Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Interference from a BFWA PMP system to a PP link system (same area, adjacent channel case).
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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 a PMP system may interfere with a point- to- point link system, operating in the same geographical area on adjacent or near – adjacent channels. The point- to- point link(s) are assumed to be individually licensed and to have "protected" status.
Purpose	To provide simulation results and draft coexistence guidelines for scenarios 5 and 6 in IEEE C802/16.2a-02/06 (interim considerations from simulations).
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Interference from a BFWA PMP system to a PP link system (same area, adjacent channel case).

This paper provides the results of an analysis of scenarios in which a PMP system may interfere with a point- to-point link system, operating in the same geographical area on adjacent or near – adjacent channels. The scenarios correspond to numbers 5 and 6 in IEEE C802.16.2a-02/06 [7]

The point- to- point link(s) are assumed to be individually licensed and to have "protected" status. Thus, the PMP system must be designed to avoid creating any interference above the acceptable threshold level. The analysis is carried out at two frequencies; 25 GHz and 38 GHz. System parameters are taken from [2].

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

PMP to PP interference scenarios

In this case, the interferer is either a single transmitter (BS) with a high probability of being received by a victim PP station or a collection of user stations (SS), which may or may not transmit simultaneously. Since the PP link must be protected from all cases of interference above the acceptable threshold, 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) cannot be relied on, so that all paths for the worst-case analysis should be assumed to be clear, line of sight.

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

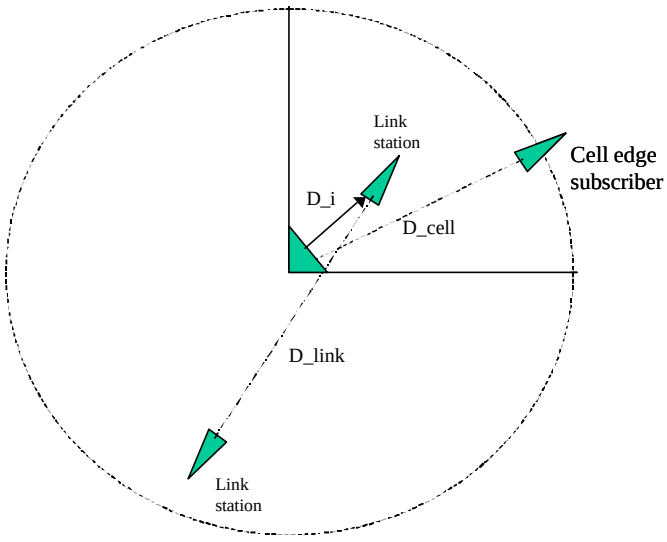

Fig. 1 Interference geometry (PMP BS to PP link)

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 BS to the victim link station is D_i.

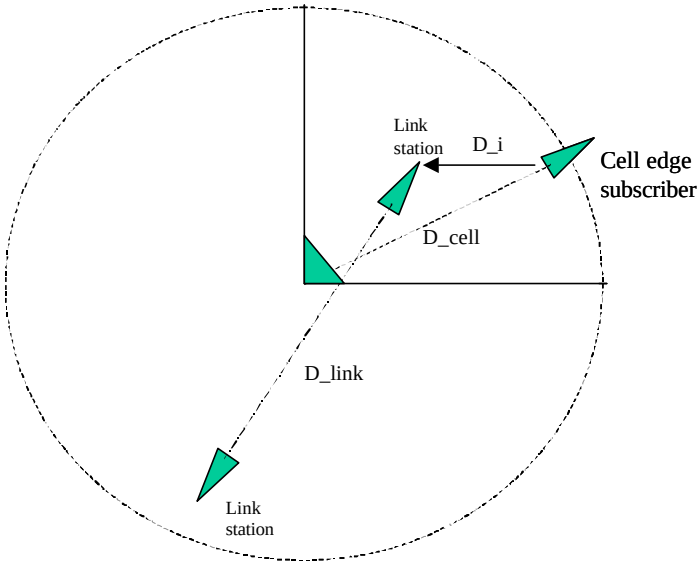

Fig. 2 Interference geometry (PMP SS to PP link)

The interfering station in fig.2 is an SS, placed at the cell edge, where it is required to operate at the highest transmitter power level. The victim station is one end of a PP link, whose path length is D_link. The distance from the 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	Antenna patterns for these frequencies are available in [3]
BS antenna gain	19dBi / 20 dBi	Typical for 90 degree sector antenna
SS antenna gain	36dBi / 38dBi	Typical values for narrow beam antennas
Link antenna gain	40 dBi / 42dBi (Note 2)	From [2]
Nominal SS Rx input level	-73dBm	Assuming 16 QAM modulation
Isolation (Note 1)	25dB	Typical value for adjacent channel operation

Isolation (Note 1)	49 dB	Typical value, from ETSI tables, for 1 guard channel
Isolation (Note 1)	70 dB	Typical value, from ETSI tables, for 2 guard channels
Note 1: The isolation may be achieved by use of guard bands or by other means. The values chosen correspond to typical NFD (net filter discrimination) data. NFD 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). Note 2: The range of values proposed in [2] is 40 - 42dB.		

Table 1: Parameters for PMP to PP interference scenarios

Results

The results of the analysis are summarised in tables 2 and 3 (BS interference) and tables 4 and 5 (SS interference).

interference from BS to PP Rx			int path 50m	100m	200m	300m	400m	500m	1km	2km	3km	5km
Frequency GHz		25										
Tx power, max	dBm	26										
wanted path length (SS - BS) km		5										
path loss dB		-123-20log d	-137.0									
interference path length, km			0.05	0.1	0.2	0.3	0.4	0.5	1.0	2.0	3.0	5.0
interference path loss dB			-97.0	-103.0	-109.0	-112.5	-115.0	-117.0	-123.0	-129.0	-132.5	-137.0
Link antenna gain dBi		40	40	40	40	40	40	40	40	40	40	40
BS antenna gain dBi		19	19	19	19	19	19	19	19	19	19	19
SS antenna gain dBi		36	36	36	36	36	36	36	36	36	36	36
wanted Rx input, 16 QAM, dBm		-73										
BS Tx power, no fade dBm			9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
interference power, no fade, dBm			-29.0	-35.0	-41.0	-44.5	-47.0	-49.0	-55.0	-61.0	-64.5	-69.0
Less NFD for adjacent channel dB		25	-54.0	-60.0	-66.0	-69.5	-72.0	-74.0	-80.0	-86.0	-89.5	-94.0
Less off axis RPE factor	3 degrees	-8	-62.0	-68.0	-74.0	-77.5	-80.0	-82.0	-88.0	-94.0	-97.5	-102.0
	5.8 degrees	-19	-73.0	-79.0	-85.0	-88.5	-91.0	-93.0	-99.0	-105.0	-108.5	-113.0
	10 degrees	-22	-76.0	-82.0	-88.0	-91.5	-94.0	-96.0	-102.0	-108.0	-111.5	-116.0
Less NFD for 1 guard channel dB		49	-78.0	-84.0	-90.0	-93.5	-96.0	-98.0	-104.0	-110.0	-113.5	-118.0
Less off axis RPE factor	3 degrees	-8	-86.0	-92.0	-98.0	-101.5	-104.0	-106.0	-112.0	-118.0	-121.5	-126.0
	5.8 degrees	-19	-97.0	-103.0	-109.0	-112.5	-115.0	-117.0	-123.0	-129.0	-132.5	-137.0
	10 degrees	-22	-100.0	-106.0	-112.0	-115.5	-118.0	-120.0	-126.0	-132.0	-135.5	-140.0
Less NFD for 2 guard channels dB		70	-99.0	-105.0	-111.0	-114.5	-117.0	-119.0	-125.0	-131.0	-134.5	-139.0
Less off axis RPE factor	3 degrees	-8	-107.0	-113.0	-119.0	-122.5	-125.0	-127.0	-133.0	-139.0	-142.5	-147.0
	5.8 degrees	-19	-118.0	-124.0	-130.0	-133.5	-136.0	-138.0	-144.0	-150.0	-153.5	-158.0
	10 degrees	-22	-121.0	-127.0	-133.0	-136.5	-139.0	-141.0	-147.0	-153.0	-156.5	-161.0

Table 2 BS to PP link Interference (25 GHz)

interference from BS to PP Rx			int path 50m	100m	200m	300m	400m	500m	1km	2km	3km	5km
Frequency GHz		38										
Tx power, max	dBm	26										
wanted path length (SS - BS) km		5										
path loss dB		-126.43-20log d	-140.4									
interference path length, km			0.05	0.1	0.2	0.3	0.4	0.5	1.0	2.0	3.0	5.0
interference path loss dB			-100.4	-106.4	-112.4	-115.9	-118.4	-120.4	-126.4	-132.4	-135.9	-140.4
Link antenna gain dBi		42	42	42	42	42	42	42	42	42	42	42
BS antenna gain dBi		20	20	20	20	20	20	20	20	20	20	20
SS antenna gain dBi		38	38	38	38	38	38	38	38	38	38	38
wanted Rx input, 16 QAM, dBm		-73										
BS Tx power, no fade dBm			9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
interference power, no fade, dBm			-29.0	-35.0	-41.0	-44.5	-47.0	-49.0	-55.0	-61.0	-64.5	-69.0
Less NFD for adjacent channel dB		25	-54.0	-60.0	-66.0	-69.5	-72.0	-74.0	-80.0	-86.0	-89.5	-94.0
Less off axis RPE factor	2 degrees	-8	-62.0	-68.0	-74.0	-77.5	-80.0	-82.0	-88.0	-94.0	-97.5	-102.0
	4 degrees	-19	-73.0	-79.0	-85.0	-88.5	-91.0	-93.0	-99.0	-105.0	-108.5	-113.0
	7 degrees	-25	-79.0	-85.0	-91.0	-94.5	-97.0	-99.0	-105.0	-111.0	-114.5	-119.0
Less NFD for 1 guard channel dB		49	-78.0	-84.0	-90.0	-93.5	-96.0	-98.0	-104.0	-110.0	-113.5	-118.0
Less off axis RPE factor	2 degrees	-8	-86.0	-92.0	-98.0	-101.5	-104.0	-106.0	-112.0	-118.0	-121.5	-126.0
	4 degrees	-19	-97.0	-103.0	-109.0	-112.5	-115.0	-117.0	-123.0	-129.0	-132.5	-137.0
	7 degrees	-25	-103.0	-109.0	-115.0	-118.5	-121.0	-123.0	-129.0	-135.0	-138.5	-143.0
Less NFD for 2 guard channels dB		70	-99.0	-105.0	-111.0	-114.5	-117.0	-119.0	-125.0	-131.0	-134.5	-139.0
Less off axis RPE factor	2 degrees	-8	-107.0	-113.0	-119.0	-122.5	-125.0	-127.0	-133.0	-139.0	-142.5	-147.0
	4 degrees	-19	-118.0	-124.0	-130.0	-133.5	-136.0	-138.0	-144.0	-150.0	-153.5	-158.0
	7 degrees	-25	-124.0	-130.0	-136.0	-139.5	-142.0	-144.0	-150.0	-156.0	-159.5	-164.0

Table 3 BS to PP link interference (38 GHz)

The value of interference at the victim PP receiver is calculated for a range of distances and variations in the isolation and antenna pointing offset. The isolation values used are typical for systems which have frequency offsets equivalent to adjacent channel operation, one guard channel or two guard channels, although the intention is not to specify the actual guard band required, only the necessary amount of isolation. 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, a simple calculation will determine whether or not the level of interference is too high. With 25 dB of isolation (typically achieved with adjacent channel operation), the interference is too high for all reasonable distances. With a single guard channel (or equivalent amount of isolation), the PP link receiver can not operate within a guard zone of radius approximately 500m, unless the antenna pointing direction is limited. For a two- channel guard band, the zone reduces to a little over 50m radius, with no pointing restrictions.

Given this analysis, a guideline for interference free operation is a two channel guard band (or equivalent isolation) combined with a forbidden zone of radius approximately 50m around any point to point link station. If this level of isolation is possible then the deployment of point to point links and PMP cells in the same area should be readily achievable. If such a value of isolation is not possible, then additional co-ordination measures and restrictions will be essential, causing significant areas of the PMP cell to be unusable by point to point link stations.

interference from SS to PP Rx			int path 50m	100m	200m	300m	400m	500m	1km	2km	3km	5km
Frequency GHz		25										
Tx power, max	dBm	26										
wanted path length (SS - BS) km		5										
path loss dB		-123-20log d	-137.0									
interference path length, km			0.05	0.1	0.2	0.3	0.4	0.5	1.0	2.0	3.0	5.0
interference path loss dB			-97.0	-103.0	-109.0	-112.5	-115.0	-117.0	-123.0	-129.0	-132.5	-137.0
Link antenna gain dBi		40	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
BS antenna gain dBi		19	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
SS antenna gain dBi		36	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
wanted Rx input, 16 QAM, dBm		-73										
BS Tx power, no fade dBm			9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
interference power, no fade, dBm			-12.0	-18.0	-24.0	-27.5	-30.0	-32.0	-38.0	-44.0	-47.5	-52.0
Less NFD for adjacent channel dB		25	-37.0	-43.0	-49.0	-52.5	-55.0	-57.0	-63.0	-69.0	-72.5	-77.0
Less off axis RPE factor	3 degrees	-8	-45.0	-51.0	-57.0	-60.5	-63.0	-65.0	-71.0	-77.0	-80.5	-85.0
	5.8 degrees	-19	-56.0	-62.0	-68.0	-71.5	-74.0	-76.0	-82.0	-88.0	-91.5	-96.0
	10 degrees	-22	-59.0	-65.0	-71.0	-74.5	-77.0	-79.0	-85.0	-91.0	-94.5	-99.0
Less NFD for 1 guard channel dB		49	-61.0	-67.0	-73.0	-76.5	-79.0	-81.0	-87.0	-93.0	-96.5	-101.0
Less off axis RPE factor	3 degrees	-8	-69.0	-75.0	-81.0	-84.5	-87.0	-89.0	-95.0	-101.0	-104.5	-109.0
	5.8 degrees	-19	-80.0	-86.0	-92.0	-95.5	-98.0	-100.0	-106.0	-112.0	-115.5	-120.0
	10 degrees	-22	-83.0	-89.0	-95.0	-98.5	-101.0	-103.0	-109.0	-115.0	-118.5	-123.0
Less NFD for 2 guard channels dB		70	-82.0	-88.0	-94.0	-97.5	-100.0	-102.0	-108.0	-114.0	-117.5	-122.0
Less off axis RPE factor	3 degrees	-8	-90.0	-96.0	-102.0	-105.5	-108.0	-110.0	-116.0	-122.0	-125.5	-130.0
	5.8 degrees	-19	-101.0	-107.0	-113.0	-116.5	-119.0	-121.0	-127.0	-133.0	-136.5	-141.0
	10 degrees	-22	-104.0	-110.0	-116.0	-119.5	-122.0	-124.0	-130.0	-136.0	-139.5	-144.0

Table 4: SS to PP link Interference (25 GHz).

interference from SS to PP Rx			int path 50m	100m	200m	300m	400m	500m	1km	2km	3km	5km
Frequency GHz		38										
Tx power, max	dBm	26										
wanted path length (SS - BS) km		5										
path loss dB		-126.43-20log d	-140.4									
interference path length, km			0.05	0.1	0.2	0.3	0.4	0.5	1.0	2.0	3.0	5.0
interference path loss dB			-100.4	-106.4	-112.4	-115.9	-118.4	-120.4	-126.4	-132.4	-135.9	-140.4
Link antenna gain dBi		42	42	42	42	42	42	42	42	42	42	42
BS antenna gain dBi		20	20	20	20	20	20	20	20	20	20	20
SS antenna gain dBi		38	38	38	38	38	38	38	38	38	38	38
wanted Rx input, 16 QAM, dBm		-73										
BS Tx power, no fade dBm			9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
interference power, no fade, dBm			-11.0	-17.0	-23.0	-26.5	-29.0	-31.0	-37.0	-43.0	-46.5	-51.0
Less NFD for adjacent channel dB		25	-36.0	-42.0	-48.0	-51.5	-54.0	-56.0	-62.0	-68.0	-71.5	-76.0
Less off axis RPE factor	2 degrees	-8	-44.0	-50.0	-56.0	-59.5	-62.0	-64.0	-70.0	-76.0	-79.5	-84.0
	4 degrees	-19	-55.0	-61.0	-67.0	-70.5	-73.0	-75.0	-81.0	-87.0	-90.5	-95.0
	7 degrees	-25	-61.0	-67.0	-73.0	-76.5	-79.0	-81.0	-87.0	-93.0	-96.5	-101.0
Less NFD for 1 guard channel dB		49	-60.0	-66.0	-72.0	-75.5	-78.0	-80.0	-86.0	-92.0	-95.5	-100.0
Less off axis RPE factor	2 degrees	-8	-68.0	-74.0	-80.0	-83.5	-86.0	-88.0	-94.0	-100.0	-103.5	-108.0
	4 degrees	-19	-79.0	-85.0	-91.0	-94.5	-97.0	-99.0	-105.0	-111.0	-114.5	-119.0
	7 degrees	-25	-85.0	-91.0	-97.0	-100.5	-103.0	-105.0	-111.0	-117.0	-120.5	-125.0
Less NFD for 2 guard channels dB		70	-81.0	-87.0	-93.0	-96.5	-99.0	-101.0	-107.0	-113.0	-116.5	-121.0
Less off axis RPE factor	2 degrees	-8	-89.0	-95.0	-101.0	-104.5	-107.0	-109.0	-115.0	-121.0	-124.5	-129.0
	4 degrees	-19	-100.0	-106.0	-112.0	-115.5	-118.0	-120.0	-126.0	-132.0	-135.5	-140.0
	7 degrees	-25	-106.0	-112.0	-118.0	-121.5	-124.0	-126.0	-132.0	-138.0	-141.5	-146.0

Table 5: SS to PP link Interference (38 GHz).

In the case where the SS is the interferer, the level of interference is greater. 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.

For a PP link station facing away from the BS, an area of the cell can be determined in which there is a high probability of unacceptable interference. The size of this area compared with the overall cell/ sector area is a measure of the probability that co-ordination will be required. Since new SS are regularly added to the PMP system, this zone may be regarded as an “interference zone”, in which SS should not be located.

With adjacent channel operation, the area of the “interference zone” will be very large. Even with a +/- 10 degree pointing restriction, the zone extends 5km from the PP station. Thus, adjacent channel operation is unlikely to be feasible under any circumstances.

With a single guard channel (or equivalent isolation), the zone extends more than 3 km from the PP station and pointing restrictions are required. The size of the interference zone is estimated to be approximately 1sq km or about 5% of the sector area (see appendix 1 for derivation of this value). This is a significant proportion of the cell area but may be acceptable in relatively low - density systems, where the number of potential subscribers affected is small. Because the PP link must be protected, subscribers in the forbidden zone can only be allowed when the PP link antenna is pointing in a favourable direction.

With a 2 channel guard- band (or equivalent isolation) the interference zone reduces to around .01% of the sector area. However, in the worst direction, the PP link station must still be around 400m from an interfering PMP SS. Thus, although operation with a 2 - channel guard band reduces the probability of interference considerably, a specific check must still be carried out in order to ensure protection of the PP link.

Conclusions for the PMP to PP scenarios

Interference Scenario	Frequency	Guideline	Notes
BS to PP link station	25 GHz	Single guard channel (note 1) plus 500m coordination zone around BS, OR Two channel guard band (note 1) plus 50m coordination zone	Coordination always required to protect PP link
BS to PP link station	38 GHz	Single guard channel (note 1) plus 500m coordination zone around BS, OR Two channel guard band (note 1) plus 50m coordination zone	Coordination always required to protect PP link
SS to PP link Station	25 GHz	Two channel guard band (note 1) plus 50m coordination zone	Single guard channel operation may be feasible in low density systems but significant coordination is likely
SS to PP link station	38 GHz	Two channel guard band (note 1) plus 50m coordination zone	Single guard channel operation may be feasible in low density systems but significant coordination is likely
Note 1: or equivalent isolation			

Table 6 Summary of results

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.

Single guard channel operation is only feasible with significant coordination. Due to the regular addition of SSs to the PMP sector, such coordination will be very difficult to manage, except for low density PMP systems (where the probability of an SS falling within the interference zone is low)

Appendix 1: Estimation of the interference area.

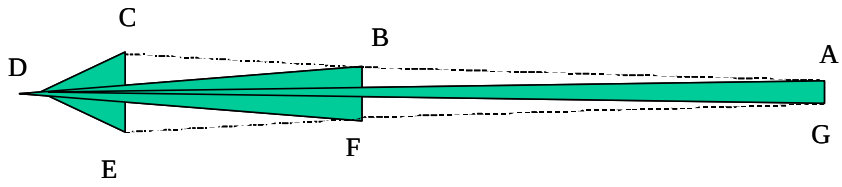

Figure 3

In figure 3, the triangles represent the areas in which the interference exceeds the required threshold of –114.4dBm/ MHz for various angles of the antenna RPE. Thus, DAG is the area in which the main beam of the antenna (+/- 1.5 degrees from pointing direction) leads to interference above the threshold. D is the location of the PP link antenna. The distance from D to the far end of this narrow triangle is approximately 5km for the case where 1 guard channel is used and the interferer is an SS. Similar triangles can be drawn for other angles of the PP link RPE. It can be seen that the total area where interference is too high is approximated by the figure DCBAGFE, which bounds all possible triangles derived from the antenna RPE. The area close to D is actually more complex than shown but represents a negligible additional area.

The area DCBAGFE is approximately 2*(.35+.125+.03) = 1.02 sq km

The total sector area is Pi*5*5/4 = 19.6 sq km

Therefore, the interference zone (when the PP antenna is pointing away from the BS) is around 5% of the sector area. The probability that a PMP SS will fall in this area is significant and coordination will therefore apply significant constraints on the PMP deployment

A similar estimation for the case where a 2 channel guard band is used leads to an interference zone of around .0025 sq km, which is very low. Coordination is still required (since the PP link must be protected) but the constraints on PMP deployment will now be very small.

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.”
[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-02/06: “interim considerations from simulations.”

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