Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Interference scenarios in 2.4GHz and 5.8GHz UNII band – LE Ad-hoc output**
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Re:	**Ad Hoc Committee on Licensed-Exempt Coexistence -** Meeting 30 to Meeting 31
Abstract	
Purpose	Start of work, to be completed
Notice	
Release	
Patent Policy and Procedures	

Interference scenarios in 2.4GHz ISM and 5.8GHz UNII bands

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1. Introduction

The scope of this work is to define the scenarios in which interference between cells can cause disruption in service. The target frequency is 5.8GHz LE band, according to UNII rules. Will be taken into account un-coordinated deployment cases, to address access providers and private networks.

2. System parameters

The following parameters are proposed, resulting as an average of product characteristics in 5.8GHz:

BST:

Tx power:
2.4GHz: 25dBm
5.8GHz: Ptb = 20dBm;
Antenna gain: omni: AGo = 10dBi; directional: AGba = 17dBi;
Connector loss: CL =1dB;

SS:

Tx power: Pts = 20dBm;
Antenna gain: omni: AGso = 10dBi; directional: AGsa = 17dBi; AGsb = 23dBi
Connector loss: 1dB.

Antenna isolation for co-located outdoor antennae:
AI = -75dB for directional – to- directional, 2m between sectors
AI = -30dB for omni-to-directional or omni-to-omni.

Signal BW for evaluation: 10MHz.
Note: for simplification, it is proposed to omit 20MHz here

Fade Margin: 10dB
The Receive Sensitivity Level (RSL), Adjacent Channel Interference (ACI) resistance, Signal-to-Noise Ratio - SNR, at minimum rate, as defined in 802.16REVd/D3 (see Annex 1), are summarized below:

Table 1 – RSL, ACI, SNR

	RSL (dBm) / Modulation	ACI (dB) / Modulation	SNR (dB) / Modulation	Blocking Rx level (dBm)
SCa	-83.2 / QPSK	-9 / QPSK	9.8 / QPSK	-40 (BS) and –20 (SS)
OFDM	-82.6 / QPSK 1/2	-11 / 16QAM 3/4	9.4 / QPSK 1/2	-30
OFDMA	-82.6 / QPSK 1/2	-11 / 16QAM 3/4	9.4 / QPSK 1/2	-30

It is proposed to use the following values:

RSL: -83dBm
SNR: 9.8dB
Blocking Level: BL= -40dBm
ACI: -12dB

Note: the value does not reflect OFDM/OFDMA QPSK rate 1/2; however, values are not available; please provide values!

3. Interference cases

3.1. Base Station to Base Station

Scenario 1: **Access Points operating with NON-synchronized Tx/Rx.**

The Tx interval can overlap the Rx intervals, making the receive periods not operational, as shown below:

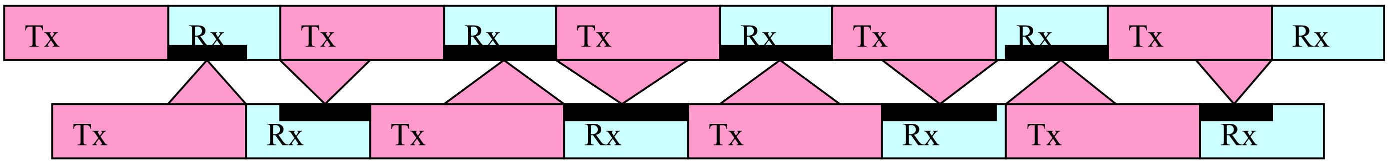

Figure 1 – Interference will mess the reception periods

Scenario 2: Synchronization: same MAC Frames and Tx/Rx interval duration

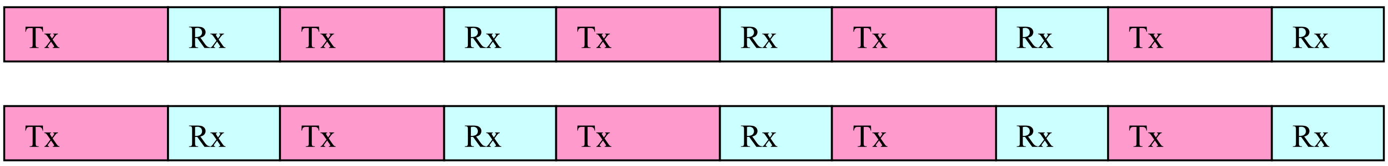

Figure 2 – Synchronized MAC Frames and Tx/Rx intervals

In this case, the problem disappears.

In continuation will be calculated the degradation in case of co-location and the minimum Base Station separation.

3.1.1. Co-located BS – 5.8GHz

In this case, will be 2 systems: one transmitting and one receiving. If the Tx and Rx intervals are not synchronized, the victim receiver will be interfered by the transmitter.

The interference level will be, in the best case (using directional antennae):

I = Ptb – AI +ACI = 20dBm – ~~40~~75dB –12 = -~~20~~67dBm.
~~As the blocking level is –40dBm, I > BL.~~
~~The interference level is higher than the Blocking Level and as result **none of co-located systems will work.**~~

The interference level in this case, for 2m antenna separation: -67dBm.

If one of the Base Stations will have an omni antenna, the interference level will be higher, with the difference of antenna isolation = 75-30=45dB.

So the interference level, for one omni antenna, will be –22dBm.

3.1.2. Co-located BS – 2.4GHz

Using same relations as before, results an interference level of -62dBm for directional antennae and –17dBm for the case when one or both antennae are omni.

3.1.3. Base Station minimum separation – 5.8GHz

3.1.3.1. Adjacent channel

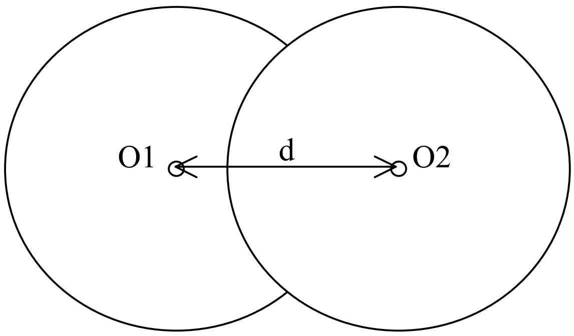

Figure 3 – BS to BS Interference

Problem: In the case of NOT synchronized transmissions, the Base Station located in O1, will create interference to the Base Station located in O2, for the duration of common Tx-Rx periods.
The worst case interference level should be calculated for Line-of-Sight (LOS) propagation, sector BS antennae.
The interfering signal at O2 is:

I2 = Ptb1+AGb1-CL1+ AGb2-CLs2 – Path_loss= 20dBm + 17dBi –1dB + 17dBi –1dB – Path_loss

I2 = 52dBm –Path_loss

However, this signal comes on the adjacent channel. The channel will affect the victim channel at a power which is lower by ACI dB. For ACI=12dB, results:

$$\text{Path\_loss} = 52\text{dBm} - I2 - ACI = 40\text{dBm} - I2 \qquad (1)$$

Lets suppose that Base Station in O2 works at 10dB (fade margin) above its RSL and can accept 1dB degradation of the RSL. The allowed interference level, I(dB), that will increase the power level by 1dB, will be:

$I(dB) = 10*\log(I(W));$ $I(W)= 10^{(I(dB)/10)}$

$P(W)+I(W) = 10^{(P(dB)/10)} + 10^{(I(dB)/10)} = P(dB) + 1dB$

$P(dB) + 1dB = 10*\log(10^{(P(dB)/10)} + 10^{(I(dB)/10)})$

$10^{(1+P(dB))/10} = 10^{(P(dB)/10)} + 10^{(I(dB)/10}$

$10^{(I(dB)/10} = 10^{(1+P(dB))/10} - 10^{(P(dB)/10)} = 10^{(P(dB)/10} * 10^{1/10} - 10^{(P(dB)/10)}$
$10^{(I(dB)/10} = 10^{(P(dB)/10)} *(10^{1/10} - 1)$

$I(dB)/10 = \log(10^{1/10} - 1) + P(dB)/10$

$I(dB) = 10*\log(10^{1/10} - 1) + P(dB) = P(dB) - 5.87dB =$ aprox. $P(dB) - 6dB$

So, the accepted interference level will be, for RSL = -83dB and FM=10dB:

$$I = RSL+FM-6= -83+10-6 = -79dB \qquad (2)$$

Replacing in (1) results:

Path_loss = 40 – (-79) = 119dB

In LOS, the path loss at frequency f(GHz) and distance d(m) is given by:

Path_loss = 32.4 + 20 * log (f) + 20 * log (d)

Path_loss - 32.4 - 20*log (f) =20*log (d)

The separation distance d (km) between Base Stations is given at the frequency f (MHz) by:

$d = 10^{(Path\_loss - 32.4 - 20 * \log(f)) / 20}$

In our case:

$d = 10^{(119-32.4-20*\log(5800))/20} = 3.685$ km

In conclusion, in order to avoid the interference between 2 Base Stations using directional antennae, and no co-ordination for adjacent channel frequency planning or synchronization, the separation distance should be higher than 3.7km!

For the case when one antenna is omni and the other one is directional, the path-loss became:

Path_loss = 119 – (17-10) = 112dB

And d= $10^{(112-32.4-20*\log(5800))/20}$ = 1.64km.

3.1.4. Base Station minimum separation – 2.4GHz

Using the same methodology as above, results:

Adjacent channel interferer:
For omni antennae, 3.2km
For directional antennae: 15.8km
Co-channel interferer:
More than 120km

3.1.5. Co-channel

In the co-channel situation, the interference should not affect the RSL by more than 1dB. As the interference is additive to noise, for 1dB degradation the interference power should be lower than:

I2 $\leq$ RSL-SNR-6dB = -83dBm – 9.8dB – 6dB = -98.8 dBm

I2 = Ptb1+AGb1-CL1+ AGb2-CLs2 – Path_loss $\leq$ -98.8dBm

For directional antennae:

Path_loss $\geq$ 52dBm – (- 98.8dBm) = 150.8dB, resulting:

d (km) = $10^{(150.8-32.4-20*\log(5800))/20} = 10^{2.116}$ = 130km

For one directional and one omni antenna:

Path_loss $\geq$ 52dBm –(17-10)- (- 98.8dBm) = 143.8dB, resulting:

d (km) = $10^{(143.8-32.4-20*\log(5800))/20} = 10^{1.8}$ = 63km

Conclusion: For non-synchronized Base Stations, with no co-ordination, for 1dB RSL degradation, no operation is possible at distances lower than the horizon distance (60km), making impossible the frequency reuse.

3.1.6. Proposed solutions in 802.16 community

See Table 2.

Table 2 – Proposed solutions to resolve BS-BS Interference

No.	Commenter	Comment	Replay Commenter	Replay Comment	Group resolution
1	Zion Hadad	Probably we will have tables of BW reference clocks, GI sizes, which will bring the PHy's to synchronize in time. I think that we have to add that to 802.16c			
2	Phil Barber	I think more robust mechanics for supporting indirect BS synchronization through SS detection and reporting of 'hidden node' conflicts might be a better mechanism in LE use.	Marianna	How will talk different PHYs?	
3	Marianna G.	Use PHY sync of MAC Frames and Tx/Rx: Co-ordination possible: Frame start PHY Sync marker and MIB for Frame duration, Tx and Rx intervals. Co-ordination not possible (private use): PHY only mechanism. Systems may use GPS or follow the Sync Markers of already deployed systems	Duncan McClure	Agree that PHY synchronization is the best solution, if it is technology independent.	

3.2. Base Station to/from Subscriber Station

3.2.1. Adjacent channel

Victim BS

Victim SS

3.2.2. Co-channel

Victim BS

Victim SS

3.3. Subscriber Station to Subscriber Station

3.3.1. Adjacent channel

Victim SS

3.3.2. Co-channel

Victim SS

ANNEX 1

Radio Characteristics

The data is taken from 802.16REVd/D3.

WirelessMAN Single Carrier (Sca)

8.2.3.9 Receiver sensitivity

Receiver sensitivity shall be better than the values listed below (computed at 10 -3 uncoded BER, and a total of 7 dB in receiver noise figure and 3 dB implementation loss). BW is specified in MHz.

QPSK: -93.2 +10*log(BW)
16-QAM: -86.2 +10*log(BW)
64-QAM: -80 +10*log(BW)

SN*Rreq* assumptions (for uncoded signals at 10 -3 BER) are the following:
QPSK: 9.8 dB
16-QAM: 16.8 dB
64-QAM: 23.0 dB.

8.2.3.10 Receiver maximum input signal

A BS shall be capable of receiving a maximum on-channel operational signal of –40 dBm and should tolerate a maximum input signal of 0 dBm without damage to circuitry. An SS shall be capable of receiving a maximum on-channel operational signal of –20 dBm and should tolerate a maximum input signal of 0 dBm without damage to circuitry.

8.2.3.11 Receiver adjacent channel interference

A system shall achieve the minimum adjacent and alternate adjacent channel interference performance as shown in Table 185. All measurements shall be performed uncoded.

Table 185—Minimum adjacent and alt. adjacent channel interference performance

	At BER 10^{-3}, for 3 dB degradation	**At BER 10^{-3}, for 1 dB degradation**
1st adjacent channel interference C/I	BPSK: –12 QPSK: –9 16-QAM: –2 64-QAM: +5 256-QAM: +12	BPSK: –8 QPSK: –5 16-QAM: +2 64-QAM: +9 256-QAM: +16
2nd adjacent channel interference C/I	BPSK: –37 QPSK: –34 16-QAM: –27 64-QAM: –20 256-QAM: –13	BPSK: –33 QPSK: –30 16-QAM: –22 64-QAM: –16 256-QAM: –9

WirelessMAN OFDM

8.3.10.1 Receiver sensitivity

The BER measured after FEC shall be less than 10^{-6} at the power levels given by Equation (90) for standard message and test conditions. If the implemented bandwidth is not listed, then the values for the nearest smaller listed bandwidth shall apply. The minimum input levels are measured as follows:

— At the antenna connector or· through a calibrated radiated test environment,

— Using the defined standardized message packet formats, and

— Using an AWGN channel.

The receiver minimum input level sensitivity (R_{SS}) shall be (assuming 5 dB implementation margin and 7dB Noise Figure):

$$R_{SS} = -102 + SNR_{Rx} + 10 \cdot \log\left(F_S \cdot \frac{N_{used}}{N_{FFT}} \cdot \frac{N_{subchannels}}{16}\right)$$

where:

SNR_{Rx} the receiver SNR as per Table 224 in dB

F_S sampling frequency in MHz as defined in 8.3.2.2

$N_{sub\text{-}channels}$ the number of allocated sub-channels (default 16 if no sub-channelization is used).

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Table 224—Receiver SNR assumptions

Modulation	Coding rate	Receiver SNR (dB)
QPSK	1/2	9.4
	3/4	11.2
16-QAM	1/2	16.4
	3/4	18.2

8.3.10.2 Receiver adjacent and alternate channel rejection

The receiver adjacent and alternate channel rejection shall be met over the required dynamic range of the receiver, from 3dB above the reference sensitivity level specified in 8.3.10.1 to the maximum input signal level as specified in 8.3.10.3.

Table 225—Adjacent and nonadjacent channel rejection

Modulation/coding	Adjacent Channel Interference C/I (dB)	Nonadjacent channel rejection (dB)
16-QAM-3/4	-11	-30
64-QAM-3/4	-4	-23

8.3.10.3 Receiver maximum input signal
The receiver shall be capable of receiving a maximum on-channel signal of –30 dBm, and shall tolerate a maximum signal of 0 dBm without damage.

WirelessMAN OFDMA

8.4.13.1 Receiver sensitivity
The BER shall be less than 10^{-6} at the power levels shown in Table 264 for standard message and test conditions.
If the implemented bandwidth is not listed, then the values for the nearest smaller listed bandwidth shall apply. The minimum input levels are measured as follows:
— At the antenna connector or· through a calibrated radiated test environment,
— Using the defined standardized message packet formats, and
Using an AWGN channel.
Table 264 (as well as Table 263) are derived assuming 5 dB implementation loss, a Noise Figure of 7 dB and receiver SNR and E_b/N_0 values as listed in Table 265.
Table 265—Receiver SNR and E_b/N_0 assumptions

Modulation	E_b/N_0 (dB)	Coding rate	Receiver SNR (dB)
QPSK	10.5	1/2	9.4
		3/4	11.2
16-QAM	14.5	1/2	16.4
		3/4	18.2
64-QAM	19.0	2/3	22.7
		3/4	24.4

8.4.13.2 Receiver adjacent and alternate channel rejection
The adjacent channel rejection and alternate channel rejection shall be measured by setting the desired signal's
strength 3 dB above the rate dependent receiver sensitivity (see Table 264) and raising the power level of the interfering signal until the specified error rate is obtained. The power difference between the interfering
signal and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a conforming OFDMA signal, not synchronized with the signal in the channel under test. For nonadjacent channel testing the test method is identical except the interfering channel shall be any channel other than the adjacent channel or the co-channel.
For the PHY to be compliant, the minimum rejection shall exceed the following:
Table 266—Adjacent and nonadjacent channel rejection

Modulation/coding	Adjacent channel rejection (dB)	Nonadjacent channel rejection (dB)
16-QAM-3/4	11	30
64-QAM-2/3	4	23

8.4.13.3 Receiver maximum input signal
The receiver shall be capable of receiving a maximum on-channel signal of –30 dBm, and shall tolerate a maximum signal of 0 dBm without damage.