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Title	**Guidelines for Geographical and Frequency Spacing between BWA Systems**
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Re:	Coexistence Recommended Practice.
Abstract	The document provides guidelines for geographical and frequency spacing of BWA systems that would otherwise mutually interfere. By following these guidelines, satisfactory psfd levels will, in most cases, be achieved at system boundaries. The information is therefore valuable as a first step in planning the deployment of systems.
Purpose	Contribution for sections 4, 8 and associated appendix of the Coexistence Recommended Practice, as agreed at meeting #9 (La Jolla).
Notice	
Release	
Patent Policy and Procedures	

Guidelines for Geographical and Frequency Spacing between BWA systems

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[The following draft text is for section 4 of the Coexistence Recommended Practice]

Guidelines for geographical and frequency spacing

Guidelines for geographical and frequency spacing of BWA systems that would otherwise mutually interfere are given in section [8] of this document, for each of a number of interfering mechanisms. This section summarises the overall guidelines, taking into account all the identified interference mechanisms.

The two main deployment scenarios are as follows:

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

The most severe of the several mechanisms that apply to each case determines the guideline spacing, as follows:

Table [ ] Summary of the guidelines for geographical and frequency spacing

	Dominant interference path (note 1)	FDD or TDD	Scenario	F(GHz)	System types	Spacing for acceptable Performance
1	Hub to hub	FDD/TDD	Adjacent Area, same frequency	26	PMP-PMP	[40km] CS-CS
2	Subs to hub	FDD/TDD	Adjacent Area, same frequency	26/28/40	Mesh - PMP	12km (note 2)
3	? [IEEE hub to hub case results not available]	FDD/TDD	Same area, adjacent frequency	26	PMP-PMP	1 guard channel (note 3)
4	Subs to sub	FDD/TDD	Same area, adjacent frequency	26/28/40	Mesh - PMP	1 guard channel (note 4)

The guidelines are not meant to replace the co-ordination process described in section [7]. However, in many (probably most) cases, by following these guidelines, satisfactory psfd levels will be achieved at system boundaries. The information is therefore valuable as a first step in planning the deployment of systems.

Note 1: The dominant interference path is that which requires the highest guideline geographical or frequency spacing

Note 2: The 12km value is based on a hub at a typical 50m height. For other values, the results change to some extent but are always well below the 40 km value calculated for the PMP – PMP case.

Note 3: The single guard channel spacing is based on both interfering and victim systems using the same channel size. The required spacing for other scenarios has not been analysed [but note the CEPT conclusion to which we could refer – i.e. the guard channel should equal the channel size of the system with wider channels]

Note 4: The single guard channel spacing for mesh to PMP is based on both interfering and victim systems using the same channel size and may be reduced in some circumstances. The required spacing for other scenarios (differing channel sizes) has not been analysed.

[text for section 8]
[use of terms to be normalised: TS/CS/RS or sub/hub/rptr]

Guidelines for Geographical and Frequency Spacing between BWA systems

Summary

This section provides guidelines for geographical and frequency spacings of BWA systems that would otherwise mutually interfere. The guidelines are not meant to replace the co-ordination process described in section [7]. However, in many (probably most) cases, by following these guidelines, satisfactory psfd levels will be achieved at system boundaries. The information is therefore valuable as a first step in planning the deployment of systems.

The actual psfd levels can then be calculated or measured, as appropriate, and any adjustments to system layout can then be made. These should be relatively small, except in unusual cases.

Interference Mechanisms

Various interference mechanisms can reduce the performance of BWA systems. Although intra – system interference is often a significant source of performance degradation, it is not considered in this analysis. Its reduction to acceptable levels requires careful system design and deployment but these are under the control of the operator, including the decision as to what constitutes an acceptable maximum level. Thus, only inter-system interference mechanisms are considered, where inter-operator co-ordination may have to be considered.

In each frequency band assigned for BWA use, there may be different types of systems deployed, some conforming to 802.16.1 standards and some designed to other specifications. Therefore, we consider a wide range of possibilities in determining the likely interference levels and methods for reduction to acceptable levels.

There are two main scenarios, each with several variants:

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

The various potential CS-TS-RS interference paths must be considered to determine how much interference will occur. Between any two systems, there may be several interference mechanisms operating simultaneously. The geographical or frequency spacing (or both) necessary to reduce interference to acceptable levels is then determined by the most severe mechanism that occurs.

A number of techniques have been used to estimate inter- system interference:
Worst case analysis
Interference Area method
Monte Carlo simulations

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

[Results for each interference mechanism are detailed separately. The worst case for typical situations is then summarised.]

Worst-case analysis

[from Howard Sandler's earlier work – should we include some of the results from the early input papers?]

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

Simulations

There are many cases where a simple worst - case analysis is of limited use. Where there are many possible interference paths between a particular type of interferer and the associated victim stations, the worst case could be very severe but may also be very improbable. Planning on the basis of the worst case would then be unrealistic. An example is the interference between subscriber stations of different operators in the same geographical area. Most interference will be negligible but a certain small proportion of cases could have very high interference levels.

Monte - Carlo simulations provide a means of assessing the probability of occurrence of a range of interference levels at victim stations. The recommended geographical or frequency spacing is then a compromise, in which an acceptably small proportion of cases suffer interference above the recommended limit (e.g. 1% of randomly positioned subscribers would suffer interference above the desired level).

A model of an interference scenario is created using realistic parameters, in which the placement of BWA stations (usually the TS) can be randomly varied. Other randomly varied parameters may be included, such as buildings and terrain factors. The simulation is run many times and the results plotted as a probability distribution.

Interference Area (IA) method

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

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

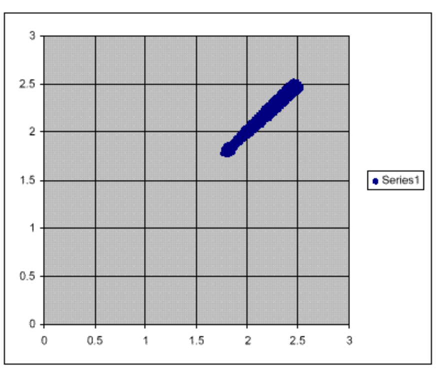


Fig. [ ] Example of Interference Area diagram (CS-TS adjacent area case)

ISOP (Interference Scenario Occurrence Probability)

Although not used in this document, the concept of ISOP may be interesting in some cases. The ISOP analysis is an extension of the IA method, in which a calculation is made of the probability that at least one victim terminal will be inside the IA. The probability may be averaged across a wide range of different frequency and polarisation assignment cases and therefore may not be representative of a specific deployment. Further information on the ISOP method can be found in a draft CEPT/ERC technical report SE19(99)195, due for completion and publication during 2000.

Table [ ] Summary of the simulations and calculations

	Path (note 1)	FDD or TDD	Scenario	F(GHz)	Method	Spacing for acceptable Performance	Source of analysis
1	Sub to Hub	FDD/TDD	Adjacent Area, same frequency	26	Monte Carlo simulation	40km CS-CS	Wavtrace (GJG)
2	Hub to Sub	FDD/TDD	Same area Adjacent channel(s)	26	Monte Carlo simulation	1 guard channel (note 2)	Wavtrace (GJG)
3	Sub to Hub	FDD/TDD	Same area, adjacent frequency	26	Monte Carlo simulation	1 guard channel (note 2)	Wavtrace (GJG)
4	Hub to Sub	FDD/TDD	Same area Adjacent channel	26/28	Interference Area (IA)	1 guard channel = 0.5-2% IA (note 2)	TTPCom (JH)
5	Sub to Sub	TDD	Adjacent channel	26/28	Monte Carlo simulation	1 guard channel (note 2)	TTPCom (JH)
6	Sub to Sub	TDD	Co-channel	26/28	Monte Carlo simulation	Low probability if CS-CS >35km	TTPCom (JH)
7	Sub to Hub	TDD/FDD	Co-channel	26/28	Interference Area (IA)	35km CS-CS	TTPCom (JH)
8	Hub to Hub (multiple interferers)	TDD-FDD	Co-channel	26GHz	Monte Carlo simulation	[60km] (note 3)	Crosspan (JLL)
10	Mesh to PMP Hub	TDD/FDD	Adjacent area, same frequency	26/28/40	Monte – Carlo Simulation	12km CS to mesh edge	Radiant
11	Mesh to PMP Sub	TDD/FDD	Adjacent area, same frequency	26/28/40 Note 3	Monte – Carlo Simulation	Low probability if mesh edge to CS >12km	Radiant (PW)
12	Mesh to PMP Hub	TDD/FDD	Same area, adjacent frequency	26/28/40 GHz	Monte – Carlo Simulation	1 guard channel (Note 4)	Radiant (PW)
13	Mesh to PMP Sub	TDD/FDD	Same area, adjacent frequency	26/28/40 GHz	Monte – Carlo Simulation	1 guard channel (Note 4)	Radiant (PW)

Note 1: All scenarios represent interference paths between two different PMP systems unless otherwise stated.

Note 2: The single guard channel result is derived from an analysis in which the channel size of interfering and victim stations is the same. Results from other work [ref to CEPT ???] indicate that where channel sizes are different, the guard channel size should be equal to that of the wider channel system.

Note 3: The results from the multiple CS interference simulation are based on an adverse terrain assumption and on the use of omni directional hub antennas. The victim hub is assumed to be at a high location, with clear line of sight to all interfering hubs. Results taking account of terrain and building losses and sectored hub antennas are for future analysis. [the 60km figure and the analysis for the CS to CS case is subject to further review and possible further input from the RA (UK)].

Note 4: The single guard channel is a conservative figure. Even with zero guard channels, a large proportion of simulation runs produced much lower interference than the desired threshold. Thus, by careful design or by use of automated interference mitigation, the guard channel could be reduced or eliminated.

Variables

In the simulations, a number of parameters have been varied in order to test the sensitivity of the results to critical aspects of system design. In particular, antennas with various RPEs have been evaluated. It is concluded that, although many results are improved significantly by use of more tightly specified antennas, the absolute value (probability of interference) tends to be quite low with all the antennas considered. On this basis, good practice is to choose the best antenna possible, consistent with system economics.

In some configurations, the intra system interference considerations will dominate the decision on antenna RPEs. Effective frequency re-use between cells will demand the use of antennas that can provide satisfactory inter-system interference levels.

Results of the analysis

Simulations have been undertaken for many of the interference mechanisms described
Below. A summary of each method and its results is given in Appendix [ ]

Co-channel case

Hub to Hub co-polar, single and multiple interferers

The hub to hub interference is not necessarily the worst case but, when interference occurs, it affects a large number of users at the same time. Mitigation, by moving or re-pointing the hub or by changing frequency is very disruptive to a system. Therefore, a relatively "safe" value should be applied to co- channel, co-polar geographical spacing. Shorter distances are possible but it is recommended that these be verified by actual signal measurement. Occasionally, the normal recommended geographical spacing will not be sufficient, due to adverse terrain conditions. Where one station is on a local high point, which is much higher than the mean level of the surrounding terrain, it is recommended that a specific calculation or measurement be made of the interference level and the necessary geographical spacing derived from this.

The results for this case section are derived from worst-case analysis (for a single interferer and a typical set of system parameters) and from simulation. The IEEE 802.16.1 standard is still evolving and results of the analysis may need to be reviewed when final systems parameters are known. Meanwhile, we have used parameters that are typical of BWA systems.

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

Subscriber to Hub, co – channel case

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

Interference may be experienced in localized areas only. In these areas, the interference may be high. However the size of the areas and hence the probability of interference is usually low.

In the case of mesh systems, there may be several interferers on a given channel, although only a small number will transmit simultaneously and very few will be visible at a particular hub. Simulation (Monte Carlo modelling) is needed to analyse this case of multiple interferers.

Subscriber to subscriber, co-channel case

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

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

Overlapping Area Case

Hub to hub interference

[No simulations available – worst case analysis only done for co-channel situation.]

[Note that the CEPT report indicates that TDD-FDD or TDD-TDD are worst cases and that these require guard channel plus possible geographical spacing]

[the following table should be incorporated into the main results table, when values have been computed – this may be in a later edition of the recommended practice]

Table [ ] Summary of hub to hub interference mechanisms

System Types	Guard band required	Rationale
Hub to Hub, single interferer TDD and non harmonized FDD	[One guard channel equal to that of the wider of the 2 systems] ??	Worst case analysis [tba] not done [new calculation required]
Hub to hub, side lobe interference on adjacent channel	[??? May be important to specifiy tighter hub sidelobe performance]	[Simulation – we are looking to conclude whether we need a better hub antenna than CS1]
Hub to Hub, multiple interferers	[??] not done – depends on frequency re-use plan – no general answer possible	Simulation [??]
Mesh to PMP	Not applicable	No hubs in mesh networks

Hub to sub interference

The interference experienced depends on the system configuration. In PMP systems, there are certain parts of the cell areas that are strongly affected and others that are not affected at all. In general, the proportion of the cell area(s) affected is small but where interference does occur, it may be at a high level. It can be reduced by the use of guard bands and more highly specified subscriber antennas.

For mesh systems, this type of interference could occur over a wide area, but has relatively low probability. In practice a mesh network can include a mechanism to detect and avoid this type of interference.

Sub to hub interference

In PMP systems, this type of interference is evaluated by use of a simulation programme. It is clear that an interfering TS could be relatively close to a victim CS but the level of interference depends on the relative locations of the hubs of the two systems (which affects the antenna pointing direction) on the use of ATPC and on possible differential rain fading. This case is analysed in [ ] and shows that a single guard channel between systems will in general be a good guideline for uncoordinated deployment.

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

Subscriber to subscriber, same area case

This problem has to be analysed by use of simulations (Monte Carlo modelling). In general, the probability of interference occurring is low but, when it does occur, the level can be high. Unlike the hub to subscriber case, the high levels of interference are not in predictable parts of the cell(s). Mitigation is by use of guard bands, improved antennas and (in mesh systems) by re-routing so as to avoid the worst pointing directions of antennas.

An analysis of this case can be found in [ ] for the PMP case and in [ ] for the mesh-PMP case.

[Other considerations:

Noise from inactive TDMA subscriber transmitters can be additive and de-sensitise a hub receiver – how to simulate? Might specify maximum noise level allowed when not in active timeslot.

Subscribers close to hubs may be facing a null in the hub pattern and therefore transmit at higher power and at an upward angle. This might cause increased interference??]

Appendix ( ) Description of Calculations and Simulation Methods

Subscriber to Hub, Adjacent area, same frequency

These simulations examine interference sensitivity across a service area or Business Trading Area (BTA) boundary. They examine the interference sensitivity between co-channel interference situations assuming an uncoordinated alignment of interference and victim sectors. Interference impairment is appropriately expressed in terms of power flux density (pfd) defined in terms of dBW/MHz/m^2.

The simulation estimates consider only a clear sky environment, as this is the trigger threshold on which operator coordination is recommended. The recommended boundary pfd trigger level for operator coordination is -114 dBW/MHz/m^2.

Simulation Model (TS to CS)

Figure [x] illustrates the simulation model. Two co-channel sectors are exposed to each other across a boundary.

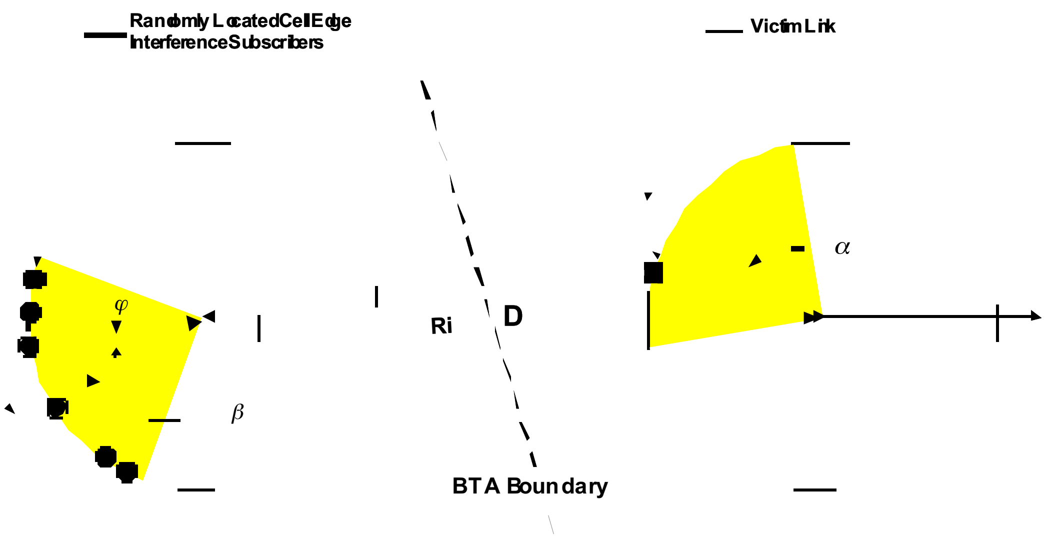


Fig [x]

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

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

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

Simulation Results

The main conclusions from this analysis are:
at distance D = 40km or greater, the cumulative distribution curves show negligible exposures above the required pfd threshold. This is therefore a satisfactory preliminary planning value for hub to hub spacing with no co-ordination.
ETSI CS1 antennas (sectored hub antennas) show much more rapid increase of pfd values above the threshold than other types. These antennas should therefore be used with care and antennas with better sidelobe performance are generally preferred.

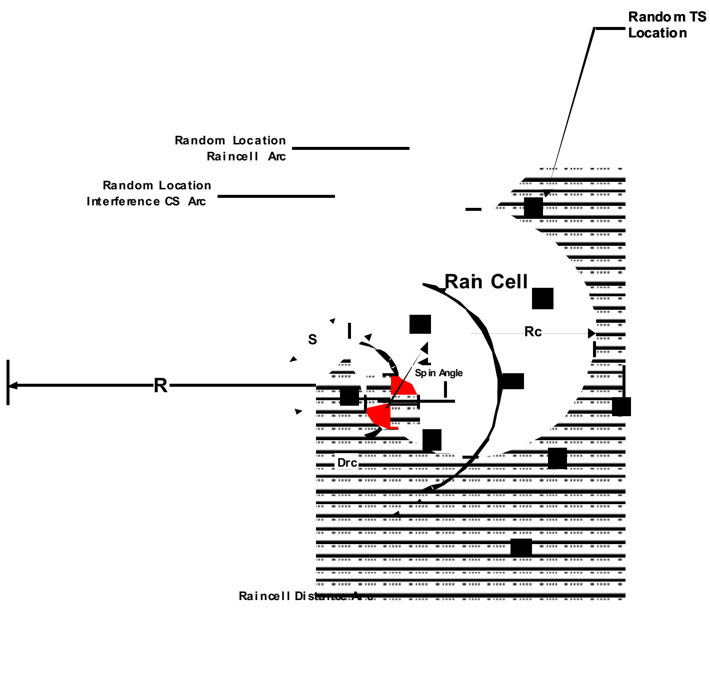
Hub to Subscriber (CS to CS), same area, adjacent frequency

These simulations address the case of multiple operators deployed in a given geographical area that are employing adjacent frequencies. In this case, the most serious conflicts occur when two operators have adjacent carriers of the same polarization. The most severe deployments are thus represented by cell overlays involving VB/VD or HB/HD. Dependent on an operator's ability to establish reserve carrier assignments there may or may not be a guard band(s). Hence, the NFD protection ratio may be either 20dB (adjacent channel operaytion) or 49 dB (one guard channel).

The simulations assume that both operators employ the same carrier bandwidth (assumed as 28 MHz for the analysis). Also assumed is that both operators employ a comparable set of transmission.

Simulation Model (CS to TS)

Figure [9] illustrates the simulation model. The interference CS is placed in the victim sector at some parameterized distance S between the hub centers.



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

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

For each rotational spin of the interference CS, the angular position of the rain cell is randomized. Angular rotation is restricted to be within +/- 45 degrees, thus ensuring that the full diameter of the rain cell is always within the victim sector.

Twenty victim subscribers are selected for each rotational spin. For each spin, the rain loss of interference and victim vectors is computed, based on the geometry and rain loss procedure described in Section 3.0. Victim signal levels are computed based on the transmission parameters, link distance and rain loss. Interference signal levels are similarly computed but with the inclusion of antenna angular discrimination, relative frequency polarization and NFD. A single interference computation accounts for the contribution of each of the four CS sectors and each spin represents 20 independent C/I estimates. Thus a simulation is represented by 1440 C/I estimates. These are sorted and employed to develop a CDF for C/I at given values for S and D_{rc}.

Simulation results

The results for adjacent channel operation, with each of the antenna types considered, is unsatisfactory, with many exposures below the required C/I ratio. With a single (in this case 28MHz) guard channel, the proportion of exposures below the required C/I ration is very low. Thus, a single guard channel is satisfactory as an initial planning guide to mitigate CS to TS.

The results were not found to be sensitive to antenna RPE, except at very high values of C/I.

TS to CS interference must also be considered in the final choice of guard bands between systems operating in the same area.

Further details of this simulation can be found in IEEE 802.16.Xc-00/NNr0 (ref.[ ])

Same Area/Adjacent Frequency (TS to CS)

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

The system frequency and polarization model is identical to that of Figure [xx] and the simulation model employs the same methodology as described in Section [5.2.1] with ATPC now included.

Simulation Model (TS to CS)

It is now convenient to consider the victim CS to be as illustrated on Figure [xxx]. The rain loss of each of the 20 interference TS links is computed based on their exposure distance within the rain cell. The TX power of each interference TS is then ATPC adjusted to ensure that its combined distance and rain loss signal level suppression is such that it meets margin objectives. The signal level of each interference path into the victim CS is then computed based on the transmission criteria of the link.

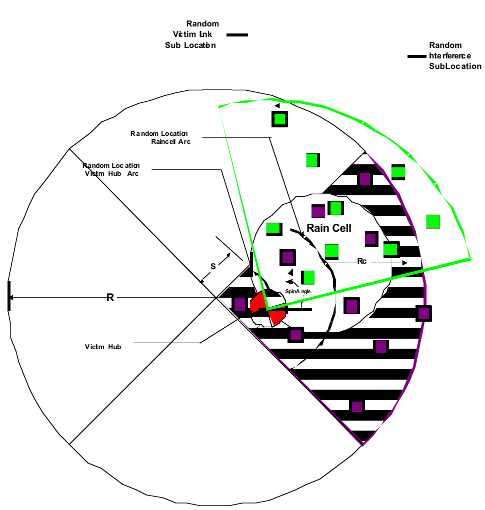


Fig xxx

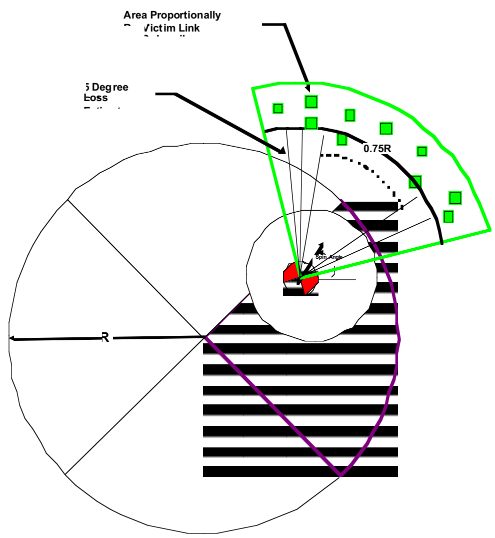


Fig xxxx

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

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

Simulation results

As with the CS to TS case, adjacent channel operation was found to be unsatisfactory, with many exposures suffering a C/I below the required limit. Similarly, a single guard channel reduces interference to an acceptable level.

Antenna RPEs have some impact on the results but are not a controlling factor.

CS to TS, Same area, adjacent channel, Interference Area method

This simulation derives the Interference Area (IA) for systems operating in the same area. It applies to FDD and TDD systems. The Interference Area (IA) is the proportion of the sector area where interference is above the target threshold, equivalent to the probability that a TS placed at random will experience interference above the threshold.

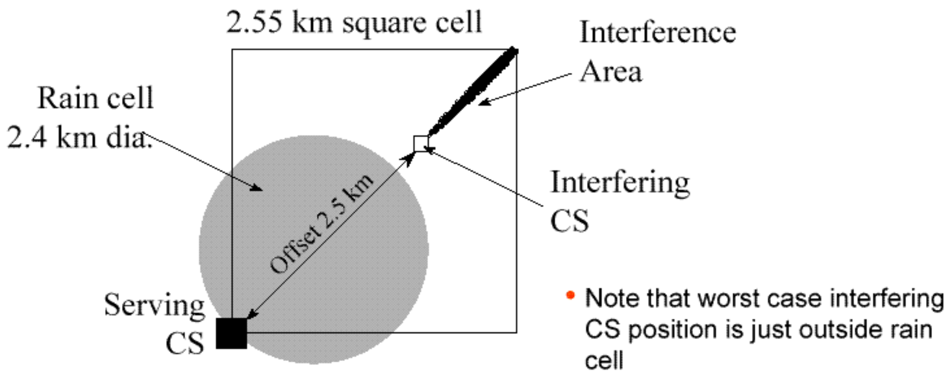


Fig. [y]

Analysis shows that the worst case is where the interfering CS is spaced approximately [0.6] times the cell diagonal away from the serving CS and when a rain cell in the most adverse position reduces the wanted signal. This is illustrated in fig. [y]

Simulation Method

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

Simulation Results

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

TS to TS, same area, adjacent channel, TDD only

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

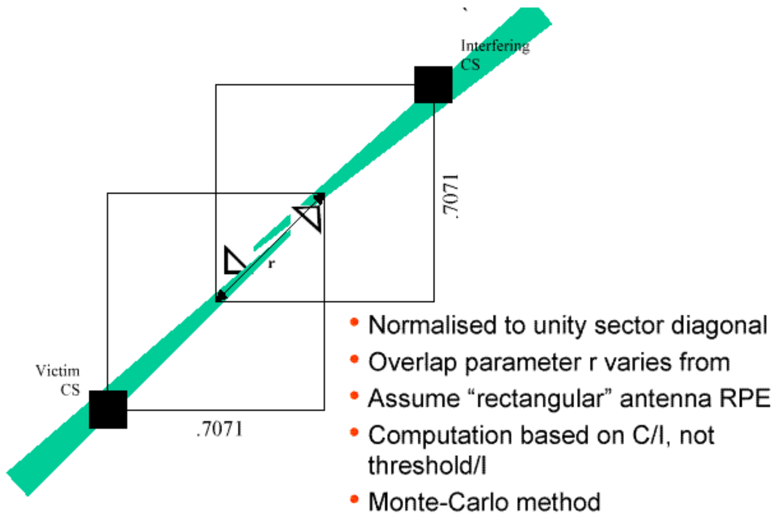


Fig [yy]

Simulation method

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

Simulation results

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

For small overlap values, the C/I ratio can be low but the probability is also very low

The maximum probability of conflict occurs at an overlap value of r=2, where the probability rises to approaching 10%. However, the C/I ratio is then at an acceptable level

Rain fading has a neutral or beneficial effect.

TS to TS, co – channel, adjacent area (TDD)

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

Simulation method

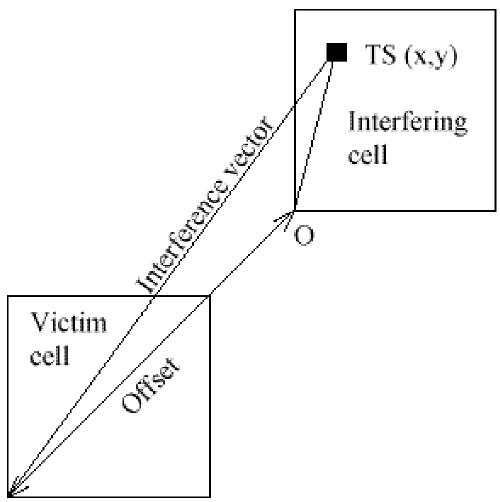
The same Monte Carlo method is used as for the TS to TS same area case, with larger cell offset values and with no NFD (i.e. the victim is co – channel to the interferer). Atmospheric attenuation is ignored in the calculations.

Simulation results

The C/I probability curves show that at overlap values of as little as r = 5, the C/I values reach acceptable levels and the probability of the highest values is still very low. This corresponds to a distance which is lower than that required to reduce CS – CS or CS – TS interference to an acceptable level.
It is concluded that TS to Ts interference is not the limiting case for adjacent area co-channel operation

TS to CS, co- channel, adjacent area

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



- Limiting case for FDD cell spacing
- Based on adjacent channel Monte Carlo method
- Allows for atmospheric attenuation and uplink ATPC
- Atm = 0.21 dB/km
- ATPC = 15 dB reduction below full power at cell edge
- Antenna A: ETSI TS1
- Antenna C: TM4069

Fig. [yyy]

Simulation method

The Interference Area (IA) is constructed in a similar way to the Hub to sub same area case. In this case, it is the interfering TS that lies in the Interference Area, the victim being the distant hub. Atmospheric attenuation and uplink ATPC are taken into account. Additionally, the effect of using different TS antennas is calculated. Charts are also constructed of the probability of interference against the cell offset value

Simulation results

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

At lower values of offset the IA can be rather large. It drops sharply as the “worst case limit is approached.

It is concluded that for TS to CS co-channel operation an offset of approximately 35km is a good guideline for uncoordinated deployment.

CS to CS, co-channel, multiple interferers

[Leland's input to be reviewed here]
[input from the UK-RA is also expected before the details of this section can be finalized]

Simulation method

[To be added]

Simulation results

[To be added]

Mesh to PMP CS, co channel, adjacent area

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

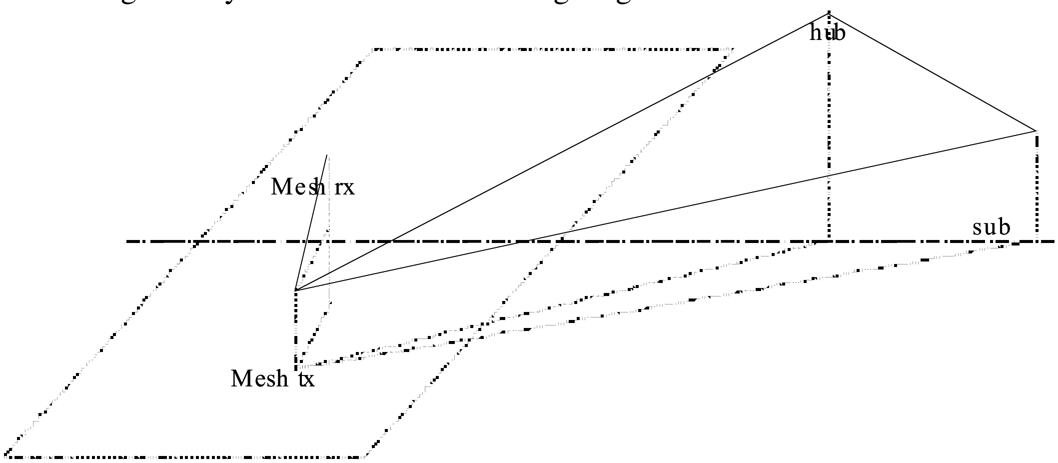


Fig. [z]

Simulation method

The main attributes of the model are:
Monte-Carlo simulation with realistic MP-MP system parameters.
Line-of-sight propagation probabilities calculated from Rayleigh roof height distribution function as per CRABS WG3 report D3P1B [ref.tba]
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 RPE's for 24-28GHz band to EN 301 215-2 V1.1.1 [ref. tba] with BS elevation profile ignored for realistic worst case.
MP-MP antenna RPE model for 24-28GHz band simulates an illuminated aperture with side-lobes to EN 301 215 V1.1.1 [ref. tba].
Atmospheric attenuation to ITU-R P.676-3 [ref. tba]
Rain attenuation to ITU-R P.840-2 [ref. tba].
Dry, storm and frontal weather patterns considered.

The interference target maximum level in the model is –114dbm/MHz measured at the victim receiver input. A large number of trial runs of the simulator tool (typically 10,000) are used to generate a histogram of interfering signal against probability of occurrence. The deduced minimum spacing is based on the worst case value of interference. In practice this has a very low probability so that the results indicated below are conservative.

Simulation results

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

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

The guideline for PMP to PMP network separation [40km] will be conservative for a mesh deployment. A reduced spacing will be possible without co-ordination and a further reduction will be possible by co-ordinating with neighbouring operators.

Mesh to PMP TS, co channel, adjacent area

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

Simulation method

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

Simulation results

For all practical hub (CS) locations, TS heights and locations in the PMP cell, it was found that interference levels were lower than those received by the corresponding hub (CS). Thus, the controlling factor is the mesh to hub spacing. At the 12 km spacing determined for mesh to 50m high hub, all TS interference is below the target level of –114dBm/ MHz, for any randomly selected mesh configuration.

Antenna RPE within the mesh was found to be uncritical.

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

Mesh to PMP CS, same area, adjacent frequency

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

Simulation method

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

Simulation results

The results are available in chart form, showing the probability that the total interference exceeds a given value. The target value for relatively interference free operation is again taken as –114dBm/MHz measured at the victim receiver input.
For adjacent channel operation (no guard channel), the probability of exceeding the target interference level is around 35%. This is too high for uncoordinated operation, although it indicates that with careful deployment adjacent channel operation may sometimes be possible.

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

Mesh to PMP TS, same area, adjacent frequency

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

Simulation method

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

Simulation results

The results are available in chart form, showing the probability that the total interference exceeds a given value. The target value for relatively interference free operation is again taken as –114dBm/MHz measured at the victim receiver input.
For adjacent channel operation (no guard channel), the probability of exceeding the target interference level is around 12%. As with the CS case, this is too high for uncoordinated operation, although it indicates that with careful deployment adjacent channel operation may sometimes be possible.

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

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

Further details of the simulation results can be found in the following

[add references to various input documents on simulation, or means of locating the source, so that the reader can trace our results fully to their source(s)]

END of document