BFWAtg(00)45

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1 INTRODUCTION

A further analysis has been conducted to supplement Section 3 of the original "Co-ordination between Broadband Fixed Wireless Access systems in the 28 and 42 GHz frequency bands" report (referred to hereafter as the original report). The analysis and the conclusions in the original report were based on a series of common assumptions reflecting existing standards and typical equipment and operational parameters. The purpose of this project is to modify some of these assumptions and to investigate the impact on the conclusions. Three specific aspects have been investigated:

- the effect of changing interference to noise ratio (I/N) from -10 dB to -6 dB on the analysis
- the impact of altering Base Station (BS) antenna downtilt on the analysis
- the impact of different cell sectorisation on the co-existence conclusions

2 CO-ORDINATION CRITERIA DEPENDENCE ON I/N ASSUMPTION

2.1 Introduction

The original analysis was based on the assumption that the acceptable I/N criterion is equal to –10 dB. Recent CEPT SE 19 work on BFWA has resulted in a draft ERC report Report "Fixed Wireless Access (FWA) Spectrum Engineering & Frequency Management Guidelines (Qualitative)" [reference SE19 Doc. 100r4]. This report suggests a more relaxed value for I/N of –6 dB.

A new analysis has investigated the effect of a revised I/N value of –6 dB on the interference PFD criterion and co-ordination distances. The methodology for determining co-ordination distances and interference PFD criterion at the service area boundary is described in detail in Section 3 of the original report. This report will illustrate the differences in these values caused by more relaxed I/N limits.

Since the nominal cell sizes (radius of 3 km), EIRP levels and visibility of the interferers used for the statistical analysis in the original analysis will not change, there was no need for any further statistical modelling to deduce the impact of the revised I/N value. Since the co-ordination distances will change as a result of a more relaxed I/N limit, the ratio between the radio horizon distance and co-ordination distance will change. As a result of this issue and due to the increased interference limit, some of the conclusions drawn from the comparison between the statistical curves and the interference criteria need to be revisited.

The reference parameters used for the analysis are same as defined in the original report, section 2.6.

Assumed BFWA parameters for interference analysis:

Nominal channel bandwidth:	28 MHz
Base station EIRP:	15 dBW = 0.5 dBW/MHz
Base station antenna gain:	15 dBi
Base station antenna radiation pattern:	EN 301 215 class C2
Subscriber station EIRP:	26 dBW = 11.5 dBW / MHz
Subscriber station antenna gain	33 dBi (PMP); 26 dBi (mesh)
Subscriber station antenna 3 dB beam width	4° (PMP); 9° (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
Receiver noise figure	8 dB (42 GHz)
	7 dB (28 GHz)

The revised interference limits (kTBF – 6 dB) are then defined as follows:

28 GHz	42 GHz
-143 dBW/MHz	-142 dBW/MHz

Actual BFWA network operating frequencies of 27.5 and 40.5 GHz have been used in the co-ordination analyses presented in this report. These frequencies have been chosen due to the fact that they are at the lower ends of the bands and the likelihood of causing interference will be greater than at other frequencies of the band. The intention of this study was to provide co-ordination requirements for the 28 and 42 GHz bands based on the worst case interference scenarios.

2.2 Base station to base station interference

2.2.1 Co-ordination at 42 GHz

The minimum separation distance between two directly aligned BSs can be derived from the link budget formulae as described in section 3.2.1.2 of the original report. Figure 2.1 shows the received interference power as a function of the separation distance from the interfering BS transmitter.

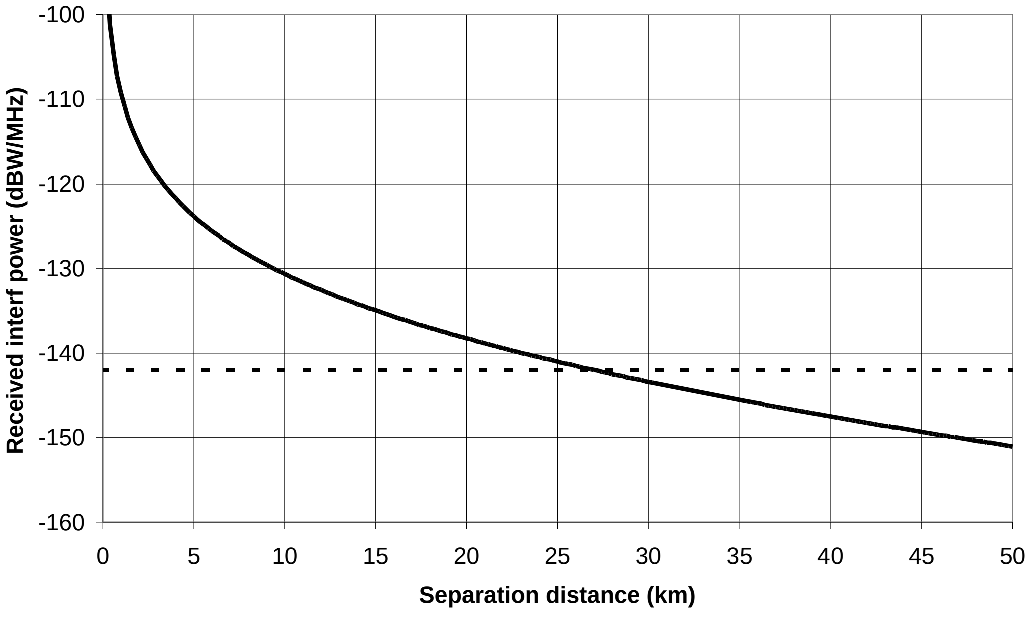

Figure 2.1: Received interference power vs. separation distance for the base station to base station interference scenario (42 GHz, line of sight)

From Figure 2.1 it can be observed that in order to meet the interference limit criterion of –142 dBW/MHz, a separation of **27 km** is required between directly aligned base stations under clear air conditions (assuming the same BS antenna characteristics). If the required separation distance is apportioned equally between the two regions, this will require any operator to ensure that each of its BS transmitters, having their antenna directed towards the adjacent operator's service boundary area, is located at least **13.5** km away from the service area boundary. If the BS antenna is not directed towards the adjacent service area boundary, then it may be located closer to the boundary as long as it satisfies the PFD criterion at the boundary. In order to derive the PFD criteria it is necessary to determine the PFD generated by the interfering BS.

The PFD generated by the interfering BS as a function of distance from the BS transmitter is illustrated in Figure 2.2.

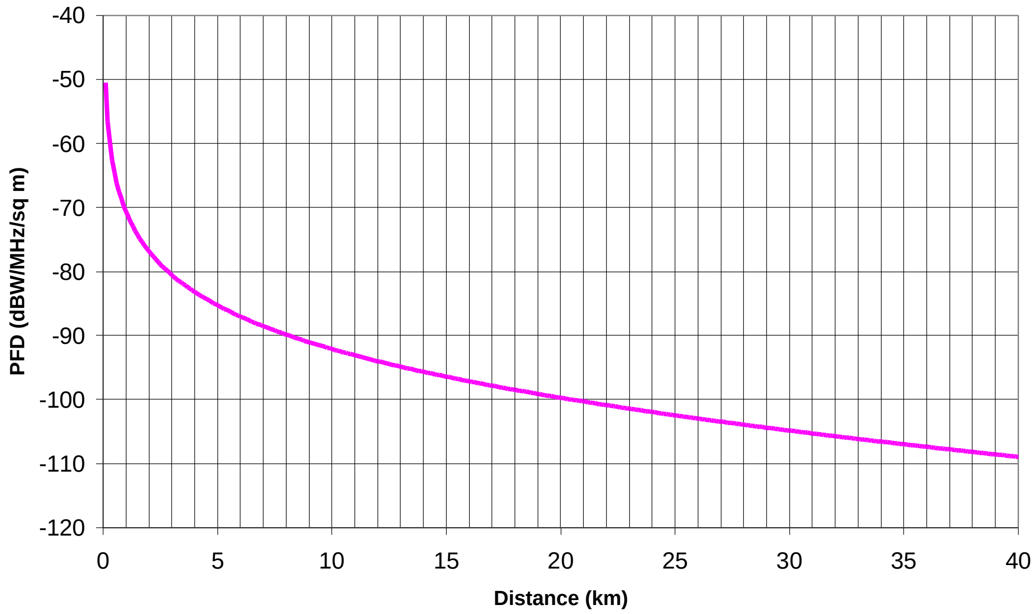

Figure 2.2: PFD vs. distance from interfering transmitter (0.5 dBW/MHz interferer EIRP)

From Figure 2.2, the PFD at the service area boundary, produced by a base station 13.5 km away and radiating 0.5 dBW / MHz EIRP, is **-95.5 dBW/MHz/m^2**. Thus, we recommend a revised value for the minimum generated boundary PFD limit of –95.5 dBW/MHz/m^2 at which the co-ordination between operators in adjacent service areas is required. The smaller value for the recommended PFD limit is due to less stringent I/N ratio of –6 dB.

The extent of additional protection required for BS antennas located closer to the boundary and directed towards the service area boundary is illustrated in Figure 2.3.

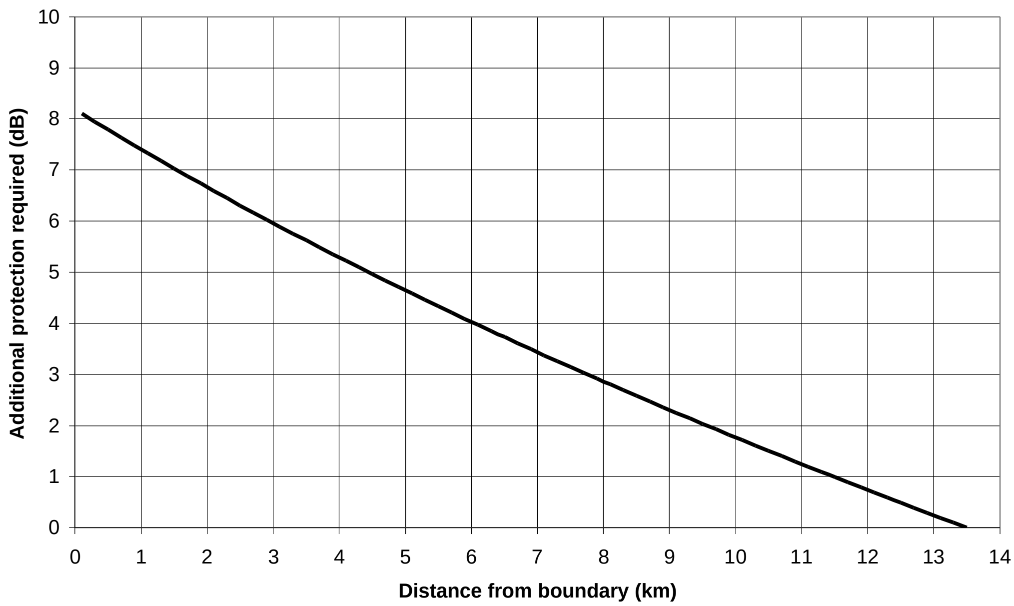

Figure 2.3: Additional shielding or off-axis discrimination required for base station as a function of distance from service area boundary (42 GHz band)

The co-ordination distance derived above is based on a transmitter EIRP of 0.5 dBW/MHz. The dependency of the co-ordination distance on the transmitter EIRP is illustrated in Figure 2.4.

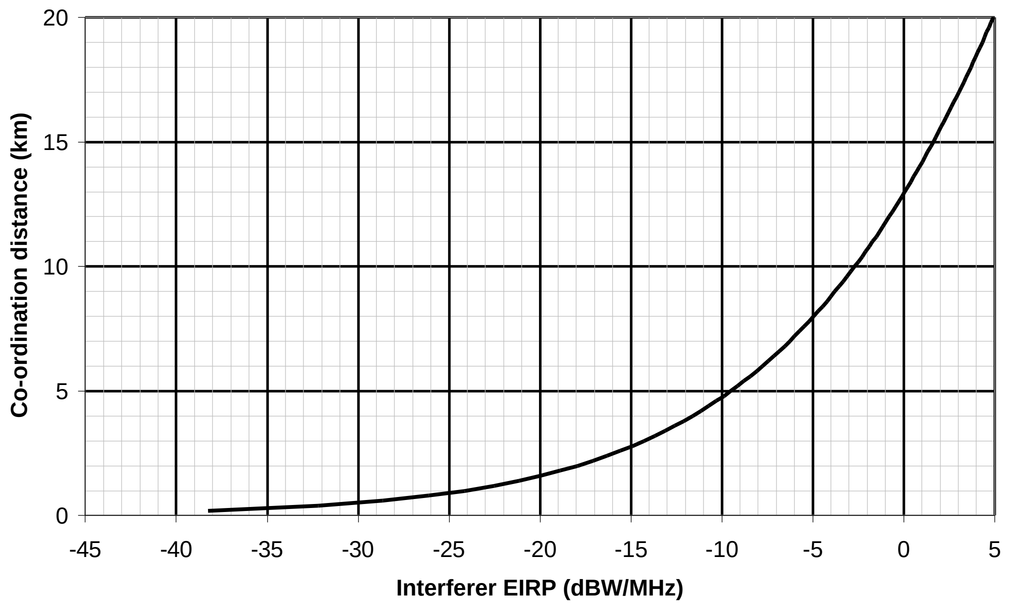

Figure 2.4: Co-ordination distance (from service area boundary) as a function of interferer EIRP at 42 GHz

2.2.2 Co-ordination at 28 GHz

The minimum separation distance between two directly aligned BSs can be derived from the link budget formulae as described in section 3.2.1.3 of the original report.

Figure 2.5 shows the received interference power as a function of the separation distance from the interfering BS transmitter.

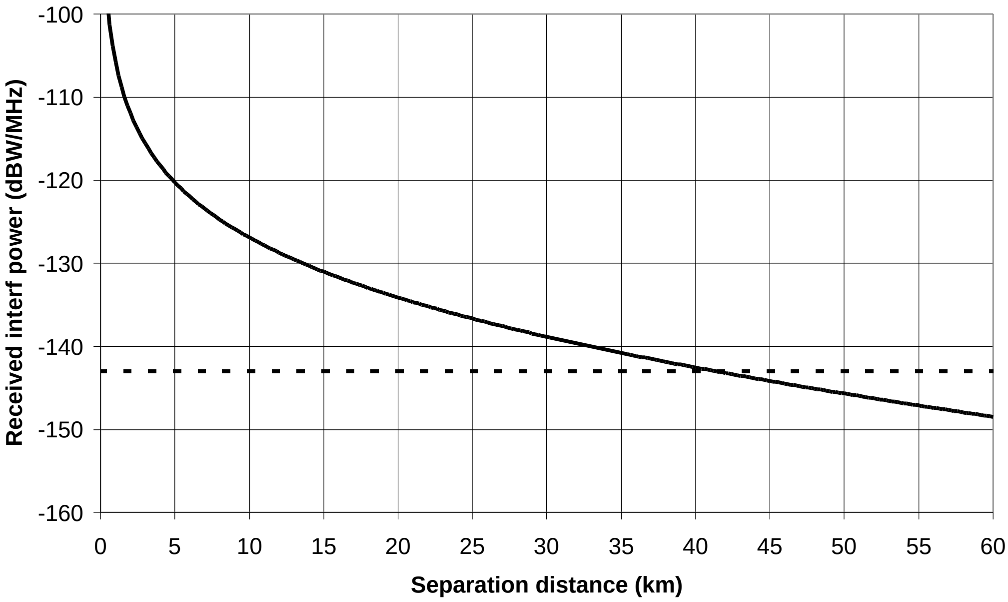

Figure 2.5: Received interference power vs. separation distance for the base station to base station interference scenario (28 GHz, line of sight)

From Figure 2.5 it can be observed that in order to meet the interference limit criterion of –143 dBW/MHz, a separation of **42 km** is required between directly aligned base stations under clear air conditions (assuming the same BS antenna characteristics). If the required separation distance is apportioned equally between the two regions, this will require any operator to ensure that each of its BS transmitters, having their antenna directed towards the adjacent operator's service boundary area, is located at least 21 km away from the service area boundary. If the BS antenna is not directed towards the adjacent service area boundary, then it may be located closer to the boundary as long as it satisfies the PFD criterion at the boundary. In order to derive the PFD criteria it is necessary to derive the PFD generated by the interfering BS.

The PFD generated by the interfering BS as a function of distance from the BS transmitter is illustrated in Figure 2.6.

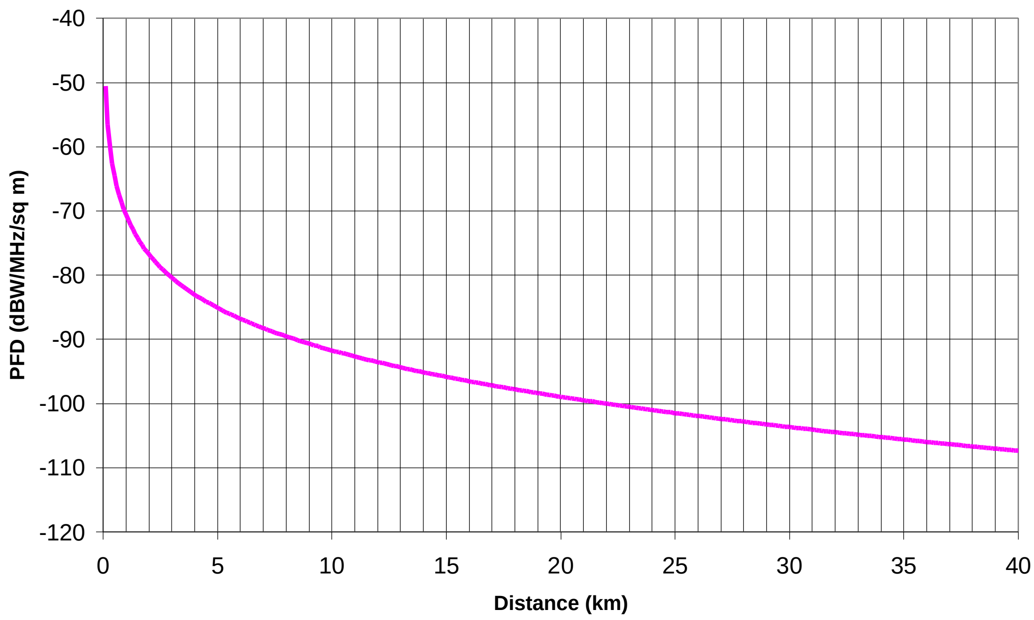

Figure 2.6: PFD vs. distance from interfering transmitter (0.5 dBW/MHz interferer EIRP)

From Figure 2.6, the PFD at the service area boundary, produced by a base station 21 km away and radiating 0.5 dBW / MHz EIRP, is **-99.5 dBW/MHz/m^2**. Thus, we recommend a revised value for the minimum generated boundary PFD limit of –99.5 dBW/MHz/ m^2 at which the co-ordination between operators in adjacent service areas is required.

The extent of additional protection required for BS antennas located closer to the boundary and directed towards the service area boundary is illustrated in Figure 2.7.

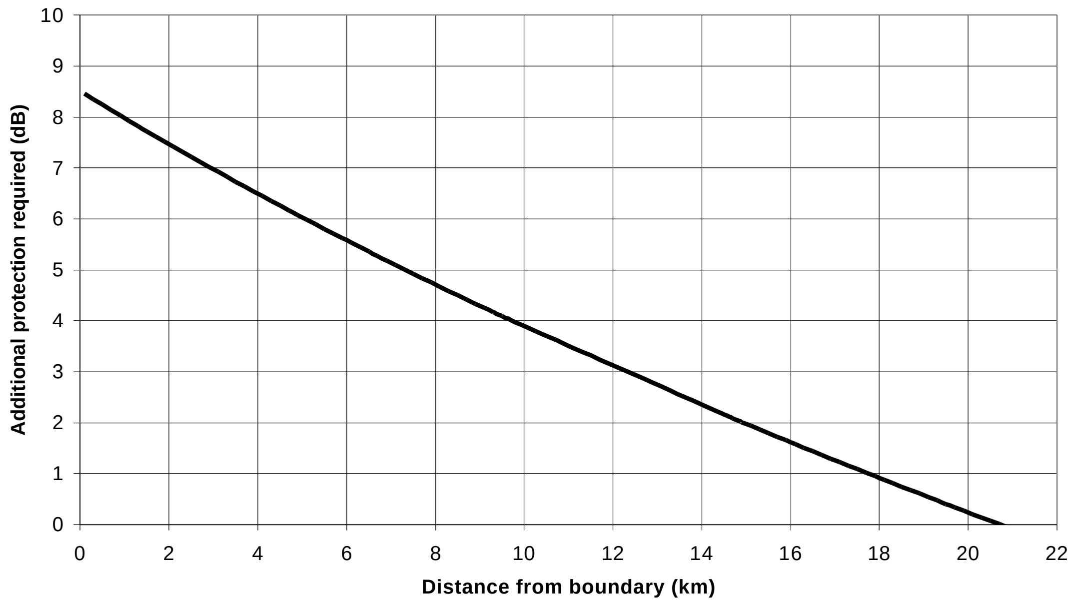

Figure 2.7: Additional shielding or off-axis discrimination required base station as a function of distance from service area boundary (28 GHz)

The co-ordination distance derived above was based on transmitter EIRP of 0.5 dBW/MHz. The dependency of the co-ordination distance on the transmitter EIRP is illustrated in Figure 2.8.

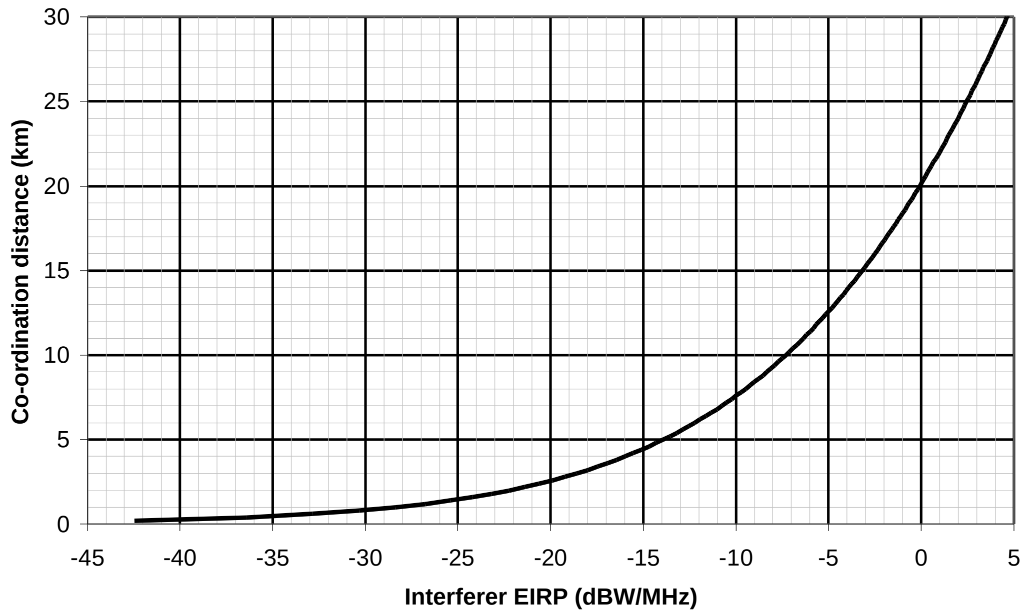

Figure 2.8: Co-ordination distance (from service area boundary) as a function of interferer EIRP at 28 GHz

2.2.3 Multiple interferer statistical analysis at 28 GHz

This section is a supplement to section 3.2.1.4 of the original report. As mentioned in section 2.1, there was no need for additional statistical modelling analysis and in this section it is intended to present the results of the original statistical analysis considering the modified co-ordination distances and I/N criteria. Figures 2.9 and 2.10 show base stations to base station interference CDF, assuming that 90° (azimuth) by 16° (elevation) base station sector antennas conforming to EN 301-215 class CS2 are deployed. Results are presented for three scenarios, with 10%, 20% and 40% of the interferers visible to the base station. Figure 2.9 shows statistical analysis results when BS antennas are downtilted by 9°, whereas Figure 2.10 shows results when downtilting of BS antennas is not deployed.

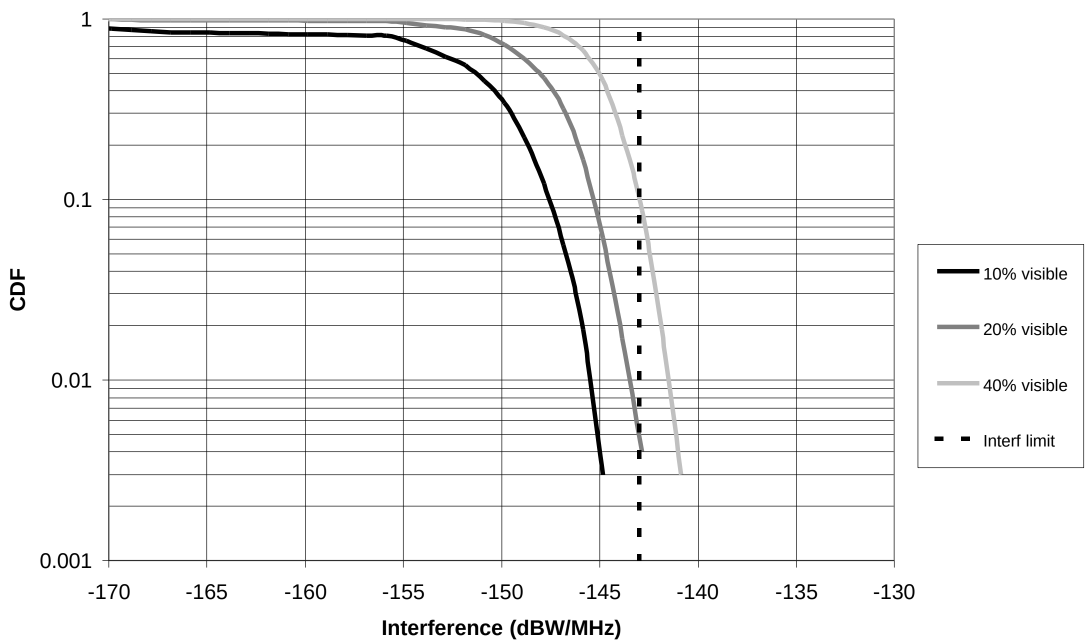

Figure 2.9: Interference CDF for base station to base station scenario (9° base station antenna down tilt)

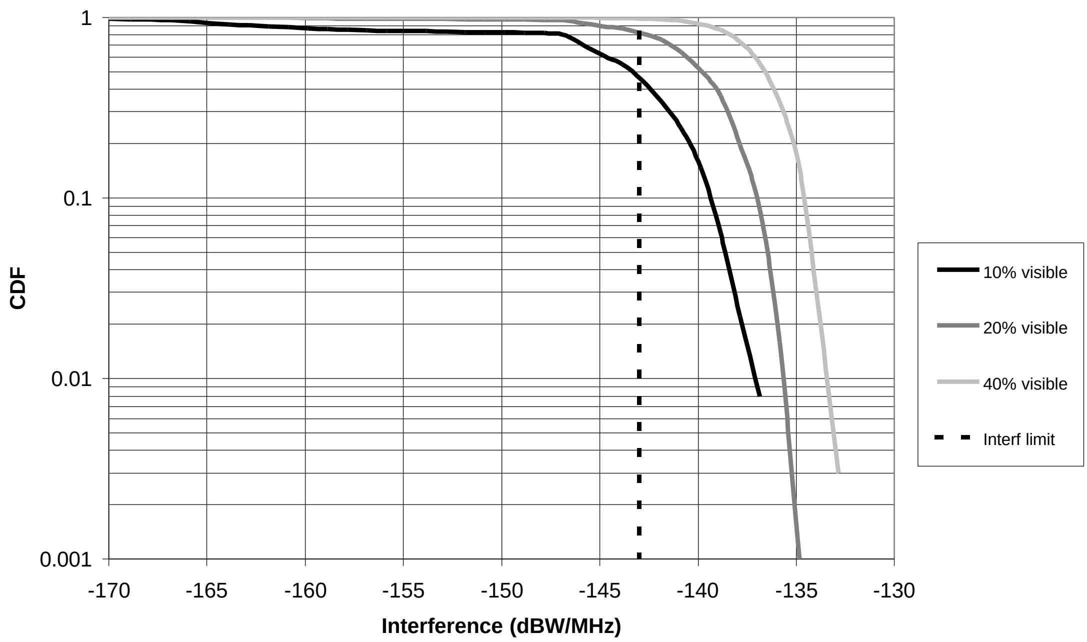

Figure 2.10: Interference CDF for base station to base station scenario (no base station antenna down tilt)

It can be seen from Figure 2.9 that interference only becomes significant when 40% or more of potential interfering stations are visible. If 40% of potential interfering base stations are visible then the highest interference case will cause the interference limit to be exceeded by 2 dB. This is still 4 dB lower than the victim receiver threshold and it is unlikely to cause any serious degradation of system performance.

On the other hand, Figure 2.10 shows that if downtilt is not applied to the base station antennas then there is a high probability that the interference from potential interfering base stations into a victim base station located in the adjacent operator service area will exceed the interference limit (even if only 10% of potential interfering BSs are visible by the victim BS). **The conclusions drawn in the original study for this case are still valid.**

2.3 Base station to subscriber station interference

The original study concluded that the worst case interference from a single base station into a subscriber station will exceed the limit by a considerable margin, because of the higher victim antenna gain. This conclusion is still valid even for the higher interference limit based on I/N=-6 dB (although the margin is slightly lower). The second finding of the original study was that the probability of a direct alignment of a narrow beamwidth subscriber antenna with the interfering BS antennas will be lower that in the case where both interferers and victim are BSs. Figure 2.11 illustrates the results of the original statistical analysis for the revised interference limit.

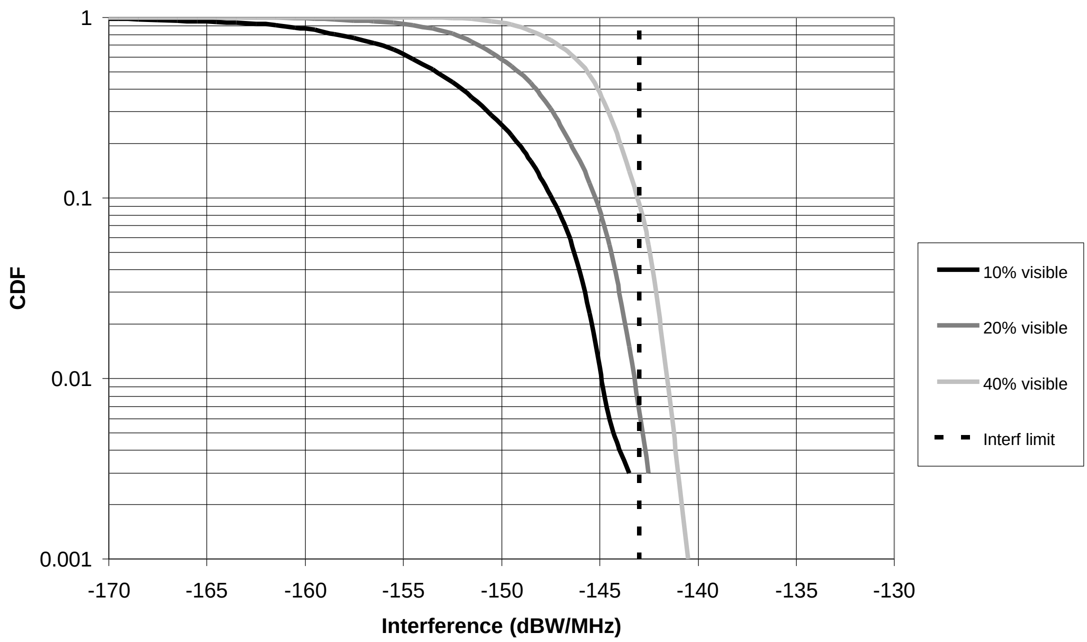

Figure 2.11: CDF for Base-to-Subscriber interference

It can be seen from Figure 2.11 that the interference limit is exceeded if 20% or more interfering BSs are visible to the victim subscriber station. However, the probability of interference being exceeded for 20% visibility is 0.7%, whereas the probability of interference being exceeded for 40% visibility is 10%. These values are considerably lower than in the original study which has concluded that the probabilities of interference limit being exceeded for 20% and 40% visibility are 15% and 50%. **The original study concluded that the BSs to subscriber station interference is not considered to be a significant factor if the proposed boundary PFD limits are observed. This conclusion is still valid if the revised interference limits are used and it can be further concluded that the BS to subscriber station interference will be much less of an issue.**

2.4 Subscriber station to Base station interference

2.4.1 Co-ordination at 42 GHz

In determining the interference level from a subscriber station into a directly aligned victim BS located in adjacent service area, it is assumed that the BS is set back from its network service area boundary by a minimum distance of 13.5 km (as derived in section 2.2.1 above). The scenario is shown in following diagram

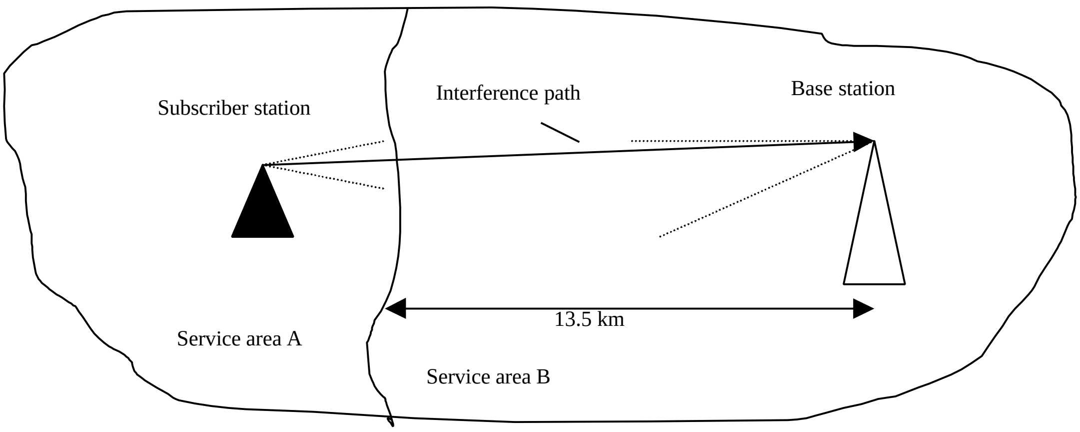

Figure 2.12. Subscriber station to Base station scenario

The maximum subscriber EIRP occurs at the edge of the cell, due to the effect of automatic transmitter power control (ATPC). The maximum cell size derived in section 3.2.3.2 of the original report is still valid since the same system parameters (as shown in section 2.2 above) are used for this study. This analysis yields the maximum cell size of 2.6 km for a PMP system operating at 40.5 GHz. The worst case interference scenario therefore occurs when the separation between an interfering subscriber station and a victim BS is 16.1 km (=13.5+2.6). Assuming the subscriber station is transmitting at the assumed maximum EIRP of 11 dBW/MHz, the received signal level at the victim base station for this scenario is

= $11.5 – FSPL - L_{atmos} - L_{rain} + G_{rec}$

= 11.5 - 148.68 - 2.57 - 18.7 + 15

= -143.48 dBW/MHz

This is approximately at the same level as the interference criterion which suggests that the PFD limit derived for the worst case BS to BS interference case (see section 2.2.1) is also applicable to the subscriber to BS interference scenario.

As in the original study, it is recommended that the PFD limit derived for the BS to BS scenario should also be applied to transmissions from subscriber stations.

Assuming a maximum subscriber EIRP of 11.5 dBW / MHz and a maximum cell size of 2.6 km, the effective EIRP after allowing for rain fading (=18.7 dB) is –7.2 dBW/MHz. Figure 2.4 (which shows the co-ordination distance as a function of interfering EIRP) shows that an EIRP of –7.2 dBW/MHz requires a co-ordination distance of 6.5 km.

Assuming this same maximum boresight EIRP, uncorrelated rain fading and an off-boresight angle of 10° in the direction of the boundary, the maximum EIRP in the direction of the boundary can be determined from the difference between the boresight antenna gain and the gain at ±10° offset. From EN 301 215, the maximum gain at 10° off boresight is defined as –17 dB relative to the boresight gain. Hence the maximum EIRP in this scenario is –5.5 dBW/MHz (11.5 - 17). From Figure 2.4, this EIRP requires a co-ordination distance of 7.5 km.

Hence, for the revised interference limits and the same system parameters as in the original analysis, the maximum distance beyond which co-ordination of subscriber stations operating in the 42 GHz band is not required is 7.5 km. **For subscriber stations located closer than 7.5 km to the service area boundary, co-ordination is required.**

2.4.2 Co-ordination at 28 GHz

In determining the interference level from a subscriber station into a directly aligned victim BS located in adjacent service area, it is assumed that the BS is set back from its network service area boundary by a minimum distance of 21 km (as derived in section 2.2.2 above). The maximum cell size is as derived in section 3.2.3.3 of original report and equal to 4.1 km. The received signal level at the victim base station at 25.1 km (21 + 4.1) is –144.5 dBW/MHz. This is 1.5 dB below the interference limit, so once again we can assume that the PFD limits derived for the BS to BS scenario will apply for this scenario.

Assuming a maximum subscriber EIRP of 11.5 dBW / MHz and a maximum cell size of 4.1 km, the effective EIRP after allowing for rain fading (=18.8 dB) is – 7.3 dBW/MHz. Figure 2.8 (which shows the co-ordination distance as a function of interfering EIRP) shows that an EIRP of –7.3 dBW/MHz requires a co-ordination distance of 10 km.

Assuming the same maximum boresight EIRP, uncorrelated rain fading and an off-boresight angle of 10° in the direction of the boundary, the maximum EIRP in the direction of the boundary can be determined from the difference between the boresight antenna gain and the gain at ±10° offset. From EN 301 215, the maximum gain at 10° off boresight is defined as –17 dB relative to the boresight gain. Hence the maximum EIRP in this scenario is –5.5 dBW/MHz (11.5-17). From Figure 2.8, this EIRP requires a co-ordination distance of 12.5 km.

Hence, for the revised interference limits and the same system parameters as in the original analysis, the maximum distance beyond which co-ordination of subscriber stations operating in the 28 GHz band is not required is 12.5 km. **For subscriber stations located closer than 12.5 km to the service area boundary, co-ordination is required.**

2.4.3 Multiple interferer statistical analysis at 28 GHz

This section is a supplement to section 3.2.3.4 of the original report. As mentioned in section 2.1, there was no need for additional statistical modelling analysis and in this section it is intended to present the results of the original statistical analysis but applying the modified co-ordination distances and I/N criteria. Figures 2.12 shows multiple interferer statistical analysis results for subscriber to BS interference at 28 GHz. Results are shown for scenarios when 10%,20% and 40% of the total number of subscribers are visible.

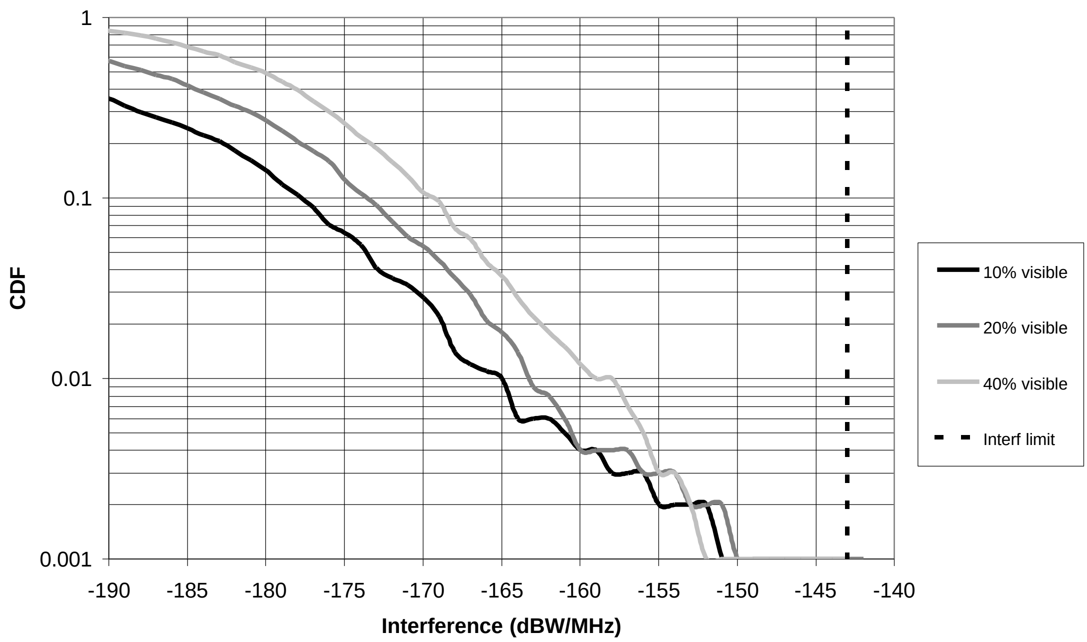

Figure 2.13: CDFs for subscriber station to base station interference

Figure 2.13 shows that the revised interference limit is not exceeded even when 40% of subscribers are visible to the victim BS. **It can be concluded that providing the co-ordination requirements (as described in sections 2.4.1 and 2.4.2) are satisfied, interference from subscriber stations into a victim BS should not cause frequency sharing problems.**

2.5 Subscriber station to subscriber station interference

This section is a supplement of section 3.2.4 of the original report. The worst case analysis is as described in the original report. The worst case single interferer scenario suggests that the revised interference limit is exceeded by approximately 9 dB. However, the probability of interfering and victim subscribers being directly aligned is remote as suggested by the multiple interferer statistical analysis results in Figure 2.14.

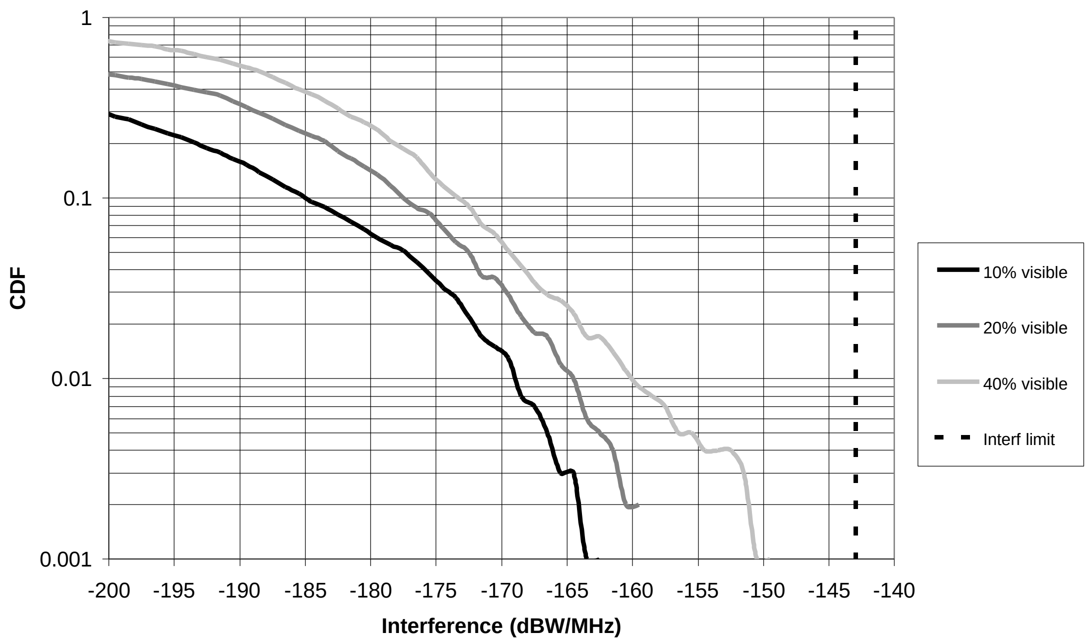

Figure 2.14: CDFs for subscriber station to subscriber station interference

Figure 2.14 shows that there is at least 7 dB margin between the worst subscriber-to-subscriber interference case and the revised interference limit, assuming that up to 40% of interfering subscribers are visible.

2.6 Interference from high density PMP networks

This issue is elaborated in detail in section 3.3 of the original report. All statements are still valid.

2.7 Interference from mesh networks

This section is a supplement to section 3.4 of the original report. The analysis that led to the recommendation for operators to avoid co-channel, co-polar operation within 5 km of their service area boundaries is still valid.

Figure 2.15 shows the interference CDFs for interference from a high density mesh network into a PMP base station, assuming various percentages of visible interferers, a total interferer density of 0.45 per km^2, a minimum 10 km separation between co-channel interferers and victims, and an I/N limit criteria equal to –6 dB. The operational frequency assumed is 28 GHz.

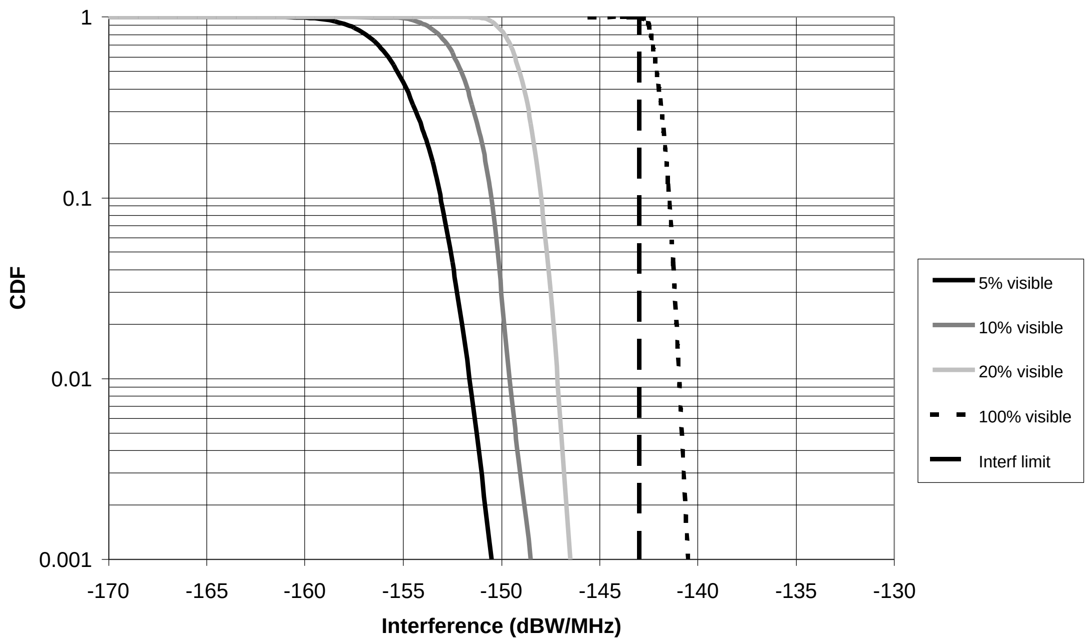

Figure 2.15: CDF for interference from a high density mesh network into a PMP base station (no co-channel operation within 5 km of service boundary)

It can be seen that even when there is 100% visibility of interfering mesh network subscriber stations, revised interference limit is exceeded by only 2.5 dB. This level is still 3.5 dB below the receiver noise threshold and it is unlikely that there will be any significant risk of interference in this scenario. It should be noted that this analysis assumes that the recommendation of avoiding co-channel, co-polar operation within 5 km of service area boundary is implemented.

3 IMPACT OF BS ANTENNA DOWNTILT ON INTERFERENCE ANALYSIS

3.1 Introduction

The original multiple interferer statistical analysis involving BSs was conducted assuming a BS antenna downtilt of 9°. This amount of downtilt was derived assuming an EN 301 215 CS2 BS antenna whose elevation radiation pattern had a 3 dB beamwidth equal to 8°. The EN 301215 CS2 antenna elevation radiation pattern is illustrated in Figure 3.1.

It was also assumed that the average BS antenna height is 60m whilst the average subscriber station antenna height is 10m. It was intended that such a BS would provide service to subscriber stations at distances from approximately 200 m to 3 km (which is used as a nominal cell radius). The intention of this section is to investigate the effect of deploying different BS antenna downtilts on the levels of interference in the multiple interferer statistical analysis. Only the scenarios where BSs are the potential interferers or victims of interference need to be investigated.

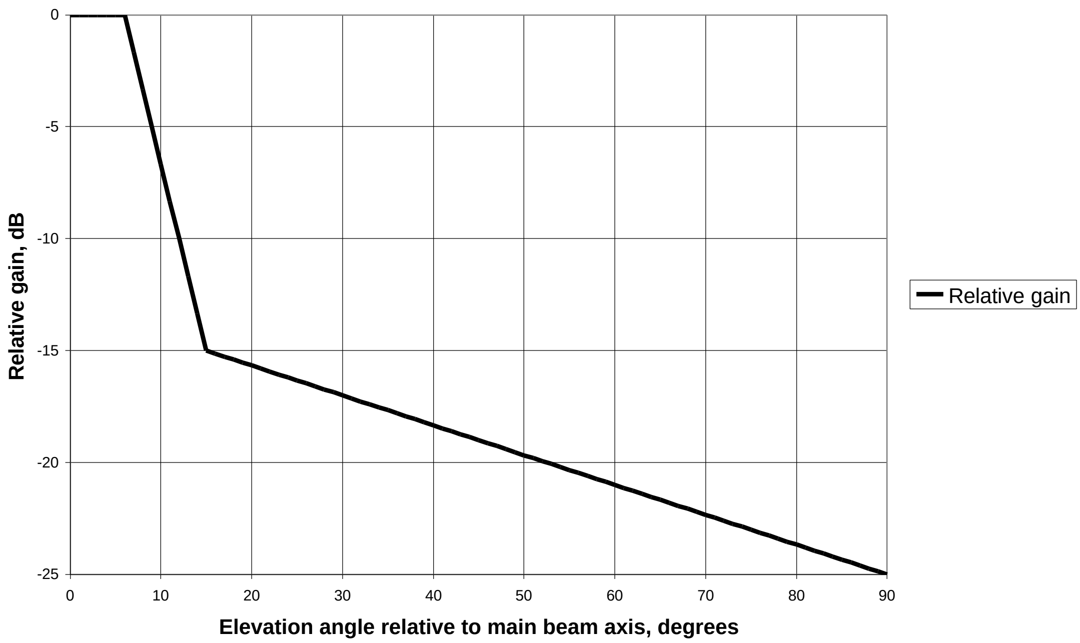

Figure 3.1: Symmetric CS antenna co-polar elevation RPE

The results presented in the next section are for networks operating in the 28 GHz band as in the original report. However, the main conclusions drawn are also valid for networks operating in the 42GHz band.

The revised interference limit based on I/N=-6 dB is used throughout the analysis for consistency.

3.2 Impact of BS antenna downtilt on BS to BS interference

The interference scenario analysed in section 3.2.1. 4 of the original report and in section 2.2.3 above has been revisited and BSs antenna downtilt at both interferer and victim side altered. The effect of different BS antenna downtilts has been analysed for 10%,20% and 40% visibility of interfering BSs. It has been noted that varying the BS antenna downtilt from 0° to 6° has virtually no effect on the multiple interferer statistical analysis results for this particular scenario. The explanation for this phenomenon can be found by observing Figure 3.1. The symmetric CS co-polar elevation RPE exhibits unchanged relative gain levels for elevation angles from 0 to 6 degrees. Since the interfering and victim BSs are assumed to be at the same height, the direct line-of-sight path (used for the interference calculations) between them will be approximately in the horizontal plane. If the BSs antenna is downtilted by up to 6 degrees from the horizontal plane, then the angle between the antenna boresight and the direct line-the line-of-sight path will also be up to 6 degrees. This means that transmitter and receiver BS antenna RPE will not change (in the direction of line-of-sight path) when the antenna downtilt is increased up to 6 degrees. Figure 3.2 shows the multiple interferer statistical analysis for BS to BS scenarios when different BS antenna downtilts are applied. Results are shown for 10% visibility. The plots for 20% and 40% visibility are shown in Annex A of the report.

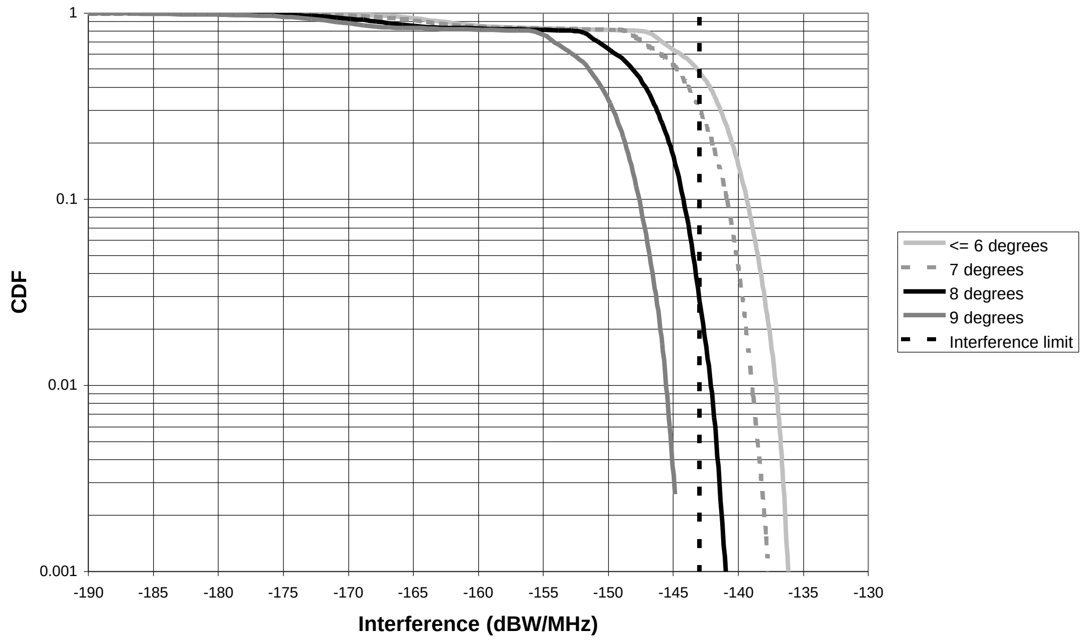

Figure 3.2: Interference CDF for base station to base station scenario (10% visibility and different base station antenna downtilts)

Figure 3.2 shows that for 10% visibility of the interfering BSs and 9 degrees downtilt deployed, the interference limit is not exceeded. If the 8 degrees downtilt is deployed at interfering and victim BS antenna, the interference limit is exceeded with 2% probability. The worst case interference in this scenario is 2 dB higher than the interference limit. This value is still approximately 4 dB lower than the receiver noise threshold and the probability of occurrence is 0.1%. This is unlikely to cause significant degradation of network performance. If the 7 degree downtilt is employed the interference limit is exceeded by 30% and the worst case interference scenario will cause interference into victim BS receiver at the levels slightly lower than receiver noise threshold. For downtilt up to 6 degrees the worst case interference will be above the receiver noise threshold.

Our recommendation is that BS antenna downtilt of 8 degrees and above is employed to avoid high interference into BSs in the adjacent operator service areas. This recommendation is based on the assumption that the EN 301 215 CS2 BS antenna pattern is used at mean heights of 60 metres.

3.3 Impact of BS antenna downtilt on BS to subscriber interference

The interference scenario analysed in section 3.2.2 of the original report and in section 2.3 above has been revisited and BSs antenna downtilt altered. The effect of different BS antenna downtilts has been analysed for 10%,20% and 40% visibility of interfering BSs.

Figure 3.3 shows the multiple interferer statistical analysis for BS to subscriber station scenarios when different BS antenna downtilt are applied. Results are shown for 10% visibility probability. The plots for 20% and 40% visibility are shown in Annex B of the report.

For similar reasons that are explained in previous section, altering the downtilt from 0 to 6 degrees does not have any significant effect on the interference CDF results. Elevation pattern of subscriber antenna (modified EN 301 215 TS1 pattern to take into account rain fading) will also be constant at elevation angles from 0 to 6 degrees. In addition to that, deploying 7 degrees downtilt on BS antenna will also have little effect on the results of the analysis. The reason for this is the fact that there is a difference in the assumed nominal antenna height between BS and victim subscriber station. Due to this difference in height (50 metres), the angle between the line-of-sight interference path and boresight of BSs antenna pattern (downtilted by 7 degrees from the horizontal level) will be less or equal to 6 degrees for the great majority of interfering BS locations. This would result in very little difference in interference levels caused by such BSs compared to BSs with antenna downtilts up to 6 degrees.

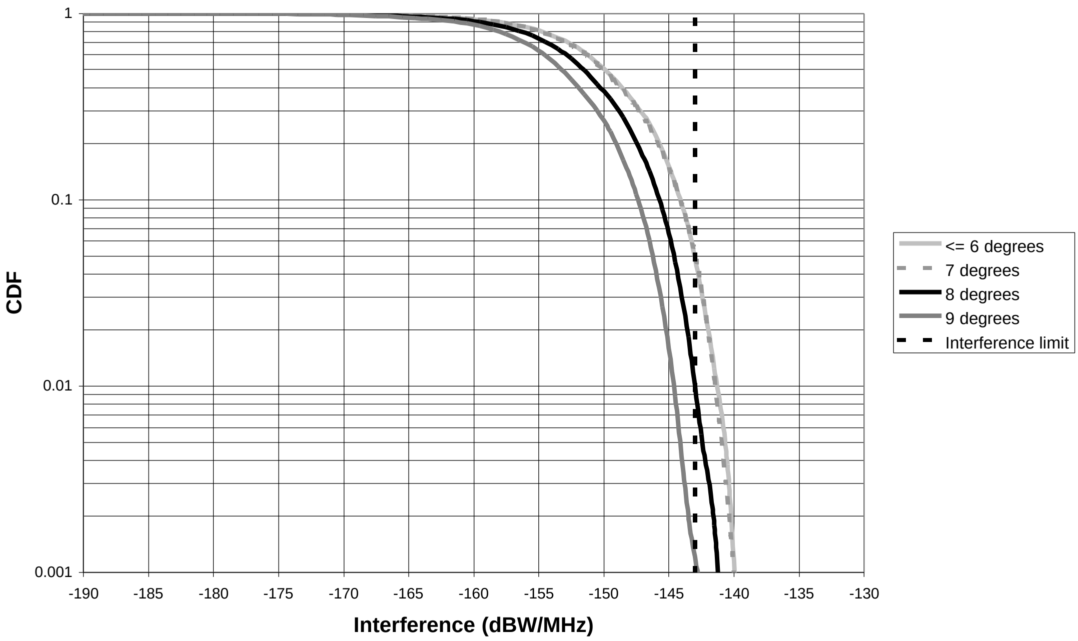

Figure 3.3: Interference CDF for base station to subscriber station scenario (10% visibility and different base station antenna downtilts)

Figure 3.3 shows that for 10% visibility of the interfering BSs and 8 degrees downtilt deployed, the interference limit is exceeded with 1% probability (the worst case interference is 1.5 dB higher than the interference limit). This value is still approximately 4.5 dB lower than the receiver noise threshold and the probability of occurring is 0.1%. This is unlikely to cause significant degradation of network performance. If the 7 degree (or less than 7 degrees) downtilt is deployed the interference limit is exceeded by approximately 5% and the worst case interference scenario will cause interference into victim BS receiver at the levels 3 dB lower than receiver noise threshold.

The recommendation for BS downtilt deployment of 8 degrees or more (for the assumed network parameters) elaborated in section 3.2 is confirmed by the result of BS to subscriber interference analysis.

3.4 Impact of BS antenna downtilt on subscriber to BS interference

The interference scenario analysed in the section 3.2.3.4 of the original report and in section 2.4.3 above has been revisited and the victim BS antenna downtilt altered. The effect of different BS antenna downtilts has been analysed for 10%,20% and 40% visibility of interfering subscriber stations.

Figure 3.4 shows the multiple interferer statistical analysis for subscriber station to BS scenarios when different BS antenna downtilt are applied. Results are shown for 10% visibility probability. The plots for 20% and 40% visibility are shown in Annex C of the report.

The geometry of the line-of-sight interference path in this scenario is same as in BS to subscriber station interference scenario discussed in section 3.3. Hence, the differences in results for analysis with BS antenna downtilted up to 7 degrees are not significant.

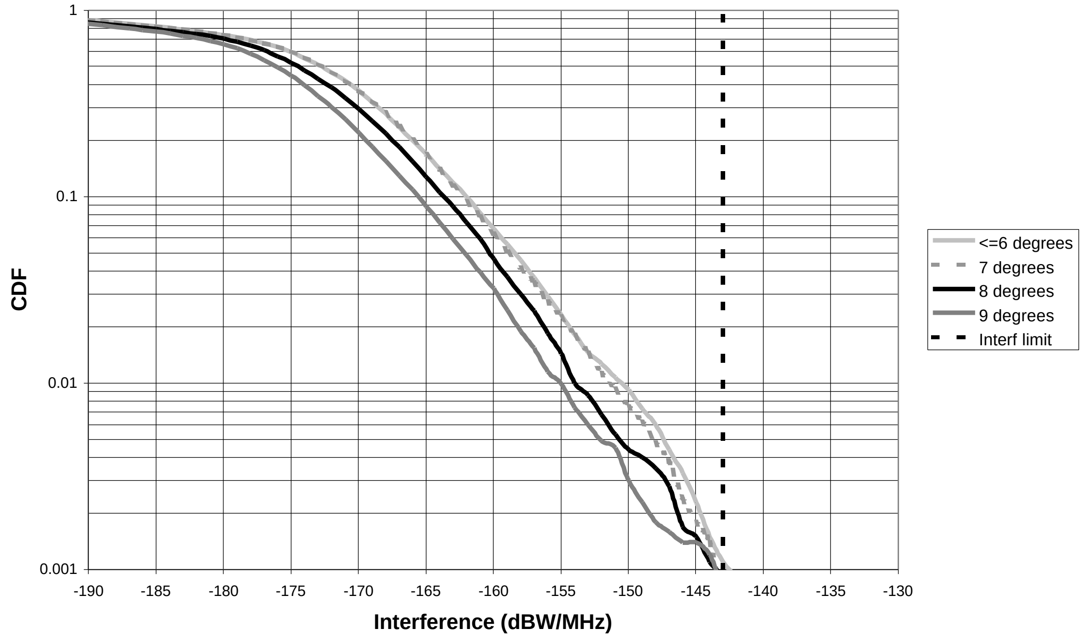

Figure 3.4: Interference CDF for subscriber station to base station scenario (10% visibility and different base station antenna downtilts)

Figure 3.4 shows that for 10% visibility of the interfering subscriber stations, the interference into a victim BS in an adjacent operator service area does not exceed the interference limit.

3.5 Impact of BS antenna downtilt on interference from mesh network subscribers into PMP BSs

The interference scenario analysed in section 3.4 of the original report and in section 2.7 above has been revisited and the victim BS antenna downtilt altered. The effect of different BS antenna downtilts has been analysed for 5%,10%,20% and 100% visibility of interfering mesh network subscriber stations.

Figure 3.5 shows the multiple interferer statistical analysis for mesh network subscriber station to BS scenarios when different BS antenna downtilts are applied. Results are shown for 20% visibility. The plots for 5%,10% and 100% visibility are shown in Annex D of the report.

The geometry of a line-of-sight interference path in this scenario is same as in the subscriber station to BS interference scenario discussed in section 3.4. Mesh network subscriber station elevation antenna pattern has even less of an influence on the results of the analysis with BSs antenna downtilted by up to 7 degrees since the elevation radiation pattern of a mesh network subscriber station has a 6 dB beamwidth equal to 72 degrees. Hence, the differences in results for the analysis with the BS antenna downtilted up to 7 degrees are very small.

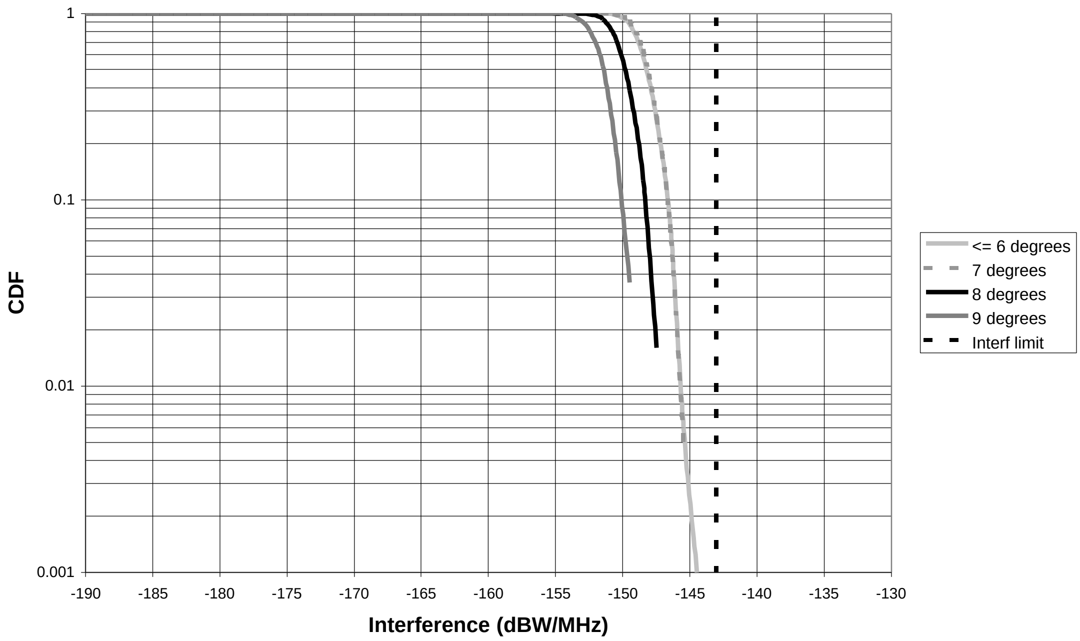

Figure 3.5: Interference CDF for mesh network subscriber station to base station scenario (20% visibility and different base station antenna downtilts)

Figure 3.5 shows that for 20% visibility of the interfering mesh network subscriber stations, the interference into a victim co-channel, co-polar PMP BS does not exceed the interference limit. This is also case for smaller percentage of mesh network subscriber station visibility, whilst the improbable case when all potential interfering mesh network subscriber stations are visible would cause interference levels exceeding the interference limit with over 95% probability regardless of the PMP BS antenna downtilt deployed (see Annex D).

It should be noted that the statistical analysis result take account of the recommendation that BFWA operators should avoid co-channel, co-polar operation within 5 km of their service area boundaries.

4 IMPACT OF BS SECTOR WIDTH ON INTERFERENCE ANALYSIS

4.1 Introduction

The original multiple interferer statistical analysis involving BSs was conducted assuming cell sectorisation with a sector width equal to 90 degrees. The purpose of this chapter is to describe an investigation into the impact of utilising different cell sectorisation on the multiple interferer statistical analysis. Additional analysis has therefore been performed with cell sector widths of 30, 60, 90 and 120 degrees.

The BS antenna used has an azimuth radiation pattern according to the EN 301 215 CS2 specification. This specification allows for variation in the azimuth radiation pattern according to the cell sector widths that have been utilised in this analysis. To facilitate comparison, the base station EIRP has been maintained throughout at the 0.5 dBW/MHz reference level defined in the original report. Since the maximum antenna gain varies with the sector width, it is also necessary to adjust the maximum transmitter power level applied to the antenna to maintain the constant maximum EIRP levels. Figure 4.1 shows the EIRP levels vs offset boresight angle for different sector widths.

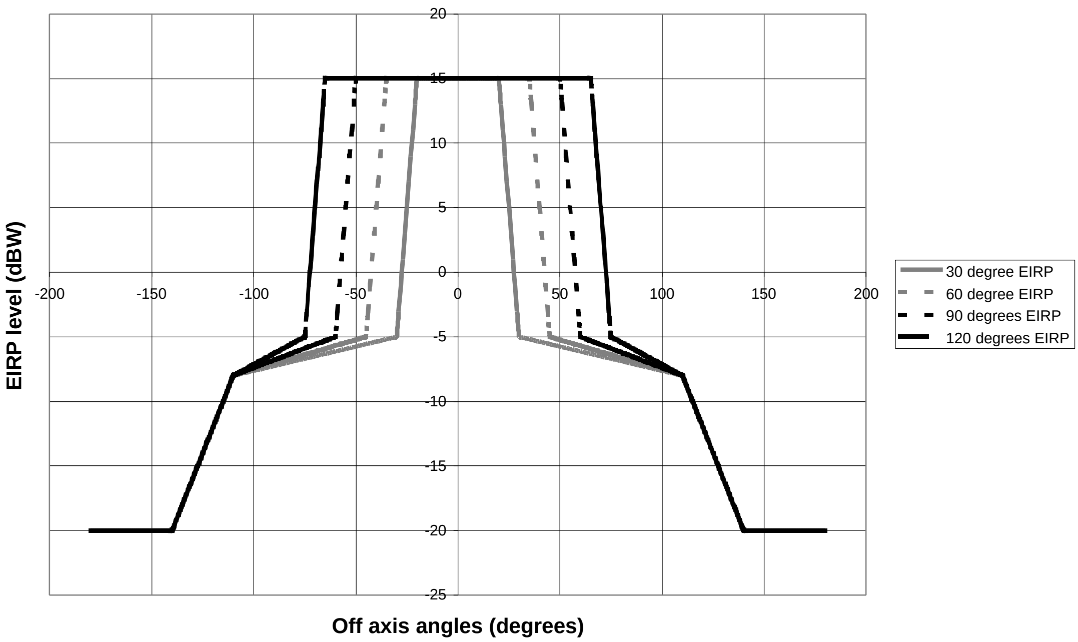

Figure 4.1. Effective isotropic radiated power level variation with PMP network cell sector width

Analysis has been performed for different percentages of interferer visibility, for scenarios where BSs are seen as potential interferers or victims of interference.

4.2 Impact of cell sector width on BS to BS interference

The interference scenario analysed in section 3.2.1. 4 of the original report and in section 2.2.3 above has been slightly modified and used as a basis for this analysis.

The statistical modelling scenario described in the original report (section 3.2.1.4) for the interference from base stations was defined so that the border PFD from any interferer is maintained at a constant level (in order to facilitate adjacent area co-ordination requirements). To achieve this, all interfering BS antennas were directed towards the service area border but their transmit power was scaled with distance so that each BS produced similar PFD levels at the border. In practice such a scenario will not occur but from the interference point of view it produces the desired outcome (i.e. required PFD level at the border between service areas). In reality, the BS antennas will be randomly orientated and some sort of shielding will be employed in order to produce the same effect (a required PFD level at the border caused by an interfering BS).

The above algorithm needs to be modified for the analyses of the impact of different cell sector widths on the interference because it does not take into account the random nature of alignment between interferer and victim antenna pattern. So an alternative method which uses random distribution of interferer antenna bearing has been modelled but which produces a similar range of interference levels for the case of 90 degree cell sectorisation as the original analysis. The new method allows each of the interfering BSs to transmit at maximum power and with random antenna orientation but the exclusion distance (in which operation of interfering BSs is not allowed) away from the border is set in order to simulate shielding and produce similar aggregate interference levels as in the original study. It was difficult to reproduce exactly the same results as in the original study, but the differences are normally not larger than ±1.5 dB and do not have any impact on any of previously outlined conclusions and recommendations.

Cell sector widths have been varied from 30 to 120 degrees, analysis performed and results compared. Figure 4.1 shows the results for the 10% visibility case. Results for 20% and 40% visibility are shown in Annex E of the report.

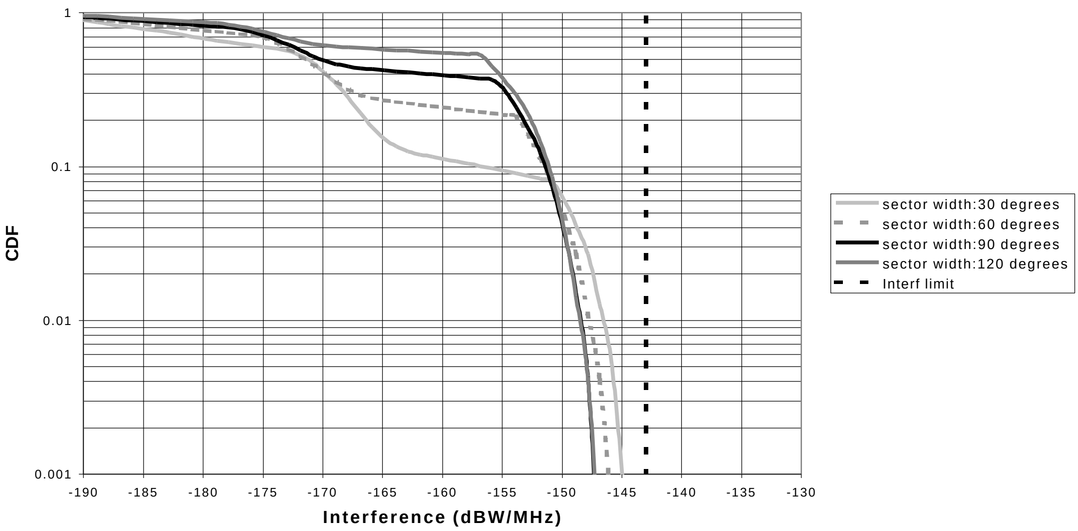

Figure 4.2: Interference CDF for base station to base station scenario (10% visibility and different cell sector widths)

Figure 4.2 shows how the sector width size has an impact on the interference CDF curves. As sector width decreases, the probability of higher interference levels occurring increases slightly. Although the maximum interferer EIRP is the same for different sector widths, the maximum gain of the victim BS receiver antenna gain is greater for the smaller sector widths and this is the reason for greater high interference levels when the narrower sectors are deployed. The interference limit is not exceeded (for the 10% visibility of the interferers) regardless of the cell sectorisation deployed and BS to BS interference should not significantly degrade PMP network performance. If the visibility of potential interference is 20% or 40%, the worst case interference level may exceed the interference limit by up to 0.5 dB (see Annex E). This will still be 5.5 dB below receiver noise threshold.

The largest effect of sectorisation can be observed in Figure 4.2 for “middle range” interference values. It can be seen that the probability of having “middle range” interference levels significantly increases with increasing the sector width. The explanation for this phenomenon can be found by observing Figure 4.1. Figure 4.1 shows that interfering EIRP levels for off axis angles between ±20 and ±65 degrees will rapidly decrease with decreasing sector width from 120 degrees to 30 degrees. Also, there is a greater probability that the main lobe of a wider sector antenna of the interfering radiated beam will be directly aligned with the main beam of the receiving antenna (particularly if the receive antenna is also wide sector antenna) than for the case of narrower beamwidth interferer.

These factors account for the variation in “middle range” interference level.

4.3 Impact of cell sector width on BS to subscriber interference

The interference scenario analysed in section 3.2.2 of the original report and in section 2.3 above has been slightly modified and used as a basis for this analysis. Cell sector widths have been varied from 30 to 120 degrees, analysis performed and results compared. Figure 4.3 shows the results for the 10% visibility case. Results for 20% and 40% visibility are shown in Annex F of the report.

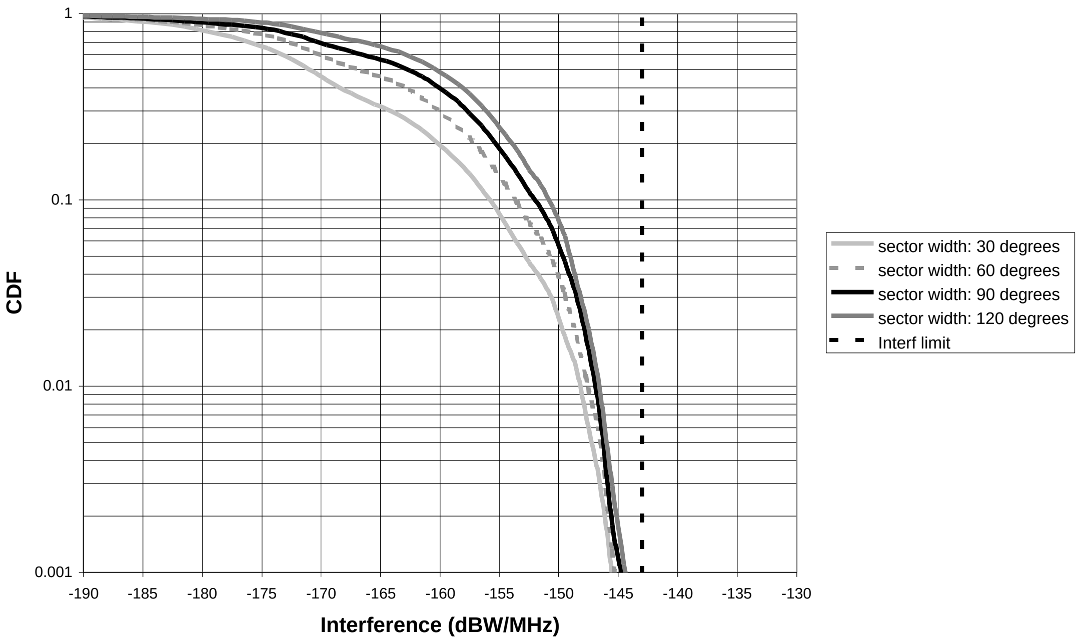

Figure 4.3: Interference CDF for base station to subscriber station scenario (10% visibility and different cell sector widths)

Figure 4.3 shows that sector width has a more significant impact on " middle range" interference level probabilities for the reasons described in the previous section. The worst case interference scenario will cause an interference level of the order of the interference limit. However, if more than 10% of base stations are visible to the victim subscriber station, the interference will be exceeded (this can be observed in Annex F). In practice, the assumption of 10% visibility of potential interfering BSs is in most cases probably an overestimate due to lower heights of subscriber station antenna. It is highly likely that each subscriber station could have line-of-sight visibility with only one or two other BSs (apart from its home BS).

For the small level of visibility of interfering BSs, the worst case interference levels do not vary significantly with increasing the sector width. This is due to the fact that the 3 dB beamwidth of subscriber station antenna is narrow. So even for cell sector of 120 degrees, the probability of having direct alignment between the interfering BSs antenna boresight and victim subscriber station antenna boresight is still very low if the number of visible interfering BSs is low. If 20% or 40% of possible interferers are visible, direct alignment is more likely to occur, and the worst case interference levels will increase with increasing the sector width (as observed in Annex F).

4.4 Impact of cell sector width on subscriber to BS interference

The interference scenario analysed in section 3.2.3.4 of the original report and in section 2.4.3 above has been revisited. Victim BS sector widths have been varied from 30 to 120 degrees, analysis performed and results compared. Figure 4.4

shows the results for 10% visibility of interfering subscribers. Results for 20% and 40% visibility are shown in Annex G of the report.

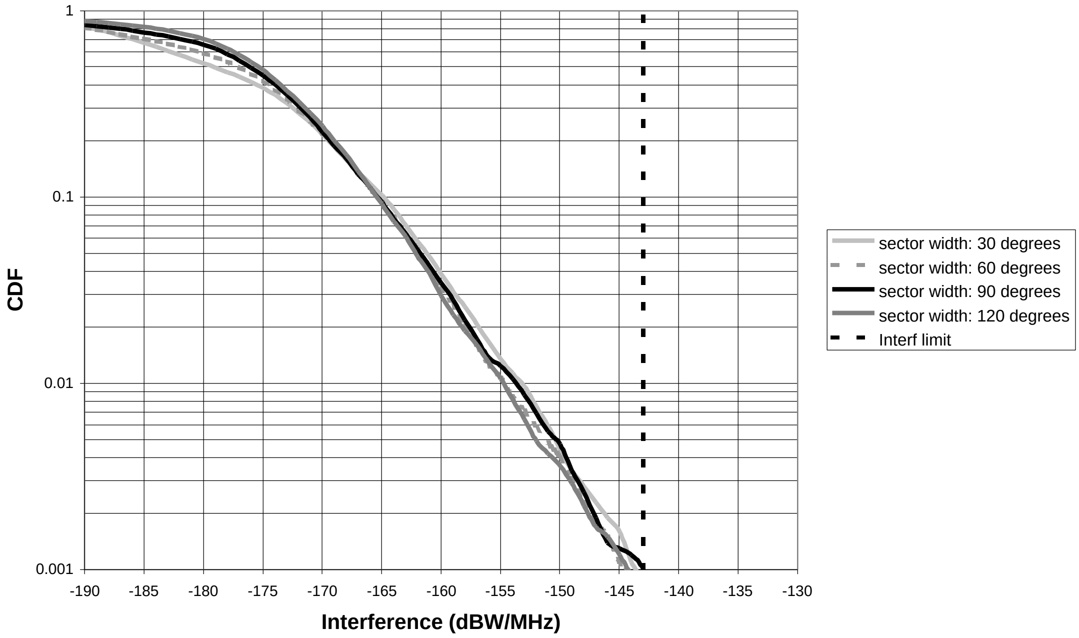

Figure 4.4: Interference CDF for subscriber station to base station scenario (10% visibility and different cell sector widths)

Figure 4.4 shows that by increasing the sector width from 30 degrees to 120 degrees, the susceptibility to interference from co-channel, co-polar subscriber stations in adjacent operator service area will on average be the same. The worst case interference levels for a narrow sector cell scenario will be larger than for the wide sector cell scenario due to the greater victim BS receiver maximum antenna gain. However, the probability of direct alignment between a narrow beamwidth subscriber station antenna and a narrow sector BS antenna patterns is so small (particularly for 10% visibility case) that there is not a great difference in the statistical interference levels for different victim cell sector widths. The interference limit is not exceeded for any victim cell sector width if only 10% of the interfering subscriber stations are visible. If 20% or 40% of interfering subscriber stations are visible, there is less than 0.25% probability that the interference limit would be exceeded and the worst case interference levels are at the level of the receiver noise threshold levels (see Annex G). In practice, only a very small number of co-channel, co-polar subscriber stations in the adjacent operator service area will be visible to the victim BS due to comparatively smaller heights of subscriber station antennas. Considering this fact and the results for the 10% visibility case, it is considered that interference from co-channel, co-polar subscriber stations in the adjacent operator service area is not likely to cause significant degradation in network performance for any cell sector width deployed.

4.5 Impact of cell sector width on mesh network subscriber to PMP BS interference

The interference scenario analysed in section 3.4 of the original report and in section 2.7 above has been revisited. The PMP network cell sector widths have been varied from 30 to 120 degrees, analysis performed and results compared. Figure 4.5 shows the results for 20% visibility case. Results for 5%,10% and 100% visibility are shown in Annex H of the report.

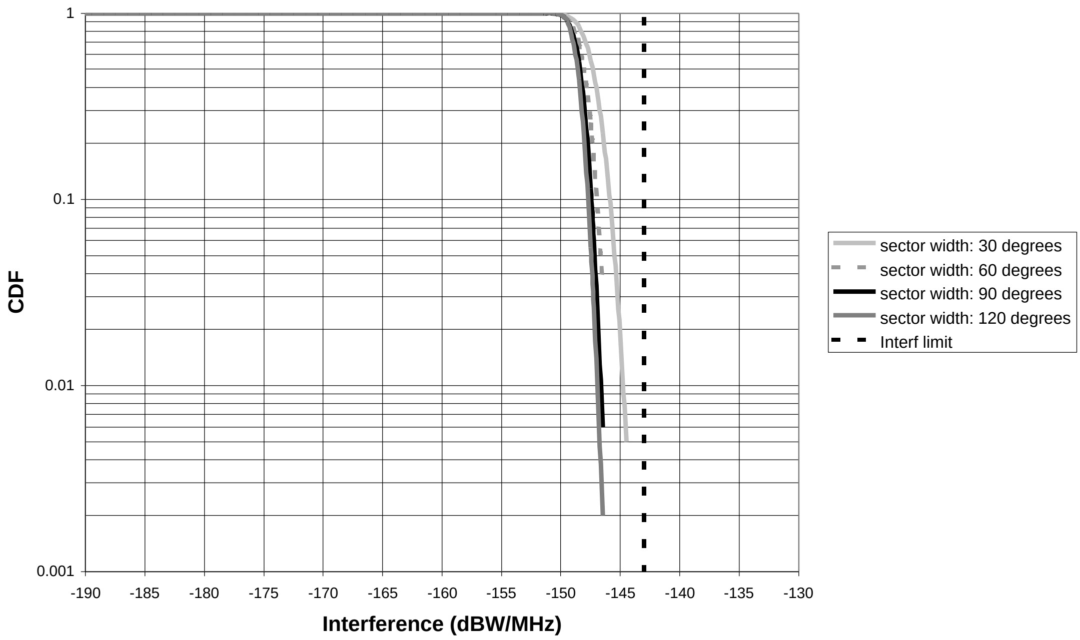

Figure 4.5: Interference CDF for mesh network subscriber station to PMP base station scenario (20% visibility and different PMP cell sector widths)

Figure 4.5 shows that by increasing the PMP cell sector width from 30 degrees to 120 degrees, the susceptibility to worst case interference levels from co-channel, co-polar mesh network subscriber stations will on average decrease by 2 dB. Observing Figure 4.5 and Annex H, it can be concluded that the interference limit will only be exceeded if all of the potential interfering mesh network subscriber stations are visible from the victim PMP BS and the PMP network deploys 90 or 120 degrees wide cell sectors. In practice, the possibility that 100% of surrounding mesh network subscriber stations are visible to a PMP network BS is negligible.

5 CONCLUSIONS

This chapter is a supplement to chapter 6 of the original report. The conclusions and recommendations below are based on the interference criteria based on the ratio I/N equal to –6 dB. The impact of different PMP cell sector widths and BS antenna downtilts on interference has been investigated and conclusions drawn as discussed below.

5.1 Boundary Power Flux Density limit for co-ordination

Our investigations have concluded that individual BFWA transmitters should be co-ordinated when the **PFD** generated at the network's service area boundary exceeds the following values:

42 GHz: -95.5 dBW/MHz/m^2 (3 dBW/MHz/m^2 higher than the original limit)

28 GHz: -99.5 dBW/MHz/m^2 (3 dBW/MHz/m^2 higher than the original limit)

5.2 PMP Base Stations

For a PMP **base** station transmitter generating an EIRP of 0.5 dBW / MHz (= 15 dBW in 28 MHz bandwidth), these PFD limits correspond to maximum co-ordination distances from the service area boundary of:

42 GHz: 13.5 km (4.5 km smaller than the original limit)

28 GHz: 21 km (6.5 km smaller than the original limit)

These maximum co-ordination distances are those at which co-ordination will be required under free space propagation conditions and are functions of EIRP. These are also the minimum distances at which a base station receiver with a directly aligned line of sight path towards the network service area boundary and a 15 dBi gain antenna will be protected against interference from individual interferers in adjacent networks.

Without co-ordination, protection from interference at locations closer to the boundary will require a reduction in the antenna gain in the direction of the boundary, or additional path loss between the receiver station and the boundary.

5.3 Subscriber Stations (PMP and Mesh)

Where uplink ATPC is deployed, and assuming a maximum transmitter EIRP of 11.5 dBW / MHz, the maximum co-ordination distances from the network service area boundary for PMP **subscriber** stations and mesh network **node** stations are:

42 GHz: **7.5 km (2.5 km smaller than the original limit)**

28 GHz: 12.5 km (3.5 km smaller than the original limit)

It is recommended that, to avoid interference from or between high density subscriber networks, operators in adjacent service areas should **avoid co-channel, co-polar operation within 5 km** of their network service area boundaries.

5.4 Effect of multiple interferers

Statistical modelling has shown that providing the following issues are satisfied:

- PMP BS antennas are downtilted by 8 degrees or more
- less than 20% of visible co-channel, co-polar interferers
- avoidance of co-polar, co-channel operation within 5 km of network service area boundaries

application of the I/N = -6 dB limits will ensure substantially interference free co-existence between adjacent service areas for both PMP and mesh architectures. Finally, this conclusion is valid regardless of the PMP network cell sectorisation deployed.

ANNEX A

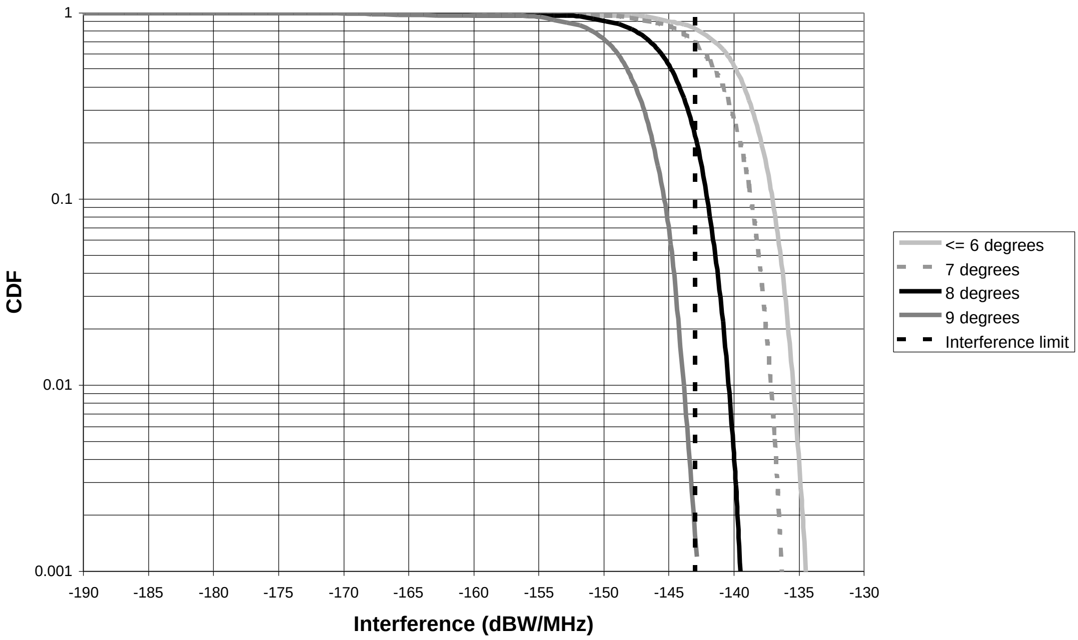

Figure A.1: Interference CDF for base station to base station scenario (20% visibility and different base station antenna downtilts)

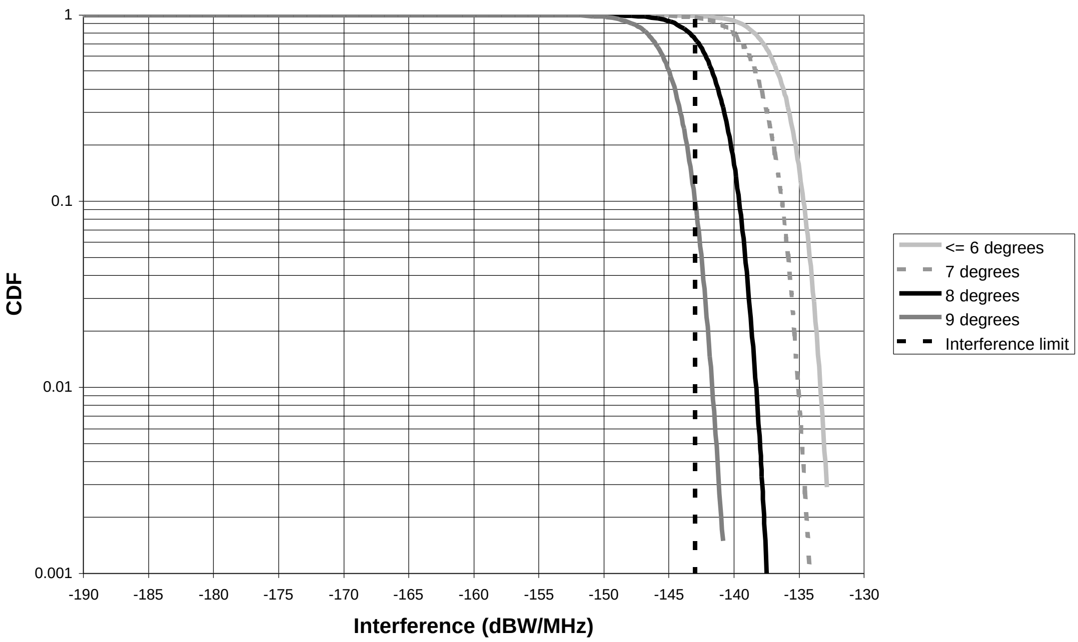

Figure A.2: Interference CDF for base station to base station scenario (40% visibility and different base station antenna downtilts)

ANNEX B

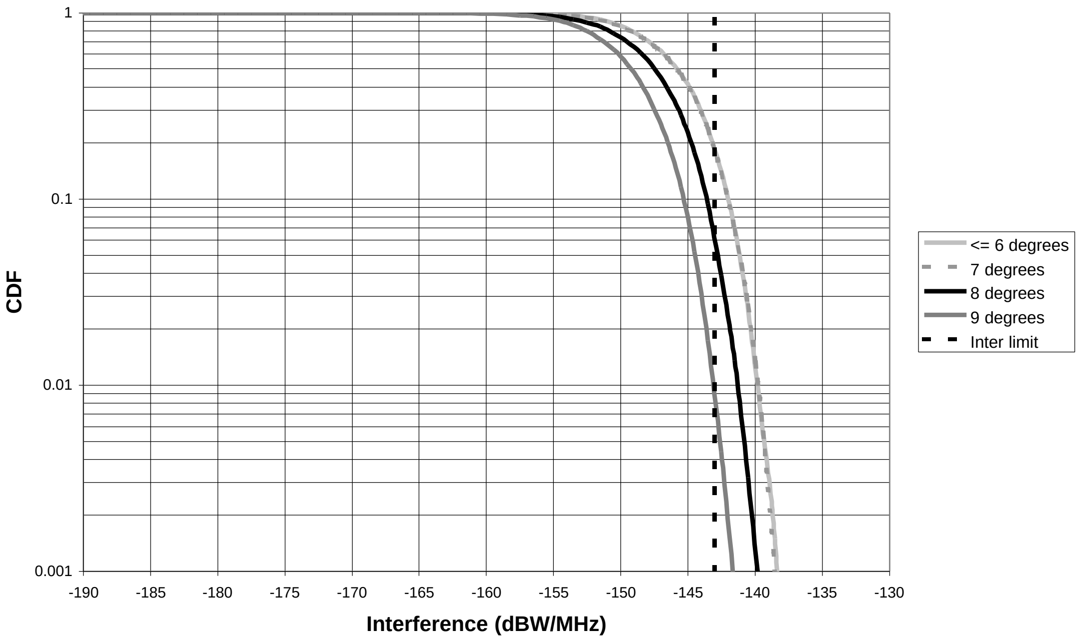

Figure B.1: Interference CDF for base station to subscriber station scenario (20% visibility and different base station antenna downtilts)

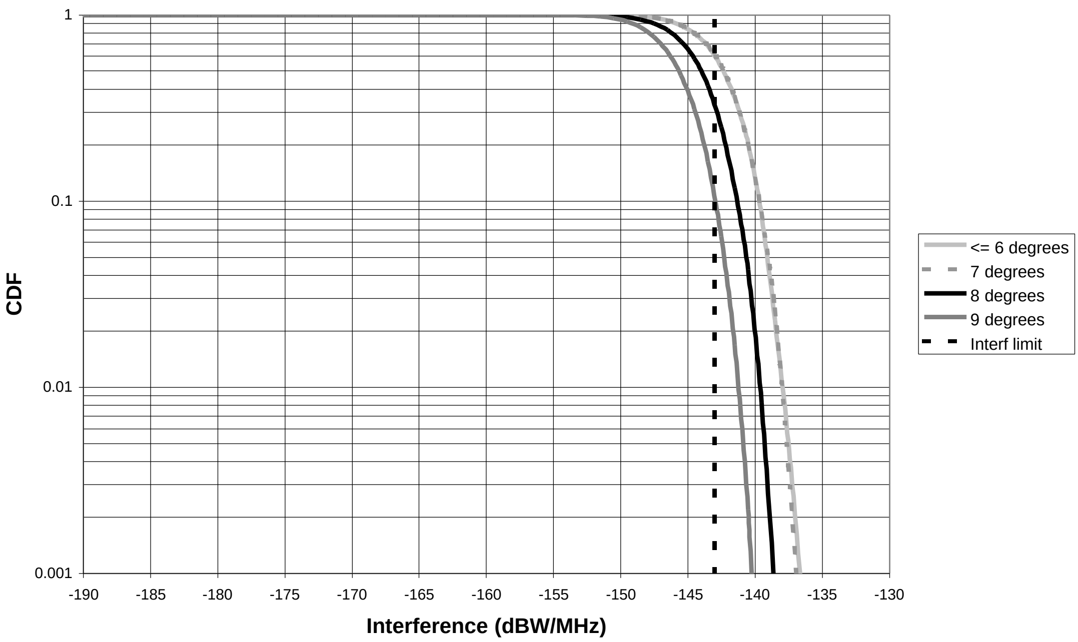

Figure B.2: Interference CDF for base station to subscriber station scenario (40% visibility and different base station antenna downtilts)

ANNEX C

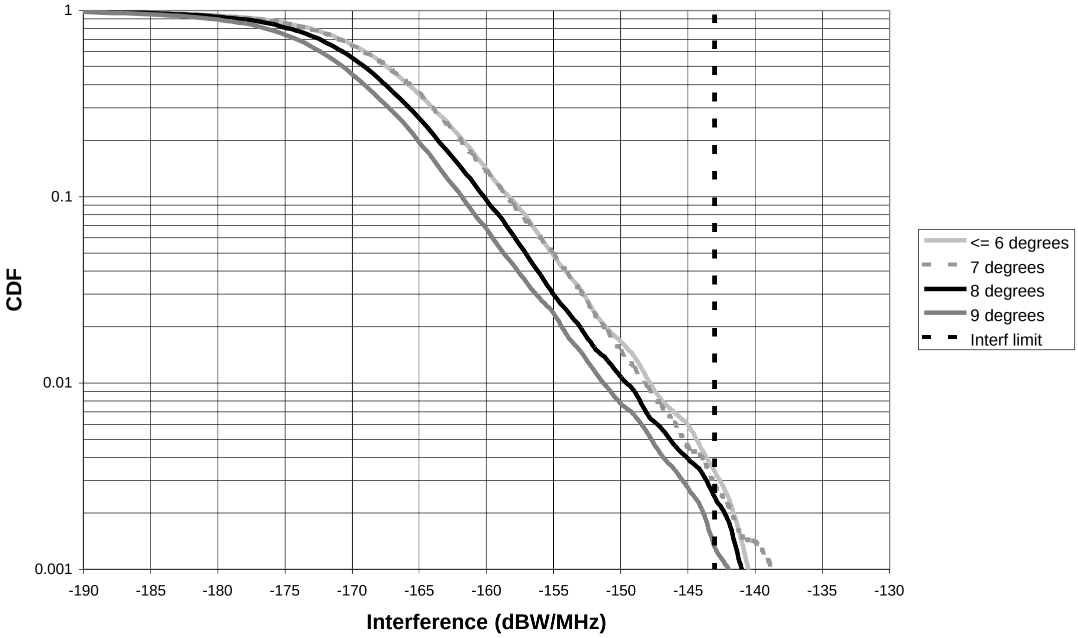

Figure C.1: Interference CDF for subscriber station to base station scenario (20% visibility and different base station antenna downtilts)

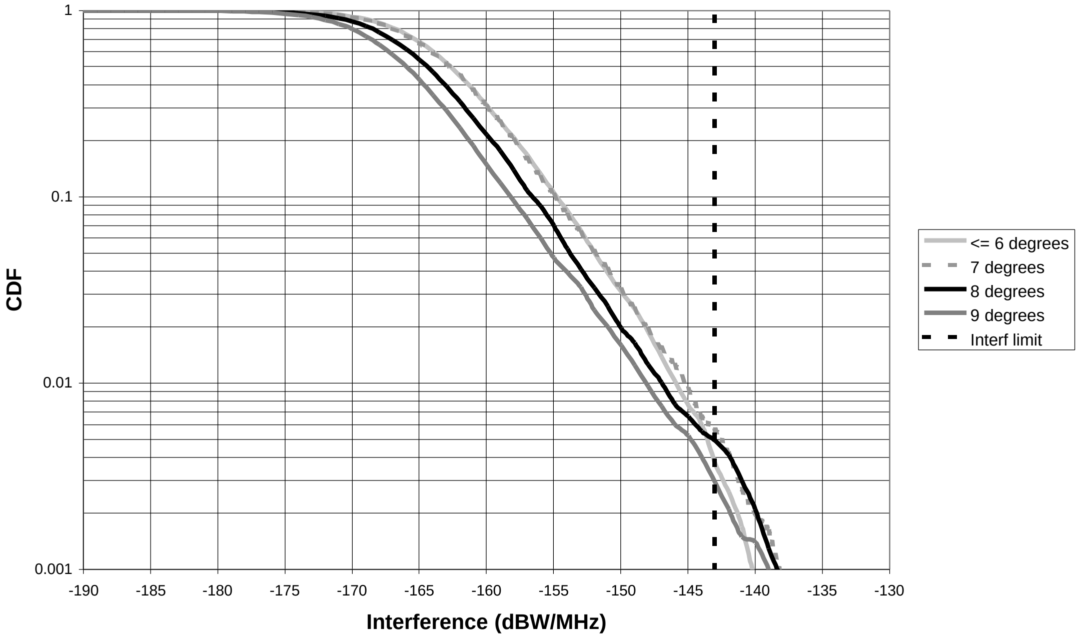

Figure C.2: Interference CDF for subscriber station to base station scenario (40% visibility and different base station antenna downtilts)

ANNEX D

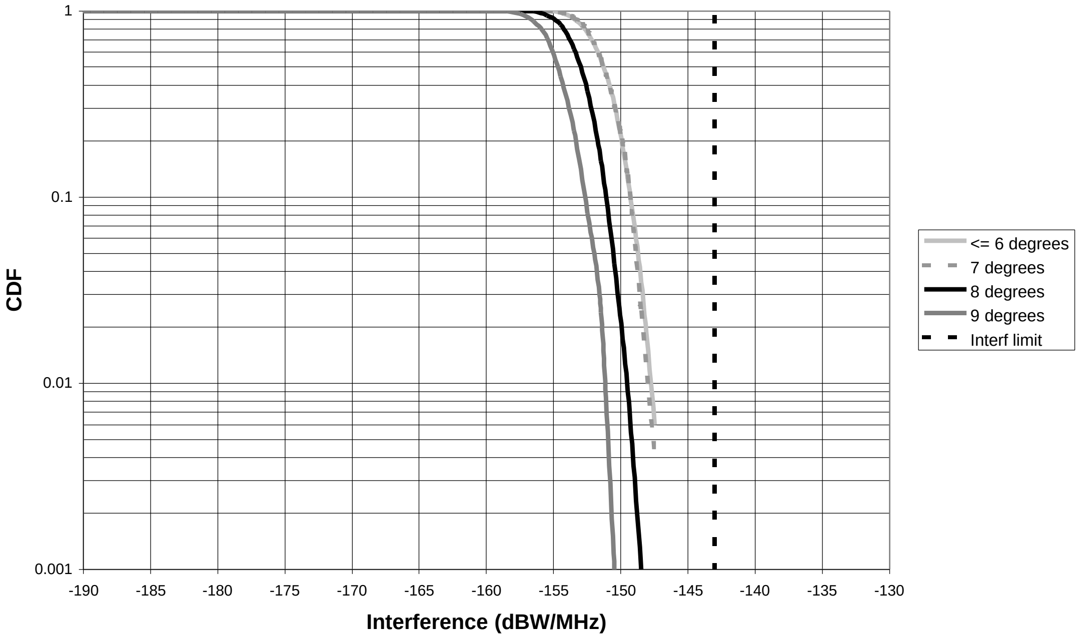

Figure D.1: Interference CDF for mesh network subscriber station to PMP base station scenario (5% visibility and different PMP base station antenna downtilts)

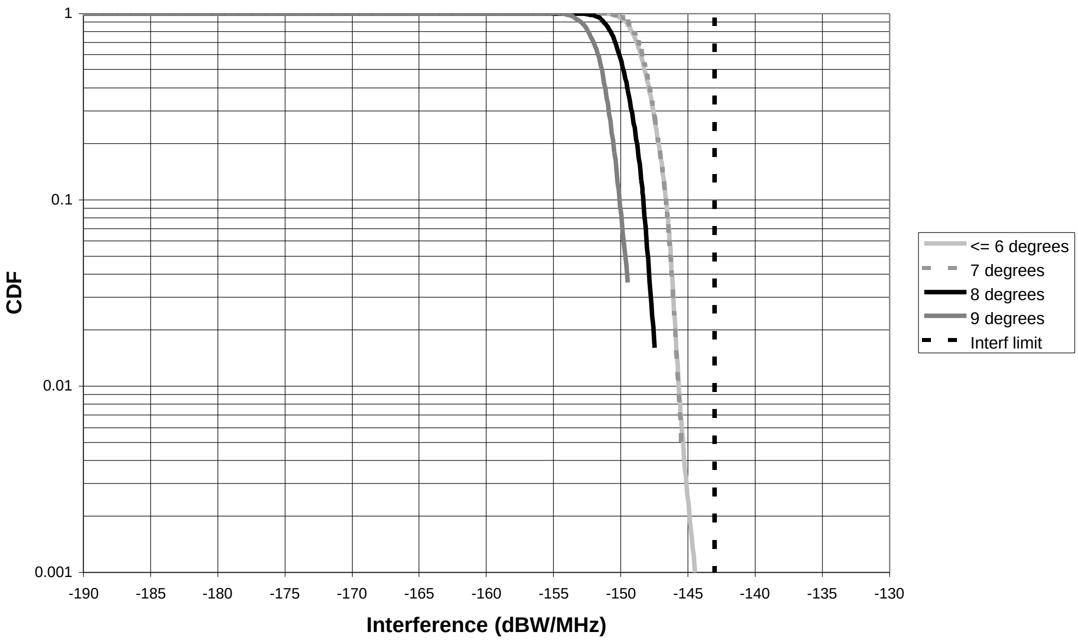

Figure D.2: Interference CDF for mesh network subscriber station to PMP base station scenario (10% visibility and different PMP base station antenna downtilts)

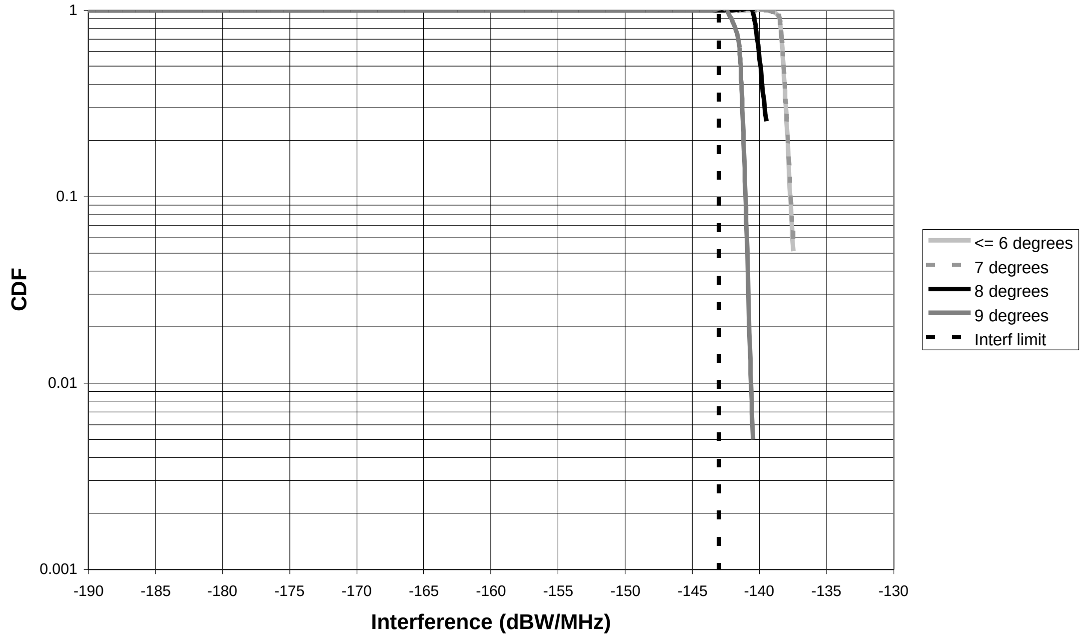

Figure D.3: Interference CDF for mesh network subscriber station to PMP base station scenario (100% visibility and different PMP base station antenna downtilts)

ANNEX E

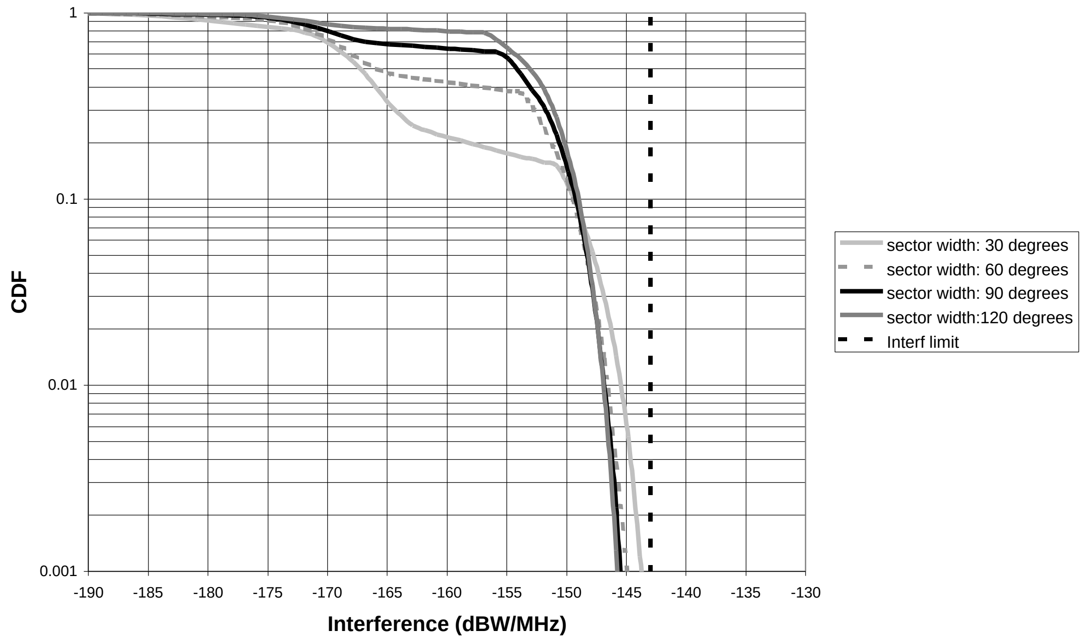

Figure E.1: Interference CDF for base station to base station scenario (20% visibility and different cell sector widths)

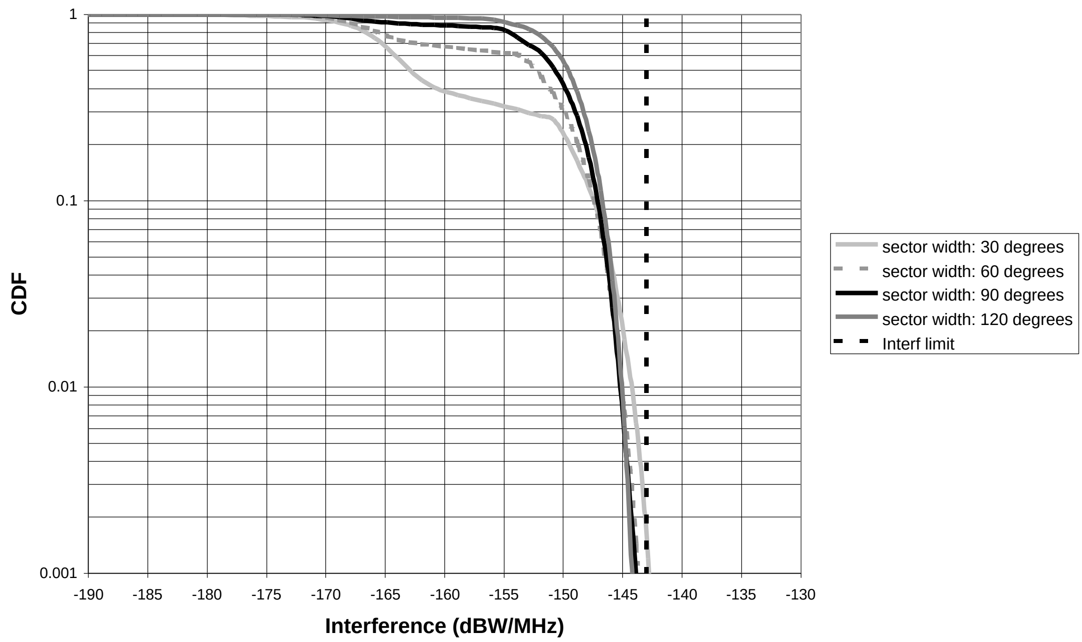

Figure E.2: Interference CDF for base station to base station scenario (40% visibility and different cell sector widths)

ANNEX F

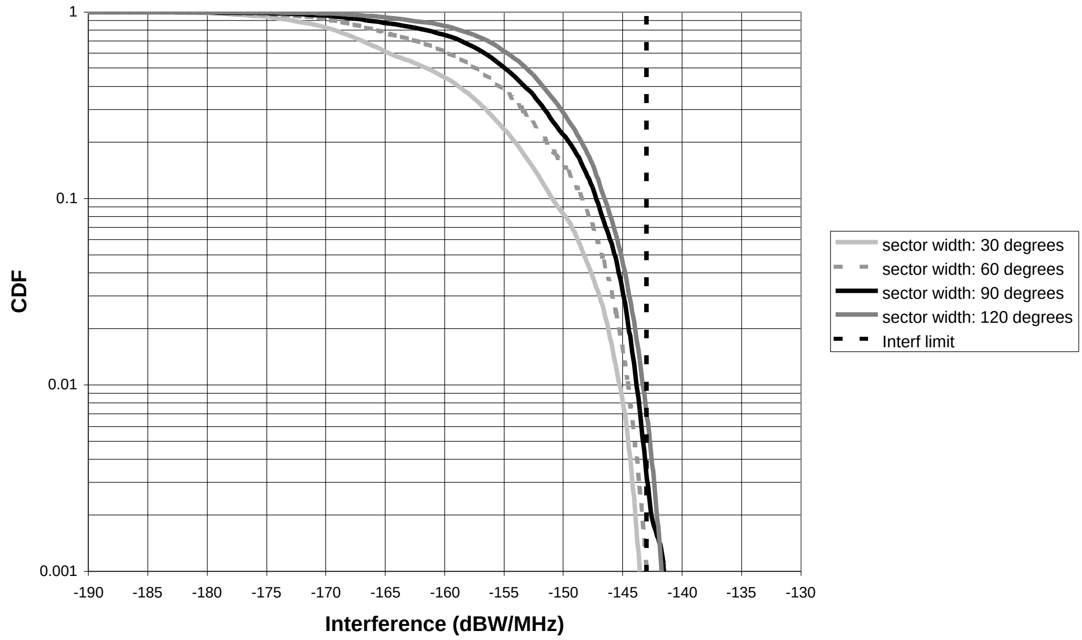

Figure F.1: Interference CDF for base station to subscriber station scenario (20% visibility and different cell sector widths)

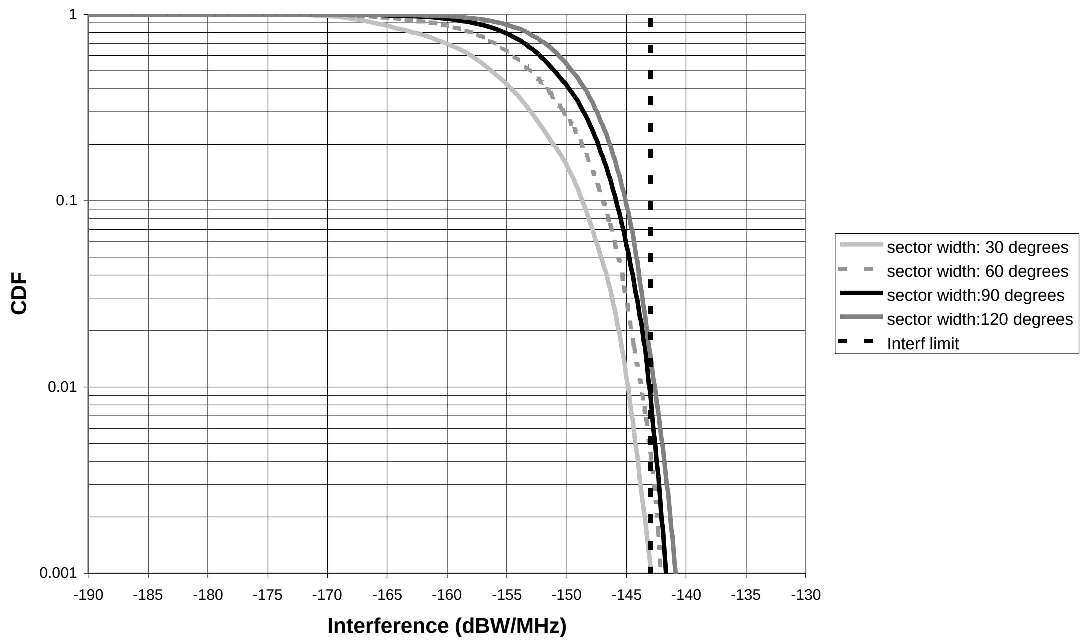

Figure F.2: Interference CDF for base station to subscriber station scenario (40% visibility and different cell sector widths)

ANNEX G

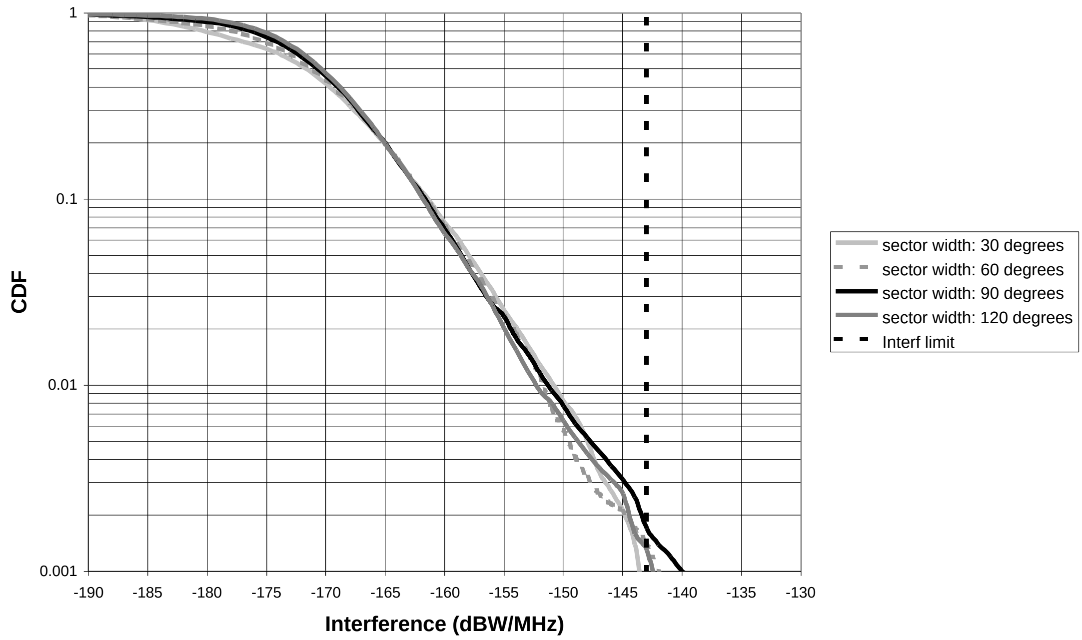

Figure G.1: Interference CDF for subscriber station to base station scenario (20% visibility and different cell sector widths)

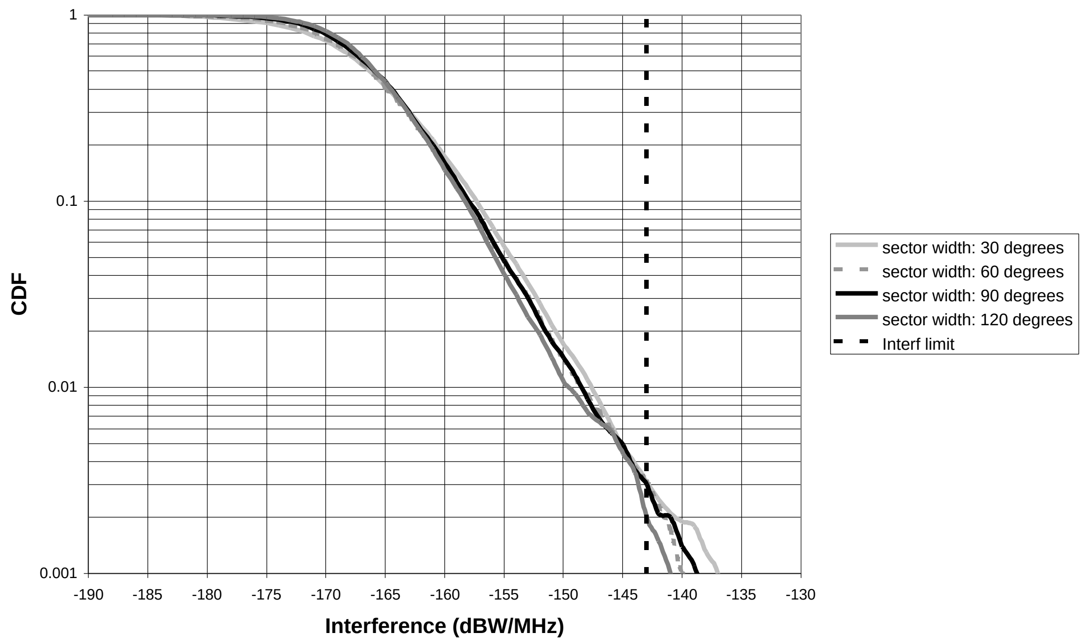

Figure G.2: Interference CDF for subscriber station to base station scenario (40% visibility and different cell sector widths)

ANNEX H

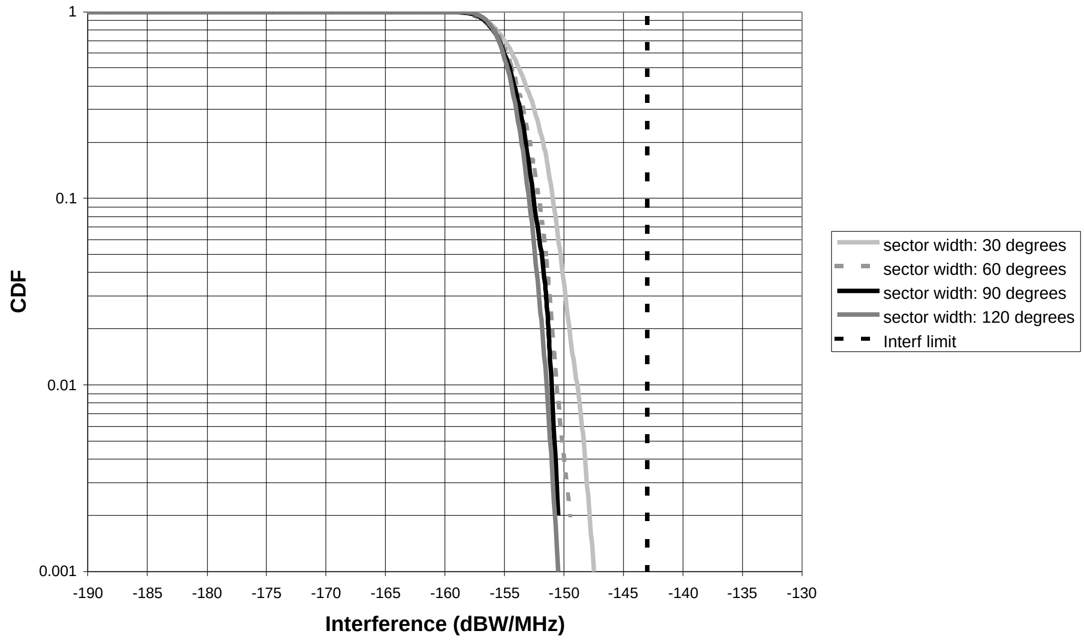

Figure H.1: Interference CDF for mesh network subscriber station to PMP base station scenario (5% visibility and different PMP cell sector widths)

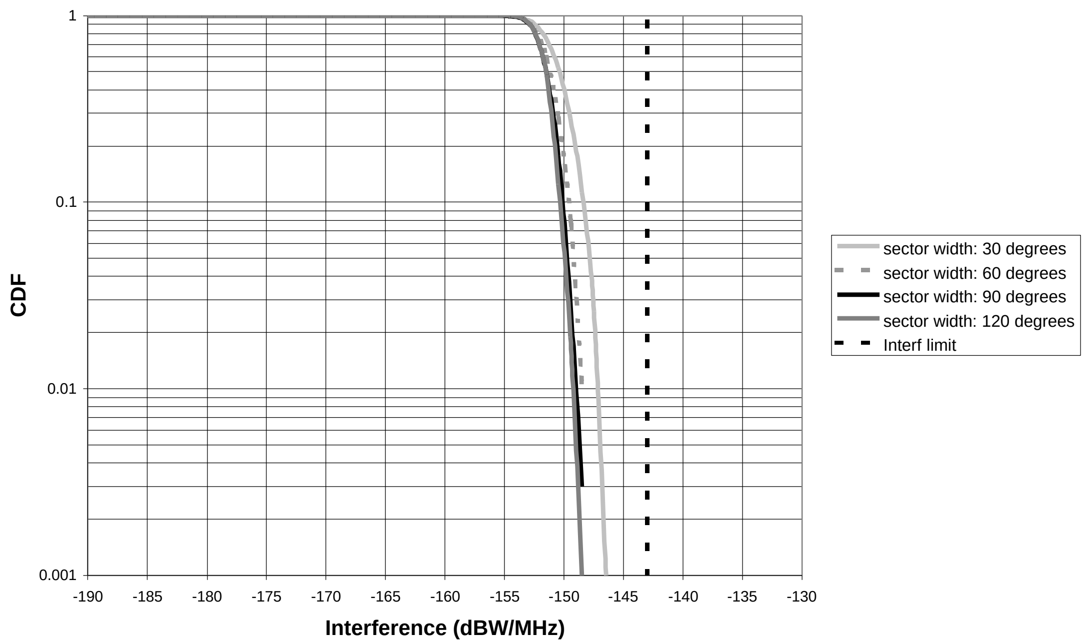

Figure H.2: Interference CDF for mesh network subscriber station to PMP base station scenario (10% visibility and different PMP cell sector widths)

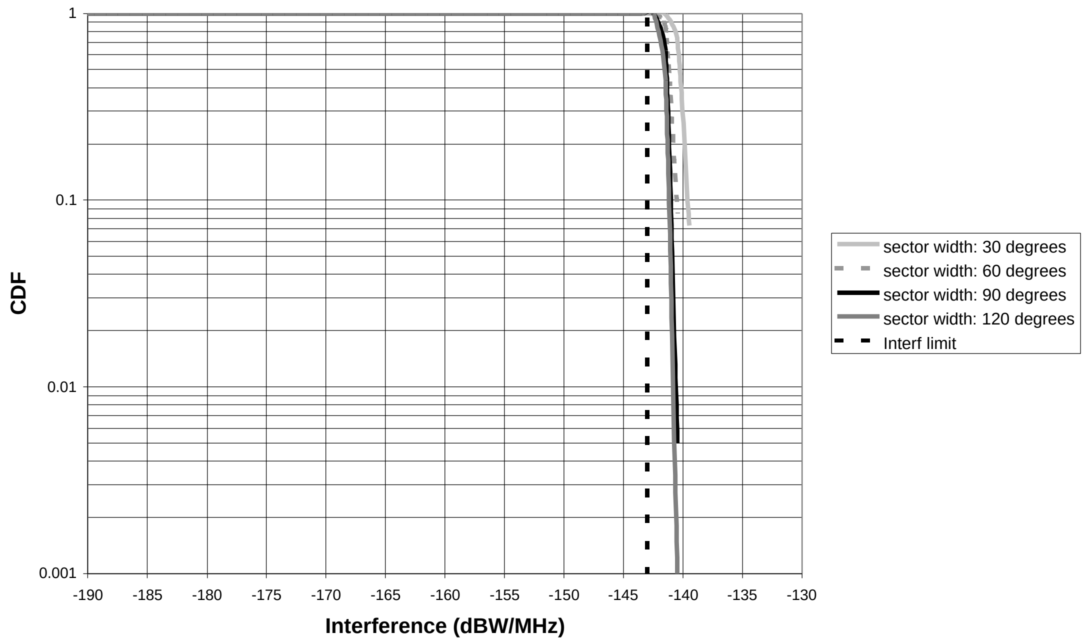

Figure H.3: Interference CDF for mesh network subscriber station to PMP base station scenario (100% visibility and different PMP cell sector width