Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Interference from a BFWA PMP system to a multi — link PP system (co-channel case; frequency range 2: 23.5 to 43.5 GHz).
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Re:	Amendment to Coexistence Recommended Practice IEEE 802.16.2-2001
Abstract	This paper provides the results of an analysis of scenarios in which BFWA PMP systems may cause interference to multi – link point- to- point systems operating in adjacent areas, on the same channels. The point- to- point links are assumed to have the same status as the PMP system i.e. they share the band on an equal basis and do not have "protected" status.
Purpose	To provide simulation results and draft coexistence guidelines for scenarios 9 and 10 in IEEE C802.16.2a-02/06 (interim considerations from simulations).
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Interference from a BFWA PMP system to a multi – link PP system (co-channel case; frequency range 2: 23.5 to 43.5 GHz).

This paper provides the results of an analysis of scenarios in which BFWA PMP systems may cause interference to multi – link point- to- point systems operating in adjacent areas, on the same channels. The point- to- point links are assumed to have the same status as the PMP system i.e. they share the band on an equal basis and do not have "protected" status. The scenarios correspond to nos. 9 and 10 in IEEE C802.16.2a-02/06 [1].

The analysis is carried out at two frequencies; 25 GHz and 38 GHz. Relevant PP system parameters are taken from the results of an earlier IEEE 802.16 study and can be found in [4].

Most of the calculations are the same as for the case where a single PP link with "protected" status is the victim. However, the conclusions and resultant guidelines are slightly different.

Interference scenarios

In this case, the interferer is either a single transmitter (BS) or a collection of user stations (SS), which may or may not transmit simultaneously. Since the number of PP links is generally small, the calculation can be carried out based on a single victim receiver with "worst case " calculation, rather than a Monte Carlo simulation.

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) for distances less than the horizon distance may be limited. However, as the PP link system may often be installed in an urban area, with antennas on or below rooftop heights. In this case, some idea of the effect of building and terrain on the probability of interference can be deduced from IEEE paper C802.16.2a-01/03 [7], which studies this issues in relation to mesh and PP multi – link systems.

For over the horizon paths, additional losses above free space will occur. The calculation of the excess loss is complex and terrain dependent. A methodology for estimating such losses can be found in ITU –Rec.452 [2]. The calculation of horizon distance can be found in the IEEE 802.16.2 Recommended Practice [3].

The interference model for the case where the BS is the interferer is shown in fig 1. A corresponding model for the SS case is shown in fig 2.

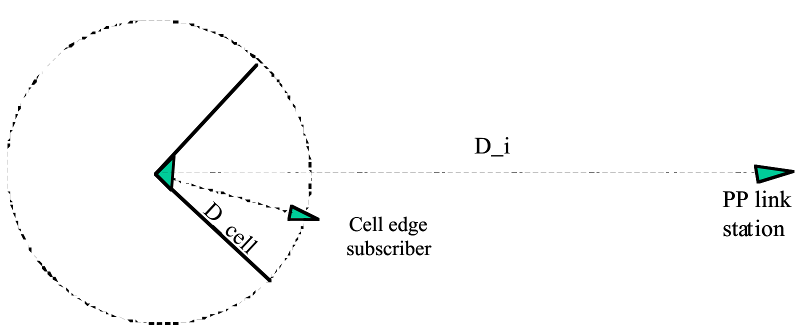


Fig. 1 Interference geometry (PMP BS to PP link)

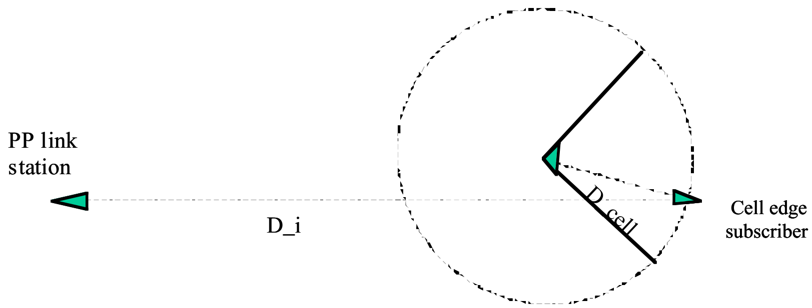


Fig. 2 Interference geometry (PMP SS to PP link station)

The PMP cell is shown as a circle. A nominal cell radius of 5km is assumed. The victim station is one end of one of the PP links. The distance from the BS or SS 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 / 38 GHz	PP link antenna patterns for these frequencies are available in [5]
BS antenna gain (25/ 38 GHz)	19dBi / 20 dBi	Typical for 90 degree sector antenna
SS antenna gain (25/ 38 GHz)	36dBi / 38dBi	Typical values for narrow beam antennas
Link antenna gain (25/ 38 GHz)	40 dBi / 42dBi (Note 1)	From [4]
Nominal SS Rx input level	-73dBm	Assuming 16 QAM modulation
Note 1: The range of values proposed in [4] is 40 - 42dB		

Table 1: Parameters for PMP to PP interference scenarios

Results

The results of the analysis are summarised in table 2 (interference from BS) and table 3 (interference from SS). The threshold for acceptable interference is taken as –100 dBm, corresponding to –114.5dBm/ MHz in a 28 MHz channel. The tables show the level of interference for various combinations of interference path distance (D_i) and PP link antenna offset angle. Line of sight propagation is assumed. Acceptable results are highlighted in the tables.

interference from BS to PP Rx			25 GHz	25 GHz	25 GHz		38 GHz	38 GHz	38 GHz
(co-channel, adjacent area, multi link PP system)									
Frequency GHz		25	25.0	25.0			38.0	38.0	38.0
Tx power, max	dBm	26							
wanted path length (SS - BS) km	D_cell	5							
SS-BS path loss dB (25 GHz)		-123-20log d	-137.0	-137.0	-137.0				
SS-BS path loss dB (38 GHz)		-126.4-20log d					-140.4	-140.4	-140.4
interference path length, km	D_i		**20.00**	**50.00**	**180.00**		**20.0**	**50.0**	**180.0**
interference path loss dB			-149.0	-157.0	-168.1		-152.5	-160.4	-171.5
Link antenna gain dBi		40	40	40	40		42	42	42
BS antenna gain dBi		19	19	19	19		20	20	20
SS antenna gain dBi		36	36	36	36		38	38	38
wanted SS Rx input, 16 QAM, dBm		-73							
BS Tx power, no fade dBm			9.0	9.0	9.0		9.4	9.4	9.4
interference power, no fade, dBm			-81.0	-89.0	-100.1		-81.1	-89.0	-100.1
Less off axis RPE factor (25 GHz)	3 degrees	-8	-89.0	-97.0	-108.1		n/a	n/a	n/a
	5.8 degrees	-19	-100.0	-108.0	-119.1		n/a	n/a	n/a
	10 degrees	-22	-103.0	-111.0	-122.1		n/a	n/a	n/a
Less off axis RPE factor (38 GHz)	2 degrees	-8	n/a	n/a	n/a		-89.1	-97.0	-108.1
	4 degrees	-19	n/a	n/a	n/a		-100.1	-108.0	-119.1
	7 degrees	-25	n/a	n/a	n/a		-106.1	-114.0	-125.1

Table 2: BS to PP Interference (25 and 38 GHz)

interference from SS to PP Rx			25 GHz	25 GHz	25 GHz		38 GHz	38 GHz	38 GHz
(co-channel, adjacent area, multi link PP system)									
Frequency GHz		25	25.0	25.0	25.0		38.0	38.0	38.0
Tx power, max	dBm	26							
wanted path length (SS - BS) km	D_cell	5							
SS-BS path loss dB (25 GHz)		-123-20log d	-137.0	-137.0	-137.0				
SS-BS path loss dB (38 GHz)		-126.4-20log d					-140.4	-140.4	-140.4
interference path length, km	D_i		**100.00**	**150.00**	**250.00**		**80.0**	**120.0**	**250.0**
interference path loss dB			-163.0	-166.5	-171.0		-164.5	-168.0	-174.4
Link antenna gain dBi		40	40	40	40		42	42	42
BS antenna gain dBi		19	19	19	19		20	20	20
SS antenna gain dBi		36	36	36	36		38	38	38
wanted SS Rx input, 16 QAM, dBm		-73							
BS Tx power, no fade dBm			9.0	9.0	9.0		9.4	9.4	9.4
interference power, no fade, dBm			-78.0	-81.5	-86.0		-75.1	-78.6	-85.0
Less off axis RPE factor (25 GHz)	3 degrees	-8	-86.0	-89.5	-94.0		n/a	n/a	n/a
	5.8 degrees	-19	-97.0	-100.5	-105.0		n/a	n/a	n/a
	10 degrees	-22	-100.0	-103.5	-108.0		n/a	n/a	n/a
Less off axis RPE factor (38 GHz)	2 degrees	-8	n/a	n/a	n/a		-83.1	-86.6	-93.0
	4 degrees	-19	n/a	n/a	n/a		-94.1	-97.6	-104.0
	7 degrees	-25	n/a	n/a	n/a		-100.1	-103.6	-110.0

Table 3: SS to PP Interference (25 and 38 GHz)

Results when the BS is the interferer

In the case where the BS is the interferer, it can be seen that, in line of sight conditions, for the worst PP link pointing direction, a system spacing of the order of 180 km is required, which in most systems will be well over – the – horizon. Where a pointing offset of a few degrees is also possible, the spacing can be reduced to approximately 20km. However, where the number of links is significant and new links are being installed regularly, this can not be relied on and a more conservative approach will be required. More likely, terrain and building effects will contribute additional path loss. This is discussed further in “impact of buildings and terrain”, below. There is negligible difference between the 25 GHz and 38 GHz results.

It must be noted that in, practice, there may well be several potential interfering BSs and a calculation must be carried out for each one separately.

Results when the SS is the interferer

In the case where the SS is the interferer, the level of interference is greater and the number of stations that may interfere is much higher. Although the SS antenna beam-width is narrower, there are many stations distributed across the cell/ sector, so that the probability of interference may still be high and the reduction of interference due to antenna pointing offset may not be as effective as might be hoped. Thus, in the table, only the PP antenna pointing - offset is considered.

For typical PP link lengths and any reasonable system spacing (up to the typical horizon distance), a combination of distance and antenna pointing restriction is typically required.

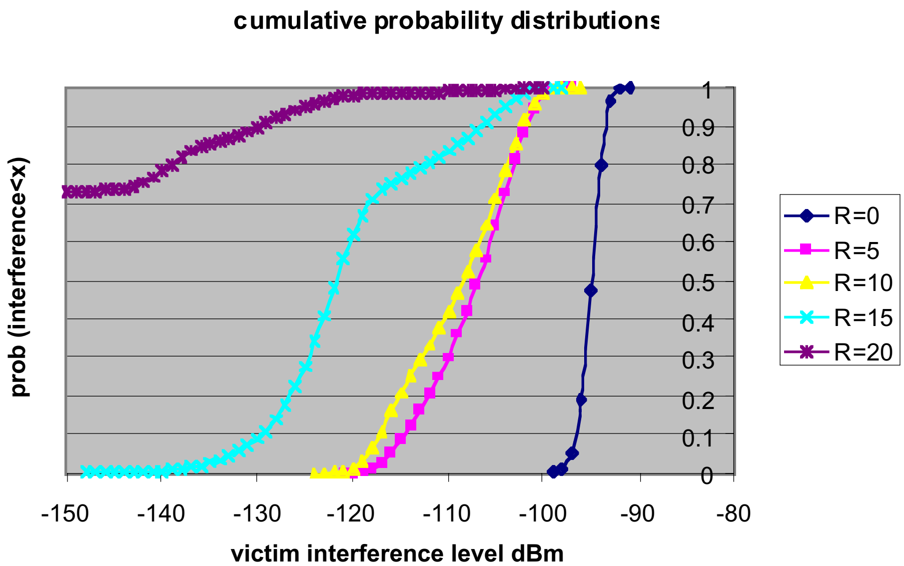
An advantage in the SS case is that the antenna heights are generally much lower than for the BS. Therefore the horizon distance will typically be much shorter and excess losses more likely at reasonable distances. This is discussed further in the section on impact of buildings and terrain, below. The difference between the 25 GHz and the 38 GHz results is negligible.

Impact of Buildings and Terrain

In [7] an analysis was made of the impact of buildings and terrain on mesh/ PP interference into PMP systems. The results shown are for the more adverse BS case. Terrain and buildings were modelled using an adaptation the well-known RAL CRABS [8] methodology. The analysis assumed random layout of the mesh / PP link stations and link orientations and derived cumulative probability functions for various Rayleigh factors (the Rayleigh factor characterises the assumed distribution of building heights). The CDF distribution curves are reproduced in fig 3, below.

For typical urban environments (5<R<20), there is a high probability that interference will be significantly attenuated. Although the calculation was based on interference to the PMP system, the geometry for the reciprocal case is similar and the results should therefore give some guide for the case where the PP system is the victim.

In pure line of sight conditions (R=0), the distribution curve is much sharper and the probability of the highest



values (<<1% probability) is approximately 7-8dB higher.

Fig 3; Interference plotted as cumulative probability curves as function of R

Thus, for a range of urban environments, typical buildings and terrain reduce interference for almost all possible configurations of PP links by several dB. Although the worst case could theoretically be at the maximum un-attenuated value, its probability is exceedingly low. Since the PP link system does not have “protected” status, the guideline spacing can be reduced from the values in tables 2 and 3 with low probability of causing difficulties.

Applying a 7dB reduction to the BS case, reduces the required system spacing to 80km, with no antenna pointing offset, and to yet lower values where pointing offset can be relied on

For the SS case, the probability of line of sight will be much lower and the probability of alignment of the antennas will also be low. Thus, the highest interference could be higher (as shown in table 4) but the probability of occurrence will be low. Analysis of the reciprocal case was carried out in the original recommended practice and concluded that the BS case would normally be dominant. Further work may be useful to determine a value for the SS case equivalent to the 7-8 dB derived in [7] for the BS case.

Conclusions for the PMP to PP multi – link co-channel scenarios

Interference Scenario	Frequency	Guideline	Notes
BS to multi link PP system	25 GHz	80km system spacing. Lower spacing possible with coordination or where the BS antenna is lower than typical	Multiple victim BSs may have to be considered
BS to multi link PP system	38 GHz	80km system spacing. Lower spacing possible with coordination or where the BS antenna is lower than typical	Multiple victim BSs may have to be considered
SS to multi link PP system	25 GHz	BS case usually dominates.	Rare (improbable) cases where SS interference is higher should be dealt with by specific coordination
SS to multi link PP system	38 GHz	BS case usually dominates.	Rare (improbable) cases where SS interference is higher should be dealt with by specific coordination

Table 4: Summary of results

A study carried out in ETSI TM4 also partly covers this topic. Further information can be found in [6].

References

[1] IEEE C802.16.2a-02/06; “Interim considerations from simulations”.
[2] Rec. ITU-R P.452.9; “Prediction procedure for the evaluation of microwave interference between stations on the surface of the earth at frequencies above about 0.7 GHz.”
[3] IEEE 802.16.2-2001; “Recommended Practice for coexistence of Fixed Broadband Wireless Access Systems.”
[4] IEEE C802.16.2a-01/06; “System parameters for point to point links for use in Coexistence Simulations (revision 1)”
[5] IEEE 802.16.2-01/14; “Proposed Antenna Radiation Pattern Envelopes for Coexistence Study”.
[6] ETSI Technical Report TR 101 853 v1.1.1 (2000-10); “Fixed Radio Systems; Point to point and point to multipoint equipment; Rules for the coexistence of point to point and point to multipoint systems using different access methods in the same frequency band.”
[7] IEEE C802.16.2a-01/03: “Impact of buildings and terrain on mesh / PP to PMP co-channel interference”
[8] ACTS Project 215, Deliverable Report D3P1B; “Cellular Radio Access for Broadband Services (CRABS)”

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