Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Coexistence Recommended Practice – proposal for annex 2C of working document**
Date Submitted	**2002-05-10**
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Re:	Amendment to Recommended Practice for Coexistence of Fixed BWA Systems IEEE802.16.2
Abstract	This is a proposal for the contents of appendix 2C of the working document. It contains a précis of each of the simulations already reviewed and for which provisional conclusions have been reached in the task group. It is intended to form part of the amended Recommended Practice for Coexistence of Fixed Broadband Wireless Access Systems.
Purpose	For review at session #19 and potential inclusion in the amended recommended practice.
Notice	
Release	
Patent Policy and Procedures	

Proposal for Annex 2C (informative): Description of calculations and simulation methods

2C 1 Interference from a PMP BS or SS to a PP link, adjacent area, same channel case

[scenarios 1 and 2]
to be discussed at session #19

2C 2 Interference from a PP link to a PMP BS or SS, adjacent area, same channel case

[scenarios 3 and 4]
to be discussed at session #19

2C 3 Interference from a PMP BS or SS to a PP link, same area, adjacent channel case

[scenarios 5 and 6]
to be discussed at session #19

2C 4 Interference from a PP link to a PMP BS or SS, same area, adjacent channel case

[scenarios 7 and 8]
to be discussed at session #19

2C 5 Interference from a PMP BS or SS to a PP multi-link system, adjacent area same channel case

[scenarios 9 and 10]
to be discussed at session #19

2C 6 Interference from a multi – link PP system into a PMP system, adjacent area, co-channel case

[scenarios 11 and 12 of “interim considerations arising from simulations”]

Summary of simulation method

The point- to- point links are modeled using a simulation tool, which models interference between multiple point to point links and PMP systems. The parameters for the point to point system are taken from IEEE C802.16.2a-01/06 [ ]. The antenna pattern conforms to the recommendations of paper IEEE 802.16.2-01/14 [ ]. (the IEEE “composite” antenna patterns). A comparison is provided with the case where an ETSI antenna pattern is used.

The simulator computes the power received from a system comprising a number of point- to- point links at a PMP BS receiver or a PMP SS receiver, in a cell adjacent to the point to point system. The geometry is shown in fig.[ ]. Each run of the simulation varies the locations and directions of the point to point links. The results of a large number of trial runs are shown in statistical form (Monte Carlo simulation)

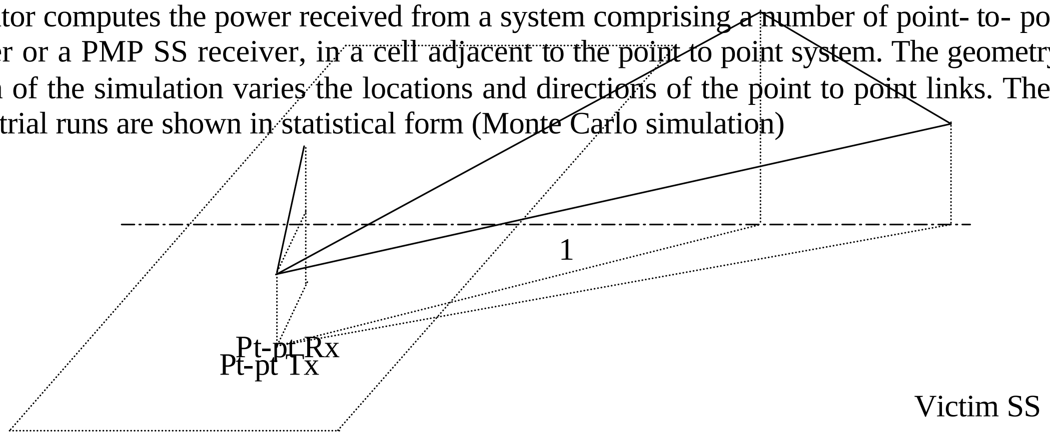

Fig. [ ] Interference Geometry

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

Most of the scenarios have been simulated with no rain fading. A small number of examples of rain storm conditions were also simulated and found to have negligible impact on the results. All rain scenarios have only a small effect on the results

The BS receiver antenna is assumed to be a 90° sector aimed directly at the centre of the interfering system. A corresponding SS antenna is placed at the cell edge, pointing at the BS.

Interfering Power Calculation

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

Simulation Results

Victim=PMP BS

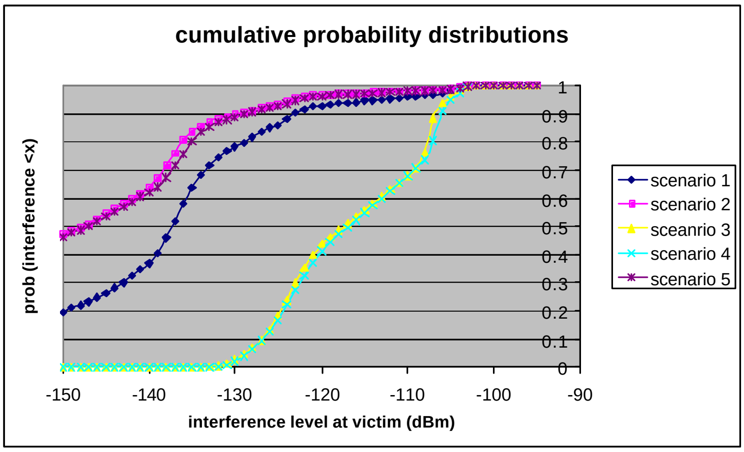

Figure [ ] Example of cumulative probability distributions (BS interference)

Fgure [ ] is an example of the cumulative probability distributions, produced from the simulations. Each curve is derived from a series of 10,000 randomly generated system models, with each model simulating the required number of point- to- point links in the chosen coverage area. The cumulative probability at each point is that for which the total interference at the victim station will be less than a given value on the x axis.

In general, a value of –100dBm (equivalent to –114.5 dBm/ MHz) is low enough to be considered fully acceptable for planning purposes. Thus, where the cumulative probability has reached a value of 1 at the –100 dBm level, there are no cases above the interference threshold. The geographical spacing corresponding to such a value is then completely safe for planning purposes.

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

Table [ ]: Summary of BS Interference Scenarios using new antenna RPE
Values in brackets ( ) are those derived when using an alternative ETSI antenna RPE

Victim=PMP SS

Scenario	**Building height parameter**	**Antenna Height above roof (interferers)**	**Links/ sq km**	**Antenna gain**	**Victim antenna height**	**Rain scenario**	**Distance to SS**	**% threshold exceeded**
1	7m	3m	5	40	20	None	15km	.05
2	7m	3m	5	40	15	None	15km (17km)	0
3	7m	3m	5	40	20	None	40km	.01
4	7m	3m	5	40	25	None	50km	.06
5	7m	3m	5	40	10	None	10km	0

Table [ ]: Summary of SS Interference Scenarios

Values in brackets ( ) are those derived when using an alternative ETSI antenna RPE

Note that in the case of a victim PMP SS, the level of interference depends strongly on the victim antenna height. Below about 15m, very little interference is experienced. Above 15m, the interference increases rapidly. Also, the probability distributions are much flatter than for the BS case, so that to eliminate the last few cases of interference above the threshold, the system spacing has to be increased significantly.

However, SS antenna heights above 15m have a relatively low probability, so that, in most cases, the base station distance required to reduce interference to the –100dBm threshold will dominate.

Conclusions

For most situations, interference to the BS victim station determines the required system spacing, which is in the range 20-24km.

- Where SS antennas are on unusually high structures, the SS interference may dominate and the distance may then need to be increased to 40 – 50 km to reduce the probability of interference to a negligible level. Since the number of such cases is always a very low percentage of the total, it may be more reasonable to apply mitigation techniques than to resort to such large geographical separations

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

2C 8 Interference from a multi – link PP system into a PMP system, same area adjacent channel case

[Scenarios 15 and 16]

In general, co-channel systems will not be able to operate successfully in this environment, so that one or more guard channels are required between the systems. The analysis derives guidelines for the size of guard band needed in each scenario.

Summary of simulation method

The system geometry is similar to [ ] but with the victim BS or SS placed in the middle of the coverage area of the point to point link system. A Monte Carlo simulation is provided, in which a series of parameters for the point-to- point links (interferers) and PMP systems (victim BS or SS) can be varied to match the required scenario. Full 3 – dimensional geometry is taken into account. Each simulation run constructs a random layout of point- to- point links over the required coverage area. A value of NFD (net filter discrimination) is assigned. The simulation tool plots the results as probability curves (probability of occurrence of a given value of interference and cumulative probability). A target maximum level is set, which in this case is –100 dBm (28 MHz channel). This corresponds to –114.5 dBm/ MHz

Interference to PMP BS

The simulation was run with adjacent channel operation and with one guard channel, as shown in fig [ ] .

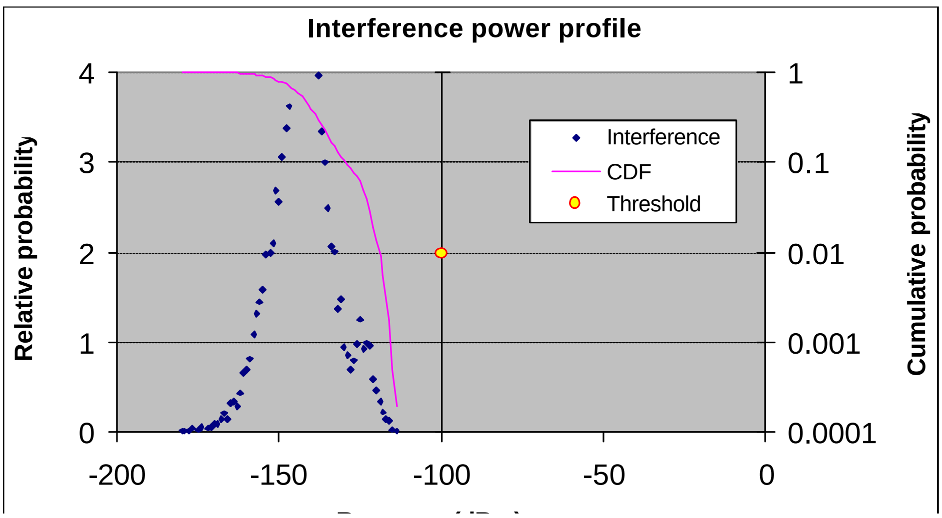

Figure [ ]: Interference from PP system to PMP BS
(1 guard channel)

It is concluded that a single guard channel is adequate in this scenario for satisfactory coexistence and that operation on the adjacent channel could be possible, given a degree of coordination by the operators concerned. However, the other scenarios between systems must also be taken into account when making an overall decision.

Interference to PMP SS

Figure [ ] shows the case where the PMP SS is the victim. One guard channel is used. In this case, the probability of exceeding the –100dBm target level is around 0.1% of random configurations. Thus, coordination would occasionally be required to eliminate all cases of interference.

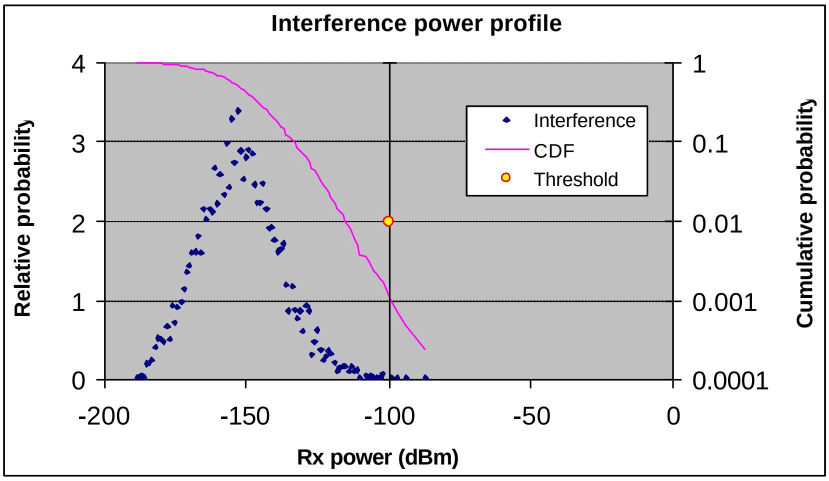

Figure [ ]: Interference from PP system to PMP SS
(1 guard channel)

2C 3 *Interference from a multi – link PP system into a PMP system, same area adjacent channel case*

[scenarios 13 and 14]

PMP to PP interference

The analysis of this scenario is different from the reciprocal case, which needs a Monte Carlo simulation. In the case of the, the interferer is a single transmitter with a high probability of being received by a victim PP station. Thus, a worst-case analysis is appropriate. The interference model is shown in fig. [ ]

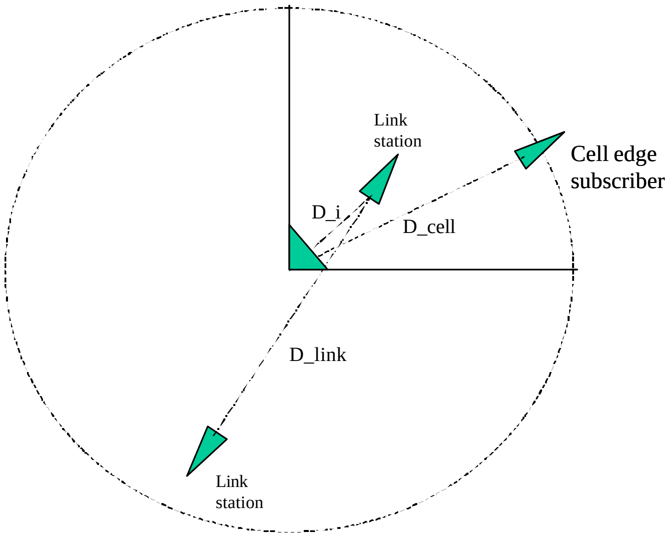

Fig. [ ] Interference geometry (PMP BS to PP link)

The following parameters are assumed for the analysis:

Parameter	**Value**	**Note**
PMP cell radius (D_cell)	5km	Larger radius leads to worse interference scenario
Frequency	25 GHz	
BS antenna gain	19dBi	Typical for 90 degree sector antenna
SS antenna gain	36dBi	
Link antenna gain	40 dBi (Note 2)	From [3]
Nominal SS Rx input level	-73dBm	Assuming 16 QAM modulation
NFD (1 guard channel) Note 1	49 dB	Typical value, from ETSI tables
NFD (2 guard channels) Note 1	70 dB	Typical value, from ETSI tables

Table 1: Parameters for PMP to PP interference scenarios

Results

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

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

Table 2 BS to PP link Interference

The value of interference at the victim PP receiver is calculated for a range of distances and variations in the number of guard channels and antenna pointing offset. The target interference level is less than or equal to –100 dBm (28 MHz channel). This corresponds to –114.5dBm/ MHz.

In the case where the BS is the interferer, many link receivers will be illuminated and so the probability of interference is high. With no guard channel, the interference is catastrophic for all reasonable distances. With a single guard channel, the PP link receiver can not operate within a guard zone of radius >500m, unless the antenna pointing direction is limited. For a two- channel guard band, the zone reduces to approximately 50m radius, with no pointing restrictions.

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

Table 3: SS to PP link Interference

In the case where the SS is the interferer, the level of interference is greater but the probability of interference is lower, due to the narrow beam of the SS antenna.

In this case, even with a 2 channel guard- band, a significant interference zone exists around each SS and pointing restrictions may have to be considered for a number of PP links.

Conclusions for the PMP to/from PP scenarios

The interference from PMP to PP systems is generally worse than the reciprocal case. In order to assure interference - free operation with a low level of coordination, a two - channel guard band is needed. This is sufficient for the BS to point- to- point case. A single guard channel might be viable provided that mitigation techniques were applied to a small proportion of links in the point- to- point system.

In the case of SS interference into a point- to- point system, the interference level can be higher but the probability lower. A two- channel guard band is not completely effective but the number of cases requiring coordination will be very low. The same general recommendation of a two- channel guard band is therefore considered appropriate.