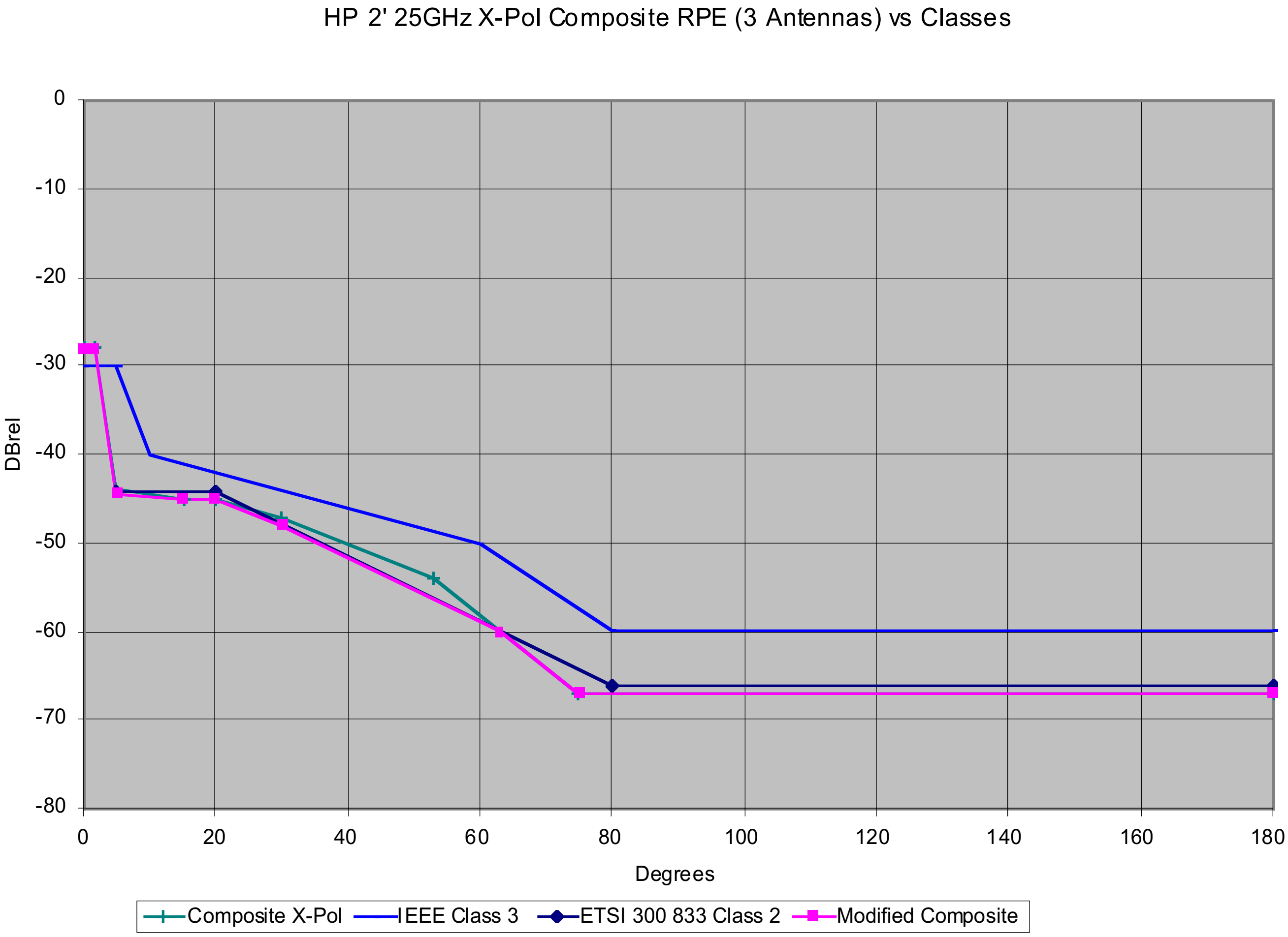


Figure 2.10-Comparison of X-Pol Composite of HP 2’ 25GHz Antennas with Selected Standards

Table 2.11- Breakpoints of X-Pol Composite of HP 1’ 25GHz Antennas

Angle (degrees)	0	1.5	5	15	20	30	63	75	180
Dbrel	-28	-28	-44.5	-45	-45	-48	-60	-67	-67

2-4 Interference Scenarios

2-4.1 Forms of interference

Interference can be classified into two broad categories:

-co-channel interference
-out-of-channel interference.

Figure 1.2 in Part 1 illustrates the power spectrum of the desired signal and co-channel interference in a simplified example. Note that the channel bandwidth of the co-channel interferer may be wider or narrower than the desired signal. In the case of a wider co-channel interferer (as shown), only a portion of its power will fall within the receive filter bandwidth. In this case, the interference can be estimated by calculating the power arriving at the receive antenna and then multiplying by a factor equal to the ratio of the filter's bandwidth to the interferer's bandwidth.

An out-of-channel interferer is also shown. Here, two sets of parameters determine the total level of interference as follows:

A portion of the interferer's spectral sidelobes or transmitter output noise floor falls co-channel to the desired signal; i.e., within the receiver filter's passband. This can be treated as co-channel interference. It cannot be removed at the receiver; its level is determined at the interfering transmitter. By characterizing the power spectral density of sidelobes and output noise floor with respect to the main lobe of a signal, this form of interference can be approximately computed in a manner similar to the co-channel interference calculation, with an additional attenuation factor due to the suppression of this spectral energy with respect to the main lobe of the interfering signal. The main lobe of the interferer is not completely suppressed by the receiver filter of the victim receiver. No filter is ideal, and residual power, passing through the stopband of the filter, can be treated as additive to the co-channel interference present. The level of this form of interference is determined by the performance of the victim receiver in rejecting out-of-channel signals, sometimes referred to as "blocking" performance. This form of interference can be simply estimated in a manner similar to the co-channel interference calculation, with an additional attenuation factor due to the relative rejection of the filter's stopband at the frequency of the interfering signal.

Quantitative input on equipment parameters is required to determine which of the two forms of interference from an out-of-channel interferer will dominate.

2-4.1.1 Acceptable level of interference

A fundamental property of any millimeter-wave fixed BWA system is its link budget, in which the range of the system is computed for a given availability, with given rain fading. During the designed worst-case rain fade, the level of the desired received signal will fall until it just equals the receiver thermal noise, kTBF, (where k is Boltzmann's constant, T is the temperature, B is the receiver bandwidth, and F is the receiver noise), plus the specified signal-to-noise ratio of the receiver. A way to account for interference is to determine C/(N + I), the ratio of carrier level to the sum of noise and interference. For example, consider a receiver with 6 dB noise figure. The receiver thermal noise is -138 dBW/MHz. Interference of -138 dBW/MHz would double the total noise, or degrade the link budget by 3 dB. Interference of -144 dBW/MHz, 6 dB below the receiver thermal noise, would increase the total noise by 1 dB to -137 dBW/MHz, degrading the link budget by 1 dB.

For a given receiver noise figure and antenna gain in a given direction, the link budget degradation can be related to a received power flux density tolerance. In turn, this tolerance can be turned into separation distances for various scenarios.

2-4.1.2 Interference paths

In this Part 2 of the recommended practice, interference to and from point to point links and link systems is considered. The interference between two separate FBWA systems is covered by Part 1 and is not considered further here.

2-4.1.2.1 Victim BS

Where the victim receiver is a fixed BWA base station (BS), with a typical sectoral-coverage antenna, interference can arise from a point point- to- link station or a number of point- to- point link stations in an area. In the worst case, the desired signal travels through localized rain cell, and is received at minimum signal strength. Thus, interference levels close to the thermal noise floor are significant. The analyses for single interferers and multiple interferers require different methods.

2-4.1.2.2 Victim SS

Where the victim receiver is a fixed BWA subscriber station (SS), with a typical narrow beam antenna, interference can arise from a point- to- point link station or a number of point- to- point link stations in an area. In this case, the interference path is between two stations with narrow beam antennas, so that normally only one interferer will be significant due to the low probability of alignment. Where rain fading occurs, it will almost certainly affect the wanted and interfering paths at the same time.

2-4.1.2.3 Victim PP link

Where the victim receiver is a fixed PP link station, the interferer may be a fixed BWA BS or SS. The probability of interference is higher when the interferer is a BS. In the case of a victim station forming part of a multi-link system, the interference scenario is similar to that for an individual PP link station but the acceptable level may be different. This occurs because the individual links considered in this scenario are assumed to have a “protected”status (where interference is managed by the regulatory body) whilst the multi – link systems are assumed to be within an operator’s block assignment, with specific frequencies determined by the operator from within the available block.

2-5 Equipment design parameters

Equipment design parameters appropriate to the fixed BWA systems considered in this section are provided in Part 1 of the recommended practice.

For the point- to- point link or multi – link system, the typical parameters in tables 2.2 and 2.3 have been assumed. These were derived from an IEEE study, with contributions from several manufacturers of equipment and antennas.

2-6 Deployment and coordination between P-MP systems and systems deploying P-P links

2-6.1 Co-frequency/adjacent area

The basis for coexistence in this scenario where co-frequency P-P links (either individually planned "static" links or multiple P-P links within a frequency block that may be operating dynamically) are to be deployed in an adjacent licence area is substantially the same as that described for PMP systems detailed in section 7.1 of Part 1.

However, it is recommended that co-ordination is carried out when distances between service area boundaries is less than 80 km. This accounts for the possibility of P-P stations having different characteristics from PMP stations and being located at greater heights than conventional P-MP stations.

Fixed BWA operators should calculate the power spectral flux density (psfd) at their own service area boundary as detailed in Part 1 and evaluate against the appropriate co-ordination trigger level.

Generally, deployment of facilities which generate a psfd, averaged over any 1 MHz at their own service area boundary, less than or equal to that stated in Table 1.11 in Part 1, should not be subject to any coordination requirements.

However there may be more stringent national criteria applied by specific administrations that should take precedence.

2-.6.2 Same Area/adjacent frequency (individually planned "static" links)

In order to evaluate the coexistence scenarios associated with P-P and PMP systems operating in the same area and in adjacent frequency blocks, reference was made to ETSI Technical Report TR 101 853 [ref]. The report derives expressions that can be used to evaluate the coexistence potential for four possible interferer and victim system scenarios classified in the report as:

Class B1 – PMP BS to P-P station.
Class B2 – P-P station to PMP BS.
Class B3 – PMP SS to P-P station.
Class B4 – P-P station to PMP SS.

For classes B1 and B2 involving BSs, expressions are developed that can be used to calculate the minimum separation distance required between the P-P station and the PMP BS in order to meet a target minimum C/I ratio. For Classes B3 and B4, expressions are developed that calculate the C/I ratio specific to decoupling angles between the SS and the P-P station. See equations 28, 32, 37 and 40 in section 7 of the ETSI report [ref].

2-6.3 Example Calculations

The expressions developed in the ETSI technical report were used to carry out "worst-case" coexistence calculations between a PMP system operating in one frequency block adjacent to another frequency block dedicated to individually planned "static" P-P links. As far as possible, parameter values shown in section 2-4.3 were used. Where suitable parameters were not available, reference was made to appropriate ETSI standards EN 301-213[ref], EN 301-215[ref] and EN 300-431[ref].

The calculation results are dependant on a large variety of possible parameter values. Definition of "typical" values is impractical since these will be different for any given scenario. Factors like P-P link length, planned availability, PMP cell size, to name a few, can impact the parameter values chosen.

Classes B1 and B2:

Table 2.12 below shows examples of minimum separation distance (Dmin) between a P-P station and a PMP BS when the P-P station is the victim (Class B1). The calculated distances are in kilometers and given for a range of Net Filter Discrimination (NFD) values corresponding to frequency offset between the two systems and P-P to BS pointing angle offset. An indication of appropriate NFD columns are shown for co-channel (although not the issue here) and for first and second adjacent channels representing the case where no guard channel is inserted between the system operating frequencies and where a single guard channel is inserted.

Co-channel

1st adjacent ch. Region.

2nd adjacent ch.region.

NFD (dB)	0	10	20	25	30	35	40	45	50	55	70
Angle											
0	1455.3	460.2	145.5	81.8	46.0	25.9	14.6	8.2	4.6	2.6	0.5
1.5	1455.3	460.2	145.5	81.8	46.0	25.9	14.6	8.2	4.6	2.6	0.5
2.0	1070.5	338.5	107.1	60.2	33.9	19.0	10.7	6.0	3.4	1.9	0.3
2.5	787.5	249.0	78.8	44.3	24.9	14.0	7.9	4.4	2.5	1.4	0.2
3.0	579.3	183.2	57.9	32.6	18.3	10.3	5.8	3.3	1.8	1.0	<200m
4.5	258.8	81.8	25.9	14.6	8.2	4.6	2.6	1.5	0.8	0.5	<200m
5.8	163.3	51.6	16.3	9.2	5.2	2.9	1.6	0.9	0.5	0.3	<200m
7.4	154.1	48.7	15.4	8.7	4.9	2.7	1.5	0.9	0.5	0.3	<200m
9.0	145.5	46.0	14.6	8.2	4.6	2.6	1.5	0.8	0.5	0.3	<200m
9.3	134.8	42.6	13.5	7.6	4.3	2.4	1.3	0.8	0.4	0.2	<200m
9.7	124.8	39.5	12.5	7.0	3.9	2.2	1.2	0.7	0.4	0.2	<200m
10.0	115.6	36.6	11.6	6.5	3.7	2.1	1.2	0.7	0.4	0.2	<200m
11.0	105.4	33.3	10.5	5.9	3.3	1.9	1.1	0.6	0.3	<200m	<200m
12.0	96.1	30.4	9.6	5.4	3.0	1.7	1.0	0.5	0.3	<200m	<200m
13.0	87.7	27.7	8.8	4.9	2.8	1.6	0.9	0.5	0.3	<200m	<200m
14.0	80.0	25.3	8.0	4.5	2.5	1.4	0.8	0.4	0.3	<200m	<200m
15.0	72.9	23.1	7.3	4.1	2.3	1.3	0.7	0.4	0.2	<200m	<200m
16.0	65.0	20.6	6.5	3.7	2.1	1.2	0.7	0.4	0.2	<200m	<200m
17.0	57.9	18.3	5.8	3.3	1.8	1.0	0.6	0.3	<200m	<200m	<200m
18.0	51.6	16.3	5.2	2.9	1.6	0.9	0.5	0.3	<200m	<200m	<200m
19.0	46.0	14.6	4.6	2.6	1.5	0.8	0.5	0.3	<200m	<200m	<200m
20.0	41.0	13.0	4.1	2.3	1.3	0.7	0.4	0.2	<200m	<200m	<200m

Table 2.12: Class B1, Example PMP CS to P-P separation distances in kilometers

For Class B2, the separation distance calculations gave lower values than for the equivalent B1 cases, leading to the conclusion that the class B1 scenario is dominant when considering interference between a P-P station and a PMP BS.

The results indicate that even a single guard channel between the systems is insufficient to allow fully uncoordinated deployment. Separation distances of several kilometers are needed if bore-sight alignment occurs.

It is interesting also to consider the impact of these results within a grid of BSs as depicted in the Figure 2.12 below. In Figure 2.12 for illustrative purposes, the P-P station is operating in the adjacent channel to the BSs (of course, a realistic frequency re-use plan may preclude all BS operating on the same frequency). Examination of Table 2.12 shows that in the adjacent channel and at a distance of 5 km then a pointing angle offset of 13 degrees is required. This leads to the range of P-P system pointing angles illustrated in Figure 2.12 (for one quadrant only) that could be possible based on the assumed parameter values for this calculation.

Alternatively, the P-P station could be operated closer to the BS with a greater constraint on the pointing angle. For example, if the offset is 45 degrees, then the P-P link could be as close as 1.5 km from the BS.

However there could be other adjacent frequency P-MP BSs located outside the grid illustrated in Figure 2.11 which would require interference avoidance, thereby further restricting the pointing angle possibilities.

Clearly, close coordination is required under these conditions.

Examination of Table 2.12 shows that if a single guard channel is inserted, then the P-P link could be operated anywhere within the grid of Figure 2.11 to within a few hundred meters of the P-MP BSs so long as care is taken to avoid the P-P main beam pointing towards the BS. Although less constraining, again detailed co-ordination would be required to account for the whole deployment of P-MP BSs.

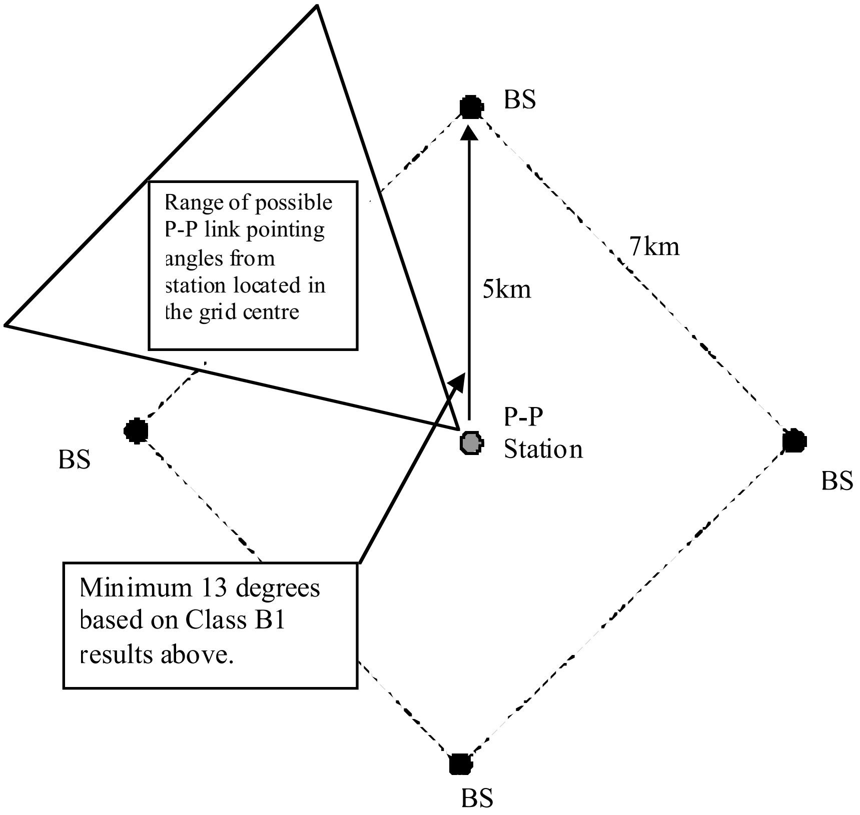


Figure 2.11: One interpretation of Table 2.12 results for no guard channel

Classes B3 and B4:

These classes refer to interference between the P-P station and PMP SSs. Care should be taken to understand the antenna decoupling angles alpha and beta by reference to Figures 12 and 13 in the ETSI technical report [ref?].

The table 2.13 below is an extract of results for PMP Terminal Station interference into a P-P station. In this example, the P-P link was sited 5 km away from the BS and the table gives the C/I values that are less than 30dB at the P-P receiver for a range of P-P decoupling angles and SS decoupling angles. Additionally, the frequency offset is one channel being consistent with a NFD assumption of 27dB.

Although the table here is truncated, the C/I for alpha equal to zero degrees becomes greater than 30dB at a beta angle of 52 degrees. This shows that in the situation where the SS decoupling angle is zero, the P-P link must “point away” by at least 52 degrees if operating in the adjacent channel to the PMP SS. Considering that SS could be located in any position in a sector facing the P-P link this could place considerable constraints on the P-P pointing angle illustrated in figure 2.12. The problem becomes more severe when a full deployment of PMP cells is considered, employing a frequency re-use plan. If the P-P link is situated at 10km from the BS, the decoupling angle required drops to 24 degrees.

CRS to TS Distance d2= 3700 metres

CRS to P-P Distance d= 5000 metres

Max
Alpha = 54 degrees

									TS Decouple Angle (Alpha)				
P-P Decouple Beta	Alpha	0	5	10	15	20	25	30	35	40	45	50	55
	Gain at Alpha	32	26.8	15	12.5	10	8.75	7.4	6.1	4.9	3.6	2.3	2
	d1 (metres)	8700	8686	8644	8574	8477	8353	8204	8031	7834	7616	7378	7122
		P-P C/I		NFD=	27	dB							
0.0		-5.6	-0.4	11.4	13.8	16.2	17.3	18.5	19.6	20.6	21.7	22.7	22.7
1.5		-5.6	-0.4	11.4	13.8	16.2	17.3	18.5	19.6	20.6	21.7	22.7	22.7
2.0		-2.9	2.3	14.0	16.5	18.9	20.0	21.2	22.3	23.3	24.3	25.4	25.4
2.5		-0.2	4.9	16.7	19.1	21.5	22.7	23.9	25.0	25.9	27.0	28.0	28.0
3.0		2.4	7.6	19.4	21.8	24.2	25.3	26.5	27.6	28.6	29.7	-	-
4.5		9.4	14.6	26.4	28.8	-	-	-	-	-	-	-	-
5.8		13.4	18.6	-	-	-	-	-	-	-	-	-	-
7.4		13.9	19.1	-	-	-	-	-	-	-	-	-	-
9.0		14.4	19.6	-	-	-	-	-	-	-	-	-	-
9.3		15.1	20.3	-	-	-	-	-	-	-	-	-	-
9.7		15.8	20.9	-	-	-	-	-	-	-	-	-	-
10.0		16.4	21.6	-	-	-	-	-	-	-	-	-	-
11.0		17.2	22.4	-	-	-	-	-	-	-	-	-	-
12.0		18.0	23.2	-	-	-	-	-	-	-	-	-	-
13.0		18.8	24.0	-	-	-	-	-	-	-	-	-	-
14.0		19.6	24.8	-	-	-	-	-	-	-	-	-	-
15.0		20.4	25.6	-	-	-	-	-	-	-	-	-	-
16.0		21.4	26.6	-	-	-	-	-	-	-	-	-	-
17.0		22.4	27.6	-	-	-	-	-	-	-	-	-	-
18.0		23.4	28.6	-	-	-	-	-	-	-	-	-	-
19.0		24.4	29.6	-	-	-	-	-	-	-	-	-	-
20.0		25.4	-	-	-	-	-	-	-	-	-	-	-
22.0		25.7	-	-	-	-	-	-	-	-	-	-	-

Table 2.13: Class B3, NFD=27dB (i.e. adjacent channel),
Example C/I at the P-P receiver from the PMP SS

Table 2.14 is an extract from calculations in the same scenario but with the P-P link operating with one guard channel separation from the PMP SS station. This is reflected in a NFD figure of 50dB.

CRS to TS	Distance	d2=	3700	metres

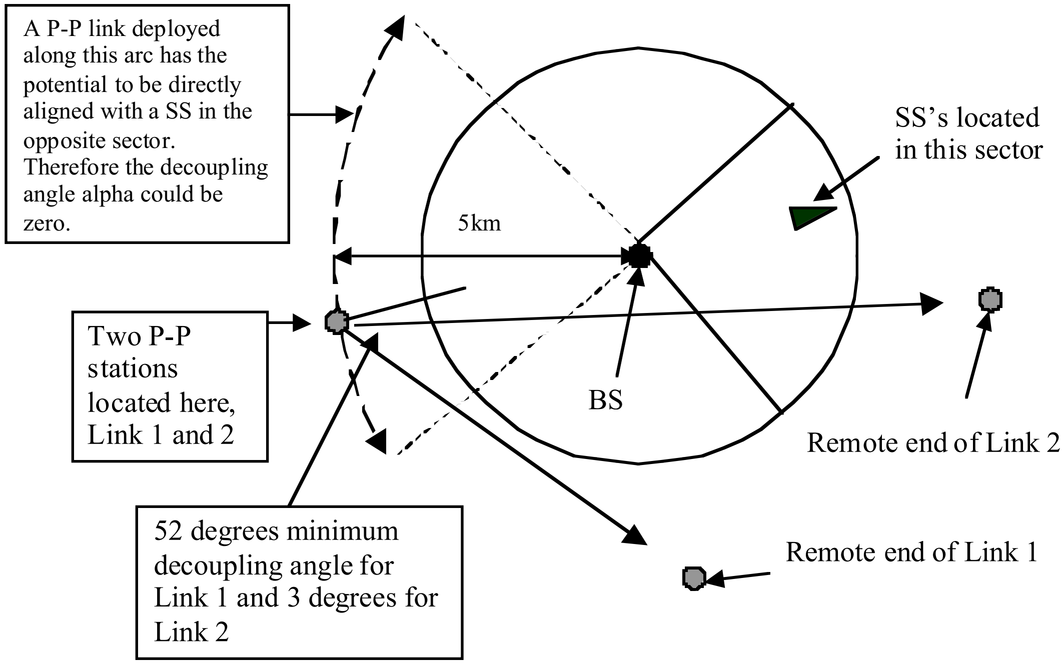
CRS to P-P	Distance	d=	5000	metres

P-P Decouple Beta	Alpha	0	5	10	15	20
	Gain at Alpha	32	26.8	15	12.5	10
	d1 (metres)	8700	8686	8644	8574	8477
		P-P C/I		NFD=	50	dB
0.0		17.4	22.6	-	-	-
1.5		17.4	22.6	-	-	-
2.0		20.1	25.3	-	-	-
2.5		22.8	27.9	-	-	-
3.0		25.4	-	-	-	-
4.5		-	-	-	-	-
5.8		-	-	-	-	-
7.4		-	-	-	-	-
9.0		-	-	-	-	-
9.3		-	-	-	-	-

Table 2.14: Class B3, NFD=50dB (i.e. one guard channel),
Example C/I at the P-P receiver from the PMP SS

The excluded decoupling angles are now considerably less being virtually limited to avoidance of bore-sight coupling. However, this can still impose considerable constraints on the positioning of the P-P link considering that PMP SSs can be located at any point in a facing sector, thereby increasing the chance of bore-sight coupling.

For Class B4, the C/I values were less for the same parameter set leading to the conclusion that the interference into the P-P system from the PMP SS is the driver when considering the PMP SS.



Link 1 is operating in the adjacent channel to the PMP SS and is constrained by the need to maintain the 52 degree decoupling angle from any SS in the facing sector. **Link 2** is operating on the second adjacent channel to the PMP SS thereby inserting one guard channel . In this case the constraint is reduced to around 3 degrees decoupling angle and 5 degrees decoupling between SS and the P-P link.

Figure 2.12:Impact of the results displayed in Tables 2.13 and 2.14

Figure 2.12 shows an example of two P-P links each with one end located on the arc 5 km away from the BS (5 km was assumed in the specific calculation in Table 2.13. It illustrates the constraint on pointing angle brought about by the need to maintain at least 52 degrees of decoupling angle when no guard band is in place and the reduced constraint with a single guard channel. These results are specific to the calculation results reported in the tables above.

Considerable pointing constraints and detailed co-ordination are required in either example to consider a whole P-MP network.

2-6.4 Considerations for Deployment

Although virtually every parameter used in these calculations is variable and scenario specific, the following broad conclusions can be drawn when considering the operation of individually planned “static” P-P links in frequency blocks adjacent to PMP systems in the same geographic area:

- Careful co-ordination will always be required.
- Regarding P-P stations and PMP BSs; operation in immediately adjacent channels may be possible despite the fact that calculations suggest minimum separation distances in the range of several kilometers, even at offset angles moderately removed from main lobe coupling. However, when considered in a wide-scale PMP deployment, there may be further constraints on possible positioning and pointing angles that may be difficult to resolve.
- If a single guard channel is inserted, then minimum separation distances reduce to “hundreds of meters”, as long as the P-P link avoids main lobe alignment with a PMP BS receiver.
- Improvements in Net Filter Discrimination directly reduce the minimum separation required between P-P stations and PMP BS.
- Regarding P-P system and PMP Terminal Stations, operation in the immediately adjacent channel will impose considerable constraints upon pointing angle. This could preclude pointing towards any adjacent channel SS in a PMP sector, for P-P to BS separation distances well in excess of normal link lengths. This problem will be exacerbated by multi-cell PMP deployment.
- If a single guard channel is imposed, then the P-P system and PMP SS constraints reduce to a need to maintain an angular offset between the P-P main beam and the PMP BS serving the SSs. This angle is virtually a sum of the P-P main beam angle and SS main beam angle, to avoid direct P-P to SS main beam coupling.
- Lower EIRP in either system reduces deployment constraints and levels of interference.

2-6.5 Same Area/adjacent frequency (multiple PP link systems, operating dynamically within a frequency block assignment)

The basis for coexistence is substantially the same as detailed in section 7.2 in Part 1. However, as stated in Recommendation 2-6, deployments of multiple PP links (using the parameters stated in [ ]) operating dynamically within a frequency block assignment will usually need two guard channels, when traditional P-MP networks are operating in adjacent frequencies in the same area. However, further analysis and simulation has shown that the actual guard frequency required is scenario - specific and depends on whether the P-MP system is considered as a victim or interferer.(See summary of analyses in section […]). Thus, as is usually the case, benefit could be obtained from close co-operation and co-ordination between the affected operators.

2-7 Description of Interference Evaluation/ example scenarios

2-7.1 Guidelines for geographical and frequency spacing between fixed BWA systems

The following subclauses describe the models, simulations and analysis used in this part of the preparation of this Recommended Practice. A number of interference scenarios have been identified that include point to point links as one system and a BFWA system as the other. For each scenario, a summary of the methodology for calculating interference levels is described and a guideline geographical or frequency spacing is derived.

2-7.2 Summary

This subclause provides guidelines for geographical and frequency spacings between fixed BWA systems and PP systems that would otherwise mutually interfere. The guidelines are not meant to replace coordination procedures. However, in many (probably most) cases, by following these guidelines, satisfactory operation will be possible. The information is therefore valuable as a first step in planning the deployment of systems. Because many point to point links have “protected” status, it will often be necessary to carry out further specific calculations or measurements. Any adjustments to system layout can then be made. These adjustments should be relatively small, except in unusual cases.

2-7.3 Interference mechanisms

Various interference mechanisms can reduce the performance of fixed BWA systems operating within interfering range of PP systems. Although intra-system interference is often a significant source of performance degradation, it is not considered in this analysis. Its reduction to acceptable levels requires careful system design and deployment, but these are under the control of the operator, who may decide what constitutes an acceptable maximum level. Thus, only intersystem interference mechanisms, where inter-operator coordination may be appropriate, are considered here. In each frequency band assigned for fixed BWA use, different types of systems may be deployed, some conforming to IEEE 802.16 standards and some designed to other specifications. The bands may be shared with PP system of various kinds. Therefore, we consider a wide range of possibilities in determining the likely interference levels and methods for reduction to acceptable levels. The following are the two main scenarios, each with several variants:

- Co-channel systems that are geographically spaced
- Systems that overlap in coverage and (in general) require different frequencies of operation

The various potential BS-PP and SS-PP interference paths need to be considered to determine how much interference will occur. Between any two systems, several interference mechanisms may be operating simultaneously [(see 5.3).] The geographical or frequency spacing (or both) necessary to reduce interference to acceptable levels is then determined by the most severe mechanism that occurs.

Two techniques have been used to estimate intersystem interference. They are as follows:

- Worst case analysis
- Monte Carlo simulations

Each of these methods is described in Part 1. The most appropriate method depends on the interference mechanism. In each case, geographical or frequency spacing between systems has been varied in the calculations until the interference is below an acceptable threshold. These values are shown in the tables of results as guidelines for nominal geographical or frequency spacing.

2-7.4 Simulations and calculations

Table 2.15 summarizes the simulations and calculations undertaken for this part of the Recommended Practice. The most appropriate method has been selected, dependent on the scenario and interference path.

Table 2.15 Summary of the simulations and calculations

Scenario	**PP system type**	**Area/ channel**	**Methodology**	**Guideline geographical or frequency spacing**
PMP BS to PP	Single link	Adjacent area, same channel	Worst case analysis	Over the horizon (typically >60km). May be reduced to approx. 20km with antenna pointing offset
PMP SS to PP	Single link	Adjacent area, same channel	Worst case analysis	Over the horizon (typically >60km) or combination of large antenna pointing offset and geographical spacing
PP to PMP BS	Single link	Adjacent area, same channel	Worst case analysis	10km for typical PP link parameters
PP to PMP SS	Single link	Adjacent area, same channel	Worst case analysis	50-80km for typical PP link parameters
PMP BS to PP	Single link	Same area, adjacent channel	Worst case analysis	Single guard channel (note 2) plus restrictions on pointing directions
PMP SS to PP	Single link	Same area, adjacent channel	Worst case analysis	Single guard channel (note 2) plus restrictions on pointing directions
PP to PMP BS	Single link	Same area, adjacent channel	Worst case analysis	Single guard channel (note 2) plus restrictions on pointing directions

PP to PMP SS	Single link	Same area, adjacent channel	Worst case analysis	Single guard channel (note 2) plus restrictions on pointing directions
PMP BS to PP	Multi - link	Adjacent area, same channel	Worst case analysis	80km for typical system parameters
PMP SS to PP	Multi - link	Adjacent area, same channel	Worst case analysis	<80 km for typical system parameters. Rare cases need greater spacing or coordination
PP to PMP BS	Multi - link	Adjacent area, same channel	Monte Carlo simulation	20-24km for typical system parameters
PP to PMP SS	Multi - link	Adjacent area, same channel	Monte Carlo simulation	15km for typical SS antenna heights. May increase to 40-50km for unusually high antennas
PMP BS to PP	Multi - link	Same area, adjacent channel	Worst case analysis	Two channel guard band (note 2)
PMP SS to PP	Multi - link	Same area, adjacent channel	Worst case analysis	Two channel guard band (note 2)
PP to PMP BS	Multi - link	Same area, adjacent channel	Monte Carlo simulation	Single channel guard band (note 2)
PP to PMP SS	Multi - link	Same area, adjacent channel	Monte Carlo simulation	Single channel guard band (note 2)

2-7.5 Results of the analysis

Simulations have been undertaken for many of the interference mechanisms described below. A summary of each method and its results is given in Annex 2.B

2-7.6 Co-channel case

2-7.6.1 BS-to-PP co-polar, co – channel case

This scenario occurs where the victim PP receiver is co-channel to the interfering BS transmitter(s). Multiple interferers can occur when the PMP system has multiple cells/ sectors with a frequency reuse pattern. The BS-to-PP interference is not usually the worst case, but has a relatively high probability because of the wide beamwidth of a typical BS antenna.

When the PP link receiver has protected status, it is essential when planning the system to reduce this kind of interference below the required threshold (typically an aggregate interference level not exceeding –114.5dBm/MHz). The guideline system spacing for a randomly chosen PP link and BS antenna pointing direction will be large. For more reasonable distances, use must be made of antenna offsets or terrain and building losses or a combination of these and specific coordination is therefore usually required.

When the victim receiver is part of a multi-link PP system, the requirement for coordination will be reduced.

2-7.6.2 PP-to-BS, co-polar, co-channel case

In general, the victim receiver does not have “protected” status and so the system can be designed to give a low (but non – zero) probability of exceeding the interference threshold value.

When the interferer is a “protected” PP link, a relatively simple worst – case analysis of the interference can be carried out. The severity of the interference will depend on the PP link length. The probability of worst – case interference is generally low, since it only occurs when two highly directional antennas are aligned.

When the interferer is a multi- link PP system, a Monte Carlo analysis is more appropriate. This provides results indicating the probability of a range of interference values. The highest values are usually of very low probability and a view can be taken on a compromise system spacing that gives a low value of interference in most cases

2-7.6.3 SS to PP, co-polar, co-channel case

This scenario occurs where the victim PP receiver is co-channel to the interfering SS transmitter(s). Multiple interferers can occur because the PMP cell has multiple subscribers. These may or may not transmit simultaneously, dependent on the systems design. The PMP system may also have multiple cells/ sectors with a frequency reuse pattern. The SS-to-PP interference is usually worse than the BS – PP case. The probability of interference from a single SS is low because both interferer and victim use narrow beam antennas. However, the potential for multiple interferers is significant. These may transmit simultaneously (in which case, the interference must be aggregated) or separately (in which case the probability of a given value of interference may increase).

When the PP link receiver has protected status, it is essential when planning the system to reduce this kind of interference below the required threshold (typically an aggregate interference level not exceeding –114.5dBm/MHz). The guideline system spacing for a randomly chosen PP link and SS antenna pointing direction will be large. For more reasonable distances, use must be made of antenna offsets or terrain and building losses or a combination of these and specific coordination is therefore usually required.

When the victim receiver is part of a multi-link PP system, the requirement for coordination will be reduced.

2-7.6.4 PP to SS, co-polar, co-channel chase

In general, the victim receiver does not have “protected” status and so the system can be designed to give a low (but non – zero) probability of exceeding the interference threshold value.

When the interferer is a “protected” PP link, a relatively simple worst – case analysis of the interference can be carried out. The severity of the interference will depend on the PP link length. The probability of worst – case interference is generally low, since it only occurs when two highly directional antennas are aligned.

When the interferer is a multi- link PP system, a Monte Carlo analysis is more appropriate. This provides results indicating the probability of a range of interference values. The highest values are usually of very low probability and a view can be taken on a compromise system spacing that gives a low value of interference in most cases

2-7.6.5 BS to PP, same area, adjacent channel case

This scenario occurs where the victim PP receiver is operating in the same area as the interfering BS transmitter(s). Multiple interferers can occur when the PMP system has multiple cells/ sectors with a frequency reuse pattern. The BS-to-PP interference is not usually the worst case, but has a relatively high probability because of the wide beamwidth of a typical BS antenna.

When the PP link receiver has protected status, it is essential when planning the system to reduce this kind of interference below the required threshold (typically an aggregate interference level not exceeding –114.5dBm/MHz). This usually requires some additional isolation over and above free space path loss. The isolation is normally achieved by using a “guard – band”, typically an integer multiple of the channel spacing of the system(s).

For typical guard – band/ isolation values, a significant proportion of the cell area may be unusable for the PP link station, unless use is made of antenna offsets or terrain and building losses or a combination of these. Specific coordination is usually required.

When the victim receiver is part of a multi-link PP system, the requirement for coordination will be reduced, since the victim system does not normally have “protected” status.

2-7.6.6 PP to BS, same area, adjacent channel case

In general, the victim receiver does not have “protected” status and so the system can be designed to give a low (but non – zero) probability of exceeding the interference threshold value.

When the interferer is a “protected” PP link, a relatively simple worst – case analysis of the interference can be carried out. The severity of the interference will depend on the PP link length, the distance from the BS and the amount of guard band isolation between the systems. Typically, satisfactory operation is possible except in an area close to the BS.

When the interferer is a multi- link PP system, satisfactory operation of the PP link station(s) will normally be possible, except in a small area close to the BS. The calculation can therefore be carried out in the same way as for the single PP case.

2-7.6.7 SS to PP, same area, adjacent channel case

This scenario occurs where the victim PP receiver is operating in the same area as the interfering SS transmitter(s). Multiple interferers can occur because the PMP cell has multiple subscribers. These may or may not transmit simultaneously, dependent on the systems design. The PMP system may also have multiple cells/ sectors with a frequency reuse pattern. The SS-to-PP interference is usually worse than the BS – PP case. The probability of interference from a single SS is low because both interferer and victim use narrow beam antennas. However, the potential for multiple interferers is significant. These may transmit simultaneously (in which case, the interference must be aggregated) or separately (in which case the probability of a given value of interference may increase).

When the PP link receiver has protected status, it is essential when planning the system to reduce this kind of interference below the required threshold (typically an aggregate interference level not exceeding –114.5dBm/MHz). Interference can be reduced by physical spacing and guard band isolation, combined with antenna pointing restrictions.

When the victim receiver is part of a multi-link PP system, the requirement for coordination will be reduced, since the PP link receiver(s) do not have “protected” status.

2-7.6.8 PP to SS, same area, adjacent channel case

In general, the victim receiver does not have “protected” status and so the system can be designed to give a low (but non – zero) probability of exceeding the interference threshold value.

When the interferer is a single PP link, a relatively simple worst – case analysis of the interference can be carried out. The severity of the interference will depend on a number of factors including the PP link length, antenna orientation and guard band isolation. The probability of worst – case interference is generally low, since it only occurs when two highly directional antennas are aligned.

When the interferer is a multi- link PP system, a Monte Carlo analysis is more appropriate. This provides results indicating the probability of a range of interference values, for a given guard band isolation. The choice of guard band is a compromise that gives a low probability of interference in most cases, so that occasional coordination may be needed between PP link stations and SSs that have the worst alignment and are close together.

2-8 Mitigation techniques for Coexistence between FBWA and PTP systems

In order to facilitate coexistence between fixed BWA PMP systems and PTP systems operating in adjacent frequency blocks in the same area, a minimum separation and angular decoupling is needed between the PTP site and any base station site. To provide the maximum decoupling, the best possible PTP antenna RPE performance is preferable. This is described further in [xxx]

For co- channel systems operating in nearby areas, adequate geographical spacing is necessary between the systems. For interference to “protected” point to point links, specific calculation will usually be necessary. However, where the victim is a multi- link point to point system, it may be possible to take into account the additional attenuation provided by buildings and terrain

2-8.1 Impact of buildings and terrain on co-channel interference

Systems with multiple point to point links can make use of terrain and buildings to reduce interference. The reduction in interference serves two functions:

- It reduces internal interference, thus allowing increased frequency reuse and significantly improved spectral efficiency.
- It reduces external interference, so that geographical spacing and guard bands can be reduced.

An analysis of the amount of additional attenuation that can be expected can be derived from [ ]. This document refers to mesh systems but the results could be used also as a guideline for multi – link PMP systems, where the operator has freedom to assign link frequencies from a block assignment.

The results are derived using a Monte Carlo simulation and give results as cumulative probability distributions. Only the most severe case between a BS and the link system is considered.

The impact of buildings is varied in the model by means of a parameter describing the distribution of building heights (Rayleigh parameter) and using a methodology adapted from the RAL CRABS report [ref].

2-8.2 Simulation Results

In order to assess the impact of different building heights, the parameters in the simulation tool were set as follows:

- Frequency = 28 GHz
- victim receiver = bases station with 90 degree sector antenna and 19dBi gain
- distance from base station = 12km (any value can be set)
- link lengths from 50m to 1000m
- link stations placed 1m above roof height in all cases

- link antenna gain = 25dBi
- Rayleigh parameter (building height distribution) varying from zero to 20m

The only parameter varied between simulation runs was the Rayleigh parameter. This characterises the building height distribution curve, so that a value of zero would mean that there are no buildings, whilst a value of 20m would be a reasonable figure for a city. An example taken from real data, for the large city of Leeds in the UK, indicates a best –fit value of R=40.

The results are shown in figure 2.13.

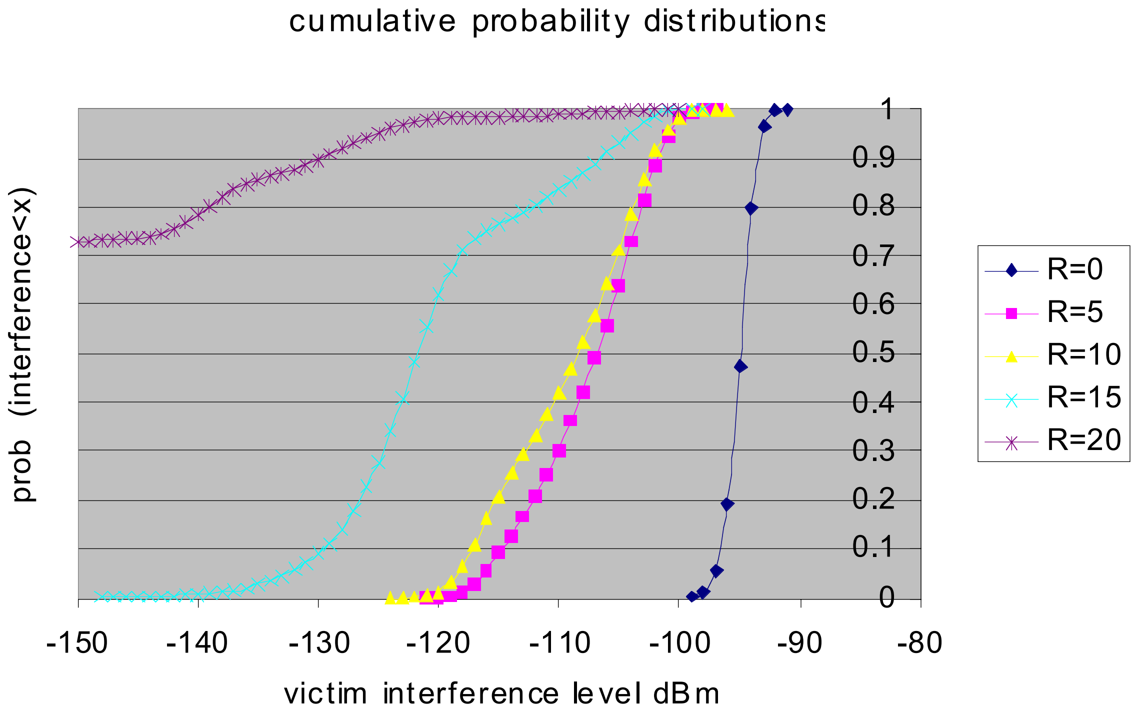


Figure 2.13- cumulative probability distributions

It can be seen that for all significant (non – zero) values of the Rayleigh parameter R, buildings have a significant impact on the level of interference. The target maximum level for interference is nominally –100dBm (-114.5dBm/ MHz).

For values of R in the range 5<R<20 the proportion of the random trials that exceed the threshold is very small, so the 12 km spacing is likely to be a reasonable value in the great majority of deployments.

For the case where there are no buildings, the highest value is 7-8 dB above the threshold, so that a wider spacing would then be required. However, a mesh would not be deployed when there are no buildings on which to mount nodes. This scenario is therefore highly pessimistic and an unrealistic representation of real deployments.

2-8.3 Conclusions

Buildings have a significant and extremely useful effect on interference, reducing the required co- channel system spacing by a factor of approximately 2. This effect does not rely on the use of any additional mitigation technique and is derived from a simple assumption that all mesh layouts are random. Even relatively low buildings are effective in reducing interference.

Annex 2-A (informative)

Sample 38GHz power spectral flux density (psfd) calculations

The P-P links used in the sample calculations below are assumed to be individually planned “static” links.

2-A.1 Thresholds

Using the same expressions detailed in Part 1 Annex B, assuming an operating frequency of 38 GHz ($\lambda = 0.079$ m), a typical base station antenna gain of 20 dBi and a typical P-P link antenna gain of 42dBi, then the tolerable interference levels are given as:

PMP Base Station:

$$\begin{aligned}\mathrm{Psfd}_{BS} &= -144 - 10\mathrm{Log}(0.0079^2) - 20 + 10\ \mathrm{Log}(4\pi)\\ &= -144 + 42 - 20 + 11\\ &= -111\ (\mathrm{dBW/m}^2)/\mathrm{MHz}\end{aligned}$$

P-P link station:

$$\begin{aligned}\mathrm{Psfd}_{PP} &= -144 - 10\mathrm{Log}(0.0079^2) - 42 + 10\ \mathrm{Log}(4\pi)\\ &= -144 + 42 - 42 + 11\\ &= -133\ (\mathrm{dBW/m}^2)/\mathrm{MHz}\end{aligned}$$

2-A.1.1 38 GHz – PMP BS Tx into victim P-P link

A sample calculation is given below to determine the feasibility of meeting the psfd limit between a BS transmitter and P-P victim receiver. The formula for psfd is given as expression B3 in Annex B of Part 1. Assuming:

P_{Tx} = transmitter power (–25 dBW/MHz)
G_{Tx} = transmitter antenna gain in the direction of the victim receiver (18 dBi)
R = range (80 000 m)
A losses = atmospheric losses, ~0.17 dB/km

Using the radio horizon range of 80 km from above, the psfd at the victim base station receiver antenna is:

$$\begin{aligned}\mathrm{psfd}_{P\text{-}Pvictim} &= -25 + 18 - 10\log(4\pi) - 20\log(80{,}000) - 80*.17\\ &= -129.6\ (\mathrm{dBW/m}^2)/\mathrm{MHz}\end{aligned}$$

Although the –129.6 (dBW/m^2)/MHz value is below the recommended “trigger for action” it is above the –133 (dBW/m^2)/MHz tolerable level for the P-P link, therefore, even at 80km some co-ordination action is advisable. However at this distance and referring to Table 12 in Part 1 it is likely that intervening terrain and clutter will more than compensate for the 3.5dB shortfall in loss.

This could be seen as justification for a more stringent psfd trigger threshold if it is considered important to ensure greater protection for neighbouring P-P links. (Perhaps already established).

2-A.1.2 38 GHz – P-P link Tx into victim PMP BS and victim P-P link

A sample calculation is given below to determine the feasibility of meeting the psfd limit between a P-P transmitter and PMP BS victim receiver. The formula for psfd is given as expression B3 in Annex B of Part 1. Assuming:

P_{Tx} = transmitter power (–25 dBW/MHz)
G_{Tx} = transmitter antenna gain in the direction of the victim receiver (42 dBi)
R = range (80 000 m)
A losses = atmospheric losses, ~0.17 dB/km

Using the radio horizon range of 80 km from above, the psfd at the victim base station receiver antenna is:

$$\begin{aligned} psfd_{P\text{-}Pvictim} &= -25 + 42 - 10\log(4\pi) - 20\log(80{,}000) - 80*.17 \\ &= -105.6\ (\mathrm{dBW/m^2})/\mathrm{MHz} \end{aligned}$$

The –105.6 (dBW/m^2)/MHz value is above the –111 (dBW/m^2)/MHz tolerable level for the PMP BS, therefore, even at 80km some co-ordination action is required. However at this distance and referring to Table 12 in Part 1 it is likely that intervening terrain and clutter will more than compensate for the 5.5dB shortfall in loss.

However if the neighbouring victim is another P-P system then the –105.6 (dBW/m^2)/MHz value is around 17.5dB above the P-P link station tolerable threshold. This would clearly justify a more stringent trigger threshold where this situation exists. This situation is not directly addressed in this recommended practice.

Annex 2-B (informative): Description of calculations and simulation methods

This annex contains a summary of each of the simulations undertaken for the interference scenario between fixed BWA systems and point to point links. Both individual links, with "protected" status and multi link point to point systems are considered. The full analysis of each scenario is available in an IEEE archive, for which document references are provided.

2B 1 Interference from a PMP BS or SS to a PP link, adjacent area, same channel case

This section analyzes scenarios in which BFWA PMP systems may cause interference to point- to - point links operating in adjacent areas, on the same channels. The point- to- point links are assumed to be individually licensed and to have "protected" status.

2B 1.1 Simulation Method

The interferer is either a single transmitter (BS) or a collection of user stations (SS). Since the PP link must be protected from all cases of interference above the acceptable threshold, a worst-case analysis is appropriate. The analysis is carried out at two frequencies; 25 GHz and 38 GHz.

The interference model for the case where the BS is the interferer is shown in fig 2B1.1 A corresponding model for the SS case is shown in fig 2B2.1

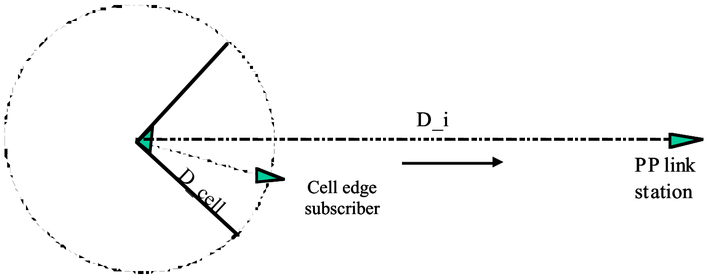


Fig. 2B1.1 Interference geometry (PMP BS to PP link)

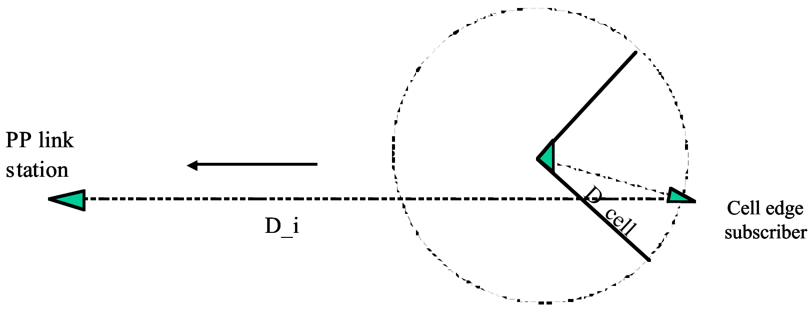


Fig. 2B1.2 Interference geometry (PMP SS to PP link station)

The PMP cell is shown as a circle. A nominal cell radius of 5km is assumed. The victim station is one end of a PP link. The distance from the BS or SS to the victim link station is D_i.

2B 1.2 Results

In the case where the BS is the interferer, A large system spacing is required, almost certainly corresponding to an over the horizon path. More acceptable distances are possible when the link antenna is pointing at an angle to the path to the BS. In the case where the SS is the interferer, the level of interference is greater and the number of stations that may interfere is higher, although the probability that any one of these would interfere is low. Results are summarized in table 2B1.1

Interference Scenario	**Frequency**	**Guideline**	**Notes**
BS to PP link station	25 GHz	PP link must be over the horizon or at least 180 km spacing from BS. OR Approx 20km spacing with PP antenna offset.	Coordination usually required. Multiple BS interferers may have to be considered
BS to PP link station	38 GHz	PP link must be over the horizon or at least 180 km spacing from BS. OR Approx 20km spacing with PP antenna offset.	Coordination usually required. Multiple BS interferers may have to be considered
SS to PP link Station	25 GHz	PP link must be over the horizon, or have a very large pointing offset plus a significant spacing from nearest SS	Coordination usually required. SS interference is worst case unless terrain losses can be relied on

SS to PP link station	38 GHz	PP link must be over the horizon, or have a very large pointing offset plus a significant spacing from nearest SS	Coordination usually required. SS interference is worst case unless terrain losses can be relied on

Table 2B1.1 Summary of results

The full analysis can be found in IEEE C802.16.2a-02/06 [ref]

2-B 2 Interference from a PP link to a PMP BS or SS, adjacent area, same channel case

This section analyzes scenarios in which BFWA PMP systems may receive interference from point links operating in adjacent areas, on the same channels. The point- to- point links are assumed to be individually licensed and to have “protected” status. However, the PMP system will not usually benefit in this way, so that higher levels of interference above the normal acceptable threshold level may occasionally be acceptable.

2B 2.1 Simulation Method

In this case, the interferer is a single PP link station transmitter (the case where there are multiple PP links is described in a separate paper). Since there is a single interferer, a simple worst-case analysis is appropriate. The analysis is carried out at two frequencies; 25 GHz and 38 GHz. The threshold for acceptable interference is taken as –100 dBm, corresponding to –114.5dBm/ MHz in a 28 MHz channel.

The interference model for the case where the BS is the victim is shown in fig 2B2.1. A corresponding model for the SS case is shown in fig 2B2.2.

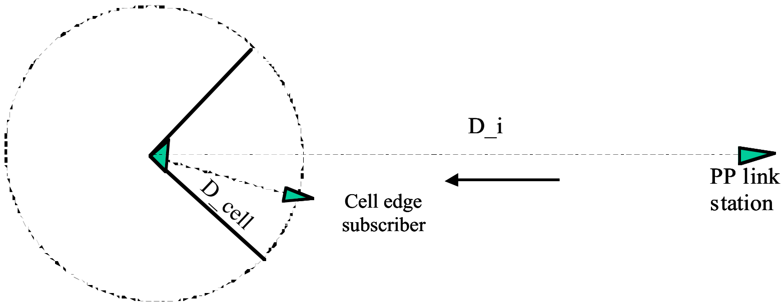


Fig. 2B2.1 Interference geometry (PP link to PMP BS)

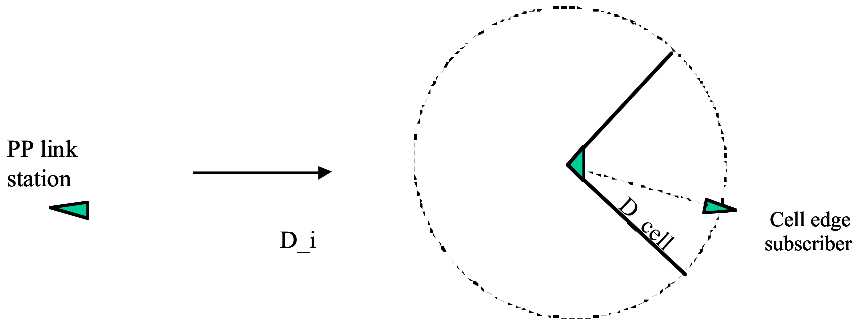


Fig. 2C2.2 Interference geometry (PP link station to PMP SS)

The PMP cell is shown as a circle. A nominal cell radius of 5km is assumed. The victim station is a BS or an SS within the sector. The distance from the BS or SS to the interfering link station is D_i.

2B 2.2 Results when the BS is the victim

In the case where the BS is the victim and with the assumed set of parameters, a system spacing of the order of 10 km is sufficient. For unusually long link paths, this distance increases, but a small pointing offset is sufficient to achieve an acceptable result.

2B 2.3 Results when the SS is the victim

In the case where the SS is the victim, the level of interference is greater than for the BS case and the number of stations that may interfere is, although the probability that any one of these will interfere is low. For typical PP link lengths a system spacing of 50 – 80 km is required. In practice this will be comparable with or less than the typical horizon distance.

In both of the above cases, the victim system does not have “protected” status, so that coordination is not essential. It will be sufficient to set a system spacing that gives an acceptably low probability of interference above the normally acceptable threshold.

Results are summarized in table 2B2.1

Interference Scenario	**Frequency**	**Guideline**	**Notes**
PP link station to BS	25 GHz	10km system spacing, with some additional isolation due to PP antenna offset for longer links (over 5km at 25 GHz or over 3km at 38 GHz).	Multiple victim BSs may have to be considered
PP link station to BS	38 GHz	10km system spacing, with some additional isolation due to PP antenna offset for longer links (over 5km at 25 GHz or over 3km at 38 GHz).	Multiple victim BSs may have to be considered
PP link station to SS	25 GHz	50- 80km system spacing required. OR where SS antennas are low, high over the horizon losses may dominate (even for shorter distances)	SS interference is worst case and dominates unless terrain losses can be relied on
PP link station to SS	38 GHz	50 - 80km system spacing required. OR where SS antennas are low, high over the horizon losses may dominate (even for shorter distances)	SS interference is worst case and dominates unless terrain losses can be relied on

Table 2B2.1: Summary of results

The scenarios are fully analyzed in IEEE C802.16.2a-02/06 [XX].

2-B 3 Interference to/from a PMP BS or SS from/to a PP link, same area, adjacent channel case

2B3.1 Introduction

The analysis extends work published by ETSI in Report TR 101 853 [ ], by providing numerical results. The ETSI report identifies four s interference scenarios:

Class B1 = PMP Central Station (BS) to P-P station.
Class B2 = P-P station to PMP Central Station (BS).
Class B3 = PMP Terminal Station (SS) to P-P station.
Class B4 = P-P station to PMP Terminal Station (SS).

The main results and conclusions from this analysis are provided in section [ ] of this recommended practice.

The full analysis is available in IEEE C802.16.2a-02/26r1[ref]

2-B 4 Interference to/ from a PP link from/ to a PMP BS or SS, same area, adjacent channel case (alternative analysis)

In addition to the methodology described in 2B.3, further documents are available on the same topics. These are:

IEEE 802.16.2a-02/19 [ref] ; “Interference from a BFWA PMP system to a PP link system (same area, adjacent channel case)” and
IEEE 802.16.2a-02/20 [ref]; “Interference from a PP link system to a BFWA PMP system (same area, adjacent channel case)”

These both follow the worst case analysis method and provide broadly similar though less detailed conclusions than the analysis referred to in 2B3.

2-B 5 Interference from a PMP BS or SS to a PP multi-link system, adjacent area same channel case

This section analyzes scenarios in which BFWA PMP systems may cause interference to multi – link point- to-point systems operating in adjacent areas, on the same channels. The point- to- point links are assumed to have the same status as the PMP system i.e. they share the band on an equal basis and do not have “protected” status.

Most of the calculations are the same as for the case where a single PP link with “protected” status is the victim. However, the conclusions and resultant guidelines are slightly different.

2B 5.1 Simulation Method

The analysis is carried out at two frequencies; 25 GHz and 38 GHz. In this case, the interferer is either a single transmitter (BS) or a collection of user stations (SS), which may or may not transmit simultaneously. Since the number of PP links is generally small, the calculation is carried out based on a single victim receiver with “worst case “ calculation, rather than a Monte Carlo simulation.

An estimate of the effect of building and terrain on the probability of interference can be deduced using the results of a previous IEEE analysis in C802.16.2a-01/03 [ref].

The interference model for the case where the BS is the interferer is shown in fig 2C 5.1. A corresponding model for the SS case is shown in fig 2C 5.2. The threshold for acceptable interference is taken as –100 dBm, corresponding to –114.5dBm/ MHz in a 28 MHz channel.

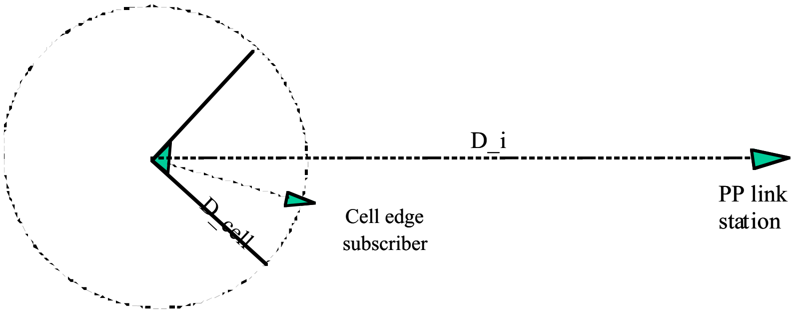


Fig. 2B 5.1 Interference geometry (PMP BS to PP link)

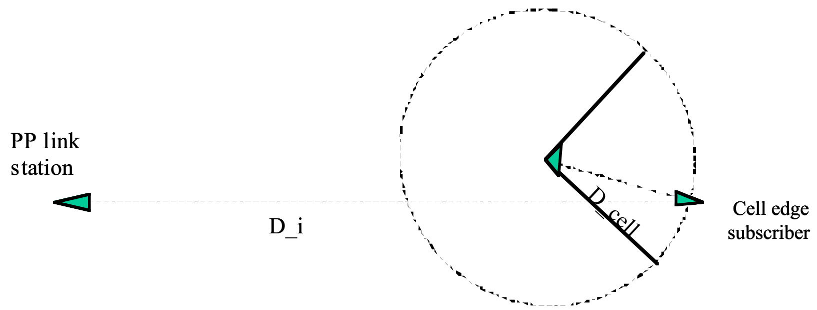


Fig. 2B 5.2 Interference geometry (PMP SS to PP link station)

The PMP cell is shown as a circle. A nominal cell radius of 5km is assumed. The victim station is one end of one of the PP links. The distance from the BS or SS to the victim link station is D_i.

2B 5.2 Simulation Results when the BS is the interferer

In the case where the BS is the interferer, in line of sight conditions, a system spacing of the order of 180 km may be required, which in most systems will be well over – the – horizon. Where a pointing offset of a few degrees is also possible, the spacing can be reduced to approximately 20km.

2B 5.3 Results when the SS is the interferer

In the case where the SS is the interferer, the level of interference is greater and the number of stations that may interfere is higher, although the probability that any one of these will interfere is low.

For typical PP link lengths and any reasonable system spacing (up to the typical horizon distance), a combination of distance and antenna pointing restriction is typically required.

2B 5.4 Impact of Buildings and Terrain

In [XX] an analysis was made of the impact of buildings and terrain on mesh/ PP interference into PMP systems. The results shown are for the more adverse BS case. Terrain and buildings were modelled using an adaptation the well-known RAL CRABS [8] methodology. The CDF distribution curves are reproduced in fig 2B5.3.

For typical urban environments (5<R<20), where R is the Rayleigh parameter), there is a high probability that interference will be significantly attenuated. Although the calculation was based on interference to the PMP system, the geometry for the reciprocal case is similar and the results should therefore give some guide for the case where the PP system is the victim. Approximately 7-8dB of excess loss occurs for a typical range of building heights.

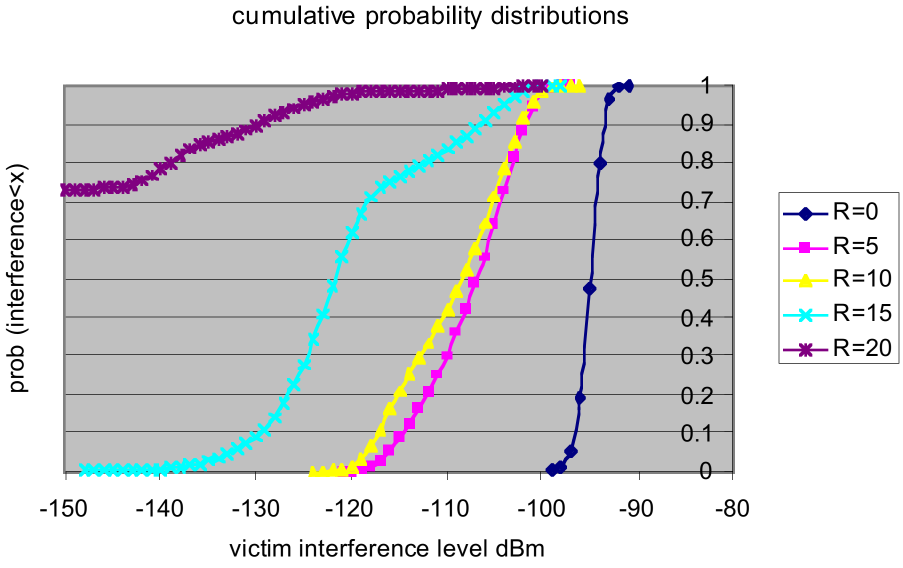


Fig 2B5. 3; Interference plotted as cumulative probability curves as function of R

Applying a 7dB reduction to the BS case, reduces the required system spacing to 80km, with no antenna pointing offset, and to yet lower values where pointing offset can be relied on

2B5.5 Summary of Simulation Results

Interference Scenario	**Frequency**	**Guideline**	**Notes**
BS to multi link PP system	25 GHz	80km system spacing. Lower spacing possible with coordination or where the BS antenna is lower than typical	Multiple victim BSs may have to be considered
BS to multi link PP system	38 GHz	80km system spacing. Lower spacing possible with coordination or where the BS antenna is lower than typical	Multiple victim BSs may have to be considered
SS to multi link PP system	25 GHz	BS case usually dominates.	Rare (improbable) cases where SS interference is higher should be dealt with by specific coordination
SS to multi link PP system	38 GHz	BS case usually dominates.	Rare (improbable) cases where SS interference is higher should be dealt with by specific coordination

Table 2B5.1- Summary of results

The scenarios are fully analyzed in 10 in IEEE C802.16.2a-02/06 [XX.]

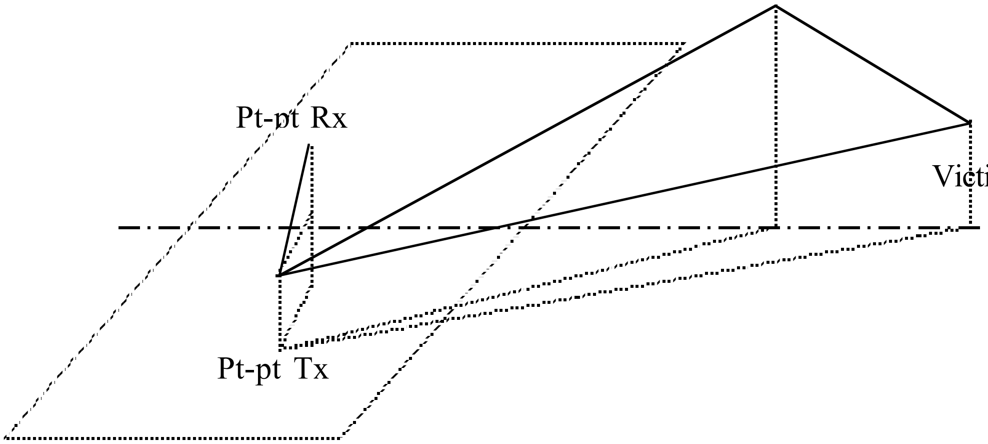
2-B 6 Interference from a multi – link PP system into a PMP system, adjacent area, co- channel case

2B6.1 Simulation method

The point- to- point links are modeled using a simulation tool, which models interference between multiple point to point links and PMP systems. The parameters for the point to point system are taken from IEEE C802.16.2a-01/06 [ ]. The antenna pattern conforms to the recommendations of paper IEEE 802.16.2-01/14 [ ]. A comparison is provided with the case where an ETSI antenna pattern is used.

The simulator computes the power received from a system comprising a number of point- to- point links at a PMP BS receiver or a PMP SS receiver, in a cell adjacent to the point to point system. The geometry is shown in fig. 2B6.1. Each run of the simulation varies the locations and directions of the point to point links. The results of a large number of trial runs are shown in statistical form (Monte Carlo simulation)

Fig. 2B6.1 Interference Geometry



The probability of interference line of sight is calculated from a model in which building heights are assumed to have a Rayleigh distribution. Most of the scenarios have been simulated with no rain fading. A small number of examples of rain storm conditions were also simulated and found to have negligible impact on the results. All rain scenarios have only a small effect on the results

The BS receiver antenna is assumed to be a 90° sector aimed directly at the centre of the interfering system. A corresponding SS antenna is placed at the cell edge, pointing at the BS.

2B 6.2 Interfering Power Calculation

From each link transmitter and, taking account of the line of sight probability, the power received by the base station or subscriber station is computed. All these powers are summed, and the result rounded to the nearest dBm and assigned to a histogram bin, so that the relative probability of each power level can be estimated and cumulative probability distributions can be derived.

2B 6.3 Simulation Results for victim BS

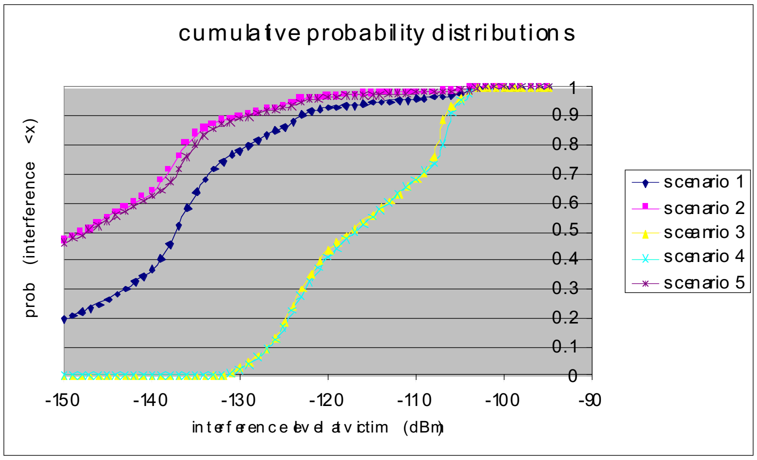


Figure 2B6.2- Example of cumulative probability distributions
(BS interference)

Fgure 2B6.2 is an example of the cumulative probability distributions, produced from the simulations. Each curve is derived from a series of 10,000 randomly generated system models, with each model simulating the required number of point- to- point links in the chosen coverage area. The cumulative probability at each point is that for which the total interference at the victim station will be less than a given value on the x axis.

In general, a value of –100dBm (equivalent to –114.5 dBm/ MHz) is low enough to be considered fully acceptable for planning purposes. Thus, where the cumulative probability has reached a value of 1 at the –100 dBm level, there are no cases above the interference threshold. The geographical spacing corresponding to such a value is then completely safe for planning purposes.

Scenario	**Building height parameter**	**Height of interferer above roof level**	**Links/sq km**	**Antenna gain dBi**	**Rain scenario**	**Distance to BS**	**% cases where threshold exceeded**
1	7m	3m	10	40	None	20km (18km)	0
2	7m	1m	10	42	None	24km (20km)	0
3	0m	4m	10	42	None	32km	0
4	0m	4m	10	42	Storm	30km	0
5	7m	3m	5	42	None	22km (20km)	0

Table 2B6.1- Summary of BS Interference Scenarios using new antenna RPE
Values in brackets ( ) are those derived when using an alternative ETSI antenna RPE

2B 6.4 Simulation Results for Victim SS

Scenario	Building height parameter	Antenna Height above roof (interferers)	Links/ sq km	Antenna gain	Victim antenna height	Rain scenario	Distance to SS	% threshold exceeded
1	7m	3m	5	40	20	None	15km	.05
2	7m	3m	5	40	15	None	15km (17km)	0
3	7m	3m	5	40	20	None	40km	.01
4	7m	3m	5	40	25	None	50km	.06
5	7m	3m	5	40	10	None	10km	0

Table 2B6.2- Summary of SS Interference Scenarios
Values in brackets ( ) are those derived when using an alternative ETSI antenna RPE

Note that in the case of a victim PMP SS, the level of interference depends strongly on the victim antenna height. Below about 15m, very little interference is experienced. Above 15m, the interference increases rapidly. Also, the probability distributions are much flatter than for the BS case, so that to eliminate the last few cases of interference above the threshold, the system spacing has to be increased significantly.

However, SS antenna heights above 15m have a relatively low probability, so that, in most cases, the base station distance required to reduce interference to the –100dBm threshold will dominate.

2B 6.5 Conclusions

For most situations, interference to the BS victim station determines the required system spacing, which is in the range 20-24km.

- Where SS antennas are on unusually high structures, the SS interference may dominate and the distance may then need to be increased to 40 – 50 km to reduce the probability of interference to a negligible level. Since the number of such cases is always a very low percentage of the total, it may be more reasonable to apply mitigation techniques than to resort to such large geographical separations

- Rain fading is not significant in determining the required geographical spacing

2-B 7 Interference from a PMP system into a multi – link PP system, same area adjacent channel case

2B 7.1 Simulation method

The analysis of this scenario is different from the reciprocal case, which needs a Monte Carlo simulation. In this case, the interferer is a single transmitter with a high probability of being received by a victim PP station. Thus, a worst-case analysis is appropriate. The interference model is shown in fig. 2C7.1

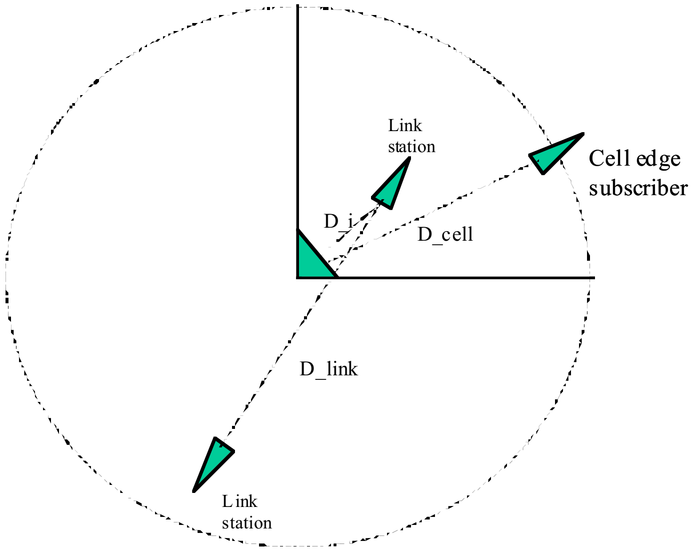


Fig. 2B7.1 Interference geometry (PMP BS to PP link)

The following parameters are assumed for the analysis:

Parameter	**Value**	**Note**
PMP cell radius (D_cell)	5km	Larger radius leads to worse interference scenario
Frequency	25 GHz	
BS antenna gain	19dBi	Typical for 90 degree sector antenna
SS antenna gain	36dBi	
Link antenna gain	40 dBi (Note 2)	From [3]
Nominal SS Rx input level	-73dBm	Assuming 16 QAM modulation
NFD (1 guard channel) Note 1	49 dB	Typical value, from ETSI tables
NFD (2 guard channels) Note 1	70 dB	Typical value, from ETSI tables

Table 2B7.1: Parameters for PMP to PP interference scenarios

2B 7.2 Results of simulations

The value of interference at the victim PP receiver is calculated for a range of distances and variations in the number of guard channels and antenna pointing offset. The target interference level is less than or equal to –100 dBm (28 MHz channel). This corresponds to –114.5dBm/ MHz.

In the case where the BS is the interferer, many link receivers will be illuminated and so the probability of interference is high. With no guard channel, the interference is catastrophic for all reasonable distances. With a single guard channel, the PP link receiver can not operate within a guard zone of radius >500m, unless the antenna pointing direction is limited. For a two- channel guard band, the zone reduces to approximately 50m radius, with no pointing restrictions.

In the case where the SS is the interferer, the level of interference is greater but the probability of interference is lower, due to the narrow beam of the SS antenna.

In this case, even with a 2 channel guard- band, a significant interference zone exists around each SS and pointing restrictions may have to be considered for a number of PP links.

2B 7.3 Conclusions for the PMP to/from PP scenarios

The interference from PMP to PP systems is generally worse than the reciprocal case. In order to assure interference - free operation with a low level of coordination, a two - channel guard band is needed. This is sufficient for the BS to point- to- point case. A single guard channel might be viable provided that mitigation techniques were applied to a small proportion of links in the point- to- point system.

In the case of SS interference into a point- to- point system, the interference level can be higher but the probability lower. A two- channel guard band is not completely effective but the number of cases requiring coordination will be very low. The same general recommendation of a two- channel guard band is therefore considered appropriate.

The full analysis is provided in IEEE802.16.2a-0x/yy [zz]

2-B 8 Interference from a multi – link PP system into a PMP system, same area adjacent channel case

In general, co-channel systems will not be able to operate successfully in this environment, so that one or more guard channels are required between the systems. The analysis derives guidelines for the size of guard band needed in each scenario.

2B 8.1 Simulation method

The system geometry is similar to figure 2B6.1 but with the victim BS or SS placed in the middle of the coverage area of the point to point link system. A Monte Carlo simulation is provided, in which a series of parameters for the point- to- point links (interferers) and PMP systems (victim BS or SS) can be varied to match the required scenario. Full 3 – dimensional geometry is taken into account. Each simulation run constructs a random layout of point- to- point links over the required coverage area. A value of NFD (net filter discrimination) is assigned. The simulation tool plots the results as probability curves (probability of occurrence of a given value of interference and cumulative probability). A target maximum level is set, which in this case is –100 dBm (28 MHz channel). This corresponds to –114.5 dBm/ MHz

2B 8.2 Interference to PMP BS

The simulation was run with adjacent channel operation and with one guard channel, as shown in fig 2C8.1.

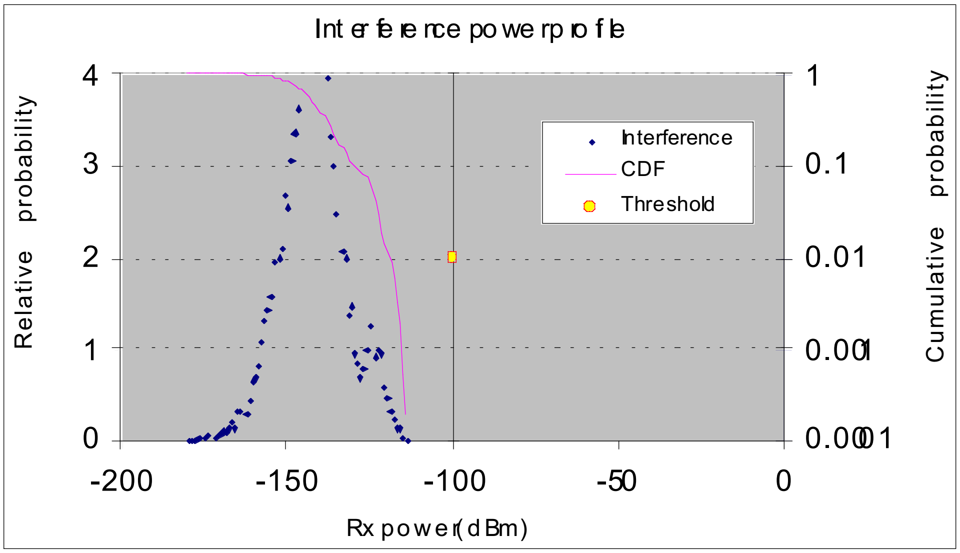


Figure 2B8.1: Interference from PP system to PMP BS
(1 guard channel)

It is concluded that a single guard channel is adequate in this scenario for satisfactory coexistence and that operation on the adjacent channel could be possible, given a degree of coordination by the operators concerned. However, the other scenarios between systems must also be taken into account when making an overall decision.

2B.8.3 Interference to PMP SS

Figure 2B8.2 shows the case where the PMP SS is the victim. One guard channel is used. In this case, the probability of exceeding the –100dBm target level is around 0.1% of random configurations. Thus, coordination would occasionally be required to eliminate all cases of interference.

Figure 2C8.2: Interference from PP system to PMP SS
(1 guard channel)

Editorial instructions:
-Add complete new section (part 3) as follows:

Part 3: Coexistence of Fixed Broadband Wireless Access Systems operating in frequency range 1; 2-11 GHz

3-1Overview of section

This section contains guidelines and recommendations for coexistence between various types of FBWA systems, operating in the frequency range 2-11 GHz. Because of the wide frequency range and variety of system types, two representative sets of results have been derived, covering operating frequencies around 3.5 GHz and 10.5 GHz. The guidelines and recommendations are supported by the results of a large number of simulations or representative interference cases. The full details of the simulation work are contained in input documents, referenced in section [4.] This section lists the full set of archived input documents used in the preparation of this document and in the preparation of the published recommended practice.

3-2 Scope

Part 3 of this Recommended Practice defines a set of consistent design and deployment recommendations that promote coexistence for fixed BWA systems that share the same bands within the frequency range 2-11GHz. The recommendations, if followed by manufacturers and operators, will facilitate a wide range of equipment to coexist in a shared environment with acceptable mutual interference.

The scope of this Part 3 of the Recommended Practice includes the examination of interference between systems deployed across geographic boundaries in the same frequency blocks and systems deployed in the same geographic area in adjacent frequency blocks.

This document is not intended to be a replacement for applicable regulations, which would take precedence.

3-3 Document philosophy

As noted in Part 1, radio waves permeate through legislated (and even national) boundaries and emissions spill outside spectrum allocations. Coexistence issues between multiple operators are therefore inevitable. The resolution of coexistence issues is an important factor for the fixed BWA industry. The Recommendations in 3.4.1 are provided for consideration by operators, manufacturers, and administrations to promote coexistence. Practical implementation within the scope of the current recommendations will assume that some portion of the frequency spectrum (at the edge of the authorized bandwidth) may be unusable. Furthermore, some locations within the service area may not be usable for deployment. Coexistence will rely heavily on the good-faith collaboration between spectrum holders to find and implement economical solutions. The document analyzes coexistence using two scenarios:

-A co-channel (CoCh) scenario in which two operators are in either adjacent territories or territories within radio line of sight of each other and have the same spectrum allocation, and

-An adjacent Channel (AdjCh) scenario in which the licensed territories of two operators overlap and they are assigned adjacent spectrum allocations.

Coexistence issues may arise simultaneously from both scenarios as well as from these scenarios involving multiple operators. As a starting point for the consideration of tolerable levels of interference into fixed BWA systems, ITU-R Recommendation F.758-2 [B16] details two generally accepted values for the interference-to-thermal noise ratio (I/N) for long-term interference into fixed service receivers. When considering interference from other services, it identifies an I/N value of -6dB or -10dB matched to specific requirements of individual systems. This approach provides a method for defining a tolerable limit that is independent of most characteristics of the victim receiver, apart from noise figure, and has been adopted for this Recommended Practice. The acceptability of any I/N value needs to be evaluated against the statistical nature of the interference environment. In arriving at the Recommendations in this document this evaluation has been carried out for an I/N value of -6 dB.

Clause 9 provides interference mitigation measures that can be utilized to solve coexistence problems. Because of the wide variation in subscriber station and base station distribution, radio emitter/receiver parameters, localized rain patterns, and the statistics of overlapping emissions in frequency and time, it is impossible to prescribe in this document which of the mitigation measures are appropriate to resolving a particular coexistence problem. In the application of these mitigation measures, identification of individual terminals or groups of terminals for modification is preferable to the imposition of pervasive restrictions.

Implementing the measures suggested in the Recommendations will, besides improving the coexistence conditions, have a generally positive effect on intrasystem performance. Similarly, simulations performed in the preparation of this Recommended Practice suggest that most of the measures undertaken by an operator to promote intrasystem performance will also promote coexistence. It is outside the scope of this document to make recommendations that touch on intrasystem matters such as frequency plans, frequency reuse patterns, etc.

3.4 Recommendations and Guidelines, including indicative geographical and physical spacing between systems.

3.4.1 Recommendations

Recommendations 1-1,1-2,1-3 detailed in Part 1 apply equally to Part 3 Additionally the following new Recommendations apply to this Part 3

3.4.1.1 Recommendation 3-1

No coordination is needed in a given direction if the transmitter is greater than 80 km from either the service area boundary or the neighbor's boundary (if known) in that direction. Based on typical fixed BWA equipment parameters and an allowance for potential LOS interference couplings, subsequent analysis indicates that a 80 km boundary distance is sufficient to preclude the need for coordination. At lesser distances, coordination may be required, but this is subject to a detailed examination of the specific transmission path details that may provide for interference link excess loss or blockage. This coordination criteria is viewed to be necessary and appropriate for both systems that conform to this Recommended Practice and those that do not.

3.4.1.2 Recommendation 3-2

(This Recommendation applies to co-channel cases only.) Recommendation 1-2 introduced the concept of using power spectral flux density "triggers" as a stimulus for an operator to take certain initiatives to collaborate with his or her neighbor. It is recommended that regulators specify the applicable trigger values for each frequency band, failing which the following values may be adopted: The coordination trigger value of [tba (dBW/m^2)/MHz] is employed in the initiative procedure described in Recommendation 6. The evaluation point for the trigger exceedance may be at either the victim operator's licensed area boundary, the interfering operator's boundary, or at a defined point in between depending to some extent on the specific geographic circumstances of the BWA licensing. These values were derived as that power spectral flux density values which, if present at a typical point-to-multipoint base station antenna and typical receiver, would result in approximately the -6 dB interference value cited in Recommendation 1. It should be emphasized that the trigger values are useful only as thresholds for taking certain actions with other operators; they do not make an absolute statement as to whether there is, or is not, interference potential.

3.4.1.3 Recommendation 3-3

(This Recommendation applies to co-channel cases only.)

The "triggers" of Recommendation 1-2 and Recommendation 3-2 should be applied prior to deployment and prior to each relevant system modification. Should the trigger values be exceeded, the operator should try to modify the deployment to meet the trigger or, failing this, the operator should coordinate with the affected operator.

3.4.1.4 Recommendation 3-4

For same area/adjacent channel interference cases, analysis and simulation indicate that deployment may require an equivalent guard frequency between systems operating in close proximity and in adjacent frequency blocks. It is convenient to think of the "guard frequency" in terms of "equivalent channels" related to the systems operating at the edges of the neighboring frequency blocks. The amount of guard frequency depends on a variety of factors such as "out of block" emission levels and in some cases is linked to the probability of interference in given deployment scenarios. Useful mitigation techniques include frequency guard bands, recognition of cross-polarization differences, antenna angular discrimination, spatial location differences, and frequency assignment substitution.

In most co-polarized cases, where the transmissions in each block are employing the same channel bandwidth, the guard frequency should be equal to one equivalent channel. Where the transmissions in neighboring blocks employ significantly different channel bandwidths, it is likely that a guard frequency equal to one equivalent channel of the widest bandwidth system will be adequate. However, analysis suggests that, under certain deployment circumstances, this may not offer sufficient protection and that a guard frequency equal to one channel at the edge of each operator's block may be required. Where administrations do not set aside guard channels, the affected operators would need to reach agreement on how the guard channel is apportioned between them. It is possible that, with careful and intelligent frequency planning, coordination, and/or use of orthogonal polarization or other mitigation techniques, all or partial use of this guard channel may be achieved. However, in order to minimize interference conflicts and at the same time maximize spectrum utilization, cooperative deployment between operators will be essential. This recommendation strongly proposes this.

3.4.2 Suggested guidelines for geographical and frequency spacing

This subclause indicates some of the models, simulations, and analysis used in the preparation of Part 3 of this Recommended Practice. While a variety of tools may be used, the scenarios studied below should be considered when coordination is required. Guidelines for geographical and frequency spacing of fixed BWA systems that would otherwise mutually interfere are given for each of a number of interfering mechanisms. This subclause summarizes the overall guidelines, taking into account all the identified interference mechanisms. The two main deployment scenarios are as follows:

- Co-channel systems that are geographically spaced
- Systems that overlap in coverage and (in general) require different frequencies of operation

The most severe of the several mechanisms that apply to each case determines the guideline spacing, as shown in Table 3.1.

3-5 System overview

BWA generally refers to fixed radio systems used primarily to convey broadband services between users' premises and core networks. The term "broadband" is usually taken to mean the capability to deliver significant bandwidth to each user. In ITU terminology, and in this document, broadband transmission refers to transmission rate of greater than around 1.5 Mbit/s, though many BWA networks support significantly

Table 3.1 Summary of the guidelines for geographical and frequency spacing

Dominant interference path (note 1)	**Scenario**	**Spacing at which interference is below target level (generally 6 dB below receiver noise floor)**
PMP BS to PMP BS	3.5 GHz; Adjacent area, same channel	Spacing to at least horizon distance needed (typically 80km)
PMP BS to PMP BS	3.5 GHz; Same area, adjacent channel	Combination of isolation (NFD etc) and physical spacing is required (typically 0.1 – 2km, dependent on available isolation) Note 1
PMP BS to PMP BS	10.5 GHz; Adjacent area, same channel	Spacing to at least horizon distance needed (typically 80km)
PMP BS to PMP BS	10.5 GHz; Same area, adjacent channel	Combination of isolation (NFD etc) and physical spacing is required Note 1
Note 1: typically a single guard channel is required		

higher data rates. The networks operate transparently, so users are not aware that services are delivered by radio. A typical fixed BWA network supports connection to many user premises within a radio coverage area. It provides a pool of bandwidth, shared automatically among the users. Demand from different users is often statistically of low correlation, allowing the network to deliver significant bandwidth-on-demand to many users with a high level of spectrum efficiency. Significant frequency reuse is employed.

The range of applications is very wide and evolving quickly. It includes voice, data, and entertainment services of many kinds. Each subscriber may require a different mix of services; this mix is likely to change rapidly as connections are established and terminated. Traffic flow may be unidirectional, asymmetrical, or symmetrical, again changing with time.

These radio systems compete with other wired and wireless delivery means for the “first mile” connection to services. Use of radio or wireless techniques result in a number of benefits, including rapid deployment and relatively low “up-front” costs.

3-5.1 System architecture

Fixed BWA systems often employ multipoint architectures. The term multipoint includes point-to-multipoint (PMP) and multipoint-to-multipoint (MP-MP). The IEEE 802.16 Working Group on Broadband Wireless Access is developing standards for multipoint systems in the frequency range 2-11 GHz with both PMP and "mesh" architectures. In PMP systems, there are one or more base stations, together with a number of subscriber stations communicating over an air interface. In the "mesh" architecture, there are no base stations. Each user station can communicate with several others within range and the connection between the core network and the end users can take place via one or more user stations. In the frequency range considered in this Part 3, mesh systems typically use omni directional antennas.

Figure 3.1 is a general reference diagram in which all the possible components of both PMP and "mesh" systems are shown. The functional equivalence of the two system architectures allows a single diagram to represent both types of systems.

A similar standard to that produced by IEEE 802.16 for the 2-11 GHz frequency range is being developed within the "HIPERMAN" topic within ETSI Project BRAN.

3-5.1.1 PMP Systems

PMP systems comprise base stations, subscriber stations and, in some cases, repeaters. Base stations use relatively wide-beam antennas, divided into one or several sectors providing up to 360-degrees coverage with one or more antennas. To achieve complete coverage of an area, more than one base station may be required. The connection between BSs is not part of the fixed BWA network itself, being achieved by use of radio links, fiber optic cable, or equivalent means.

Links between BSs may sometimes use part of the same frequency assignment as the fixed BWA itself. Routing to the appropriate BS is a function of the core network. Subscriber stations use directional antennas, facing a BS and sharing use of the radio channel. This may be achieved by various access methods, including frequency division, time division, code division, OFDM/ OFDMA.

In some parts of the frequency range 2-11 GHz, particularly at low frequencies, non line-of-sight paths may be useable and systems may be designed and planned accordingly.

3-5.1.2 MP systems (Mesh)

Multipoint-to-multipoint (MP-MP) systems have the same functionality as PMP systems. Base stations provide connections to core networks on one side and radio connection to other stations on the other. A subscriber station may be a radio terminal or (more typically) a repeater with local traffic access. Traffic may pass via one or more repeaters to reach a subscriber. Antennas in this frequency range are generally omni-directional types, avoiding the requirement for remote alignment when the network adapts to new subscribers or changes in traffic flow.

3-5.1.3 System components

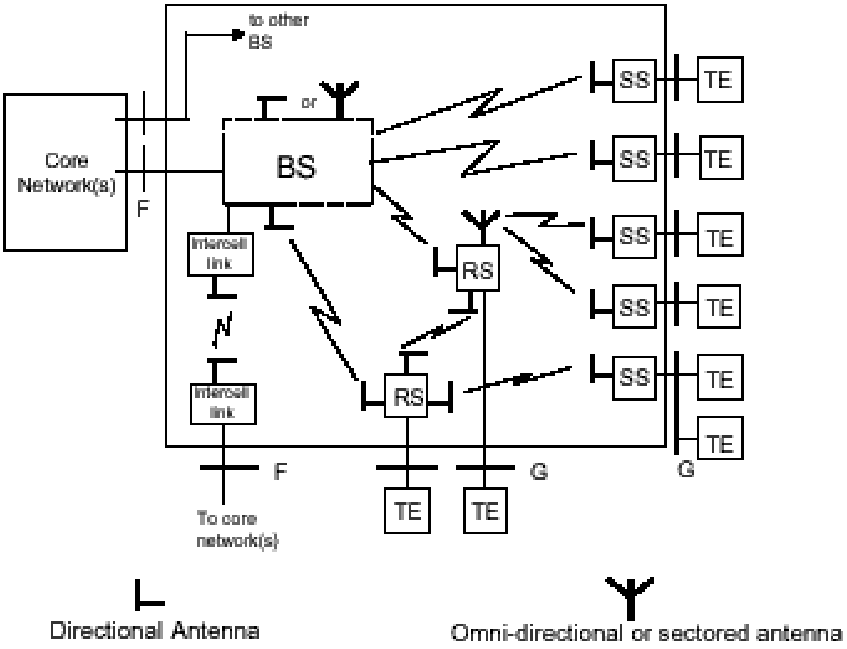


Figure 3.1 Reference Diagram for Fixed BWA Systems

Insert original diagram (better quality) pw

3-6 System description (interferer and victim systems)

3-6.1 Description of system interference scenarios

The interference scenarios identified in Part 1 are equally applicable to this Part 3 of the recommended practice

3-6.2 System parameters assumed in the simulations

The system parameters assumed in the simulations are based on the data in document IEEE 802.16.2a-01/12 [ref]

Table 3.2: Parameters for 3.5 GHz systems with a cellular architecture.

Characteristic (cellular systems)	**Examples**
Layout of system(s) including diagrams	Multi – cell (uniformly distributed)
Typical sector arrangements and frequencies	Typically 4-sectors per cell, 4 frequencies, V and H polarization both used [1]; Some systems will use adaptive antennas, pointing at individual users. FDD and TDD used
Propagation	Partly obstructed paths allowed For coexistence purposes line of sight loss up to 7km, then d^4 beyond that point. Rain fading assumptions – negligible. Atmospheric multipath ignored on interfering paths.
Cell size	Typically 7km
Availability objective	99.9 – 99.99% of time for 80 – 90% cell area coverage
Number of cells in a system	1 to 25 (typical range)
Number of terminal stations per MHz per T/R per cell	Up to 70
Distribution of terminal stations	Uniform per unit area.
Frequency of operation (for each variant to be studied)	3.4 to 3.8 GHz (use 3.6 GHz for coexistence calculations)
Duplex method	TDD, FDD, Half duplex
Receiver parameters	
Channel bandwidth	1.5/3/6/12/25 MHz (N. America) 1.75/3.5/7/14 MHz (Europe) (use 7 MHz for coexistence calculations)
filter response	Root Nyquist with 25% roll off factor assumed
noise floor	4dB noise figure upstream 5dB noise figure downstream
Acceptable level for co-channel interference	I/N = –6dB (aggregate of all interferers)
Transmitter parameters	
Channel bandwidth	1.5/3/6/12/25 MHz (N. America) 1.75/3.5/7/14 MHz (Europe) (use 7 MHz for coexistence calculations)
emission mask	See figures 4 and 5 of IEEE 802.16ab-01/01
Maximum eirp	Not specified

typical transmitter power	3W at base station, 1W at subscriber
use of ATPC, steps and range	Uplink only, 2dB steps, 40dB range
Tx-Rx parameters	ERC NFD values used (report 99)
Antenna characteristics (base station)	ETSI RPE for 90 degree sector or similar Gain = 14.5 dBi
Antenna characteristics (subscriber station)	ETSI RPE or similar Gain = 18dBi
Antenna characteristics (repeater station)	Assume same as BS and SS
Backhaul links	Separate frequency assignments

Table 3.3: Parameters for 10.5 GHz systems with a cellular architecture.

Characteristic (cellular systems)	**Examples**
Layout of system(s) including diagrams	Multi – cell (uniformly distributed)
Typical sector arrangements and frequencies	Typically 4-sectors per cell, 4 frequencies, V and H polarization.
Propagation	Line of sight paths only. Rain fading important – ITU equations to be used. Atmospheric multipath fading ignored for coexistence purposes
Cell size	Typically 7km
Availability objective	99.9 – 99.99% of time for approx. 50% cell area coverage
Number of cells in a system	1 to 25 (typical range)
Number of terminal stations per MHz per T/R per cell	70
Distribution of terminal stations	Uniform per unit area.
Frequency of operation (for each variant to be studied)	10.5 to 10.68 GHz
Duplex method	TDD, FDD, Half duplex
Receiver parameters	
Channel bandwidth	3/6/12/25 MHz (N. America) 3.5/7/14 MHz (Europe) Use 7 MHz for coexistence calculations
filter response	Root Nyquist with 25% roll off factor assumed
noise floor	6dB noise figure
Acceptable level for co-channel interference	I/N = –6dB (aggregate of all interferers)
Transmitter parameters	
Channel bandwidth	3/6/12/25 MHz (N. America) 3.5/7/14 MHz (Europe) Use 7 MHz for coexistence calculations
emission mask	ETSI masks and NFD values used
Maximum power	Not specified
typical power	1W at base station, 1W at subscriber)
use of ATPC, steps and range	Uplink only, 2dB steps, 40dB range
Tx-Rx parameters	ERC NFD values used (report 99)
Antenna characteristics (base station)	ETSI RPE for 90 degree sector or similar Gain = 16 dBi

Antenna characteristics (subscriber station)	ETSI RPE or similar Gain = 25 dBi
Antenna characteristics (repeater station)	Assume same as BS and SS
Backhaul links	Separate frequency assignments

3-6.3 Medium Overview

For relatively short transmission paths, propagation over the frequency range 2-11 GHz is relatively nondispersive. Rain attenuation is negligible at the lower end of the band, but increases with frequency and can be significant for frequencies greater than around 7 GHz. Attenuation of emissions by terrain, foliage and human-generated structures can be significant. However, diffraction loss is finite. This allows consideration of both LOS and NLOS transmission links.

LOS radio systems in these frequency bands may be a combination of thermal and interference noise-limited. Dispersive multipath is not significant until path lengths become greater than 10 km. For NLOS radio systems, consideration must also be given to the excess path loss experienced from diffraction and the fading experienced from reflective facets that are in motion. Measurement data indicates that this form of fading follows a Rician distribution with parameters set by the characteristics of a specific NLOS transmission path. For severely attenuated NLOS links, the fading distribution characteristics approach those of Rayleigh. A variety of channel models have been developed to group-classify different terrain types. This information is valuable for generalized system design.

For the "typical" system and equipment parameters employed in this document, it has been concluded that high availability links will be required to be LOS. Subsequent coexistence considerations are thus based on an assumption of an LOS primary transmission path.

3-6.3.1 Interference Scenarios

The interference scenarios reported in Part 1 of this recommended practice apply equally to this Part 3. Victim and interfering systems are assumed to be fixed BWA networks with a point to multipoint or mesh architecture.

3-7 Deployment and coordination

This clause provides a recommended structure process to be used to coordinate deployment of fixed BWA systems in order to minimize interference problems.

NOTE- National regulation and/or international agreements may impose tighter limits than the following and shall take precedence in this case.

This methodology will facilitate identification of potential interference issues and, if the appropriate recommendations are followed, will minimize the impact in many cases, but compliance with this process will not guarantee the absence of interference problems.

NOTE- In the following, “coordination” implies, as a minimum, a simple assessment showing the likelihood of interference. It may imply a detailed negotiation between operators to mitigate problem areas for the benefit of both systems.

3-7.1 Co frequency, adjacent area

3.7.1.1 Methodology

Coordination is recommended between licensed service areas where both systems are operating co-channel, i.e., over the same fixed BWA frequencies, and where the service areas are in close proximity, e.g., the shortest distance between the respective service boundaries is less than 80km.The operators are encouraged to arrive at mutually acceptable sharing agreements that would allow for the provision of service by each licensee within its service area to the maximum extent possible. Under the circumstances where a sharing agreement between operators does not exist or has not been concluded, and where service areas are in close proximity, a coordination process should be employed.

Fixed BWA operators should calculate the power spectral flux density (psfd) at their own service area boundary. Power spectral flux density should be calculated using good engineering practices, taking into account such factors as propagation loss, atmospheric loss, antenna directivity toward the service area boundary, and the curvature of Earth. The psfd level at the service area boundary should be the maximum value for elevation point up to 500 m above local terrain elevation. No aggregation is needed because principal interference processes are direct main beam to main beam coupling. The limits here refer to an operator’s own service boundary, since that is known to the operator and will frequently be the same as the adjacent operator’s service boundary. In cases where the two boundaries are separate (e.g., by a large lake), dialog between operators, as part of the coordination process, should investigate relaxing the limits by applying the limits at the adjacent service boundary. In cases where there is an intervening land mass (with no licensed operator) separating the two service areas, a similar relaxation could be applied. However, in this case, caution is needed since both existing operators may have to re-engineer their systems if service later begins in this intervening land mass. Deployment of facilities which generate a psfd, averaged over any 1 MHz at their own service area boundary, less than or equal to that stated in table 3.4, should not be subject to any coordination requirements.

3.7.1.2 Coordination trigger

As described above, distance is suggested as the first trigger mechanism for coordination between adjacent licensed operators. If the boundaries of two service areas are within 80km of each other, then the coordination process is recommended.

In case of sites of very high elevation relative to local terrain, BWA service areas beyond 80 km may be affected. The operator should coordinate with the affected licensee(s).

The rationale for 80 km is based upon several considerations, including radio horizon calculations, propagation effects, and power flux density levels.

The radio horizon, defined as the maximum line-of-sight distance between two radios, is defined as follows:

$$R_h=4.12(\sqrt{h1}+\sqrt{h2})$$

where

R_h = radio horizon (km)
h1 = height of Radio 1 above clutter (m)
h2 = height of Radio 2 above clutter (m)

Annex 3B contains details of horizon range calculations for various combinations of BS and SS antenna heights and for two frequency ranges, 3.5 GHz and 10.5 GHz Note that if the antenna is erected on a mountain (or building), then the “height of radio above clutter” will probably also include the height of the mountain (or building). The tables in Annex 3C also identify the diffraction loss for a spherical earth for the various BS/SS height combinations.

The worst-case interference scenario involves two base stations, as these are typically located on relatively high buildings or infrastructures and hence have greater radio horizon distances than subscriber stations. A typical height for a base station is 65 m above ground level, or 55 m above clutter, assuming an average clutter height of 10 m over the whole path length. This produces a radio horizon of 80 km. There will be cases where the base station equipment may be located on higher buildings, which would produce a greater radio horizon. However, these base stations tend to tilt their antennas downward. This effectively reduces the amount of power directed towards the adjacent base station and therefore reduces the interference.

3.7.2 Same area/adjacent frequency

As stated in Recommendation 3-4, deployments will usually need one guard channel between nearby transmitters. Where administrations do not set aside guard channels, the affected operators would need to reach agreement on how the guard channel is apportioned between them. Where channel sizes are different, the guard channel should be equal to that of the wider channel system. This document does not consider the case where an operator deploys multiple channel sizes within his or her allocation.

3.7.3 Co frequency, adjacent area

Coordination is recommended between licensed service areas where both systems are operating co-channel, i.e., over the same fixed BWA frequencies, and where the service areas are in close proximity, e.g., the shortest distance between the respective service boundaries is less than 80km. The operators are encouraged to arrive at mutually acceptable sharing agreements that would allow for the provision of service by each licensee within its service area to the maximum extent possible. Under the circumstances where a sharing agreement between operators does not exist or has not been concluded, and where service areas are in close proximity, a coordination process should be employed.

Fixed BWA operators should calculate the power spectral flux density (psfd) at their own service area boundary. Power spectral flux density should be calculated using good engineering practices, taking into account such factors as propagation loss, atmospheric loss, antenna directivity toward the service area boundary, and the curvature of Earth. No aggregation is needed because principal interference processes are direct main beam to main beam coupling. The limits here refer to an operator’s own service boundary, since that is known to the operator and will frequently be the same as the adjacent operator's service boundary. In cases where the two boundaries are separate (e.g., by a large lake), dialog between operators, as part of the coordination process, should investigate relaxing the limits by applying the limits at the adjacent service boundary. In cases where there is an intervening land mass (with no licensed operator) separating the two service areas, a similar relaxation could be applied. However, in this case, caution is needed since both existing operators may have to re-engineer their systems if service later begins in this intervening land mass.

Deployment of facilities which generate a psfd, averaged over any 1 MHz at their own service area boundary, less than or equal to that stated in Table 3.4, should not be subject to any coordination requirements.

Table 3.4 Maximum psfd limits

Frequency band	**psfd (dBW/m^2)/MHz**
3.5 GHz	-125
10.5 GHz	-126

3.7.4 Same area/ adjacent frequency

As stated in Recommendation 3-4, deployments will usually need one guard channel between nearby transmitters. Where administrations do not set aside guard channels, the affected operators would need to reach agreement on how the guard channel is apportioned between them. Where channel sizes are different, the guard channel should be equal to that of the wider channel system. This document does not consider the case where an operator deploys multiple channel sizes within the authorized frequency assignment.

3.7.5 Use of power spectral flux density (psfd) as a coexistence metric

This subclause addresses the maximum power flux density that can be tolerated as a result of co-channel interference originating from an adjacent licensed operator. For the purposes of the Recommendations in this document, the amount of interference generally considered acceptable or tolerable is a level which produces a degradation of 1 dB to the system's C/N This degradation is usually taken into consideration during the original link budget exercise. For the noise floor to increase by 1 dB, the interference power level must be 6 dB below the receiver's thermal noise floor.

3-8 Interference and propagation evaluation/ examples of coexistence in a PMP environment

3-8.1 Guidelines for geographical and frequency spacing between fixed BWA systems

The following subclauses indicate some of the models, simulations, and analysis used in the preparation of part 3 of this Recommended Practice. While a variety of tools can be used, it is suggested that the scenarios studied below be considered when coordination is required.

3-8.1.1 Summary

This subclause provides guidelines for geographical and frequency spacings of fixed BWA systems that would otherwise mutually interfere. In many (probably most) cases, by following these guidelines, satisfactory psfd levels will be achieved at system boundaries. The information is therefore valuable as a first step in planning the deployment of systems. The actual psfd levels can then be calculated or measured, as appropriate, and any adjustments to system layout can then be made. These adjustments should be relatively small, except in unusual cases.

3-8.1.2 Interference mechanisms

Various interference mechanisms can reduce the performance of fixed BWA systems. Although intra-system interference is often a significant source of performance degradation, it is not considered in this analysis. Its reduction to acceptable levels requires careful system design and deployment, but these are under the control of the operator, who may decide what constitutes an acceptable maximum level.

Thus, only inter-system interference mechanisms, where inter-operator coordination may be appropriate, are considered here. In each frequency band assigned for fixed BWA use, different types of systems may be deployed, some conforming to IEEE 802.16 standards and some designed to other specifications. Therefore, we consider a wide range of possibilities in determining the likely interference levels and methods for reduction to acceptable levels.

The following are the two main scenarios, each with several variants:

- Co-channel systems that are geographically spaced
- Systems that overlap in coverage and (in general) require different frequencies of operation

The various potential BS-SS-RS interference paths need to be considered to determine how much interference will occur. Between any two systems, several interference mechanisms may be operating simultaneously. The geographical or frequency spacing (or both) necessary to reduce interference to acceptable levels is then determined by the most severe mechanism that occurs.

Two different techniques have been used to estimate intersystem interference. They are as follows:

- Worst case analysis
- Monte Carlo simulations

Each of these is described below. The most appropriate method depends on the interference mechanism. In each case, geographical or frequency spacing between systems has been varied in the calculations until the interference is below an acceptable threshold. These values are shown in the tables of results as guidelines for nominal geographical or frequency spacing.

3-8.1.3 Worst-case analysis

Some interference mechanisms arise from a single dominant source and affect each victim in a similar way. A relatively simple calculation of the worst-case interference can then be made, using realistic values for system parameters and ignoring additional radio path terrain losses. An example is the interference from a single dominant BS into the victim BS of an adjacent system.

3-6.1.4 Monte Carlo Simulations

There are many cases where a simple worst-case analysis is of limited use. Where there are many possible interference paths between a particular type of interferer and the associated victim stations, the worst case could be very severe, but may also be very improbable. Planning on the basis of the worst case would then be unrealistic. An example is the interference between subscriber stations of different operators in the same geographical area. Most interference will be negligible, but a certain small proportion of cases could have very high interference levels. Monte Carlo simulations provide a means of assessing the probability of occurrence of a range of interference levels at victim stations. The recommended geographical or frequency spacing is then a compromise in which an acceptably small proportion of cases suffer interference above the recommended limit. For example, 1% of randomly positioned SSs might suffer interference above the desired level. A model of an interference scenario is created using realistic parameters in which the placement of fixed BWA stations (usually the SSs) can be randomly varied. Other randomly varied parameters, such as buildings and terrain factors, may be included. The simulation is run many times and the results plotted as a probability distribution.

3-8.1.5 Other methods

Two other methods, not used in the calculations for part 3 of this recommended practice, are described in part 1. These are the Interference Area (IA) method and the ISOP (Interference scenario occurrence probability) method. As well as the descriptions in part 1, further information on both the ISOP method and the IA method can be found in ERC Report 099 [B2].

3-8.1.6 Simulations and calculations

Table 3.5 summarizes the simulations and calculations undertaken for this Recommended Practice. The most appropriate method has been selected, dependent on the scenario and interference path.

Table 3.5 Summary of the simulations and calculations

Scenario	**Frequency**	**Area/ channel**	**Guideline spacing**	**Methodology**
BS to BS	3.5 GHz	Adjacent area, same channel	Spacing to at least horizon distance needed (typically 80km)	Monte Carlo analysis
BS to SS	3.5 GHz	Adjacent area, same channel	Spacing to at least horizon distance needed (typically 80km)	Monte Carlo analysis
SS to BS	3.5 GHz	Adjacent area, same channel	Typically 40 – 80 km spacing needed	Monte Carlo analysis
SS to SS	3.5 GHz	Adjacent area, same channel	Very Low probability. Coordination needed for the bad cases.	Worst case (simulation not required)
BS to BS	3.5 GHz	Same area, adjacent channel	Combination of isolation (NFD etc) and physical spacing is required (typically 0.1 – 2km, dependent on available isolation)	Monte Carlo analysis
BS to SS	3.5 GHz	Same area, adjacent channel	Isolation needed depends on modulation. In some cases it may be possible to operate in the adjacent channel but typically 1 guard channel is required.	Monte Carlo analysis
SS to BS	3.5 GHz	Same area, adjacent channel	Isolation needed depends on modulation. In some cases it may be possible to operate in the adjacent channel but typically 1 guard channel is required.	Monte Carlo analysis
SS to SS	3.5 GHz	Same area, adjacent channel	Low probability Coordination needed for the bad cases.	Worst case (simulation not required)
BS to BS	10.5 GHz	Adjacent area, same channel	Spacing to at least horizon distance needed (typically 80km)	Monte Carlo simulation

BS to SS	10.5 GHz	Adjacent area, same channel	Spacing to at least horizon distance needed (typically 80km)	Monte Carlo simulation
SS to BS	10.5 GHz	Adjacent area, same channel	Typically 40 – 80 km spacing required	Monte Carlo simulation
SS to SS	10.5 GHz	Adjacent area, same channel	Very low probability. Coordination needed for the bad cases.	Worst case (simulation not required)
BS to BS	10.5 GHz	Same area, adjacent channel	Combination of isolation (NFD etc) and physical spacing is required	Monte Carlo simulation
BS to SS	10.5 GHz	Same area, adjacent channel	Isolation needed depends on modulation. In some cases it may be possible to operate in the adjacent channel but typically 1 guard channel is required.	Monte Carlo simulation
SS to BS	10.5 GHz	Same area, adjacent	Isolation needed depends on modulation. In some cases it may be possible to operate in the adjacent channel but typically 1 guard channel is required.	Monte Carlo simulation
SS to SS	10.5 GHz	Same area, adjacent	Low probability. Coordination needed for the bad cases.	Monte Carlo simulation

3- 9 Mitigation techniques

A number of mitigation techniques are described in Part 1. These are also generally of relevance to the types of system analyzed in this Part 3. In addition, adaptive antenna (AA) techniques may also be useful in some circumstances.

The direct effect of AA on coexistence is due to the fact that the RF energy radiated by transmitters is focused in specific areas of the cell and is not radiated in all directions. Moreover, beam-forming with the goal of maximizing the link margin for any given user inside the cell coverage area at any given time makes the AA beams' azimuth and elevation vary from time to time. Given the differences in height and surrounding environment of the base and subscriber station antennas, chances for main-beam coupling as depicted in figure 3.1A, are greatly reduced. These factors suggest that, in simulating the coexistence, the adaptive antenna pattern and gain need to be considered as random variables both in E- and H-plane. This characteristic plays a major role in determining the likelihood of interference in coexistence scenarios. While an absolute worst case may look prohibitive, the statistical factor introduced by the use of AA determines the percentage of time that the worst case happens. If this percentage is satisfactorily small, the coexistence rules may be relaxed, thus helping the economics of the wireless deployment.

3-9.1Co-channel – Adjacent Area

If one or both operators in adjacent areas use adaptive beam-forming antennas at their base stations, the cross-border interference can be greatly reduced due to null-steering capabilities of such antennas. It should be noted that an M-element array is capable of suppressing up to M-1 interferers as long as they can be spatially separated from the wanted users. The main source of serious interference in co-channel adjacent area situations, however, is main beam coupling when wanted and interfering signals cannot be spatially separated. As an example, the SS-to-BS interference due to main-beam coupling is depicted in figure 3.1A. This phenomenon, which happens irrespective of the types of antennas used, could create more severe interference power when the victim BS is using AA. This is due to the typically higher gain of the AA beams compared to a conventional wide-sectored antenna. An M-element array could produce an additional $10\log_{10}(M)$ dB of gain towards the intended users through spatial processing that may affect the co-channel stations of the other system. However, due to the statistical factor introduced by the AA, the likelihood of this scenario occurring is greatly reduced compared to the case with conventional antennas. Simulation results confirm this. In the case of uplink beamforming at the base station (AA being the victim), spatial signatures used in the process are uniquely attributed to the propagation environment surrounding the intended user and could be significantly different from that of an interfering station miles away in the adjacent service area, thus being affected by less or no additional gain from the interferer.

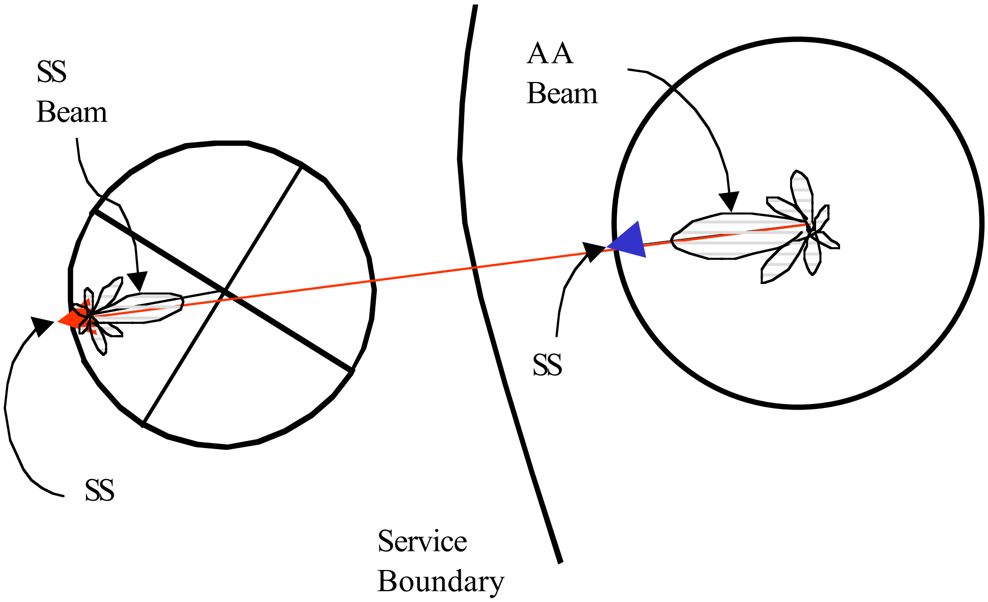


FIGURE 3.1A-MAIN BEAM COUPLING

3-9.1 Same Area – Adjacent Channel

The introduction of a statistical factor in the creation and reception of interference power also helps coexistence in the same area – adjacent channel case. In this case, the uplink of the AA may be affected more than the co-channel, adjacent area case due to the fact that in same area the intended user and the interferers could be much closer to each other, thus producing spatial signatures with higher degree of correlation. On the other hand, the additional array gain of the AA is reduced because of the loss of baseband coherency in its out-of-band operation. Therefore, although in this case the distances between interferers and victims are smaller, the reduction in the main beam gain of the AA further reduces the interference power into AA from other antennas operating in adjacent bands and vice versa. All simulations point to the fact that the BS-to-BS direct antenna coupling is the most problematic case for coexistence. With the use of AA, the loss of coherency in out-of-band operations reduces the gain towards the interferers/victims, thus lowering the amount of interference power.

Annex 3-A

(informative)

Sample 3.5GHz power spectral flux density (psfd) calculations

3-A.1 Thresholds

Using the same expressions detailed in Part 1 Annex B, assuming an operating frequency of 3.5 GHz ($\lambda = 0.09$ m), a noise figure of 5 dB and a typical base station antenna gain of 15 dBi , then the tolerable interference levels are given as:

PMP Base Station: $\mathrm{Psfd}_{BS} = -145 - 10\mathrm{Log}(0.09^2) - 15 + 10\ \mathrm{Log}(4\pi)$

$= -145 + 21 - 15 + 11$

$\underline{= -128\ (\mathrm{dBW/m^2})/\mathrm{MHz}}$

3-A.2 3.5 GHz – PMP BS Tx into victim PMP SS

A sample calculation is given below to determine the feasibility of meeting the psfd limit between a BS transmitter and PMP SS victim receiver. The formula for psfd is given as expression B3 in Annex B of Part 1.

Assuming:

P_{Tx} = transmitter power (–10 dBW/MHz)
G_{Tx} = transmitter antenna gain in the direction of the victim receiver (15 dBi)
R = range (80 000 m)
A losses = atmospheric losses, ~0.01 dB/km

Using the radio horizon range of 80 km from above, the psfd at the victim base station receiver antenna is:

$$\mathrm{psfd}_{\text{P-Pvictim}} = -15 + 18 - 10\log(4\pi) - 20\log(80{,}000) - 80{*}.01$$

$$\underline{= -105\ (\mathrm{dBW/m^2})/\mathrm{MHz}}$$

The interference level is well in excess of the objective for an I/N=-6 dB. Thus the horizon range of 80 km must be considered as a first level trigger point and satisfactory performance requires additional diffraction loss beyond the horizon. Note that the computation assumes LOS transmission across the full length of the interference path.

Annex 3-B

(Informative)

Description of calculations and simulation methods

3-B.1Description of Simulation Parameters

For the Monte Carlo simulations subsequently described in sections 3B.2 and 3B.3, typical fixed BWA transmission parameters were employed. Table 3B.1 summarizes these parameters for both the 3.5 GHz and 10.5 GHz frequency bands. The simulation models assume a maximum cell radius of R = 7 km for both frequency bands. Link budget calculations indicated that, for this cell radius, a 2-way link availability of 99.99 % is achievable under LOS propagation conditions. The link budget estimates further indicated that at 3.5 GHz, an outbound transmission modulation index of 64-QAM could be supported and that an inbound modulation index of 16-QAM could be supported. Corresponding estimates for 10.5 GHz were 16-QAM outbound and 4-QAM inbound. For the three modulation indices, threshold C/N performance limits were assumed to respectively be 12 dB, 18 dB and 24 dB. C/I interference levels that would degrade threshold performance by 1 dB are 6 dB greater, at 18 dB, 24 dB and 30 dB.

Frequency Band	**3.5 GHz**	**10.5 GHz**
Maximum Cell Radius	7 km	7 km
Channel Bandwidth	7 MHz	5 MHz
Excess Bandwidth	25 %	25 %
Nyquist Bandwidth	5.6 MHz	4 MHz
SS TX Power	+21 dBm	+20 dBm
BS TX Power	+29.5 dBm	+26 dBm
SS Antenna Gain	+18 dBi	+25 dBi
BS Antenna Gain	+14.5 dBi	+16 dBi
TX/RX RF Losses	3 dB at each end	3 dB at each end
Receiver Noise Figure	5 dB	5 dB
SS/BS Antenna RPE	As specified in table 3.2	As specified intable 3.3
Link Availability Objective	99.99 % @ BER = 10^{-6}	99.99 % @ BER = 10^{-6}

Table 3B.1. Representative System and Equipment Parameters

As the available fade margin for all of the link options was identified to be modest, no clear sky cell edge ATPC was assumed. For simulations that involve shorter link distances, distance proportional ATPC was employed for inbound links. No ATPC was assumed for outbound links. At 10.5 GHz, relative rain attenuation between interference and victim links may be an issue. The computational procedure for estimation of this differential is described in section 3B.2.1 as well as in references [H3.5] and [H3.3]. ITU-R rain regions K and P were examined in the simulations.

For identification of the necessary co-channel coordination distance required by operators across a service area boundary, it is desirable to estimate the horizon distance. Estimates of the horizon distance for a spherical earth, and the diffraction loss beyond it, are summarized in section 3B.1.1 and are detailed in reference [H3.6]. To identify the necessary adjacent channel coordination distance and guard bands required by operators who have deployed in the same area, it is necessary to specify the net filter discrimination (NFD). This is the transmission cascade of the interference signal out-of-band emissions and the receiver filtering of the victim link. For the simulations, a 1'st adjacent NFD of 27 dB and a 2'nd adjacent channel NFD of 49 dB was assumed.

To estimate interference levels, the discrimination provided by antenna RPE patterns is required. The simulations assumed the RPE patterns detailed in [H3.13] for 3.5 GHz and the RPE patterns detailed in [H3.14] for 10.5 GHz.

3B.1 Adjacent Area - Same Frequency

These Monte Carlo simulations examined co-channel interference sensitivity across a service area boundary. The simulations assumed an uncoordinated alignment of interference and victim sectors. In accordance with the coordination criteria common to many regulatory agencies, interference sensitivity is expressed in terms of power spectral flux density (pfd) as defined by dBW/m^2/MHz. The critical value for pfd is set to be an I/N = -6 dB. This is a value that would degrade the receiver performance threshold by 1 dB. Critical pfd values vary with frequency and with the assumptions set for the link parameters. These values are detailed in the reference documents.

3B.1.1 Horizon Distance and Diffraction Loss

For the boundary co-channel pfd simulation estimates that follow, it was found necessary to evoke a horizon distance limit for many interference scenarios. To place the horizon distance into perspective, Tables 3C.2 through 3C.9 estimate the excess diffraction loss to be expected from a spherical earth for interference link distances of 30, 60, 70 and 80 km. The Table entries are parameterized against the relative elevations of the link antennas. Table entries of zero indicate that the link has become LOS.

For specific link analysis, actual terrain data is required. The spherical earth assumption employed represents a worst case estimate. The computational analysis is detailed in [H3.4] and is based on the procedures given in [H3.10].

Tables 3B.2 and 3B.3 define diffraction loss estimates for a quite modest separation distance of Di = 30 km. While it is quite unlikely that this distance would ever be considered as an appropriate horizon distance, the purpose of these two tables is to highlight the fact that, when Di is small, LOS transmission may result, even for quite low relative antenna elevations.

Table 3B.2. Spherical Earth Diffraction Loss at 3.5 GHz (Di = 30 km)

Height of Radio 2 (m)	Height of Radio 1 (m)								
	10	20	30	40	50	60	70	80	90
10	24	16	10	5	0.5	0	0	0	0
20	16	7.5	1	0	0	0	0	0	0
30	10	1	0	0	0	0	0	0	0
40	5	0	0	0	0	0	0	0	0
50	0.5	0	0	0	0	0	0	0	0

Table 3B.3. Spherical Earth Diffraction Loss at 10.5 GHz (Di = 30 km)

Height of Radio 2 (m)	Height of Radio 1 (m)

	10	20	30	40	50	60	70	80	90
10	23.5	12	4	0	0	0	0	0	0
20	12	1	0	0	0	0	0	0	0
30	4	0	0	0	0	0	0	0	0

Table 3B.4. Spherical Earth Diffraction Loss at 3.5 GHz (Di = 60 km)

Height of Radio 2 (m)	Height of Radio 1 (m)								
	10	20	30	40	50	60	70	80	90
10	63.5	55	49	44	40	36	32.5	29	26
20	55	47	40.5	35.5	31.5	27.5	24	21	18
30	49	40.5	34.5	29.5	25	21.5	18	14.5	11.5
40	44	35.5	29.5	24.5	20.5	16.5	13	10	6.5
50	40	31.5	25	20.5	16	12	8.5	5.5	2.5
60	36	27.5	21.5	16.5	12	8.5	5	1.5	0
70	32.5	24	18	13	8.5	5	1.5	0	0
80	29	21	14.5	10	5.5	1.5	0	0	0
90	26	18	11.5	6.5	2.5	0	0	0	0

Table 3B.5. Spherical Earth Diffraction Loss at 3.5 GHz (Di = 70 km)

Height of Radio 2 (m)	Height of Radio 1 (m)								
	10	20	30	40	50	60	70	80	90
10	77	68.5	62.5	57.5	53.5	49.5	46	42.5	39.5
20	68.5	60.5	54	49	45	41	37.5	34.5	31
30	62.5	54	48	43	39	35	31.5	28	25
40	57.5	49	43	38	34	30	26.5	23	20
50	53.5	45	39	34	29.5	25.5	22	19	16
60	49.5	41	35	30	25.5	22	18.5	15	12
70	46	37.5	31.5	26.5	22	18.5	15	11.5	8.5
80	42.5	34.5	28	23	19	15	11.5	8.5	5
90	39.5	31	25	20	16	12	8.5	5	2

Table 3B.6. Spherical Earth Diffraction Loss at 3.5 GHz (Di = 80 km)

Height of Radio 2 (m)	Height of Radio 1 (m)								
	10	20	30	40	50	60	70	80	90

10	90.5	82	76	71	67	63	59.5	56	53
20	82	74	67.5	62.5	58.5	54.5	51	47	44.5
30	76	67.5	61.5	56.5	52.5	48.5	45	41.5	38.5
40	71	62.5	56.5	51.5	47.5	43.5	40	36.5	33.5
50	67	58.5	52.5	47.5	43	39	35.5	32.5	29.5
60	63	54.5	48.5	43.5	39	35.5	32	28.5	25.5
70	59.5	51	45	40	35.5	32	28.5	25	22
80	56	47	41.5	36.5	32.5	28.5	25	22	18.5
90	53	44.5	38.5	33.5	29.5	25.5	22	18.5	15.5

Table 3B.7. Spherical Earth Diffraction Loss at 10.5 GHz (Di = 60 km)

Height of Radio 2 (m)	Height of Radio 1 (m)								
	10	20	30	40	50	60	70	80	90
10	81.5	70.5	62	55	49	43.5	38.5	34	29.5
20	70.5	59	51	44	38	32.5	27.5	22.5	18
30	62	51	42.5	35.5	29.5	24	19	14.5	10
40	55	44	35.5	28.5	22.5	17	12	7.5	3
50	49	38	29.5	22.5	16.5	11	6	1.5	0
60	43.5	32.5	24	17	11	5.5	.5	0	0
70	38.5	27.5	19	12	6	.5	0	0	0
80	34	22.5	14.5	7.5	1.5	0	0	0	0
90	29.5	18	10	3	0	0	0	0	0

Table 3B.8. Spherical Earth Diffraction Loss at 10.5 GHz (Di = 70 km)

Height of Radio 2 (m)	Height of Radio 1 (m)								
	10	20	30	40	50	60	70	80	90
10	101.5	90	82	75	69	63.5	58.5	53.5	49
20	90	79	70.5	63.5	57.5	52	47	42.5	38
30	82	70.5	62	55.5	49	44	38.5	34	29.5
40	75	63.5	55.5	48.5	42.5	37	32	27	22.5
50	69	57.5	49	42.5	36.5	31	25.5	21	16.5
60	63.5	52	44	37	31	25.5	20.5	15.5	11
70	58.5	47	38.5	32	25.5	20.5	15	10.5	6
80	53.5	42.5	34	27	21	15.5	10.5	6	1.5
90	49	38	29.5	22.5	16.5	11	6	1.5	0

Table 3B.9. Spherical Earth Diffraction Loss at 10.5 GHz (Di = 80 km)

Height of Radio 2 (m)	Height of Radio 1 (m)								
	10	20	30	40	50	60	70	80	90
10	121	110	101.5	94.5	88.5	83	78	73.5	69
20	110	98.5	90.5	83.5	77.5	72	67	62	57.5
30	101.5	90.5	82	75	69	63.5	58.5	54	49.5
40	94.5	83.5	75	68	62	56.5	51.5	47	42.5
50	88.5	77.5	69	62	56	50.5	45.5	40	36.6
60	83	72	63.5	56.5	50.5	45	40	35.5	31
70	78	67	58.5	51.5	45.5	40	35	30.5	26
80	73.5	62	54	47	40	35.5	30.5	25.5	21.5
90	69	57.5	49.5	42.5	36.5	31	26	21.5	17

3B.1.2 Outbound BS to SS Interference

3B.1.2.1 Simulation Model

Figure 3B.1 illustrates the simulation model. Both interference and victim sectors are independently spun in 5 degree increments. For each spin, the most severe interference level is selected from 20 randomly located cell edge SS locations and entered into a database. A simulation run thus consists of 72↔72 = 5184 pfd estimates that are sorted and presented as a cumulative distribution function (CDF) as a function of separation distance D. For any one spin combination, boresight BS sector angles are set by α and β . Interference distance D_i is set by D and the geometry. Interference RPE discrimination angles are set by θ and φ . The assignment of victim links to cell edge represents a worst case estimate as these links experience the minimum outbound signal level.

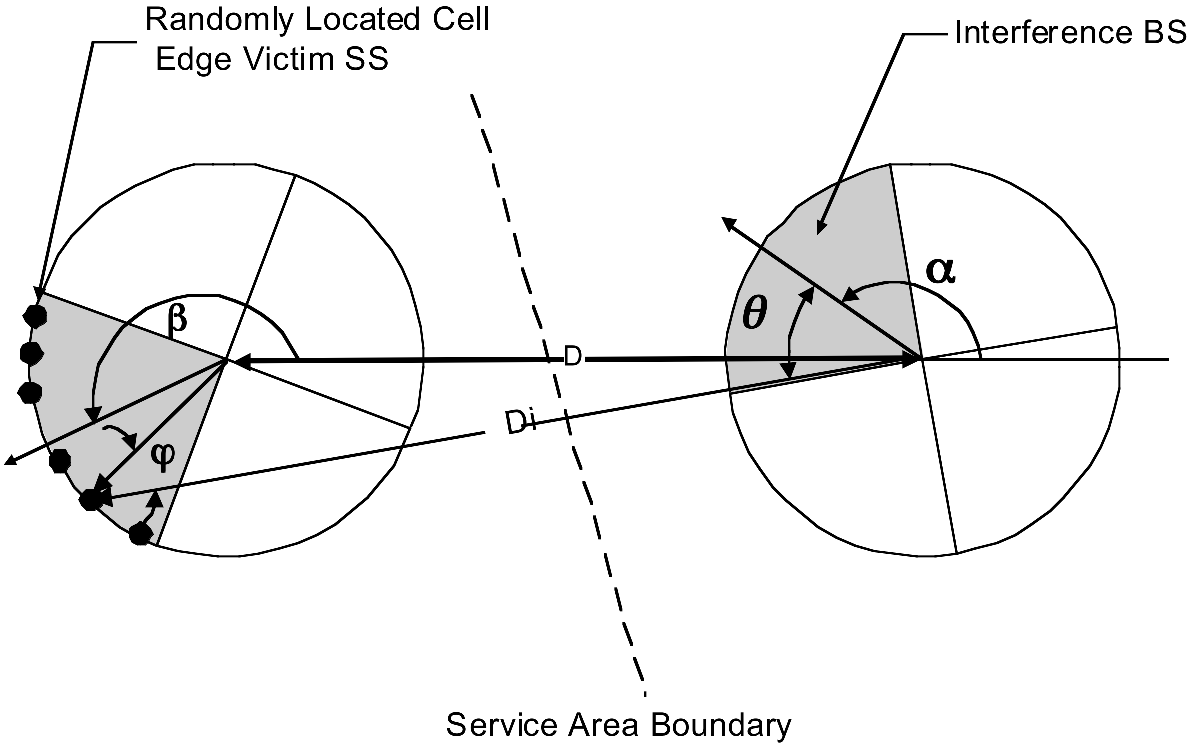


Figure 3B.1. Boundary BS to SS Simulation Model

3B.1.2.2 Simulation Results

Details of the simulation results for 3.5 GHz are described in [H3.7] and for 10.5 GHz in [hhh]. While the critical pfd values that correspond to an I/N = -6 dB differ for the two frequency bands, the simulation conclusions are comparable. For LOS interference vectors, both simulation estimates indicated that between 15 to 20 % of uncoordinated deployments would experience pfd exposures that exceed the objectives. This would occur for all distances D up to the horizon distance of approximately 80 km.

Additional simulation estimates examined the case for a path loss exponent of 4 for interference link distances greater than 7 km. For this scenario, the coordination distance could be reduced to 60 km. However, this propagation environment cannot be assured.

3B.1.3 Inbound SS to BS Interference

3B.1.3.1 Simulation Model

The simulation model for the inbound case is essentially the same as that of Figure 3B.1, except that the roles of the interference and victim vectors are reversed. The interference link is now a randomly positioned cell edge SS. When the SS is positioned at cell edge, the transmit power of the SS is maximized, thus this represents the most severe location for interference generation.

The victim is now an inbound SS to BS link. As distance proportional ATPC is applied to all inbound links, all such links would experience the same receive signal level. Thus, the simulation is required to consider only one such link.

3B.1.3.2 Simulation Results

Details of the simulation results for 3.5 GHz are described in [H3.8] and for 10.5 GHz in [H3.11]. As in the preceding outbound case, pfd levels were found to be excessive up to the horizon distance assumption of 80 km. For both frequency bands, between 10 - 15 % of uncoordinated deployments were found to exceed the I/N objective of -6 dB.

Again, the simulation results indicated that if interference links could be expected to experience excess path loss, then the coordination distance could be reduced. For the inbound interference cases, this was identified to be approximately 40 km. However, again, this propagation scenario cannot be assured.

3B.1.4 BS to BS Interference

3B.1.4.1 Simulation Model

Figure 3B.2 illustrates the simulation system model. The figure illustrates an uncoordinated alignment of interference and victim co-channel sectors, but one for which both sectors illuminate each other within their primary sector beam width. An inbound victim link is also illustrated. It is placed at cell edge. Distance proportional ATPC would place all victim links at the same received signal level. Thus, it is necessary to consider one such link with referenced to critical pfd levels.

The interference separation distance D_i is simply D, the distance between the two BS locations. For any one interference estimate, angles β and θ set the RPE discrimination of the sector antennas.

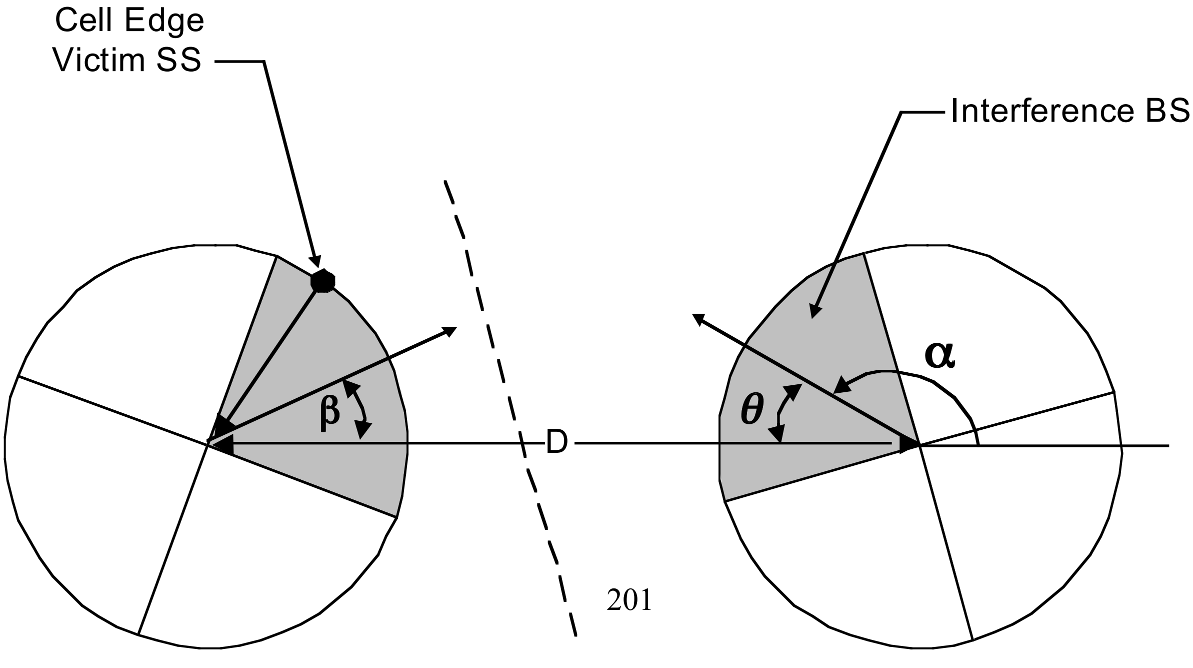


Figure 3B.2 Boundary BS to BS Simulation Model

3B.1.4.2 Simulation Results

Details of the simulation results for 3.5 GHz are described in [H3.4] and for 10.5 GHz in [H3.10]. As both interference and victim antennas are wide beam width - 90 degreed sectored it would be expected that there would be a high probability of occurrence for worst case couplings. The simulations confirmed this assumption. For LOS couplings, the simulations indicated that the pfd objectives would be exceeded in 23 % of cases up to the assumed horizon distance of D_i = 80 km.

The problem becomes manageable if excess path loss or horizon diffraction losses such as those described in section 3C.1.1 can be assumed. This would apply except for cases where both BS antennas are extremely high and exceed 70 m.

3B.1.4 SS to SS Interference

3B.1.4.1 Analysis Model and Conclusions

The geometrical relationships for SS to SS interference are illustrated on Figure 3B.3. This scenario was not subjected to simulation as it was concluded that the probability of serious exposures was very low. The reasoning is as follows:

1. Most SS elevations are likely to be at a low elevation. This increases the probability that the interference path would experience excess path loss.
2. Low SS elevations reduce the horizon distance and increase the likelihood of diffraction loss. For example, if both SS antennas are at an elevation of 30 m, then; for D_i = 60 km, Tables 3C.4 and Tables 3C.7 indicate that the diffraction loss would be 34.5 dB/42.5 dB for the two frequency bands.
3. Both interference and victim antennas are narrow beam width. Hence, almost boresight alignments of both are required in order to create a worst-case interference conflict. For such alignments angle φ is quite small and most of the RPE discrimination is set by angle θ . For 10.5 GHz RPE discrimination is greater than 20 dB for θ larger than 5.5 degrees. RPE discrimination is less at 3.5 GHz due to the wider beam width SS antenna. It requires θ to be larger than 13 degrees in order to achieve 10 dB of discrimination.
4. There is no ATPC on the outbound link. Hence, a victim CS link located at a distance less than cell edge will experience receive signal levels in excess of the link margin requirements. Conversely, distance proportional ATPC is assumed for the inbound link. Thus, an interference SS located at a distance less than cell edge will experience a reduction in TX power, again favoring the victim link.
5. Full or partial time alignment is required between the "active data" segments of the interference TDMA frame and the victim TDM frame.

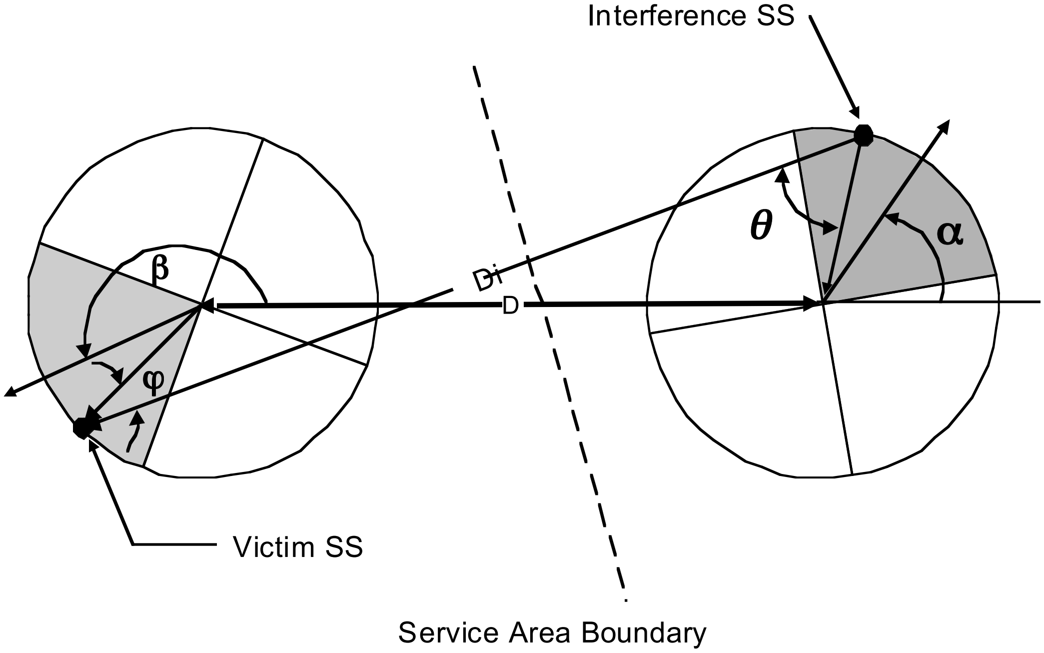


Figure 3B.3 Boundary SS to SS Interference Geometry

3-B.2 Same Area - Adjacent Frequency

When multiple system operators deploy on adjacent carriers in the same geographical area, the possibility of experiencing excessive interference can occur. This is a direct result of the finite emission limits of an interference transmitter for energy that falls in adjacent frequency channels. The protection limits of a victim receiver are set by Net Filter Discrimination (NFD). NFD is simply the cascade of the undesired signal spectra with the victim receiver filter.

The probability of experiencing excessive interference is dependent, in part, by the separation distance S of the victim BS location from that of the interference BS and, additionally; relative BS antenna orientation. As interference emissions usually continue to diminish with increasing frequency offset, frequency guard bands between operators offer an interference mitigation technique. Alternative interference techniques, such as cross-polarized operation of flanking carriers can also be considered.

Using Monte Carlo simulation techniques, these studies examined the preceding scenario. CDF estimates are developed that identify the probability of victim links experiencing excessive interference levels.

Figure 3B.4 illustrates a simple frequency re-use plan whereby each operator employs only two frequencies and two polarization's, V and H. As illustrated, the closest carriers are shown to have the same polarization. This is a worst case scenario. The guard channel C may or may not exist. It's need is to be determined as a conclusion of the simulations.

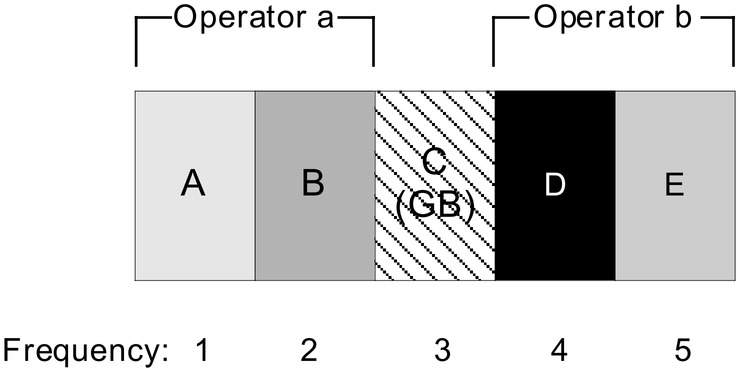


Figure 3B.4. Illustrative Multiple Operator Frequency Assignments

Figure 3B.5 illustrates a generic simulation model. As illustrated, BS-b is overlaid within the same sector of Bs-a. It is positioned at some parameterized distance S from BS-a. For any one set of simulation estimates, the relative position of BS-b on the arc defined by S is assumed to be random, and hence this is specified within the simulation.

As the relative alignment of the BS-a and BS-b sectors is unknown, the simulations shift the relative boresight position of BS-b in 5 degree increments. Thus, one complete simulation involves 72 increments. To establish statistical significance, a number of randomly positioned SS locations are established. Simulation sensitivity analysis has identified that no more than 20 assignments are required. These locations are randomly reassigned for each BS-b increment shift. The SS locations are constrained to be randomly located are distance biased on an area proportional basis. Generally speaking, it is only necessary to develop one set of 20 TS locations, either for interference or victim link assignments. The choice is dependent on the interference scenario under examination.

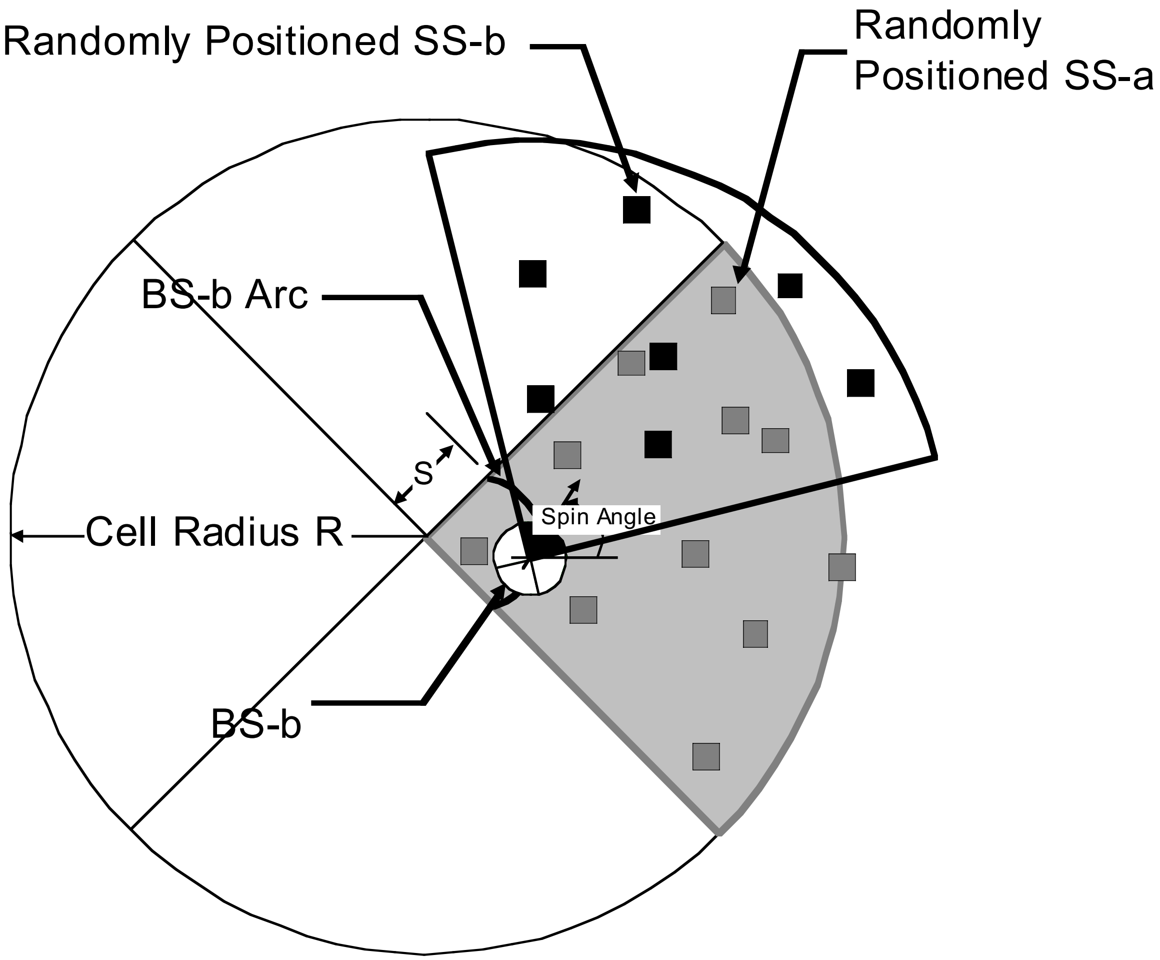


Figure 3B.5. Generic Same Area Simulation Model

3B.2.1 Rain Attenuation Computational Procedure

At 3.5 GHz, propagation attenuation due to rain is essentially negligible. This is also essentially true at 10.5 GHz for short links in regions where the probability of intense rain rates is small. However, there are rain rate regions where 10.5 GHz rain propagation attenuation may be of significance, even for short paths. At issue here, is the relative rain attenuation differential that results between an interference link and a victim link, and the impact it may have on C/I performance.

In order to address this issue, a simplified method for estimating rain loss has been developed as detailed in [H2.22] and [H2.23]. The procedure is illustrated on Figure 3B.6. As before, a second BS is positioned within the sector at some parameterized distance S and at some random angle θ . Overlaid on the clear sky simulation model is a circular rain cell of radius R_c. As proposed in [B20], the radius of the cell is approximately 1.2 km and, for a 1'st approximation, the rain rate is uniform within the cell. For any one set of simulation computations, the rain cell is randomly positioned at some central distance D_{rc} and angle γ .

The location of the rain cell is constrained so that the full diameter of the cell is within the victim sector. Hence, for a number of randomly positioned victim links, it is highly likely that at least one such link experiences the maximum attenuation of the rain cell. The maximum attenuation is set by the ITU-R rain region and the specified link availability requirements [H2.21]. A link availability of 99.99 % was set for the simulations. The simulations examined ITU-R rain regions K and P. The respective fade margin requirements (FM) are 7 and 16 dB for these two regions.

To simplify the estimation of relative rain attenuation, the simulation assumptions for the area having a uniform rain rate were altered to be that enclosed in bold on Figure 3B.6. This area is defined by the tangential intersections of both distance and angle to the edges of the rain cell. This allows the identification of inclusion distances ($\boldsymbol{D}_{\max}$ /$\boldsymbol{D}_{\min}$) and inclusion angles ($\boldsymbol{\varphi}_{\max}$ /$\boldsymbol{\varphi}_{\min}$) for rain loss estimates. To illustrate, consider the case for inbound SS to BS interference:

1. If the victim and/or interference vectors fall outside the exclusion angles, then the rain attenuation is set to zero.
2. If the victim and/or interference distance vectors are less than $\boldsymbol{D}_{\min}$, then the rain attenuation is set to zero.
3. If the victim and/or interference distance vectors fall within the exclusion angles and are greater than $\boldsymbol{D}_{\max}$, then the rain attenuation is set to the maximum value of FM.
4. If the victim and/or interference distance vectors fall within the exclusion angles and are within the inclusion distances $\boldsymbol{D}_{\max}$ /$\boldsymbol{D}_{\min}$, then the rain attenuation is proportionally adjusted to the distance of the vectors within the rain area. For a vector distance of $\boldsymbol{R}_v$, this would just be $\frac{\boldsymbol{R}_v - \boldsymbol{D}_{\min}}{2\boldsymbol{R}_c} \leftrightarrow \boldsymbol{FM}$.

Each same area interference scenario invokes a somewhat difference set of inclusion/exclusion criteria for relative rain loss estimates. The reader is referred to [mmm]and [nnn] for details.

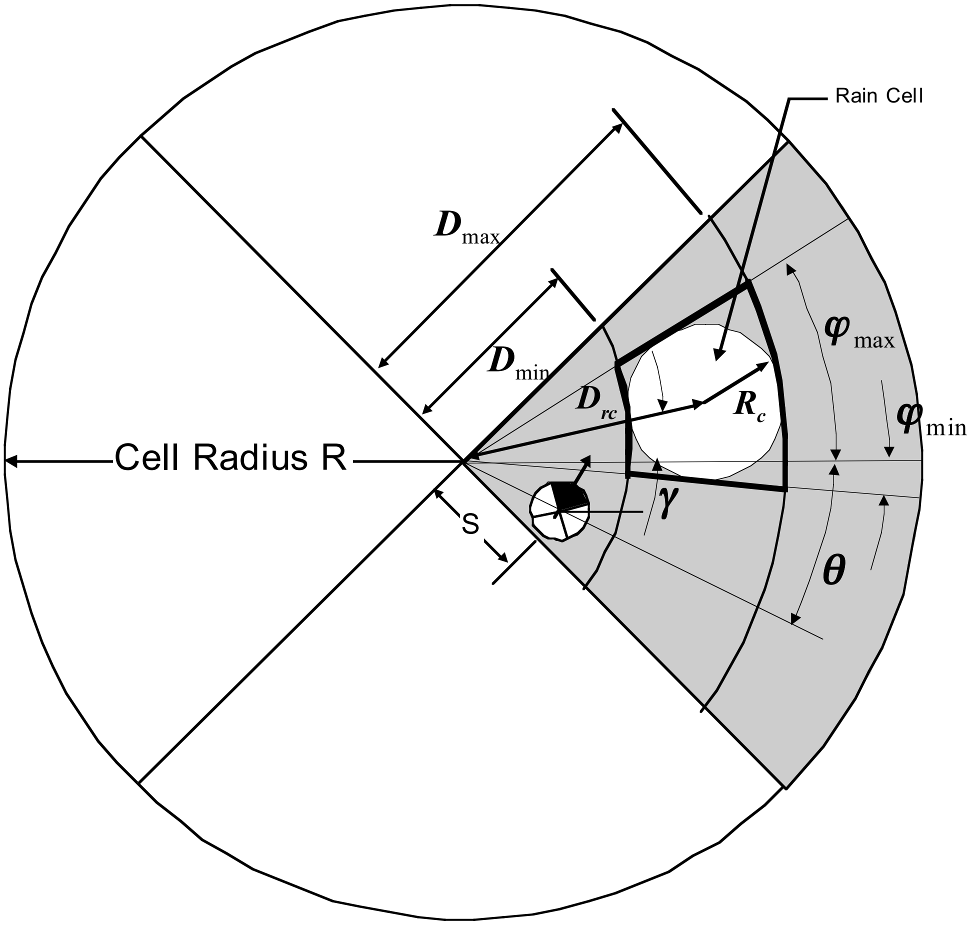


Figure 3B.6. Rain Attenuation Model.

3B.2.2 Outbound Same Area BS to SS Interference

3B.2.2.1 Simulation Model

The simulation model specific to outbound BS to SS interference is illustrated on Figure 3B.7. With the interference BS located in the victim sector at distance S, 20 victim TS locations are assigned for each angular 5 degree spin. These TS locations are assumed to be randomly biased on an area proportional basis. Consequently, 50% of the TS locations would be expected to be at a distance greater than 0.75R, R being the cell radius.

As the interference BS is, by definition, located within the victim sector, it is only required to spin the interference BS sector alignment. For each interference estimate, the impact of each of the four interference sectors is added. A composite simulation run thus consists of 1440 interference estimates. For each interference computation, the simulation C/I examines antenna RPE, NFD, distance differentials and, if it applies, antenna XPD. Each time the sector alignment is incremented, all of the SS random parameters are adjusted based on a randomizing seed. For the 10.5 GHz simulations, this also applies to the positioning of the rain cell.

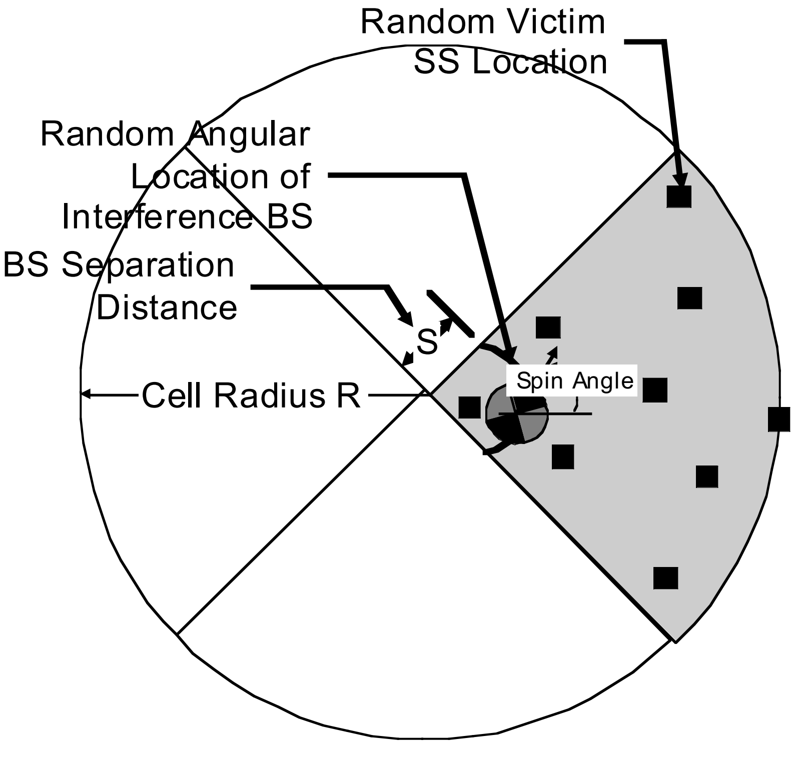


Figure 3B7. Outbound CS to TS Simulation Model.

3B.2.2.2 Simulation Results

As previously discussed, link budget estimates concluded that outbound transmissions could support 64-QAM at 3.5 GHz and 16-QAM at 10.5 GHz. Hence, critical C/I values that impact performance threshold by 1 dB are correspondingly 30 dB and 24 dB. Details of the simulation results may be found in [qqq] and [rrr]. Simulation sensitivity estimates relative to BS separation distance S demonstrated that C/I performance is poorest when S is small, noticeably for S < 0.5 km. Subsequent discussions are thus focused on such distances.

For clear sky estimates, the C/I performance was found to be comparable for both frequency bands. For same polarization operation without a guard band, NFD was set to 27 dB. CDF probabilities were found to increase rapidly at, or about, this C/I value.

At 3.5 GHz, and this NFD, the simulations indicated that from 1 to 7 percent of the exposures would exceed the 64-QAM performance threshold of 24 dB. The percentage exceeding the 1 dB C/I = 30 dB threshold impairment increased, were significantly greater, ranging between 15 - 50 percent.

At 10.5 GHz, only a fractional percentage of the clear sky exposures (< 0.5 %) were found to exceed the 16-QAM performance threshold of 18 dB. Those exposures exceeding the 1 dB threshold C/I value of 24 dB were found to be less than 4 percent.

When the relative rain attenuation differential at 10.5 GHz was examined, the simulations indicated that, in rain region K, the performance threshold impairment increased to a maximum of 3 % for S = 0.1 km and the 1 dB threshold impairment increased to 6 % at the same distance. For rain region P, these values increased to 4 % and 7 % respectively for the two C/I limiting values.

However, the CDF vs C/I simulation estimates demonstrated a very sharp knee in the vicinity of the assumed NFD value of 27 dB. Except for rain region P, an improved NFD of 35 dB would move all the remaining scenarios to within acceptable performance objectives. Such an NFD improvement is likely reasonable for modern transmitters. For rain region K, threshold impairment at a C/I =18 dB and 1 dB impairment at a C/I = 24 dB both improve to less than 1%.

For rain region P, the CDF knee was found to be less pronounced. Hence, modestly improved NFD was found to have a lesser impact. Here, the simulations indicated that a CS separation distance of 350 to 500 m might also be required.

Interference mitigation techniques, such as cross-polarized frequency assignments, or the specification of a guard band, would reduce the probabilities of critical C/I levels to negligible magnitudes. They enhance isolation to well more than would be required. The first mitigation technique involves operator coordination while the second is wasteful of bandwidth. Both techniques can be avoided if the stated NFD improvements are achievable.

3B.2.3 Inbound Same Area SS to BS Interference

3B.2.3.1 Simulation Model

For inbound SS to BS interference, the generic simulation model of Figure 3B.5 is appropriate. The choice as to which sector is deemed to be the victim and which sector is deemed to be associated with interference is arbitrary.

For the clear sky cases, the overlay sector/cell was set to be victim. As all victim links are assumed to employ distance proportional ATPC, all victim links are expected to arrive at the victim BS at the same level of signal strength. Thus, the C/I estimates need to only consider the signal level of one cell edge victim SS to BS link. Twenty interference TS locations were assigned. These were positioned based on a random distance biased/area proportional basis. The transmit power of each was ATPC adjusted in accordance with their relative distance from the interference BS. As with the outbound case, a simulation run consists of 1440 interference estimates.

For rain faded C/I estimates at 10.5 GHz, it was found to be computationally convenient to consider the overlay sector as the source of interference. Assuming that the inbound multiple access method is TDMA, a randomly positioned-cell edge interference SS is selected to be actively transmitting. Twenty randomly positioned victim SS locations are assigned for each spin and the clear sky C/I of each is computed. Signal levels C and interference levels I are adjusted in accordance with the rain attenuation methodology described in Section 3C.2.1. As the interference vectors are set to maximum power at celledge, they require no ATPC adjustment. Each potential victim SS is ATPC signal level adjusted inaccordance with distance and rain attenuation. The ATPC adjustment is set to reestablish the cell edgereceived signal level. If this is not possible, then the TX power of a victim SS is just set to maximum power level.

As previously discussed, inbound link budgets identified that 16-QAM could be supported at 3.5 GHz but that only 4-QAM could be supported at 10.5 GHz. This sets the respective inbound C/I threshold limits at 18 dB and 12 dB. The corresponding inbound 1 dB impairment C/I limits are thus 24 dB and 18 dB.

3B.2.3.1 Simulation Results

Except for differences in detail, outbound interference simulation results were found to be comparable to the inbound cases discussed in section 3C.2.2.2. The outbound results are detailed in [sss] and [ttt]. Again, the CDF vs C/I estimates were found to have a sharp knee in the vicinity of the value set for NFD.

For 3.5 GHz, and an assumption of 16-QAM, it was found that only a very small fraction of exposures would exceed the performance threshold of 18 dB. At the 1 dB threshold impairment level of 24 dB, less than 4 % of the exposures would exceed the requirement. As previously discussed, an improvement of NFD to 35 dB, would essentially eliminate all interference problems, up to 16-QAM.

Referenced to 4-QAM, clear sky estimates at 10.5 GHz were found to be even more improved. There were no C/I estimates that exceeded the critical limiting values of 12 and 18 dB. This was found to be the case even for rain region K. However, in rain region P, it was again observed that the sharp CDF knee was lost. Between 1 and

2 % of the exposures were found to exceed the performance limit of 12 dB and 3-6 % to exceed the 1 dB threshold limit of 18 dB. NFD improvement to 35 dB would reduce the 1 dB impairment excedance to 1%.

3B.2.4 Same Area BS to BS Interference

3B.2.4.1 Simulation Model

The generic simulation model given by Figure 3B.5 and the rain attenuation estimation model given by Figure 3C.6 again apply. Inbound links are now victim so the assumed modulation indices are 16-QAM at 3.5 GHz and 4-QAM at 10.5 GHz.

As the inbound links employ ATPC, clear sky interference estimates only need to consider one cell edge victim link. The simulation clear sky spin increment was set to one degree. A composite clear sky simulation run is thus represented by 360 C/I estimates.

For the rain faded simulation estimates at 10.5 GHz, 20 distance biased victim TS locations were set for a spin increment of 5 degrees. To examine rain loss differential the TS locations were randomly positioned in accordance with prior discussions. Rain faded CDF estimates were thus based on 1440 C/I interference exposures.

3B.2.4.2 Simulation Results

As both interference and victim antennas are wide beam width, it would be expected that interference sensitivity would be significantly more severe than previously reported for the other scenarios. The simulations confirmed this to be the case.

For clear sky operation and same polarization operation without a guard band, interference exposures that exceed the performance objectives were found to range from 20 to 50 %. These would not be resolvable unless excessively large separation distance limits were placed on the two BS sites (of the order of 3 km or greater). If operator coordination is possible, then it is likely that cross-polarized sector assignments would resolve the problems. Alternatively, a guard band could be considered, but this, of course, is wasteful of bandwidth. A much preferable solution would be to consider the use of ultra-linear BS transmitters that achieve NFD improvements equal to or greater than the previously noted mitigation techniques.

Similar arguments apply to rain faded operation at 10.5 GHz. However, the simulation conclusions were more restrictive. NFD improvement up to that of a guard band (49 dB), is still insufficient to meet margin limits unless distance BS separation S is set to greater than 350 m. Operation in rain region P was found to be even more restrictive. For S < 0.5 km, there were no simulation estimates that would achieve 4-QAM performance limit objectives for an NFD of 49 dB. Consideration of linearized TX power amplifiers that achieve emission suppression of -60 dBc in the 1'st adjacent channel would resolve all of the aforementioned interference issues associated with BS to BS couplings.

3B.2.4 Same Area SS to SS Interference

3B.2.4.1 Analysis Model and Conclusions

This interference mechanism was not simulated. The conclusions are comparable to those given in Section 3B.1.4.

Annex 3-C

Work of other bodies

The reader may wish to refer to the following documents for more information on regional or national regulation or standards:

- Industry Canada SRSP 303.4 – Technical Requirements for Fixed Wireless Access Systems Operating in the Band 3400 – 3700 MHz
- Industry Canada RSS-192 – Radio Standards Specification "Fixed Wireless Access Systems in the Band 3400 – 3700 MHz"

Annex G

(informative)

Bibliography

[B1] CEPT/ERC Recommendation 74-01, “Spurious Emissions.”

[B2] CEPT/ERC Report 099, “Preliminary Report on the analysis of the coexistence of two FWA cells in the 24.5-26.5 GHz and 27.5-29.5 GHz bands.”

[B3] ETSI DEN/TM 04097, “Fixed Radio Systems; Radio equipment for use in Multimedia Wireless Systems (MWS) in the band 40.5 GHz to 43.5 GHz.”

[B4] ETSI EN 301 213, parts 1-3, “Point-to-Multipoint digital radio systems in frequency bands in the range 24,5 GHz to 29,5 GHz using different access methods.”

[B5] ETSI EN 301 215-1, “Point-to-Multipoint Antennas: Antennas for point-to-multipoint fixed radio systems in the 11 GHz to 60 GHz band; Part 1: General aspects.”

[B6] ETSI EN 301 215-2, “Point to Multipoint Antennas: Antennas for point-to-multipoint fixed radio systems in the 11 GHz to 60 GHz band; Part 2: 24 GHz to 30 GHz.”

[B7] ETSI TR101 177 V1.1.1, “Broadband Radio Access Networks (BRAN); Requirements and architectures for broadband fixed radio access networks (HIPERACCESS).”

[B8] ETSI TR101 853 V1.1.1 (2000-10), “Rules for Coexistence of P-P and P-MP systems using different access methods in the same frequency band.”

[B9] IEEE 100, The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition.

[B10] Industry Canada Interim Arrangement Concerning the Sharing between Canada and the United States of America on Broadband Wireless Systems in the Frequency Bands 24.25-24.45 GHz, 25.05-25.25 GHz, and 38.6-40.0 GHz.

[B11] Industry Canada Radio Standards Specifications, RSS-191, “Local Multi Point Communication Systems in the 28 GHz Band; Point-to-Point and Point-to-Multipoint Broadband Communication Systems in the 24 GHz and 38 GHz Bands.”

[B12] Industry Canada Standard Radio Systems Plan (SRSP) 324.25, “Technical Requirements for Fixed Radio Systems Operating in the Bands 24.25 - 24.45 GHz and 25.05-25.25 GHz.”

[B13] Industry Canada Standard Radio Systems Plan (SRSP) 325.35, “Technical Requirements for Local Multipoint Communication Systems (LMCS) Operating in the Band 25.35-28.35 GHz.”

[B14] Industry Canada Standard Radio Systems Plan (SRSP) 338.6, “Technical Requirements for Fixed Radio Systems Operating in the Band 38.6Œ40.0 GHz.”

[B15] ITU-R Recommendation F.746-1, “Radio frequency channel arrangements for fixed services in the range 22.0 GHz to 29.5 GHz.”

[B16] ITU-R Recommendation F.758-2, “Considerations in the development of criteria for sharing between the terrestrial fixed service and other services.”

[B17] ITU-R Recommendation F.1191, “Bandwidths and unwanted emissions of digital radio relay systems.”

[B18] ITU-R Recommendation F.1249-1, “Maximum equivalent isotropically radiated power of transmitting stations in the fixed service operating in the frequency band 25.25Œ27.5 GHz shared with the intersatellite service.”

[B19] ITU-R Recommendation F.1399, “Vocabulary of terms for wireless access.”

[B20] ITU-R Recommendation P.452, “Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz.”

[B21] ITU-R Recommendation P.676-4, “Attenuation by atmospheric gases.”

[B22] ITU-R Recommendation P.838, “Specific attenuation model for rain for use in prediction methods.”

[B23] ITU-R Recommendation P.840-3, “Attenuation due to clouds and fog.”

[B24] ITU-R Recommendation P.1410, “Propagation data and prediction methods required for the design of terrestrial broadband millimetric radio access systems”

[B25] Radio Advisory Board of Canada (RABC) RABC Publication 99-2, “RABC Study Leading to a Coordination Process for Systems in the 24, 28 and 38 GHz Bands.l”

The following documents, while not directly referenced in the text, are related and may be helpful to the reader:

[B26] CEPT Recommendation T/R 13-02, “Preferred channel arrangements for the Fixed Services in the range 22.0-29.5 GHz.”

[B27] ETSI EN 301 215-3, “Characteristics of Multipoint Antennas for use in the Fixed Service in the band 40.5 GHz to 43.5 GHz.”

[B28] IEC Publication 154-2, “Flanges for wave guides, rectangular.”

[B29] ITU-R Recommendation P.526-6, “Propagation by diffraction.”

[B30] ITU-R Recommendation P.530-8, “Propagation data and prediction methods required for the design of terrestrial line-of-sight systems.”

[B31] ITU-R Recommendation P.837-1, “Characteristics of precipitation for propagation modeling.”

[B32] ITU-R Recommendation P.841-1, “Conversion of annual statistics to worst-month statistics.”

[B33] ETSI TM4 Technical Report DEN TR 4120;

[B34] IEEE; Recommended Practice for Coexistence of Fixed Broadband Wireless Systems

[B35] IEEES802.16.2a-02/11; “Simulation on Aggregate Interference from Wireless Access Systems including RLANs into Earth Exploration-Satellite Service in the 5250-5350 MHz Band” (Rebecca Chan, 02/03/08)

[B36] IEEES802.16.2a-02/10; “Canadian Proposals for the WRC-03 on 5GHz RLAN issues” (Rebecca Chan, 02/03/08)

Editorial instruction:
- add new annex H of references to complete simulation analysis, as follows:

Annex H Bibliography of references to complete simulation analysis

This list includes references for all relevant contributions to the simulation work for all parts of the amended recommended practice, including those relating to the document published in September 2001. The source documents may be found in the current 802.16 directory or in the archive.

Simulations and related documents used in the compilation of Part 1

[H1.1] ERC Report; "SE19 Report on the analysis of the coexistence of two FWA cells in the 24.5-29.5GHz bands".

Simulations and related documents used in the compilation of Part 2

[H2.1] IEEEC802.16.2a-01/06: “System parameters for point to point links for use in Coexistence Simulations (revision 1)” (Philip Whitehead, 01/09/13)

[H2.2] IEEEC802.16.2a-02/22; “Interference from a BFWA PMP system to a multi-link PP system (co-channel case; frequency range 2: 23.5 to 43.5 GHz)” (Philip Whitehead, 02/04/24)

[H2.3] IEEEC802.16.2a-02/21; “Interference from a BFWA PMP system to a PP link system (co-channel case; frequency range 2: 23.5 to 43.5 GHz)” (Philip Whitehead, 02/04/24)

[H2.4] IEEEC802.16.2a-02/20; “Interference from a BFWA PMP system to a PP link system (same area, adjacent channel case)” (Philip Whitehead, 02/04/24)

[H2.5] IEEEC802.16.2a-02/19; “Interference from a PP link system to a BFWA PMP system (same area, adjacent channel case)” (Philip Whitehead, 02/04/24)

[H2.6] IEEEC802.16.2a-02/18; “Interference from a BFWA PMP system to a multi-link PP system (co-channel case; frequency range 2: 23.5 to 43.5 GHz)” (Philip Whitehead, 02/04/23)

[H2.7] IEEEC802.16.2a-01/15r1; “Distance Resulting in a -100 dBm Interference Level into a 25 GHz PTP Receiver from a 25 GHz PTMP Transmitter” (Rémi Chayer, 01/09/13)

[H2.8] IEEEC802.16.2a-01/11;Simulation data (point to point links interfering with PMP systems) (Philip Whitehead, 01/10/30)

[H2.9] IEEEC802.16.2a-01/10; “Interference between a PMP system and a multi-link PP system (same area, adjacent channel case)” (Philip Whitehead, 01/10/30)
[H2.10] IEEEC802.16.2a-01/09; “Coexistence between point to point links and PMP systems (revision 1)” (Philip Whitehead, 01/10/30)

[H2.11] IEEEC802.16.2a-01/04; “Simulation data (point to point links interfering with PMP systems)” (Philip Whitehead, 01/09/13)
[H2.12] IEEEC802.16.2a-01/03: “Impact of buildings on Mesh/PP to PMP Co-channel Interference” (Philip Whitehead, 01/09/04)

[H2.13] IEEEC802.16.2a-01/02: “Coexistence between point to point links and PMP systems” (Philip Whitehead, 01/08/30)

[H2.14] IEEE802.16.2-01/14: “Proposed Antenna Radiation Pattern Envelopes for Coexistence Study” (Robert Whiting, 01/07/12)

[H2.15] IEEE802.16c-01/03r1; “Amendments for Coexistence of High Density Fixed Systems (HDFS) Point-to-Multipoint (PMP), Point-to-Point (PTP) and Mesh Systems” (Reza Arefi, Peter A. Soltesz, and Fred Ricci, 01/03/08)

[H2.16] IEEE 802.16.2p-00/13: “Coexistence analysis at 26 GHz and 28 GHz” (This paper contains an explanation of NFD and provides NFD values derived from an ETSI report)

[H2.17] IEEE C802.16-2a-01/03; “Impact of buildings on Mesh/ PP to PMP co-channel interference”; Philip Whitehead

[H2.18] IEEE C802.16-2a-01/04: “Simulation data (point to point links interfering with PMP systems)”; Philip Whitehead

[H2.19] ACTS Project 215, Deliverable Report D3P1B; Cellular Radio Access for Broadband Services (CRABS)

[H2.20] ITU-R P.838; “Specific attenuation model for rain for use in prediction methods”

[H2.21] ITU-R P.452-8; “Prediction procedure for ... microwave interference ...”

[H2.22] ITU-R P.676-3; Atmospheric attenuation

[H2.23] ITU-R P.840-2; Rain attenuation

[H2.24] ETSI EN 301 215-2,V1.1.1; “Antennas for use in PMP systems (24GHz to 30GHz)”

[H2.25] ETSI EN 301 213-3,V1.1.1; “Transmitter characteristics for TDMA PMP systems”

[H2.26] IEEE 802.16.2; “Recommended Practice for Coexistence of Fixed Broadband Wireless Systems”

[H2.27] IEEE 802.16.2-01/14; “Proposed Antenna Radiation Pattern Envelopes for Coexistence Study” by Robert Whiting, 01/07/12

[H2.28] IEEE 802.16.2-01/12; “System parameters for point to point links for use in Coexistence Simulations”; Phil Whitehead, 01/07/12

Simulations and related documents used in the compilation of Part 3

[H3.1] IEEE 802.16c-01/02; Coexistence studies for frequencies below 11GHz and with point to point links; Philip Whitehead

[H3.2] IEEEC802.16.2a-02/23; “Coexistence Same Area C/I Simulation Estimates at 10.5 GHz (CS to CS)” (G. Jack Garrison, 02/04/25)

[H3.3] IEEEC802.16.2a-02/17; “An Addendum to: "A Simplified Method for the Estimation of Rain Attenuation at 10.5 GHz" (G. Jack Garrison, 02/04/15)

[H3.4] IEEEC802.16.2a-02/16; “Coexistence Same Area Simulations at 10.5 GHz (Outbound)” (G. Jack Garrison, 02/04/10)

[H3.5] IEEEC802.16.2a-02/15; “A Simplified Method for the Estimation of Rain Attenuation at 10.5 GHz”(G. Jack Garrison, 02/04/01)

[H3.6] IEEEC802.16.2a-02/14; “Estimates of the Horizon Distance at 3.5 and 10.5 GHz” (G. Jack Garrison, 02/03/28)

[H3.7] IEEEC802.16.2a-02/13; “Outbound Boundary pfd Simulations at 3.5 GHz” (G. Jack Garrison, 02/03/28)

[H3.8] IEEEC802.16.2a-02/12; “CS to CS Boundary pfd Simulations at 3.5 GHz” (G. Jack Garrison, 02/03/28)

[H3.9] IEEEC802.16.2a-02/09; “Coexistence Same Area C/I Simulation Estimates at 3.5 GHz (CS to CS)” (G. Jack Garrison, 02/03/19)

[H3.10] IEEEC802.16.2a-02/08; “Coexistence Same Area Simulations at 3.5 GHz (Inbound)” (G. Jack Garrison, 02/03/16)

[H3.11] IEEEC802.16.2a-02/07; “Coexistence Same Area Simulations at 3.5 GHz (Outbound)” (G. Jack Garrison, 02/03/16)

[H3.12] IEEEC802.16.2a-02/03; “A TS Antenna RPE Sensitivity Analysis for Boundary Coexistence at 10.5 GHz” (G. Jack Garrison, 02/01/02)

[H3.13] IEEEC802.16.2a-02/02r1 [Rev. 0: 01/12/15]; “Coexistence Co-Channel Boundary pfd Simulations at 3.5 GHz (Inbound)” (G. Jack Garrison, 02/03/01)

[H3.14] IEEEC802.16.2a-02/01r1 [Rev. 0: 01/12/02]; “Coexistence Co-Channel Boundary pfd Simulations at 10.5 GHz (Inbound)” (G. Jack Garrison, 02/03/01)

[H3.15] IEEEC802.16.2a-01/14; “Path Loss Calculation Plots for 2.5 GHz Systems” (James C. Cornelius, 02/01/07)

[H3.16] IEEEC802.16.2a-01/13: “Propagation in the frequency range 2-11 GHz” (G. Jack Garrison, 01/11/15)

[H3.17] IEEEC802.16.2a-01/12: “System parameters for 2-11 GHz Coexistence Simulations, Revision 2” (Philip Whitehead, 01/11/15)

[H3.18] IEEEC802.16.2a-01/08; “Methods of Predicting Interference - FCC Appendix D” (David Chauncey, 01/09/13)

[H3.19] IEEEC802.16.2a-01/05; “System parameters for 2-11 GHz Coexistence Simulations (revision 1)” (Philip Whitehead, 01/09/13)

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[H3.21] C802.16.2a-02/34, "CS to CS and CS to TS Boundary pfd Estimates at 10.5 GHz", 02/06/03.

[H3.22] C802.16.2a-02/10, "Coexistence Same Area C/I Simulations at 3.5 GHz (CS to CS)", 02/03/29.

Editorial instruction:

-this section is temporary and is to be deleted from the final document

Document History

Version	Date	Notes
1.0	September 2001	First version of working document (output of session #15)
1.1	January 2002	Includes results from contributions prior to session #17
1.2	January 2002	Includes modifications as a result of contributions and conclusions reached at session # 17
1.3	May 2002	Includes modifications as a result of contributions and conclusions reached at session # 18. This version is intended to the basis for a first formal WG draft, subject to completion and review of all simulations at session #19
1.4	May 2002	Includes revised editing instructions, following agreed actions from session#19
1.5	July 2002	First substantially complete draft, includes several new sections to be reviewed at session #20.
1.5a	July 2002	Temporary version used during editing at session #20
1.5b	July 2002	Temporary version used during editing at session #20
IEEE 802.16.2a-02/10	July 2002	First complete draft

END