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Re:	Amendments to Recommended Practice for Coexistence of Fixed BWA Systems IEEE802.16.2
Abstract	This is a task group 2 working document containing draft material accepted for inclusion in the amended Recommended Practice for Coexistence of Fixed Broadband Wireless Access Systems. It is intended as a placeholder for accepted results and is not a formal WG draft document..
Purpose	Placeholder for accepted contributions and simulation results
Notice	
Release	
Patent Policy and Procedures	

Coexistence Recommended Practice – Working document (version 1.1)

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1. Introduction

This document provides a first working document/ draft outline for the amendment to the Recommended Practice for Coexistence of Fixed Broadband Wireless Access Systems. The amendment covers extensions to the origin content and updates to the existing content. The revised document will then contain three main parts

a. Coexistence of FBWA systems in frequency range 2 (23.5 –43.5 GHz)

b Coexistence of point to point systems with FBWA systems in frequency range 2 (23.5 –43.5 GHz)

c Coexistence of FBWA systems in the frequency range 2-11 GHz

Part a is covered by the IEEE recommended practice IEEE802.16.2 published on September 10, 2001.

An outline and initial draft text for part b is included below (section 2 of this document).

An outline and initial draft text for part c is included below (section 3 of this document)

Proposed draft revisions to the text of the published document (to bring it up to date) are included in section 4

A draft record of archived documents is included in section 5

All text is in early draft form, incomplete and subject to change. The final layout of the amended document is to be determined. Section and paragraph numbering are subject to change.

This document is not a formal draft and is intended only as a working document for the task group to collect provisionally approved material. A formal draft will be prepared in accordance with the timeline.

2. Outline for section on coexistence of point to point links with PMP systems

This section extends the work of IEEE802.16.2 to include interference with point to point links. The frequency range studied is the same as in part a (i.e. 23.5 – 43.5 GHz)

2.1. Overview of section

This section contains guidelines and recommendations for coexistence between PMP systems and point to point link systems, corresponding to two main scenarios. 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.

2.2. Scope statement (summary of what scenarios have been studied – derived from PAR)

[frequency range 2 (23.5-43.5 GHz); single PP links or systems comprising multiple PP links; FBWA system as victim or interferer]

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

2.3.1 Recommendations

[list to be developed – some of those in the published recommended practice may be relevant
e.g. rec. 1, 2, 3, 4, plus modified versions of rec. 5,6,7 and new recommendations concerning antennas, emission masks and EIRP limits]

2.3.2 Guidelines (summary)

Dominant Interference Path (Note 1)	**Scenario**	**Spacing at which interference is below target level (generally 6dB below receiver noise floor)**
PMP BS to PP link station	Adjacent area, same channel	Tba km
PP link station to PMP BS	Adjacent area, same channel	Tba km
PMP BS to PP link station	Same area, adjacent channel	Tba guard channels
PP link station to PMP BS	Same area, adjacent channel	Tba guard channels
PMP BS to multi PP link system	Adjacent area, same channel	Tba km
multi PP link system to PMP BS	Adjacent area, same channel	Tba km
PMP BS to multi PP link system	Same area, adjacent channel	Tba guard channels
multi PP link system to PMP BS	Same area, adjacent channel	Tba guard channels

Notes
1- the dominant interference path is that which requires the highest guideline geographical or frequency spacing
2- the guard channel size assumes that the interferer and victim use the same channel size [what if not?]

2.4. System description (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.

[insert reference diagram]

Fixed BWA systems are described in IEEE802.16.2 section [insert latest ref.]. 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.

2.4.1 Interference scenario 1:multiple point to point links in a frequency block and individually licensed links

In some territories, point- to- point links may share frequency bands with PMP systems. In this scenario, the links are permitted to operate within a frequency block, where 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 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.

2.4.2 Interference scenario 2: individually licensed links

In territories where point- to- point links share frequency bands with PMP 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 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 may be 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.

2.4.3 System parameters assumed in the simulations

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

[insert latest version of the point to point parameters tables]

[the tables could be moved to an appendix in the final document]

Some preliminary characteristics of point to point systems were derived in an output paper from session #14; IEEE 802.16.2-01/12 [3]. These and some variations on them have been used in the simulations, to test the sensitivity of the results to various parameters.

The main characteristics are as follows:

- Frequency = 28 GHz
- Polarisation = Vertical
- APC on, with step size = 4 dB
- Link antenna gain = 40/ 42 dBi
- % of links using same channel = 12.5
- Density of point to point links = 5/ 10 stations per sq km
- Area covered by links = 10 x 5 km
- Link length = 50 — 5000m
- Building density = 750/ sq km
- Fractional Building Area = 0.1
- Building Height Parameter = 0 to 7m

2.4.4 Typical antenna characteristics

Research into typical antennas for links operating around 25GHz and around 38GHz was used to compile a set of "composite" antenna characteristics. Whilst these are not intended as a basis for antenna design, they are considered to be adequate to meet reasonable interference objectives and at the same time 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 adopted as the starting point for interference simulations.

2.5. Description of Interference Scenarios

This section describes each of the interference scenarios identified that include point to point links as one system and a BFWA system as the other. For each scenario, a methodology for calculating interference levels is described and a guideline geographical or frequency spacing is derived.

The scenarios are summarized in table XX

	Scenario	PP system type	Area/ channel	Methodology
1	PMP BS to PP	Single link	Adjacent area, same channel	Worst case analysis
2	PMP SS to PP	Single link	Adjacent area, same channel	Worst case analysis
3	PP to PMP BS	Single link	Adjacent area, same channel	Worst case analysis
4	PP to PMP SS	Single link	Adjacent area, same channel	Worst case analysis
5	PMP BS to PP	Single link	Same area, adjacent channel	Worst case analysis
6	PMP SS to PP	Single link	Same area, adjacent channel	Worst case analysis
7	PP to PMP BS	Single link	Same area, adjacent channel	Worst case analysis
8	PP to PMP SS	Single link	Same area, adjacent channel	Worst case analysis
9	PMP BS to PP	Multi - link	Adjacent area, same channel	Worst case analysis
10	PMP SS to PP	Multi - link	Adjacent area, same channel	?
11	PP to PMP BS	Multi - link	Adjacent area, same channel	Monte Carlo simulation
12	PP to PMP SS	Multi - link	Adjacent area, same channel	Monte Carlo simulation
13	PMP BS to PP	Multi - link	Same area, adjacent channel	Worst case analysis
14	PMP SS to PP	Multi - link	Same area, adjacent channel	Worst case analysis
15	PP to PMP BS	Multi - link	Same area, adjacent channel	Monte Carlo simulation
16	PP to PMP SS	Multi - link	Same area, adjacent channel	Monte Carlo simulation

Notes

1 – a multi- link PP system means one in which a significant number of PP links are deployed by the operator in a block assignment, so that the interference created varies as the system evolves.

2.5.1Methodology for scenarios 11 and 12

Note: This is a complete description of the simulation work. For the final document, a précis should suffice, plus a reference to the complete (archived) source contribution.

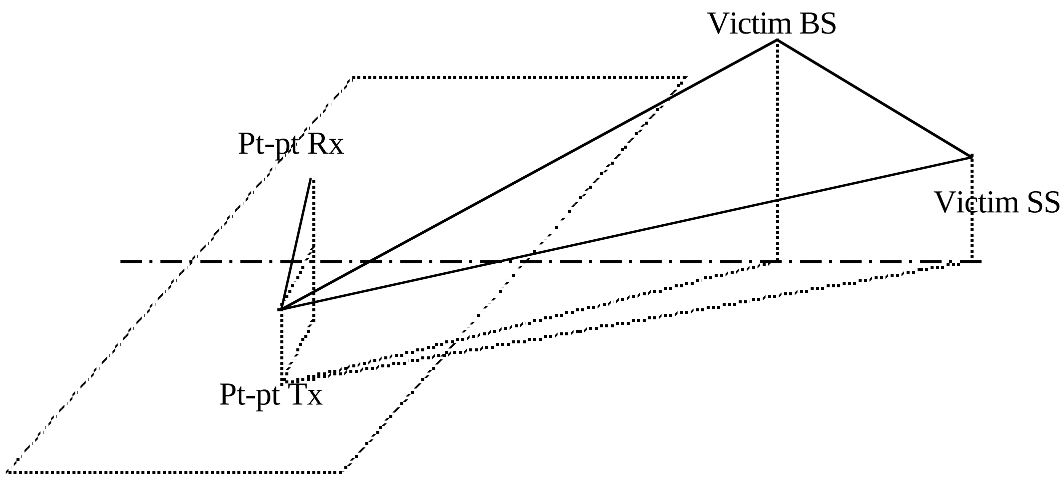
The point- to- point links are modeled using a simulation tool, adapted from a previously used model for interference between mesh systems and PMP systems. The density of point- to- point links can be varied, as can the antenna beam pattern. The model uses a variant of an ETSI specified antenna pattern and an antenna pattern conforming to the recommendations of paper IEEE 802.16.2-01/14 [2] (the IEEE "composite" antenna patterns). The difference in results is not significant, since most interference in this scenario is from the antenna main beam (s).

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 simulation program was described in [1] It can be applied to any frequency up to at least 43.5GHz (i.e. at least the whole of frequency range 2 of the IEEE coexistence recommended practice [4]).

System Modeling

A model has been created for a P-MP sector and for a corresponding system of multiple point to point links, using antenna patterns appropriate to each type of system, a model for wanted path length distribution and a propagation model. The geometry is shown in Fig.1.

Fig.1 Interference Geometry



The main attributes of the model are:

- Monte-Carlo simulation with realistic point- to- point system parameters.
- Line-of-sight propagation probabilities calculated from Rayleigh roof height distribution function as per CRABS report D3P1B [5]
- Interfering power summed at PMP base or subscriber using full 3D geometry to compute distances and angles between lines of sight and antenna bore-sights.
- Effect of Automatic Power Control granularity (ATPC) included.
- PMP BS RPE for 24-28GHz band to EN 301 215-2 V1.1.1 [8] with elevation profile ignored for realistic worst case.
- Point to point antenna RPE model as per composite 1ft antenna (25 GHz) in [3].
- Atmospheric attenuation to ITU-R P.676-3 [6]
- Rain attenuation to ITU-R P.840-2 [7].
- Dry and rain storm weather patterns considered.

Rain Fading

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

Point to Point System Characteristics

Some preliminary characteristics of point to point systems were derived in an output paper from session #14; IEEE 802.16.2-01/12, subsequently revised in [2]. These and some variations on them have been used in the simulations, to test the sensitivity of the results to various parameters.

The main characteristics are as follows:

- Frequency = 25 GHz
- Polarisation = Vertical
- APC on, with step size = 4 dB
- Link antenna gain = 40/ 42 dBi
- Link antenna RPE= composite 1ft antenna RPE from [3]
- % of links using same channel = 12.5
- Density of point to point links = 5/ 10 stations per sq km
- Area covered by links = 10 x 5 km
- Link length = 50 — 5000m
- Building density = 750/ sq km
- Fractional Building Area = 0.1
- Building Height Parameter = 0 to 7m

Propagation

Only line of sight paths for wanted signals and interference are considered, using line of sight probabilities and free-space propagation.

The probability of interference line of sight is calculated from a model in which building heights are assumed to have a Rayleigh distribution, as in [5], although the probability calculations follow a slightly different method.

Antenna Beam Profiles

The current modeling for the 24-28GHz band (nominal frequency of 25 GHz in the simulations) is based on an antenna with half power beam-width of 4.3° in both azimuth and elevation. The antenna RPE is as shown in figure 2. This was derived in [3], from a series of commercially available antennas and is considered to be a useful basis for planning purposes (and possibly for recommending minimum antenna performance requirements.)

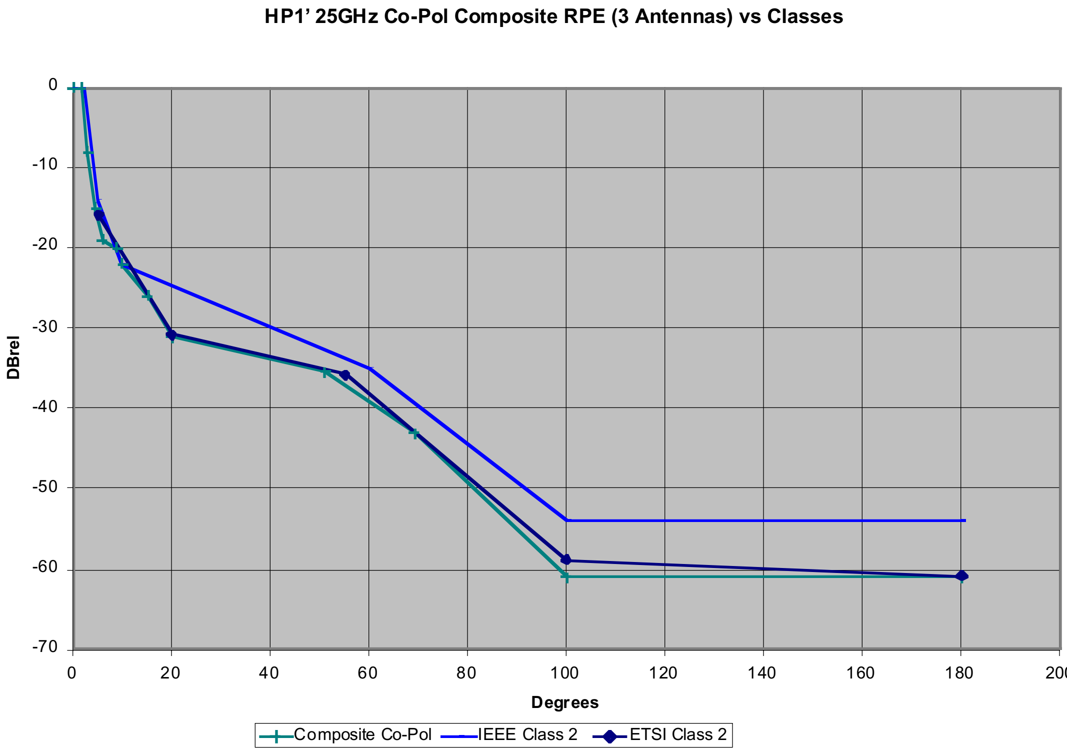


Fig. 2 Antenna RPE for Interfering Point to Point Links

The basic arrangement of the model is shown in fig. 1. Given a point to point station density and the percentage of stations that can transmit simultaneously on a given channel, the simulator places the appropriate number of transmitters randomly within the prescribed system area at heights following the Rayleigh distribution.

For each transmitter, it then randomly places a receiver within the limits of link length and at an arbitrary angle. [Conditions near the edge of the system are satisfied by repeating any receiver placements that fall to the right of the system boundary].

The effects of buildings are modeled by their density and fractional area, and terrain (the result of both building and land height variation) is modeled with a Rayleigh distribution.

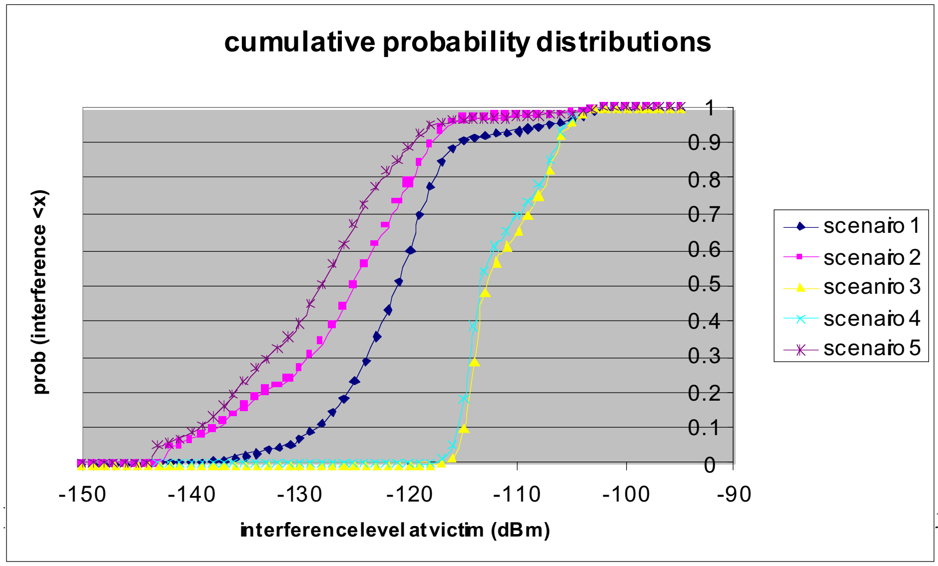
The BS receiver antenna is assumed to be a 90° sector aimed directly at the centre of the interfering system, with a gain which is flat to ±50°, falling off thereafter at 1dB every 4.5°.

Interfering Power Calculation

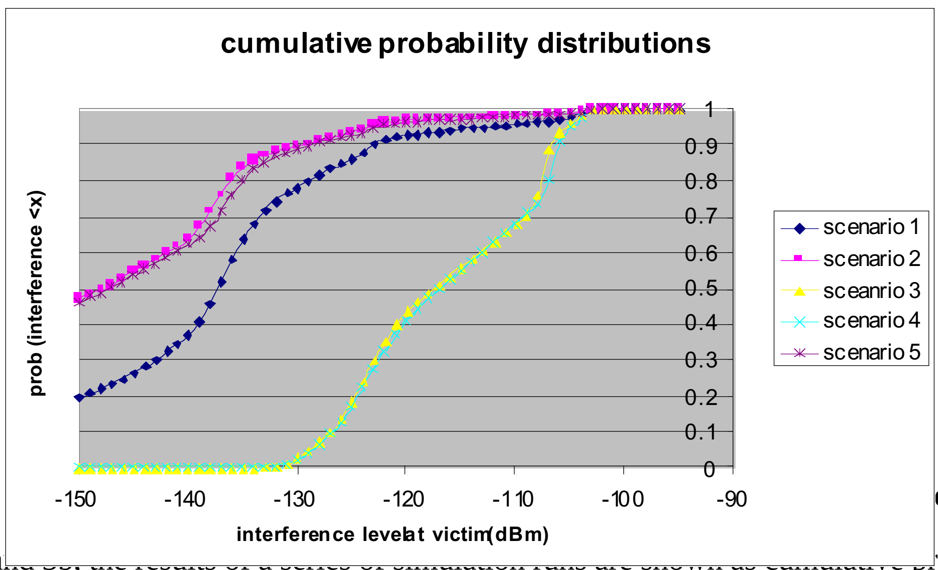
From each link transmitter and, taking account of the line of sight probability, the power received by the base station or subscriber station is computed. All these powers are summed, and the result rounded to the nearest dBm and assigned to a histogram bin, so that the relative probability of each power level can be estimated and cumulative probability distributions can be derived.

Simulation Results

Victim=PMP BS



us results)



esults)

In figures 3a a… probability distributions. Figure 3a shows the previous results from [1] and fig 3b shows the results using the new antenna composite RPE. 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 BS receiver 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.

Even when there are a few cases above the –100dBm level, the situation may still be acceptable, since the probability of interference above the threshold level is very low and simple interference mitigation procedures may be available to mitigate these rare cases.

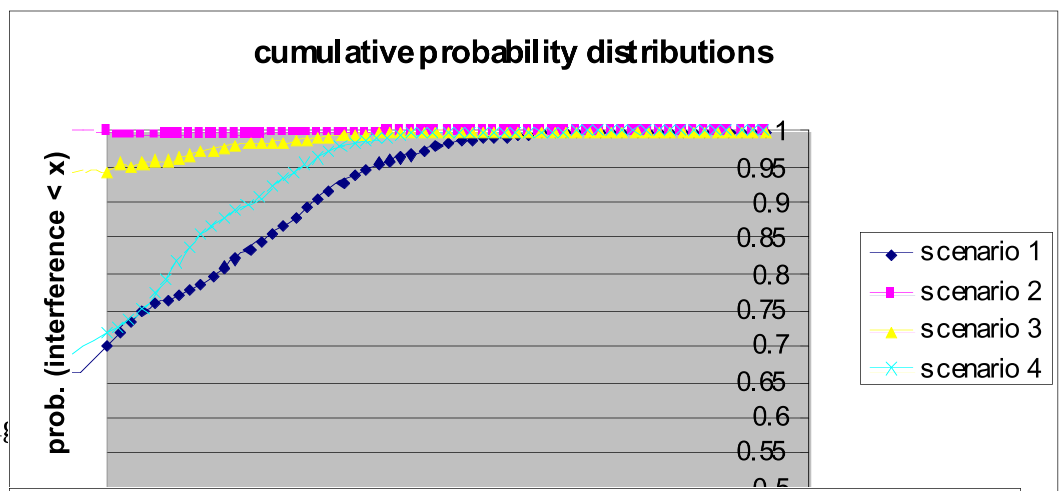
Scenario	Building height parameter	Height of interferer above roof level	Links/sq km	Antenna gain dBi	Rain scenario	Distance to BS	% cases where threshold exceeded
1	7m	3m	10	40	None	20km (previously 18km)	0
2	7m	1m	10	42	None	24km (previously 20km)	0
3	0m	4m	10	42	None	32km	0
4	0m	4m	10	42	Storm	30km	0
5	7m	3m	5	42	None	22km (previously 20km)	0

Table 1: Summary of BS Interference Scenarios using new antenna RPE

As can be seen from table 1, the previous conclusion that a system spacing of 18-20km is generally sufficient to eliminate all possibility of interference is now insufficient. The spacing should be increased to 20 –24km. The two scenarios where this spacing is insufficient have been included to show what happens when terrain and building obstructions are removed from the simulations. They are unrealistic of real deployment using moderate densities of point to point links, since such systems by their nature require buildings on which to place the equipment.

One example of the effects of rain- storm fading has also been included. As can be seen, the effects are negligible. Although not included here, there are many more results from the simulation that indicate a very low sensitivity of the results to rain fading.

Victim=PMP SS



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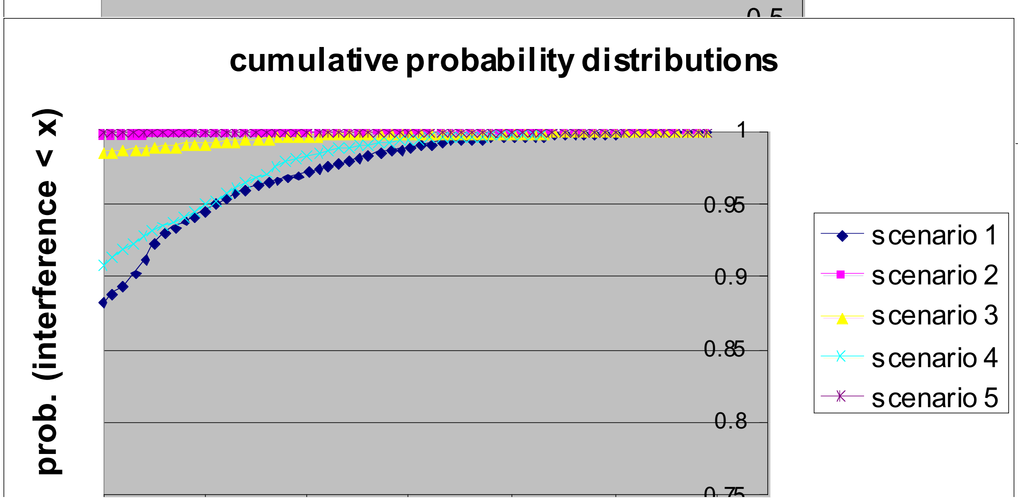


Fig 4b Cumulative Probability Distributions for SS Interference (new results)

In figures 4a and 4b, the results of are shown for the SS victim scenarios. As in fig.3 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 base station receiver will be less than a given value on the x axis.

The same interference limit value of –100dBm (equivalent to –114.5 dBm/ MHz) is used as in the BS case.

Scenario	**Building height parameter**	**Antenna Height above roof (interferers)**	**Links/sq km**	**Antenna gain**	**Victim antenn a height**	**Rain scenari o**	**Distance to SS**	**% threshol d exceeded**
1	7m	3m	5	40	20	None	15km	.05
2	7m	3m	5	40	15	None	15km (previously 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 2: Summary of SS Interference Scenarios using new 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.

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

- The conclusions are only slightly different from those in the previous analysis. The antenna RPE does have some impact but it is not a critical factor

- Rain fading is not significant in determining the required geographical spacing

Visual Basic sub – routine for IEEE Composite Antenna RPE

```
REM creates subscriber RPE as per IEEE 25 GHz composite 1ft antenna
REM creates sinsubs lookup table for first 90 degrees
REM and cossubs lookup table for next 90 degrees
REM tables are power relative to main beam
```

```
REM in this case sinref is the same as sinsubs (node antenna RPE same as PMP SS)
REM next line is 1170
step=0.001
temp1=180 / pi
For i=0 To 1000
If i < 1000 Then
v=step * i
Rem asin function not available:
temp = Atn(v / Sqr(1 - v * v)) * temp1
Else
temp = 90
End If
Rem sinsubs entry
If temp <1.5 Then
sinsubs(i) = 1
sinref(i) = sinsubs(i)
ElseIf temp < 3 Then
sinsubs(i) = 10 ^ (-8/1.5 * (temp – 1.5) / 10)
sinref(i) = sinsubs (i)
ElseIf temp < 4.5 Then
sinsubs(i) = 10 ^ ((-8 - 7/1.5 * (temp - 3)) / 10)
sinref(i) = sinsubs(i)
ElseIf temp<5.8 Then
sinsubs(i)=10-^((-15-4/1.3*(temp-4.5))/10)
sinref(i)=sinsubs(i)
ElseIf temp<9 Then
sinsubs(i)=10^((-19-1/3.1*(temp-5.8))/10)
sinref(i)=sinsubs(i)
ElseIf temp<10 Then
sinsubs(i)=10^((-20-2/1*(temp-9))/10)
sinref(i)=sinsubs(i)
Elseif temp<15 Then
sinsubs(i)=10^((-22-4/5*(temp-10))/10)
sinref(i)=sinsubs(i)
ElseIf temp<20 Then
sinsubs(i)=10^((-26-5/5*(temp-15))/10)
sinref(i)=sinsubs(i)
ElseIf temp<51 Then
sinsubs(i)=10^((-31-4.5/31*(temp-20))/10)
sinref(i)=sinsubs(i)
Elseif temp<69 Then
sinsubs(i)=10^((-35.5-7.5/18*(temp-51))/10)
sinref(i)=sinsubs(i)
Else
sinsubs(i)=10^((-43-12.2/21*(temp-69))/10)
sinref(i)=sinsubs(i)
EndIf
REM cossubs table starts here
Temp=temp+90
If temp<100 Then
cossubs(i)=10^((-55.2-5.8/10*(temp-90))/10)
Else cossubs(i)=10^(-61/10)
EndIf
Next I
```

2.5.2 Methodolgy for scenarios 13 - 16

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.

PP to PMP interference

The PP system is modeled as a randomly organized collection of links, with characteristics as defined in paper IEEE C802.16.2a-01/06 [2]. Because there are significant numbers of links and an assumed random layout, a Monte Carlo simulation is appropriate. To reduce the task of developing a new simulation tool, an available routine for mesh to PMP interference has been used and the results extrapolated. The rationale for this is described in (4.1) below. The main differences in the computation are as follows:

- Much lower density of PP links
- Significantly higher gain antennas
- Longer link paths

Simulation Tool

The simulation tool uses a routine similar to that described in IEEE C802.16.2a-01/03 [4].but modified to deal with interference to a BS or SS operating in the same area and on an adjacent/ near adjacent channel. 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, with the specified link density (in this case 5 per sq km) and with link lengths evenly distributed over a specified range of distances. A value of NFD (net filter discrimination) is assigned, taken from ETSI tables (see table 1, below), according to whether required the guard band is a single guard channel or more than one channel.

Typically, 10,000 simulation trials are carried out for each scenario. 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, the value at which the total interference is 6dB below the receiver noise floor, corresponding to the point where receiver sensitivity is degraded by 1dB. This level is used generally in the published IEEE Recommended Practice [5]. The guard band between the interfering and victim systems is varied until every trial (or nearly every trial) gives interference level below the required threshold.

Results for PP to PMP interference

Interference to PMP BS

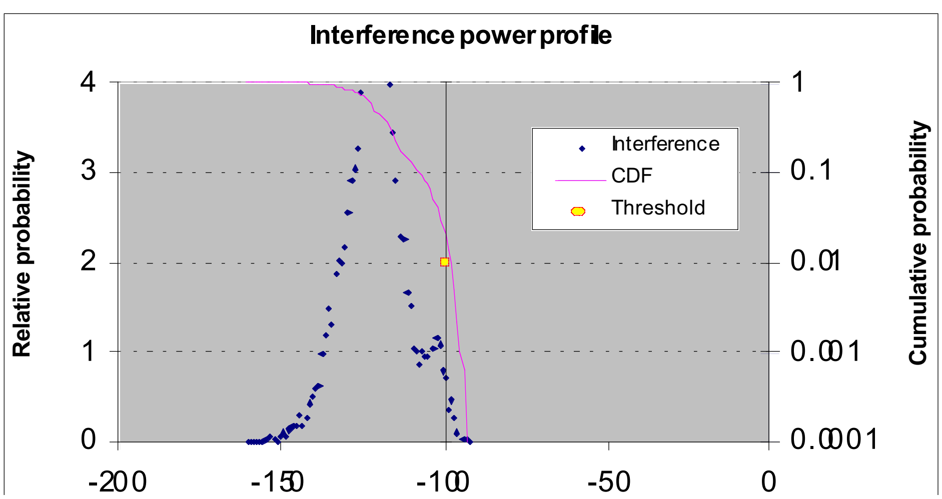


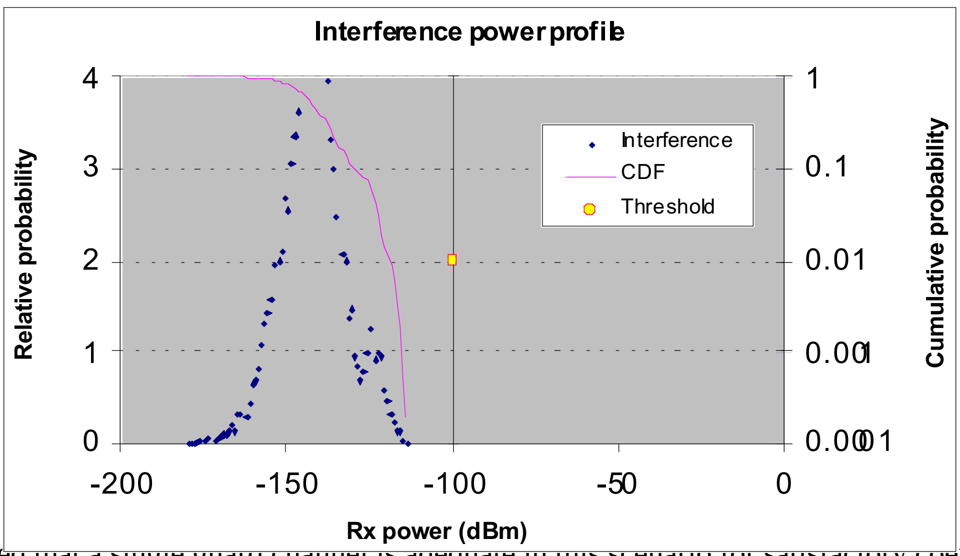
Figure 1: Interference from PP system to PMP BS
(adjacent channel)

The simulation tool was run using the appropriate lower density of PP links (5/ sq km) but with lower gain antennas than those required for the specified PP system. In order to avoid significant reprogramming of the complex simulation tool, the validity of the results using available parameters has been considered, as follows:

The simulation tool sets link lengths randomly between the minimum value (in this case 50m) and a maximum value of 1000m. Since a maximum value of 5000m is required to correspond with the recommendations in [2] the coverage area is set to 5000 x 5000m. However, the tool does not readily permit a change to the antenna RPE or gain value, which is set at 25dBi. The required system uses a 40 dBi antenna gain. In practice, this will have a small effect, since the maximum (unfaded) transmit power alters by +30 -14 dB = 16dB, so that the transmit eirp for the longest link will change by –16 + 15 dB = -1 dB, which is negligible.

Thus, the existing simulation can be used to provide an estimate of the required guard band, without significant reprogramming.
Figure 1 shows the results for the case where the PP system interferes with the PMP BS. There is no guard channel in this case the PMP system is operating in the adjacent channel). It can be seen that a small but significant number of results (a few %) exceed the –100dBm target level.

When a single guard channel of 28 MHz is introduced, using an NFD value from ETSI tables, the interference is reduced to a fully acceptable level. This is shown in figure 2 (below).



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. The analysis of these is provided below.

Interference to PMP SS

Figure 3 is 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.

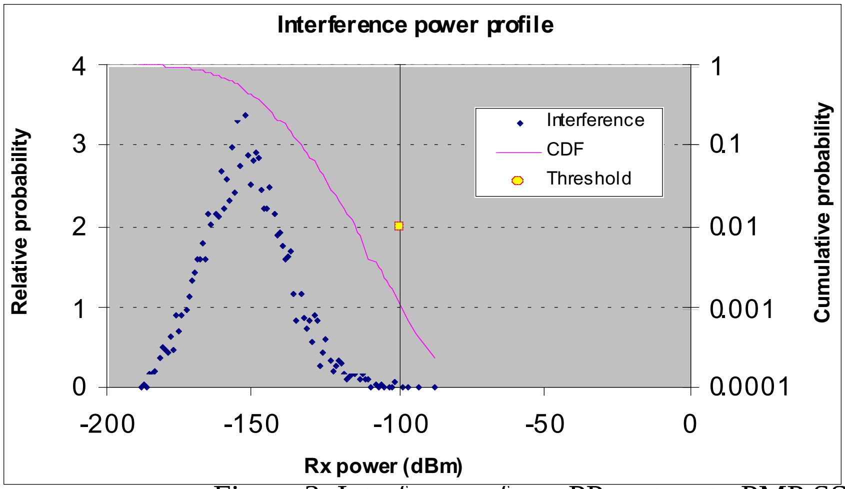


Figure 3: Interference from PP system to PMP SS
(1 guard channel)

Although a 2 channel guard- band eliminates all cases of interference, the level with one guard channel is a acceptably low. The case of interference with SS is more adverse than the BS case and so will normally dominate in the choice of guard band.

There remains a small but finite possibility of exceeding the target interference level. In the absence of automated interference mitigation, some occasional requirement for coordination must therefore be accepted.

PMP to PP interference

The analysis of this scenario is different from the reciprocal case, which needs a Monte Carlo simulation. In the case of the, 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. In the case of a typical PMP BS, the antenna beam-width and height above surrounding terrain are such that terrain losses (over and above free space) can not be relied on, so that all paths for the worst case analysis should be assumed to be clear, line of sight.

The interference model is shown in fig 4

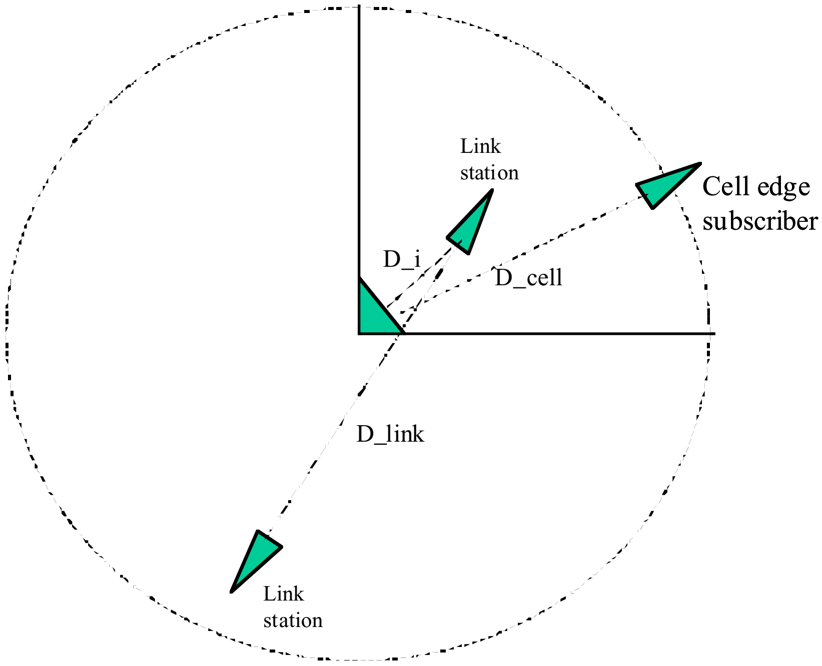


Fig. 4 Interference geometry (PMP BS to PP link)

The PMP cell is shown as a circle. A nominal cell radius of 5km is assumed. The victim station is one end of a link, whose path length is D_link. The distance from the hub to the victim link station is D_i. 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 1: Parameters for PMP to PP interference scenarios

Note 1: NFD (net filter discrimination) is a measure of the additional isolation between a transmitter and receiver that are on near-adjacent channels, compared with the on – channel case. There is little available data from actual systems and no standardised method of measurement (In the UK, there is a proposal from the RA to study this topic). Data in the table above is taken from [1]

Note 2: The range of values proposed in [3] is 40 - 42dB.

Results

The results of the analysis are summarised in tables 2 and 3.

Interference from hub (BS) to link Rx	value	int path, 50m	100m	200m	500m	1km	2km	3km	5km
Frequency GHz	25								
Tx power, max, dBm	26								
wanted path length km	5		5						
path loss dB	-123-20log d	-137	-137						
interference path length, km		0.05	0.1	0.2	0.5	1	2	3	4
interfernce path loss dB		-97	-103	-109	-117	-123	-129	-132.5	-135
Link antenna gain dBi	40								
BS antenna gain dBi	19								
SS antenna gain dBi	36								
wanted Rx input, 16 QAM, dBm	-73								
BS Tx power, no fade, dBm		9	9	9	9	9	9	9	9
Interference power no fade, dBm		-29	-35	-41	-49	-55	-61	-64.5	-67
less NFD for 1 ch, dB	49	-78	-84	-90	-98	-104	-110	-113.5	-116
less off axis RPE factor, dB at 3 deg	-8	-86	-92	-98	-106	-112	-118	-121.5	-124
less off axis RPE factor, dB at 5.8 deg.	-19	-97	-103	-109	-117	-123	-129	-132.5	-135
less off axis RPE factor, dB at 10 deg.	-22	-100	-106	-112	-120	-126	-132	-135.5	-138
less NFD for 2 ch, dB	70	-99	-105	-111	-119	-125	-131	-134.5	-137
less off axis RPE factor, dB at 3 deg	-8	-107	-113	-119	-127	-133	-139	-142.5	-145
less off axis RPE factor, dB at 5.8 deg.	-19								
less off axis RPE factor, dB at 10 deg.	-22								

Table 2 BS to PP link Interference

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.

Interference from sub (SS) to link Rx	value	int path, 50m	100m	200m	500m	1km	2km	3km	5km
Frequency GHz	25								
Tx power, max, dBm	26								
wanted path length km (SS at cell edge)	5		5						
path loss dB	-123-20log d	-137	-137						
interference path length, km		0.05	0.1	0.2	0.5	1	2	3	4
interfernce path loss dB		-97	-103	-109	-117	-123	-129	-132.5	-135
Link antenna gain dBi	40								
BS antenna gain dBi	19								
SS antenna gain dBi	36								
wanted Rx input, 16 QAM, dBm	-73								
SS Tx power, no fade, dBm		9	9	9	9	9	9	9	9
Interference power no fade, dBm		-13	-19	-25	-33	-39	-45	-48.5	-51
less NFD for 1 ch, dB	49	-62	-68	-74	-82	-88	-94	-97.5	-100
less off axis RPE factor, dB at 3 deg	-8	-70	-76	-82	-90	-96	-102	-105.5	-108
less off axis RPE factor, dB at 5.8 deg.	-19	-81	-87	-93	-101	-107	-113	-116.5	-119
less off axis RPE factor, dB at 10 deg.	-22	-84	-90	-96	-104	-110	-116	-119.5	-122
less NFD for 2 ch, dB	70	-83	-89	-95	-103	-109	-115	-118.5	-121
less off axis RPE factor, dB at 3 deg	-8	-91	-97	-103	-111	-117	-123	-126.5	-129
less off axis RPE factor, dB at 5.8 deg.	-19	-102	-108	-114	-122	-128	-134	-137.5	-140
less off axis RPE factor, dB at 10 deg.	-22	-105	-111	-117	-125	-131	-137	-140.5	-143

Table 3: SS to PP link Interference

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.

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 However, unlike mesh systems, this kind of point- to- point system has no automated mitigation techniques and significantly higher antenna gains. Thus, the two- channel guard band is a suitable general guideline.

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 few cases of unacceptable interference must be dealt with as they arise, by appropriate coordination between operators.

2.6. Mitigation techniques

2.6.1 Impact of buildings on Mesh to PMP co-channel interference

Mesh systems make use of terrain and buildings, combined with use of low transmit power and relatively short links, 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.

In this paper, the impact of buildings on coexistence of a mesh system is calculated, using a simulation tool. The simulator computes the cumulative interference from a mesh system into a victim receiver, which may be a PMP base station, PMP terminal station or a mesh node station. For the purposes of this document, only the most severe case (the PMP base station) is examined.

Since a mesh system is designed specifically to make use of buildings for reduction of interference, the model includes additional path losses due to buildings, using a methodology adapted from that used in the RAL CRABS report [4].

The impact of buildings is varied in the model by means of a parameter describing the distribution of building heights (Rayleigh parameter).

Simulation Methodology

The simulator computes the power received from a complete MP- MP system (mesh) at a PMP base station receiver, a PMP subscriber station receiver or other victim receiver, in a cell adjacent to the mesh. The simulation is performed using a purpose-written program, which repeatedly constructs random (but adequately legitimate) MP-MP (mesh) systems and integrates the total power received at a given range and elevation, based on system, beam and terrain geometries.

A description of the simulation tool is provided in [] and will therefore not be repeated here.

The main analysis and all the results presented are based on systems operating in the 24- 28GHz band, but can be applied to any frequency up to at least 43.5GHz.

Interfering Power Calculation

From each mesh transmitter and in line with the line of sight probability, the power received by the victim base 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.

Simulation Results

In order to assess the impact of different building heights, the parameters in the simulation tool were set as follows:

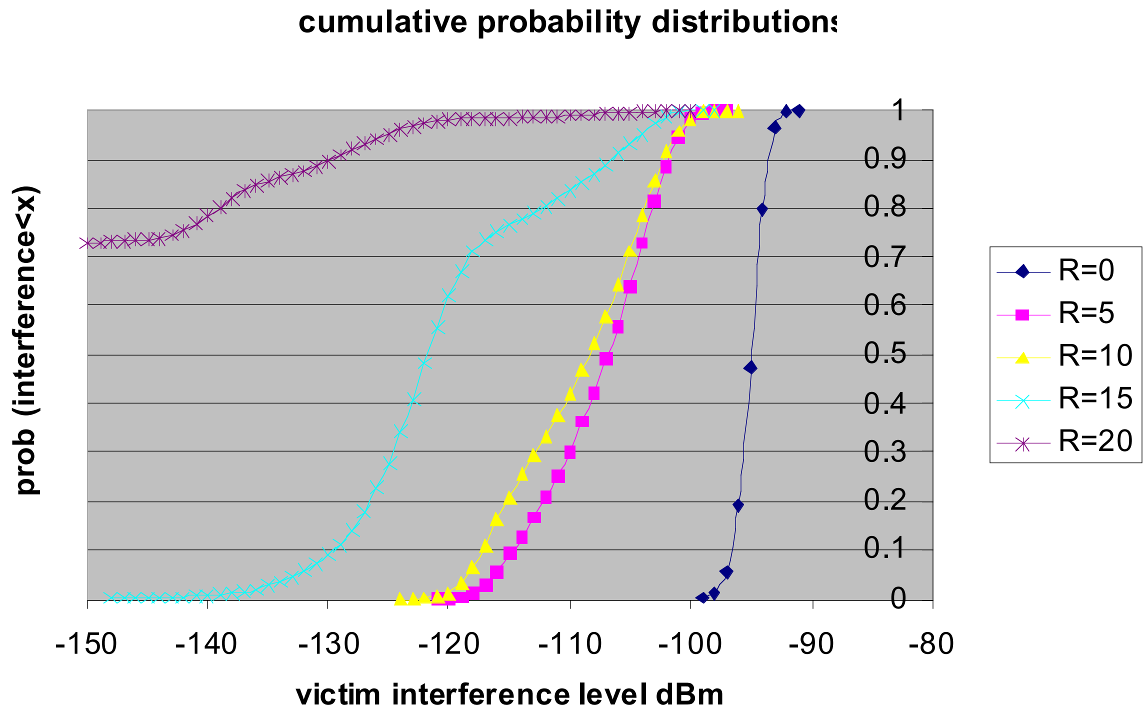
Frequency = 28 GHz
victim receiver = bases station with 90 degree sector antenna and 19dBi gain
distance from mesh edge to base station = 12km (any value can be set)
mesh link lengths from 50m to 1000m
mesh nodes placed 1m above roof height in all cases
mesh antenna gain = 25dBi
Rayleigh parameter (building 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.

Each simulation run was based on 10,000 trials, in which each trial represented a separate random mesh with 100 nodes per sq km. A cumulative distribution curve was produced for each run, showing the probability that the total interference received at the victim station was less than a particular value (x axis of the graph)

The results are shown in figure [x] .

Figure x



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 meshes 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.

Conclusions

Buildings have a significant and extremely useful effect on interference from a mesh system, 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, because mesh nodes are placed at or near building height rather than on tall masts.

Even with no buildings, the co-channel spacing is similar to or less than that recommended for PMP systems in SE19 report [3].

2.7. Work of other bodies

[The following sources are believed to have relevant material that could be included (with appropriate permission) in the recommended practice. ETSI has produced at least one technical report on coexistence between fixed links and FBWA systems. The RA is working on similar topics.]

2.7.1 ETSI TM4 work on point to point link interference
2.7.2 UK RA work on point toot point link interference

2.8. References to complete simulation analysis

3. Outline for section on coexistence of 2-11 GHz systems

3.1. Overview 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, three sets of results have been derived, covering operating frequencies around 2.5 GHz, 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 statement (summary of what scenarios have been studied – derived from PAR)

[frequency range 2-11 GHz; licensed bands only]

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

3.4. System description (interferer and victim systems)

3.4.1 Description of system interference scenarios

(e.g. line of sight systems, lower frequency systems operating with path obstructions, external systems such as satellites)

3.4.2 System parameters assumed in the simulations

The system parameters assumed in the simulations are based on the data in document

3.4.3 Typical antenna characteristics

3.5. Description of simulations – 2.5 GHz

[simulation results not yet available]

3.5.1 Methodology

3.5.2 Outline results from each simulation

3.6. Description of simulations – 3.5 GHz

[simulation work is currently being undertaken – see contributions from GJG]

3.61 Methodology

3.6.2 Outline results from each simulation

3.7. Description of simulations – 10.5 GHz

[simulation work is currently being undertaken – see contributions from GJG]

3.71 Methodology

3.7.2 Outline results from each simulation

3.6. Mitigation techniques

3.8. Work of other bodies

3.9. 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. [add refs.]

[1] IEEE 802.16c-01/02; Coexistence studies for frequencies below 11GHz and with point to point links; Philip Whitehead
[2] IEEE C802.16-2a-01/03;Impact of buildings on Mesh/ PP to PMP co-channel interference; Philip Whitehead
[3] IEEE C802.16-2a-01/04: Simulation data (point to point links interfering with PMP systems); Philip Whitehead

4. Updating the existing Recommended Practice

4.1 Introduction (refer to new sections)

4.2 Participants (new list)

4.3 Acknowledgements (update)

4.4 Contents (update)

4.5 References (update)

[new references added as follows / check for duplication]

[1] ETSI TM4 Technical Report DEN TR 4120;
[2] IEEE; Recommended Practice for Coexistence of Fixed Broadband Wireless Systems
[3] ERC Report; “SE19 Report on the analysis of the coexistence of two FWA cells in the 24.5-29.5GHz bands”.
[4] ACTS Project 215, Deliverable Report D3P1B; Cellular Radio Access for Broadband Services (CRABS)
[5] ITU-R P.838; “Specific attenuation model for rain for use in prediction methods”
[6] ITU-R P.452-8; “Prediction procedure for ... microwave interference ...”
[7] ITU-R P.676-3; Atmospheric attenuation
[8] ITU-R P.840-2; Rain attenuation
[9] ETSI EN 301 215-2,V1.1.1; Antennas for use in PMP systems (24GHz to 30GHz)
[10] ETSI EN 301 213-3,V1.1.1; “Transmitter characteristics for TDMA PMP systems”
[11] IEEE 802.16.2; “Recommended Practice for Coexistence of Fixed Broadband Wireless Systems”
[12] IEEE 802.16.2-01/14; “Proposed Antenna Radiation Pattern Envelopes for Coexistence Study” by Robert Whiting, 01/07/12

[13] IEEE 802.16.2-01/12; “System parameters for point to point links for use in Coexistence Simulations”; Phil Whitehead, 01/07/12

[14] IEEE 802.16.2-01/xx, System parameters for .2-11GHz systems ..

check the following for repeats

[1] 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)
[2] IEEE C802.16.2a-01/06; “System parameters for point to point links for use in Coexistence Simulations (revision 1)”
[3] IEEE 802.16.2-01/14; “Proposed Antenna Radiation Pattern Envelopes for Coexistence Study”.
[4] IEEE C802.16.2a-01/02; “Coexistence between point to point links and PMP systems.”
[5] IEEE 802.16.2-2001; “Recommended Practice for coexistence of Fixed Broadband Wireless Access Systems.”

4.6 Definitions, Acronyms and Abbreviations (update)

4.7 Out of block emission limits (review values of Bo and consequent emission limits)

4.8 Simulation descriptions (add references to complete archived descriptions and results)

5 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