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Title	**Interference between a PMP system and a multi-link PP system (same area, adjacent channel case).**
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Re:	Coexistence of point- to- point links and PMP systems – adjacent channel case
Abstract	This paper provides the results of an analysis of several scenarios in which interference may occur between PMP systems and point- to- point systems, operating in the same geographical area. The point- to- point systems comprise multiple links, for which the operator chooses frequencies from a block assignment.
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Interference between a PMP system and a multi- link PP system (same area, adjacent channel case).

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1. Introduction

This paper provides the results of an analysis of several scenarios in which interference may occur between PMP systems and point- to- point systems, operating in the same geographical area. The point- to- point systems comprise multiple links, for which the operator chooses frequencies from a block assignment. Such links do not have a protected status, so that the management of interference is largely the operator's responsibility.

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 paper derives guidelines for the size of guard band needed in each scenario.

2. PP to PMP interference

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

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

3. Simulation Tool

The simulation tool uses a routine similar to that described in IEEE C802.16.2a-01/03 [4].but modified to deal with interference to a BS or SS operating in the same area and on an adjacent/ near adjacent channel. A Monte Carlo simulation is provided, in which a series of parameters for the point- to- point links (interferers) and PMP systems (victim BS or SS) can be varied to match the required scenario. Full 3 – dimensional geometry is taken into account. Each simulation run constructs a random layout of point- to- point links over the required coverage area, with the specified link density (in this case 5 per sq km) and with link lengths evenly distributed over a specified range of distances. A value of NFD (net filter discrimination) is assigned, taken from ETSI tables (see table 1, below), according to whether required the guard band is a single guard channel or more than one channel.

Typically, 10,000 simulation trials are carried out for each scenario. The simulation tool plots the results as probability curves (probability of occurrence of a given value of interference and cumulative probability). A target maximum level is set, which in this case is –100 dBm (28 MHz channel). This corresponds to –114.5 dBm/ MHz, the value at which the total interference is 6dB below the receiver noise floor, corresponding to the point where receiver sensitivity is degraded by 1dB. This level is used generally in the published IEEE Recommended Practice [5]. The guard band between the interfering and victim systems is varied until every trial (or nearly every trial) gives interference level below the required threshold.

4. Results for PP to PMP interference

4.1 Interference to PMP BS

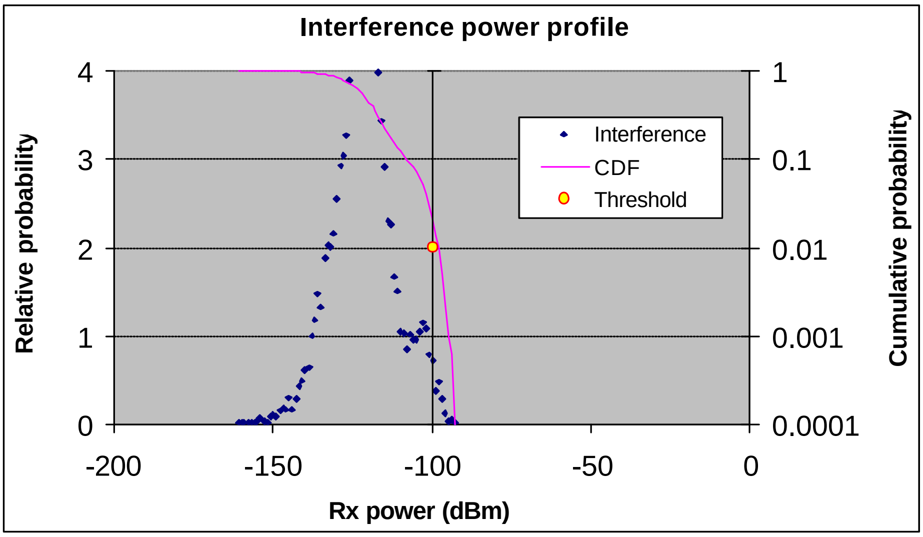

Figure 1: Interference from PP system to PMP BS (adjacent channel)

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

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

Thus, the existing simulation can be used to provide an estimate of the required guard band, without significant reprogramming.

Figure 1 shows the results for the case where the PP system interferes with the PMP BS. There is no guard channel in this case the PMP system is operating in the adjacent channel). It can be seen that a small but significant number of results (a few %) exceed the –100dBm target level.

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

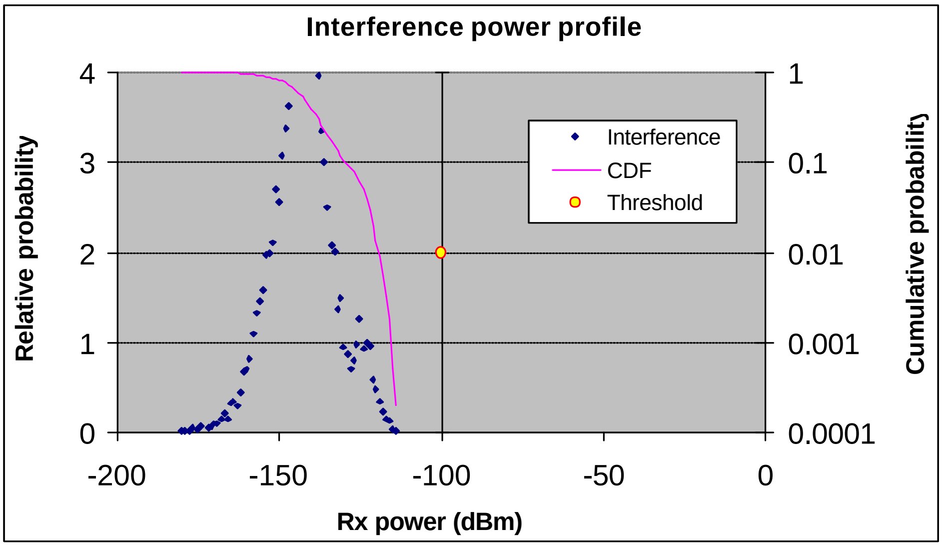

Figure 2: Interference from PP system to PMP BS
(1 guard channel)

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. The analysis of these is provided below.

4.2 Interference to PMP SS

Figure 3 is the case where the PMP SS is the victim. One guard channel is used. In this case, the probability of exceeding the –100dBm target level is around 0.1% of random configurations. Thus, coordination would occasionally be required to eliminate all cases of interference.

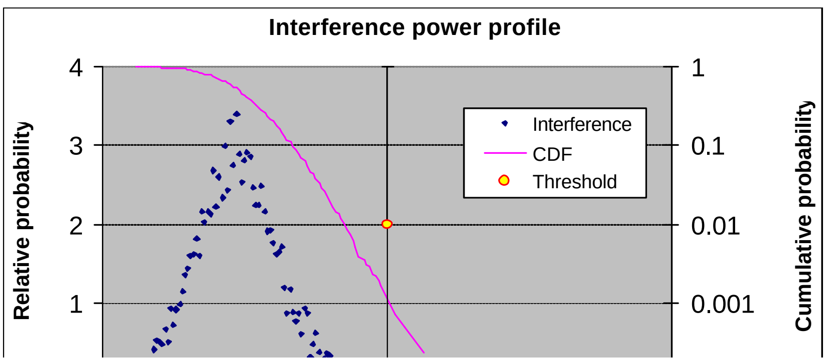

Figure 3: Interference from PP system to PMP SS
(1 guard channel)

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

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

5. PMP to PP interference

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

The interference model is shown in fig 4

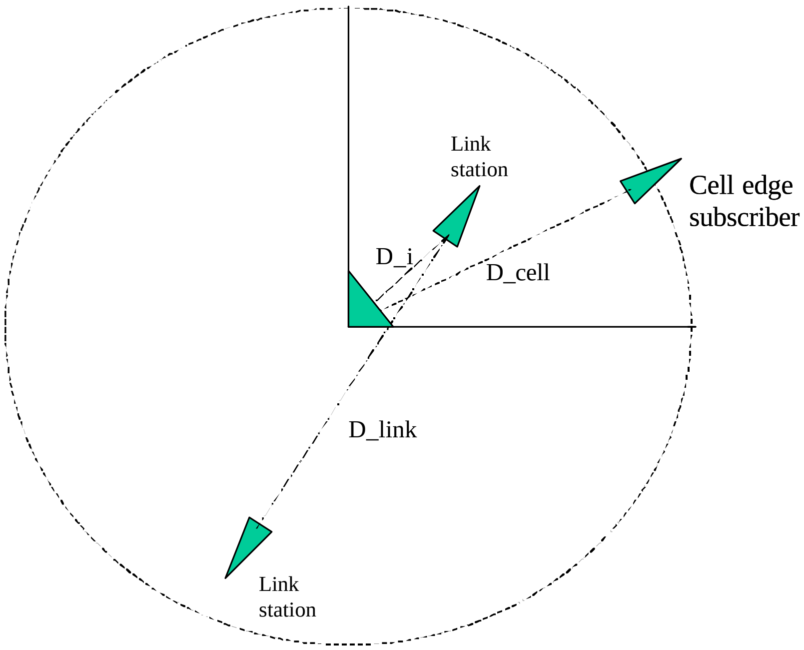

Fig. 4 Interference geometry (PMP BS to PP link)

The PMP cell is shown as a circle. A nominal cell radius of 5km is assumed. The victim station is one end of a link, whose path length is D_link. The distance from the hub to the victim link station is D_i. The following parameters are assumed for the analysis:

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

Table 1: Parameters for PMP to PP interference scenarios

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

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

5.1 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.

6. Conclusions for the PMP to PP scenarios

The interference from PMP to PP systems is generally worse than the reciprocal case. In order to assure interference - free operation with a low level of coordination, a two - channel guard band is needed. This is sufficient for the BS to point- to- point case. A single guard channel might be viable provided that mitigation techniques were applied to a small proportion of links in the point- to- point system However, unlike mesh systems, this kind of point- to- point system has no automated mitigation techniques and significantly higher antenna gains. Thus, the two- channel guard band is a suitable general guideline.

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

7. References

[1] IEEE 802.16.2p-00/13: “Coexistence analysis at 26 GHz and 28 GHz” (This paper contains an explanation of NFD and provides NFD values derived from an ETSI report)
[2] IEEE C802.16.2a-01/06; “System parameters for point to point links for use in Coexistence Simulations (revision 1)”
[3] IEEE 802.16.2-01/14; “Proposed Antenna Radiation Pattern Envelopes for Coexistence Study”.
[4] IEEE C802.16.2a-01/02; “Coexistence between point to point links and PMP systems.”
[5] IEEE 802.16.2-2001; “Recommended Practice for coexistence of Fixed Broadband Wireless Access Systems.”

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