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| Re: | Amendments to Recommended Practice for Coexistence of Fixed BWA Systems IEEE802.16.2 |
| Abstract | This is a task group 2a 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 – outline of amended document.

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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 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

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

2.1. Overview of section
2.2. Scope statement (summary of what scenarios have been studied – derived from PAR)
2.3. Recommendations and Guidelines, including indicative geographical and physical spacing between system.

[Insert table for scenario XXX]

2.4. System description (interferer and victim systems)

2.4.1 Describe 2 interference scenarios (multiple point to point links in a frequency block and individually licensed links)

Point to point links scenario 1

In some territories, point- to- point links may share frequency bands with PMP systems. The links may be individually licensed or may be permitted to operate within a frequency block, where the operator assigns specific frequencies. In the first scenario, the national regulator assigns the link frequencies, determines the antenna characteristics and manages coexistence issues.

Point to point links scenario 2

[PW to add text]

2.4.2 System parameters assumed in the simulations XXX

### 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 [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

2.4.3 Typical antenna characteristics

2.5. Description of simulations

2.5.1 Methodology for scenario 1

2.5.1 Methodology for scenario 2

…

…

2.5.N Methodology for scenario XXX

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 currently uses a variant of an ETSI specified antenna pattern, but this will be altered in a future version to fit the recommendations of paper IEEE 802.16.2-01/14 [2]. The difference in results is not expected to be significant, since most interference in this scenario is likely to be from the antenna main beam (s).

Simulation methodology

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 is performed using a purpose-written program, which repeatedly constructs random (but adequately legitimate) point- to- point systems and integrates the total power received at a given range and elevation, based on system, beam and terrain geometries. 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 (i.e. frequency range 2 of the coexistence recommended practice [1]).

## 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.x

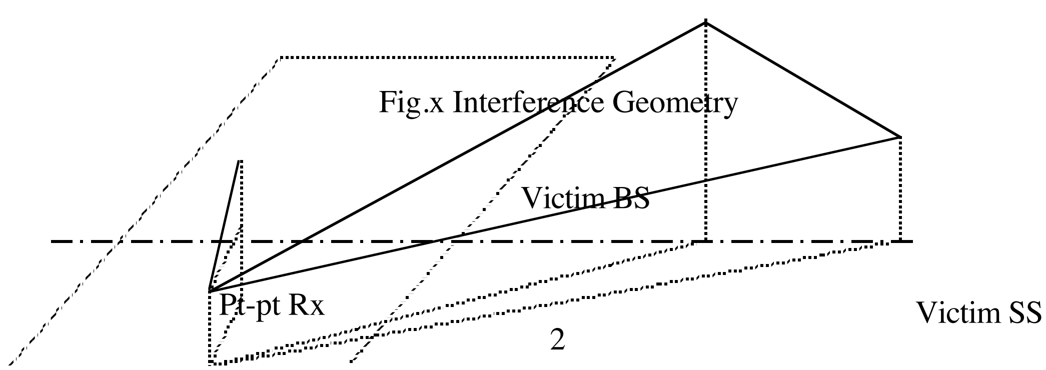



Fig.x Interference Geometry

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 [4]
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.

Pt-pt Tx

Effect of Automatic Power Control granularity (ATPC) included.
PMP RPE's for 24-28GHz band to EN 301 215-2 V1.1.1 [7] with BS elevation profile ignored for realistic worst case.
Point to point antenna RPE model for 24-28GHz band simulates an illuminated aperture with side-lobes to EN 301 215 V1.1.1 [7].
Atmospheric attenuation to ITU-R P.676-3 [5]
Rain attenuation to ITU-R P.840-2 [6].
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

## 2.4 Propagation

This document considers only line of sight paths for wanted signals and interference, 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 [4], although the probability calculations follow a slightly different method.

## 2.5 Antenna Beam Profiles

The current modeling for the 24-28GHz band is based on an antenna with half power beam-width of 4° in both azimuth and elevation. A simplified model of the antenna pattern has been used. Although a real antenna will perform better than this model, it turns out not to be critical from a coexistence point of view or from an intra system interference point of view. For the 24- 28GHz band, the simplified model is based on a formula to represent the main beam and a side lobe pattern conforming to ETSI EN 301 215 part 2 (TS1 antenna) [7]. This is shown in the following figure:

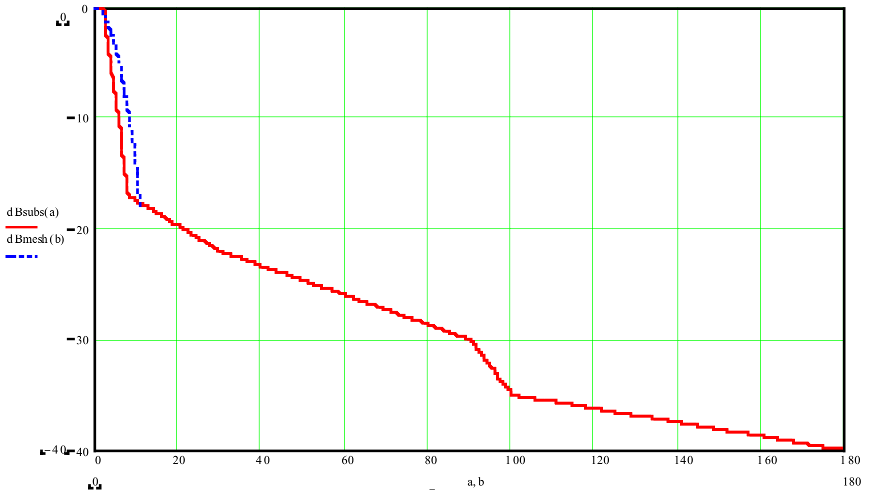



Fig. 2 Antenna RPE for Interfering Point to Point Link

Further work will be carried out to calculate the effect of using antennas corresponding to the output paper [2] from session #14. However, it is not expected that the results will be significantly different.

## 2.6 Geometry

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 base station receiver horn 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°.

## 2.7 Interfering Power Calculation

From each link transmitter and in line with 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.

2.5.2 Outline results from each simulation

## Simulation Results for scenario XXX

## Victim = PMP BS

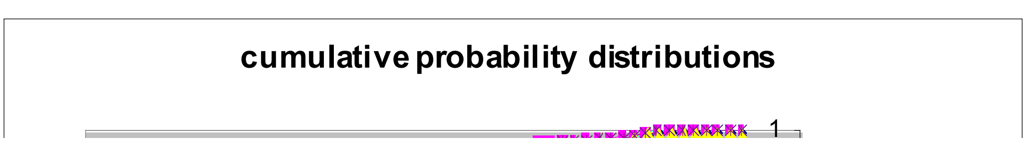


Fig. 3: Cumulative Probability Distributions for BS Interference

In figure 3, the results of a series of simulation runs are shown as cumulative probability distributions. 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.

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 is very low and simple interference mitigation procedures may be available.

| 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 | 18km | 0 |
| 2 | 7m | 1m | 10 | 42 | None | 20km | 0 |
| 3 | 0m | 4m | 10 | 42 | None | 32km | .04 |
| 4 | 0m | 4m | 10 | 42 | Storm | 32km | .06 |
| 5 | 7m | 3m | 5 | 42 | None | 20km | 0 |

Table 1: Summary of BS Interference Scenarios

As can be seen from table 1, a system spacing of 18-20km is generally sufficient to eliminate all possibility of interference. The two scenarios where this 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 cell 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

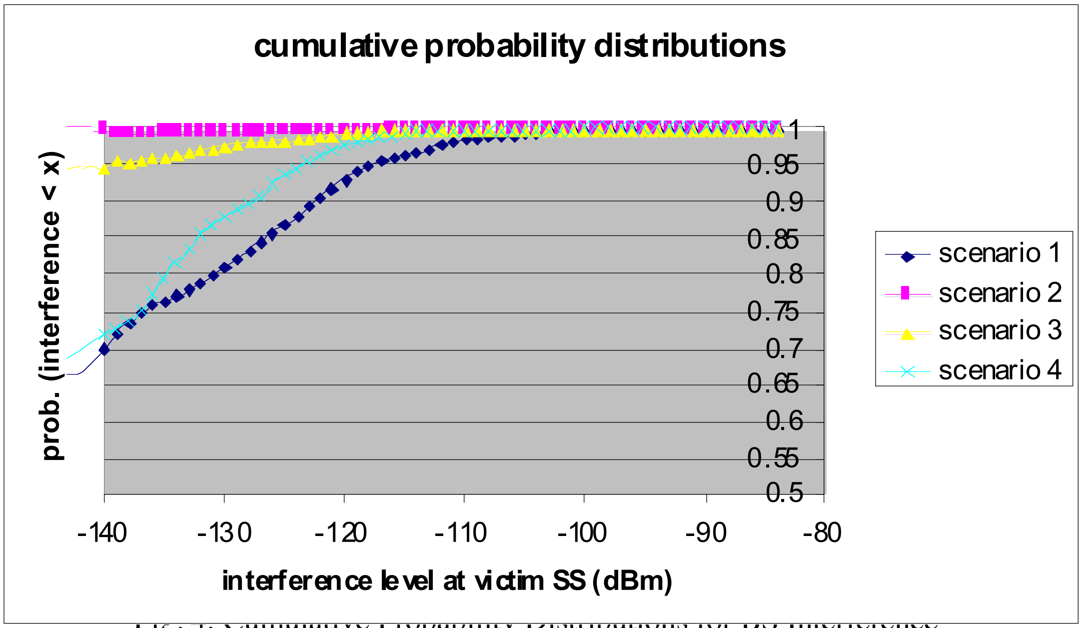



Fig. 4: Cumulative Probability Distributions for BS Interference

In figure 4, 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 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 antenna height | Rain scenario | Distance to SS | % threshold exceeded |
|---|---|---|---|---|---|---|---|---|
| 1 | 7m | 3m | 5 | 40 | 20 | None | 15km | .15 |
| 2 | 7m | 3m | 5 | 40 | 15 | None | 17km | .01 |
| 3 | 7m | 3m | 5 | 40 | 20 | None | 40km | .02 |
| 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

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 required base station distance will dominate.

## Conclusions

- For most situations, interference to the BS victim station determines the required system spacing, which is in the range 15-20km.

- 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 eliminate all probability of interference. 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

2.6. Mitigation techniques
2.7. Work of other bodies
2.7.1 ETSI TM4 work on point to point link interference
2.7.2 UK RA work on point ot 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
3.2. Scope statement (summary of what scenarios have been studied – derived from PAR)
3.3. Recommendations and Guidelines, including indicative geographical and physical spacing between system.

3.4. System description (interferer and victim systems)
3.4.1 Describe 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
3.4.3 Typical antenna characteristics
3.5. Description of simulations
3.5.1 Methodology
3.5.2 Outline results from each simulation
3.6. Mitigation techniques
3.7. Work of other bodies
3.8. References to complete simulation analysis

# 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

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)

[Update existing section on mitigation techniques to include results of buildings on interference ]

4.9 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:

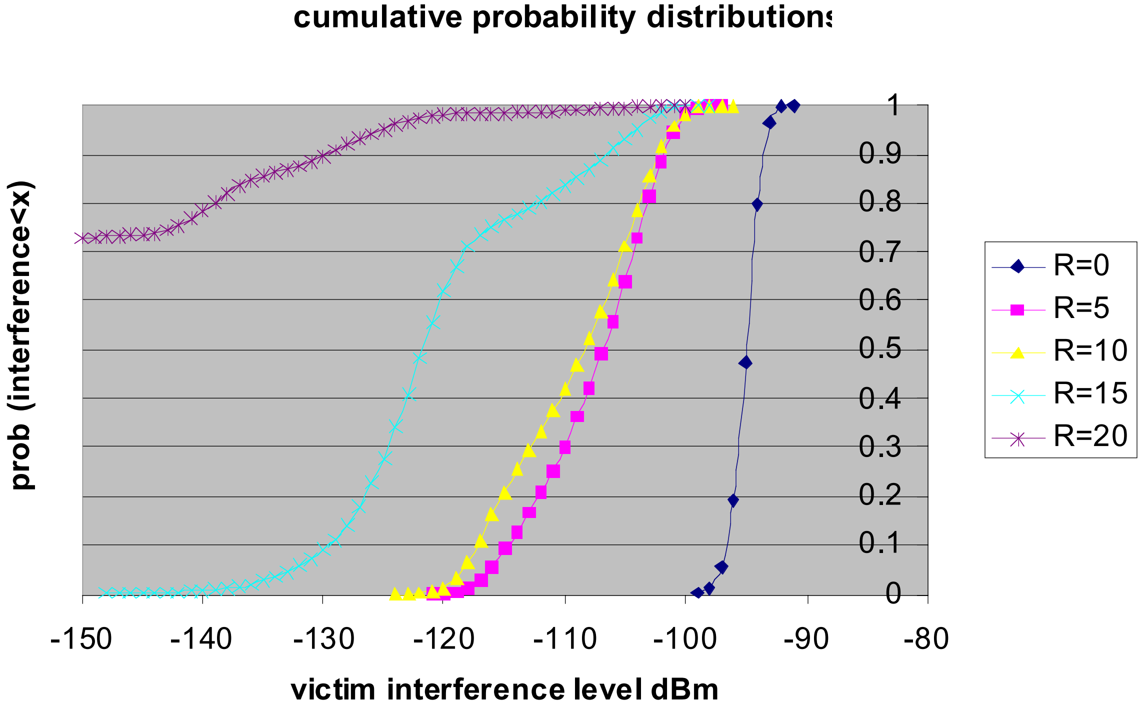
Frequency = 28 GHz
victim receiver = bases station with 90 degree sector antenna and 19dBi gain
distance from mesh edge to base station = 12km (any value can be set)
mesh link lengths from 50m to 1000m
mesh nodes placed 1m above roof height in all cases
mesh antenna gain = 25dBi
Rayleigh parameter (building 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 SE10 report [3].

END