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Interference between systems sharing spectrum in 3.65GHz

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1 Introduction

In order to receive a better idea of the coexistence between different systems sharing a channel and also for the suitable power levels to be used by systems operating as Slaves or by systems operating during Common and Shared Frames are needed simulation results. This contribution provides results, basically as SNR degradation due to interference, for the following situations:

- A. Co-channel operation
    - 3 systems share a channel in 3.65GHz, one being an 802.11 system and two being 802.16h systems;
    - 2 systems share a channel, both being 802.16h systems
    - The systems are populated with at least 4 subscriber units situated at the margin of the cell
    - The target rate at the cell margin is corresponding to QPSK3/4; however in order to compensate the link-budget in DL it was necessary to reduce the up-link rate correspondingly to QPSK1/2.
    - 1dB is reserved for interference accommodation, 7 dB are reserved as fading loss
    - The propagation model used is dual-slope
    - The radius of 802.16e system is considered as reference R
    - The systems are separated by at least √3*R/2.
- B. Adjacent channels operation
    - An 802.16h-based receiver is interfered by an 802.11-based transmitter operating on the adjacent or second adjacent (alternate) channel.

The computations (see fig.1 and Table 1) for systems type 1 and 4 conduct to R=10km for an 802.16e-OFDMA and r= 5.2km for an 802.11y system. A distance of 8.5km separates the units C1, A2 and B4.

The geometry of the basic system is shown in fig.1:

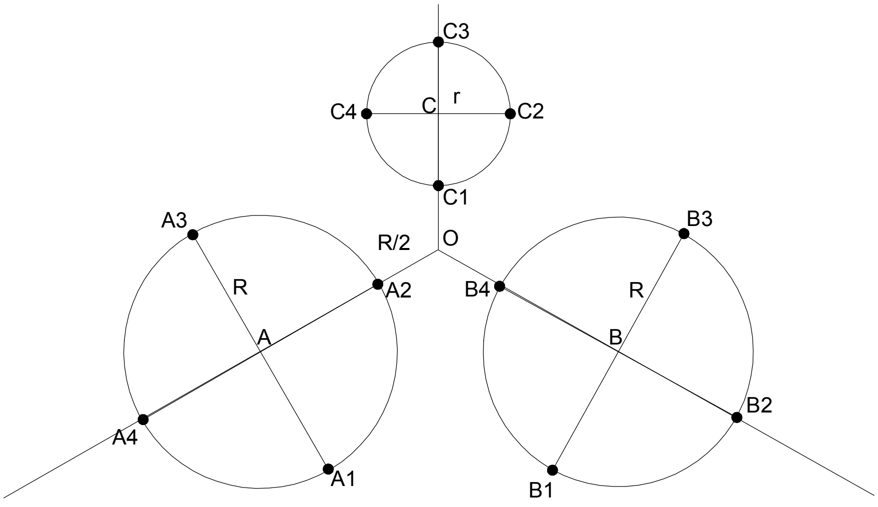


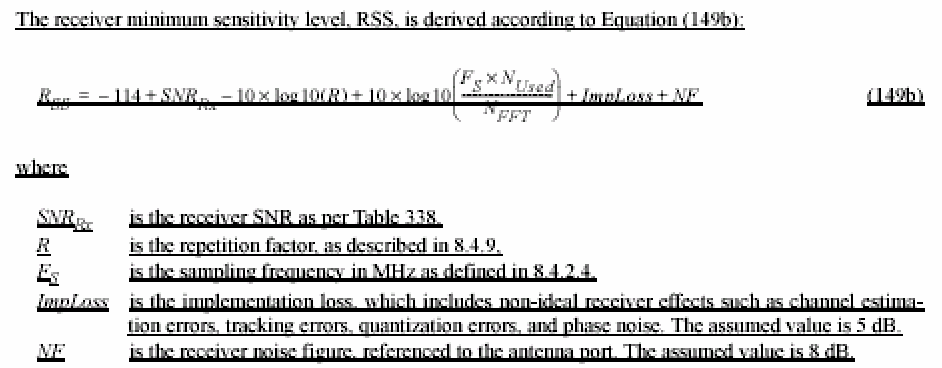
Fig. 1 Geometry

The systems around Base Stations A and B are based on 802.16 technology and are named “System A” and “System C”. The system around the Base Station C is based on 802.11y technology.

2 System parameters and link budget

2.1 802.16 Sensitivity level and SNR

The sensitivity level for the OFDMA PHY is defined as:



The receiver minimum sensitivity level, RSS, is derived according to Equation (149b):

$$R_{SS} = -114 + SNR_{Rx} - 10 \times \log 10(R) + 10 \times \log 10\left(\frac{F_S \times N_{Used}}{N_{FFT}}\right) + ImpLoss + NF \qquad (149b)$$

where

SNR_{Rx}	is the receiver SNR as per Table 338.
R	is the repetition factor, as described in 8.4.9.
F_S	is the sampling frequency in MHz as defined in 8.4.2.4.
$ImpLoss$	is the implementation loss, which includes non-ideal receiver effects such as channel estimation errors, tracking errors, quantization errors, and phase noise. The assumed value is 5 dB.
NF	is the receiver noise figure, referenced to the antenna port. The assumed value is 8 dB.

However, the industry is using better NF and Implementation loss. The typical implementation parameters are shown in Table 1.

The SNR for the OFDMA PHY is specified as:

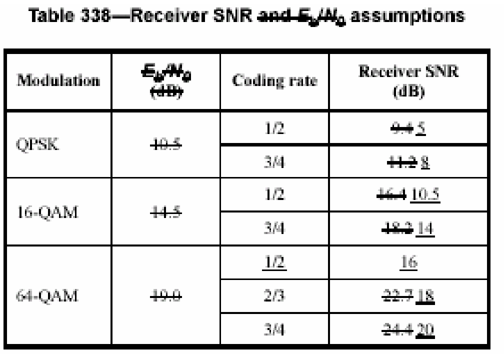


Table 338—Receiver SNR ~~and E_b/N_0~~ assumptions

Modulation	~~E_b/N_0 (dB)~~	Coding rate	Receiver SNR (dB)
QPSK	~~10.5~~	1/2	~~9.4~~ 5
		3/4	~~11.2~~ 8
16-QAM	~~14.5~~	1/2	~~16.4~~ 10.5
		3/4	~~18.2~~ 14
64-QAM	~~19.0~~	1/2	16
		2/3	~~22.7~~ 18
		3/4	~~24.4~~ 20

2.2 802.11 Receive Sensitivity level for different modulations

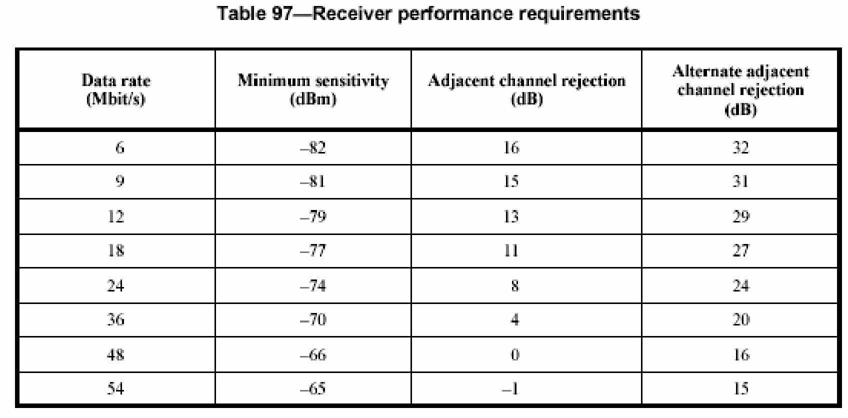


Table 97—Receiver performance requirements

Data rate (Mbit/s)	Minimum sensitivity (dBm)	Adjacent channel rejection (dB)	Alternate adjacent channel rejection (dB)
6	–82	16	32
9	–81	15	31
12	–79	13	29
18	–77	11	27
24	–74	8	24
36	–70	4	20
48	–66	0	16
54	–65	–1	15

The following table shows the modulations relative to the data rates:

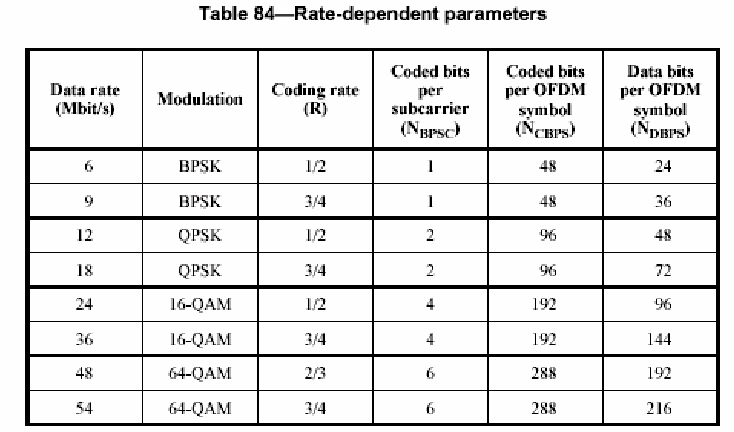


Table 84—Rate-dependent parameters

Data rate (Mbit/s)	Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

However the Base Station parameters, according to the industry implementations, are performing better. Table 1 indicates the parameters used in calculations.

2.3 System parameters and link budget

The system parameters and the link budget are shown in continuation. These assumptions are developed for outdoor deployments. For outdoor-to-indoor deployments the SS (Subscriber Station) / MS(Mobile Station) antenna gains, the fade margin and the propagation models will be different.

System 2, based on OFDM, has a link budget differing only with 1 dB from the OFDMA system and was not considered as a separate case.

System 3, based on the RSL (Receive Sensitivity Level) indicated in the 802.11 standards was not considered a typical implementation for the Base Station. System 4 reflects an 802.11 system having the Base Station parameters in line with the market offering for large area deployments in 5GHz.

Table 1

	System type 1		System type 2		System type 3		System type 4	
	BS to outdoor 802.16 OFDMA PHY		**BS to outdoor 802.16 OFDM PHY**		**BS to outdoor 802.11 v1**		**BS to outdoor 802.11 v2**	
System/direction	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**
Frequency (MHz)	3650	3650	3650	3650	3650	3650	3650	3650
Lambda (m)	0.0822	0.0822	0.0822	0.0822	0.0822	0.0822	0.0822	0.0822
BS height (m)	25	25	25	25	25	25	25	25
SU height (m)	7	7	7	7	7	7	7	7
Wall penetration (dB)	0	0	0	0	0	0	0	0
Supplementary margin to accommodate interference (dB)	1	1	1	1	1	1	1	1
Fade Margin - LOS	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Supplementary Fade Margin - All LOS	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Sub-channel number	**4.0**	**1.0**	**4.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
OFDMA gain	6.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0
Tx power [dBm]	25	33	25	33	25	25	**25**	**33**
Tx antenna cable loss [dB]	0	0	0	0	0	0	0	0
Tx Antenna Gain [dB]	6	10	6	10	6	10	6	10
Tx array gain factor[dB]	0	0	0	0	0	0	0	0
Tx EIRP [dBm]	**31**	**43**	**31**	**43**	**31**	**35**	**31**	**43**
FCC Limitation in 3.65GHz	43.01	43.01	43.01	43.01	43.01	43.01	43.01	43.01
Rx antenna gain [dB]	10	6	10	6	10	6	10	6
Rx antenna cable loss [dB]	0	0	0	0	0	0	0	0
Rx array gain factor[dB]	0	0	0	0	0	0	0	0
Rx Noise figure [dB]	5	7	5	7			7	11
Rx noise Bandwidth [MHz]	20	20	20	20	20	20	20	20
Implementation loss (dB)	2	2	2	2			2	3
Rx noise power [dBm]	-96.0	-94.0	-96.0	-94.0	-101.0	-101.0	-94.0	-90.0
SNR at BPSK1/2	2	2	3	3			4	4
Sensitivity at BPSK1/2	-92.0	-90.0	-91.0	-89.0	-82.0	-82.0	-88.0	-82.0
SNR at QPSK 1/2	5.0	5.0	6.0	6.0				
Sensitivity at QPSK1/2	-89.0	-87.0	-88.0	-86.0	-79.0	-79.0	**-85.0**	-79.0
SNR at QPSK 3/4	8.0	8.0	9.0	9.0				
Sensitivity at QPSK3/4	**-86.0**	**-84.0**	**-85.0**	**-83.0**	**-77.0**	**-77.0**	-83.0	**-77.0**

SNR at 16QAM 1/2	10.5	10.5	11.5	11.5				
Sensitivity at 16QAM 1/2	-83.5	-81.5	-82.5	-80.5	-74.0	-74.0	-80.0	-74.0
SNR at 16QAM 3/4	14	14	15	15				
Sensitivity at 16QAM 3/4	-80.0	-78.0	-79.0	-77.0	-70.0	-70.0	-76.0	-70.0
System gain at BPSK1/2	139.0	139.0	138.0	138.0	123.0	123.0	129.0	131.0
System gain at QPSK1/2	136.0	136.0	135.0	135.0	120.0	120.0	126.0	128.0
System gain at QPSK3/4 DL	**133.0**	**133.0**	**132.0**	**132.0**	**118.0**	**118.0**	**126.0**	**126.0**
System gain at 16QAM1/2	130.5	130.5	129.5	129.5	115.0	115.0	121.0	123.0
System gain at 16QAM 3/4	127.0	127.0	126.0	126.0	111.0	111.0	117.0	119.0
Supplementary Fade Margin – Interference allowance	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Fade Margin - LOS	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Supplementary Fade Margin - All LOS	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Sys gain at QPSK3/4 DL, LOS	**125.0**	**125.0**	**124.0**	**124.0**	**110.0**	**110.0**	**118.0**	**118.0**

3 Cell size

The following table summarizes the cell size calculation.

The dual slope model gives the loss at a distance d, for the height of the BS and SS noted with H_{BS} and H_{SS}:

$$D_o = 4 * H_{BS} * H_{SS} / \lambda$$

$$\text{If } d < D_o,\ \text{Loss} = \text{freespace}(d)$$

$$\text{If } d \geq D_o,\ \text{Loss} = \text{freespace}(D0) + 40 * \log(d/D_o)$$

	System type 1		System type 2		System type 3		System type 4	
System/direction	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**	**UL**	**DL**
Dual Slope								
Do (km)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Loss at Do	122.25	122.25	122.25	122.25	122.25	122.25	122.25	122.25
Range (km) at min rate	**9.98**	**9.97**	**9.42**	**9.41**	**2.08**	**2.08**	**5.22**	**5.22**

4 Signal levels

The signal levels are defined for each system in down-link and in up-link. The signal levels include:

- fade margin
- implementation loss
- interference margin.

The following table shows the signal levels for systems A,B,C:

	UL (SS/STA Receiver)	DL (BS, AP Receiver)
System A,B	-87dBm	-85dBm
System C	-86dBm	-79dBm

5 Basic interference

We will analyze the interference power and the connectivity for the systems in fig.1. We will assume a value of -72dBm to be used by both 802.11y and 802.16h UCP.
The color scheme indicate good conditions for blue, acceptable degradation for light yellow, not acceptable up to denial of service for orange to magenta.
The interference levels lower than the -72dBm detection thresholds are colored with green.

5.1 Interference into 802.11y systems

The maximum interference energy in the elements of the system around the Base Station C is shown below, for the case that only System A is active:

Element in system C	I+N (dBm)	SINR	Connectivity
C	-77.398	-8.60	No
C1	-81.676	2.68	No
C2	-87.895	8.89	QPSK1/2
C3	-88.273	9.27	QPSK1/2
C4	-85.508	6.51	BPSK1/2

The connectivity is considered for the worst case situation, when the 7dB fade margin will not be enough.
For the case in which both Systems A and B are active, the situation in system C is shown below:

Element in system C	I+N (dBm)	SINR	Connectivity
C	-74.4356	-11.56	No
C1	-81.6762	2.68	No
C2	-84.799	5.80	BPSK
C3	-87.0456	8.05	QPSK1/2
C4	-84.799	5.80	BPSK

The Energy Detect in 802.11y, even at levels of -72dB, will not work at this interference levels.
As any transaction in 802.11 implies ACK, both links need to be operational. The most affected part of the system is the Base Station.

The stations of system C see low interference levels and are not aware that the Base Station C is not able to decode their transmissions.

5.2 Interference into 802.16h systems

The maximum interference energy in the elements of System A or B is shown below, for the case that only System C is active:

Element in system A	I+N (dBm)	SINR	Connectivity
A	-81.49	-5.52	No
A1	-93.77	8.76	QPSK3/4
A2	-81.25	-3.76	No
A3	-88.30	3.29	QPSK1/2 rep 2
A4	-95.83	10.82	QPSK3/4

In this case the Base Station of the System A cannot work. The cell size is reduced accordingly to:

SNR – SINR = 8 – (-5.52) = 13.52dB.

The new cell size becomes:

R’ = Inv_Dual_slope (SysGain – SNR+SINR) = 125 – 13.5 = Inv_Dual_slope (111.5) = 2.46km.

So the cell size was reduced from 10km to 2.46 km, considering same data rate at the cell margin; **the cell coverage was reduced from 100% to 6.7%!**

If we accept the degradation of the data rate, at the margin of the cell, from QPSK2/3 to BPSK1/2, or by more than 60%, the new cell size will be: Inv_Dual_slope (117.5) = 4.92km and the covered area **will be reduced by aprox. 75%.**

If both System B and System C are active, the situation is:

Element in system A	I+N (dBm)	SINR	Connectivity
A	-81.0093	-6.00	No
A1	-87.5752	2.56	QPSK1/2 rep 2
A2	-79.8877	-5.12	No
A3	-86.7591	1.75	QPSK1/2 rep 4
A4	-90.8556	5.85	QPSK1/2 rep 2

The degradation of the cell size and its area will be worse than before.

The Subscriber Stations of the system A see relatively low interference levels and are not aware that the Base Station A will not be able to decode their transmissions.

Significant interference is caused to system A by the System B, as results from the table below:

Element in system A	I+N (dBm)	SINR	Connectivity
A	-85.90	3.19	QPSK1/2 rep 2
A1	-83.89	3.76	QPSK1/2 rep 2
A2	-80.32	0.77	QPSK1/2 rep 4
A3	-88.83	7.00	QPSK1/2
A4	-89.84	7.51	QPSK1/2

In conclusion, the coexistence solution needs to address a multitude of cases to give a suitable solution.

It is possible to see that all the systems interact in all their points, even if the distance between them is relatively high and was used the dual-slope propagation model. However, the most affected are the Base Stations and the stations situated towards the geometric center of the 3 cells. The interference levels which cause harmful degradation of the cell size are lower than the energy detection levels intended for 802.11y or 802.16h with UCP. The energy detection needs to use much lower levels in order to protect the cell size and the operator investments.

6 Using the Master/Slave/Shared frame concept

In the following calculations we will consider for simplicity that the Common sub-frames use the same power as transmitted during the Master sub-frames.

6.1 No parallel operation during the Master Frames

In this case there is no SNR degradation and all the 3 Master systems operate at the maximum rates.
The following table illustrates the connectivity during the Master sub-frames:

Receiver in system A	SNR (dB)	Connectivity	Receiver in system B	SNR (dB)	Connectivity	Receiver in system C	SNR (dB)	Connectivity
A	9	QPSK3/4	B	9	QPSK3/4	C	5	QPSK1/2
A1	9	QPSK3/4	B1	9	QPSK3/4	C1	9	QPSK3/4
A2	9	QPSK3/4	B2	9	QPSK3/4	C2	9	QPSK3/4
A3	9	QPSK3/4	B3	9	QPSK3/4	C3	9	QPSK3/4
A4	9	QPSK3/4	B4	9	QPSK3/4	C4	9	QPSK3/4

6.2 Slave systems during the Master Frames

The usage of the Slave slot implies that may be caused interference to some of the Master system elements, however the Master system can tolerate it because the traffic requirements are lower than planned. This is an issue of negotiation. However, a ruling can be made for a conservative situation.

In continuation will be analyzed the case of a DL Slave operation. For example, lets suppose that Base Station B tries to operate in parallel with the Master Base Station A. The Base Station B has to reduce its transmission power and by this is limiting its cell size. The Master system, based on the DL traffic requirements of its different subscribers and also on overall traffic load, will decide which interference levels will be acceptable. Due to reduced power, the Base Station B will give service to subscribers relatively nearly located.
In rural areas a significant amount of subscribers will be located in the village center, so having subscribers concentrated inside a circle of 1-2km relative to the village center is a real situation. Fig. 2 shows the location of the additional SS/MS in system B, located at the distance D_slave from the Base Station B.

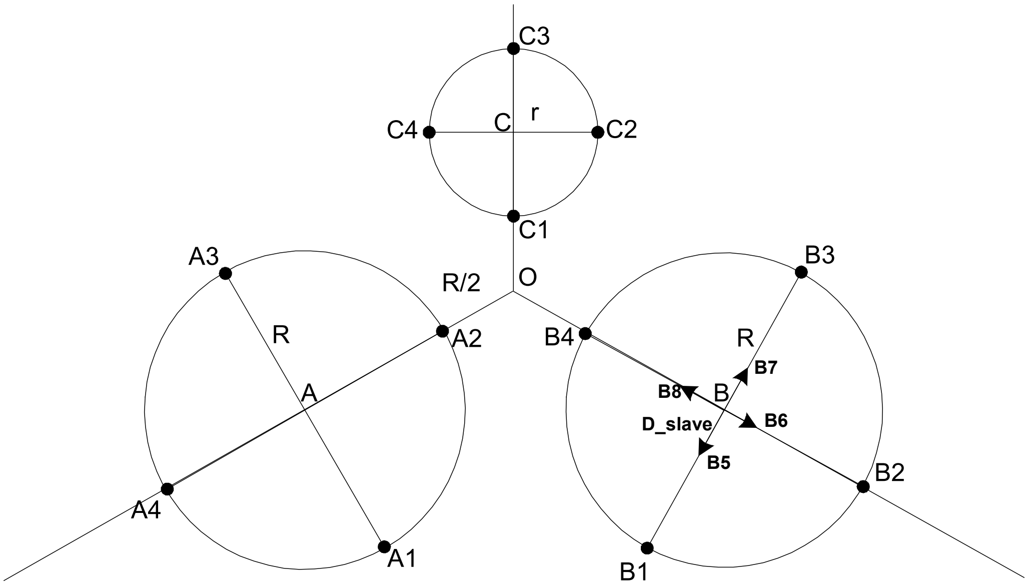


Fig 2 Slave subscriber stations in System B

6.2.1 Slave systems using same Tx/Rx splitting as the Master system

The assumptions in this case are based on the implementation by 802.11y of:

- Quiet Element in Beacons (see 7.3.2.23 Quiet element in 802.11h**);**
- Change of the Time Unit from 1024 us to 1000us;
- Beacon period equal with four MAC periods of 802.16 (typically 20ms).

In this case we considered a number of situations. The performance of the Master system is slightly reduced, but it will be the decision of the Master system what level of reduction may be acceptable.

Case 1: System B power reduction 9dB, System B slave cell radius=3km
The performance of system A, for the case that the Base Station B is operating with 9dB under the maximum power, is shown below:

Element in system A	I+N (dBm)	SINR	Connectivity
A1	-92.87	7.86	QPSK1/2
A2	-91.67	6.66	QPSK1/2
A3	-93.69	8.68	QPSK3/4
A4	-93.77	8.76	QPSK3/4

Due to the interference from Base Station A, only the subscribers in the relative vicinity of the Base Station will receive service. The case for the D_slave = 3km is shown below, while assuming no interference:

Element in system B	Signal (dBm)	SNR	Connectivity
B5	-82.19	11.80	QPSK3/4
B6	-82.19	11.80	QPSK3/4
B7	-82.19	11.80	QPSK3/4
B8	-82.19	11.80	QPSK3/4

The degradation of the system B (Slave) due to the interference of the Base Station A (Master) conducts to reduced SINR, as shown below:

Element in system B	I+N (dBm)	SINR	Connectivity
B5	-89.63	7.44	QPSK1/2
B6	-91.17	8.98	QPSK3/4
B7	-90.87	8.68	QPSK3/4
B8	-89.15	6.97	QPSK1/2

Case 2: System B power reduction 12dB, System B Slave - cell radius =2km

The performance of Master system A, for the case that the Base Station B is operating with 12dB under the maximum power, is shown below:

Element in system A	I+N (dBm)	SINR	Connectivity
A1	-93.39	8.38	QPSK3/4
A2	-92.67	7.66	QPSK1/2
A3	-93.83	8.82	QPSK3/4
A4	-93.88	8.87	QPSK3/4

The case for the D_slave = 2km is shown below, while assuming no interference:

Element in system B	Signal (dBm)	I+N (dBm)	SINR	Connectivity
B5	-81.67	-89.95	8.28	QPSK3/4
B6	-81.67	-90.87	9.20	QPSK3/4
B7	-81.67	-90.62	8.95	QPSK3/4
B8	-81.67	-89.51	7.85	QPSK1/2

Conclusion: the Master/Slave concept allows to significantly increase the cell capacity, as compared with Master only operation. In our case, a double number of subscriber stations were able to receive the downlink traffic.

6.3 Shared frames usage

The use of the Shared Frames is based on the reciprocal power reduction of the transmitters, having as effect a reduced interference and also a relatively reduced cell size. However, the communication can be established at higher distances as compared with the case of the Slave sub-frames.

We have based our DL calculations on the rule that all the 802.16-based Base Stations will reduce their power by 6dB or by 9dB. The 802.11 – based Base Stations are not considered in the following example. The new points – A9…A12 and B9…B12 represent the cell size for the case of the Shared sub-frames.

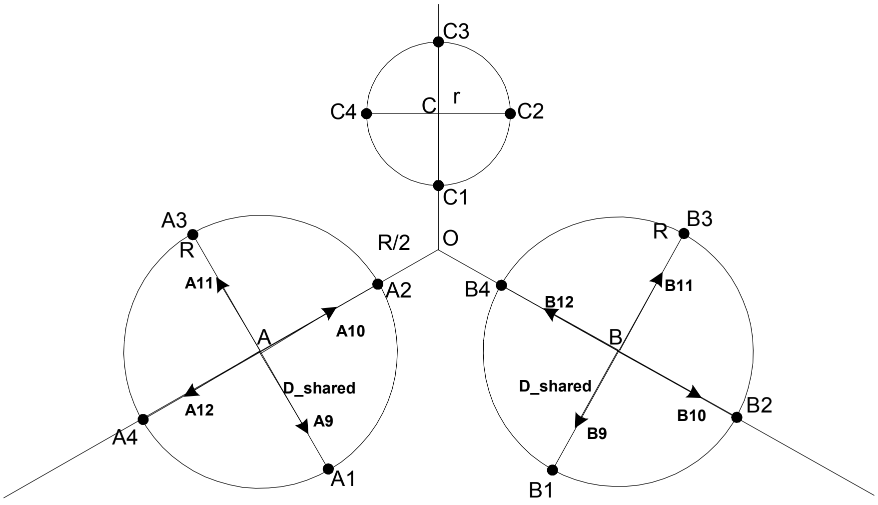


Fig 3 Subscriber stations in Shared sub-frames

Case 1: <u>Base Station A and B power reduction 6dB, cell radius=6km</u>

The performance of either system A or system B, for the case that the Base Stations A&B operate 6dB under the maximum power, is shown below:

Element in system A or B	I+N (dBm)	SINR	Connectivity
A9, B9	-92.19	8.98	QPSK3/4
A12, B10	-93.27	10.06	QPSK3/4
A11, B11	-93.12	9.91	QPSK3/4
A10, B12	-91.42	8.21	QPSK3/4

Case 2: Base Station A and B power reduction 9dB, cell radius=7km

The performance of either system A or system B, for the case that the Base Stations A&B are operating with 9dB under the maximum power, is shown below:

Element in system A or B	I+N (dBm)	SINR	Connectivity
A9, B9	-92.96	8.41	QPSK3/4
A12, B10	-93.66	9.11	QPSK3/4
A11, B11	-93.60	9.05	QPSK3/4
A10, B12	-92.33	7.78	QPSK1/2

6.4 Conclusion

The Coexistence Frame provides maximum spectrum resource utilization for 802.16 systems. A system may be able to use 100% of the time for communication and also to provide a maximum cell size.

The systems based on energy sensing have a lower time utilization, due to the fact that based on "Listen before send" mechanism, only part of the time may be used for communication. Even if the time is used, the cell size is restricted due to the harmful interference at levels below the "energy detect" levels.

7 Adjacent Channel Interference

7.1 802.11a mask

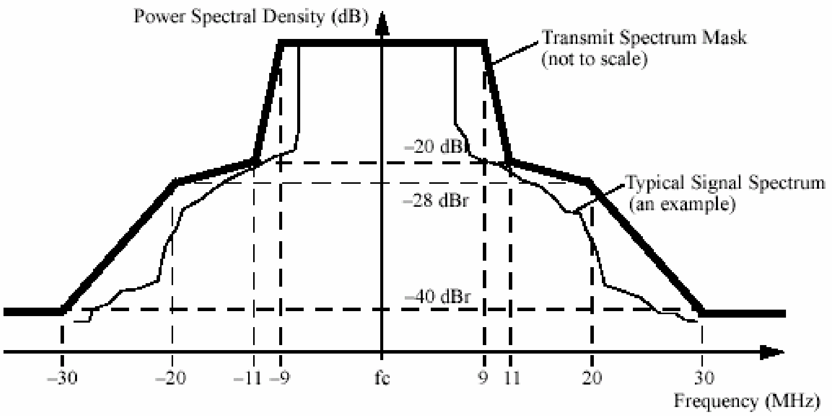


Figure 124—Transmit spectrum mask

7.2 802.16 mask

The mask defined for Wireless Human is shown below:

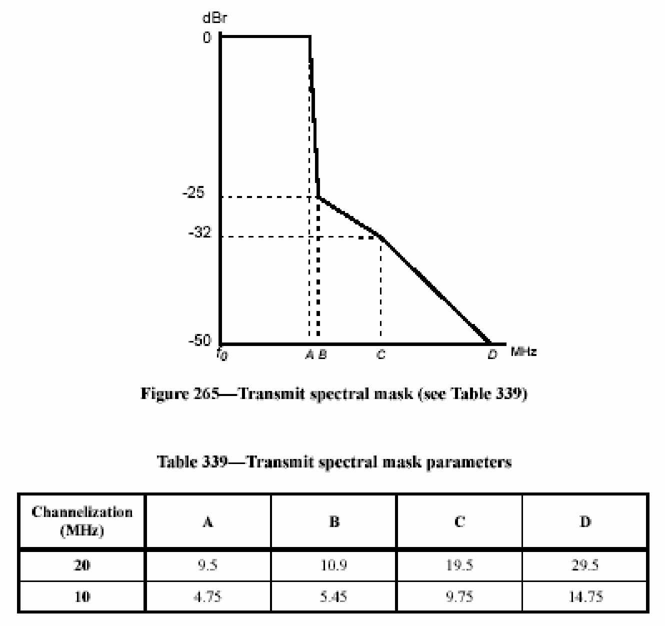


Figure 265—Transmit spectral mask (see Table 339)

Table 339—Transmit spectral mask parameters

Channelization (MHz)	A	B	C	D
20	9.5	10.9	19.5	29.5
10	4.75	5.45	9.75	14.75

The 802.16 WirelessHUMAN mask (5GHz) is 4-5dB more stringent than the 802.11a mask.

7.3 802.11a - Adjacent and alternate channel rejection

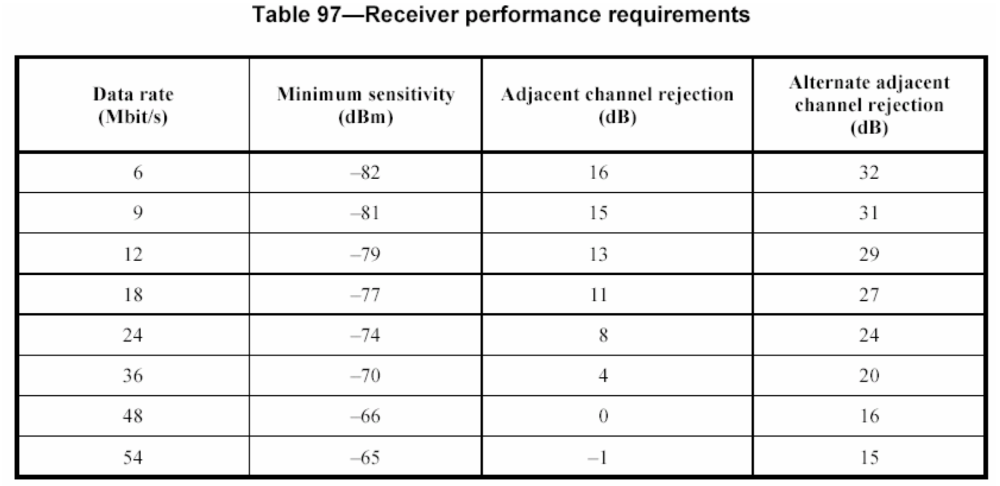
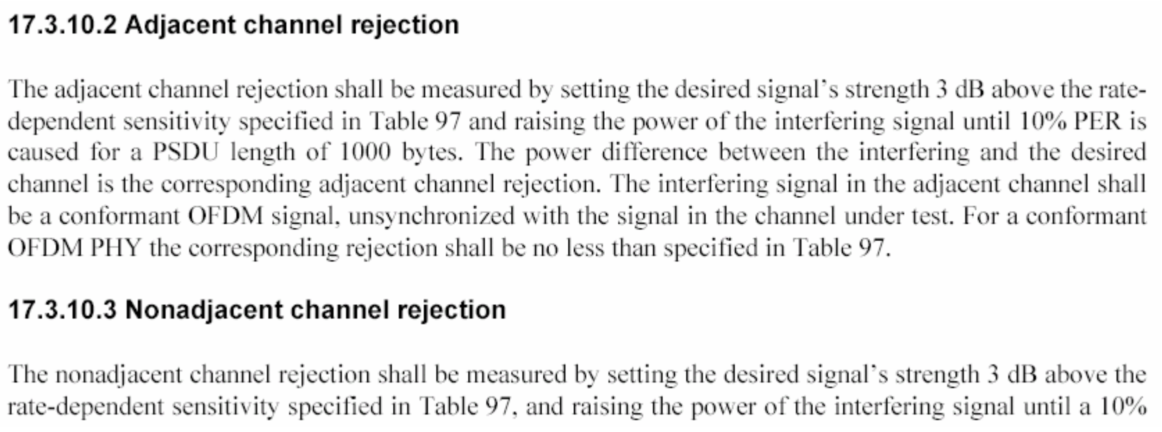


Table 97—Receiver performance requirements

Data rate (Mbit/s)	Minimum sensitivity (dBm)	Adjacent channel rejection (dB)	Alternate adjacent channel rejection (dB)
6	–82	16	32
9	–81	15	31
12	–79	13	29
18	–77	11	27
24	–74	8	24
36	–70	4	20
48	–66	0	16
54	–65	–1	15

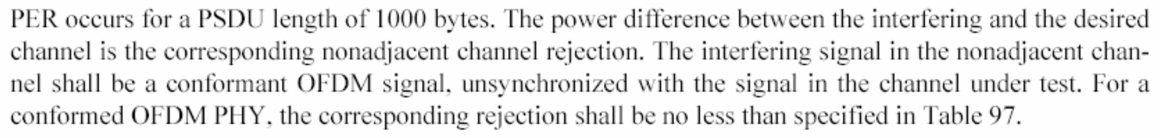


17.3.10.2 Adjacent channel rejection

The adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 97 and raising the power of the interfering signal until 10% PER is caused for a PSDU length of 1000 bytes. The power difference between the interfering and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a conformant OFDM signal, unsynchronized with the signal in the channel under test. For a conformant OFDM PHY the corresponding rejection shall be no less than specified in Table 97.

17.3.10.3 Nonadjacent channel rejection

The nonadjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 97, and raising the power of the interfering signal until a 10%



PER occurs for a PSDU length of 1000 bytes. The power difference between the interfering and the desired channel is the corresponding nonadjacent channel rejection. The interfering signal in the nonadjacent channel shall be a conformant OFDM signal, unsynchronized with the signal in the channel under test. For a conformed OFDM PHY, the corresponding rejection shall be no less than specified in Table 97.

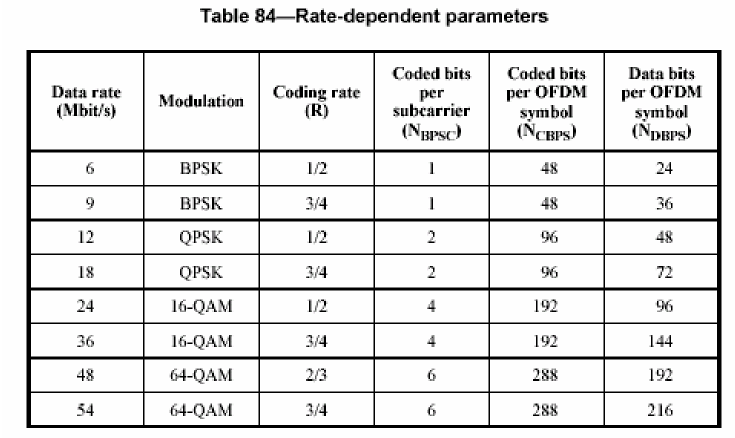
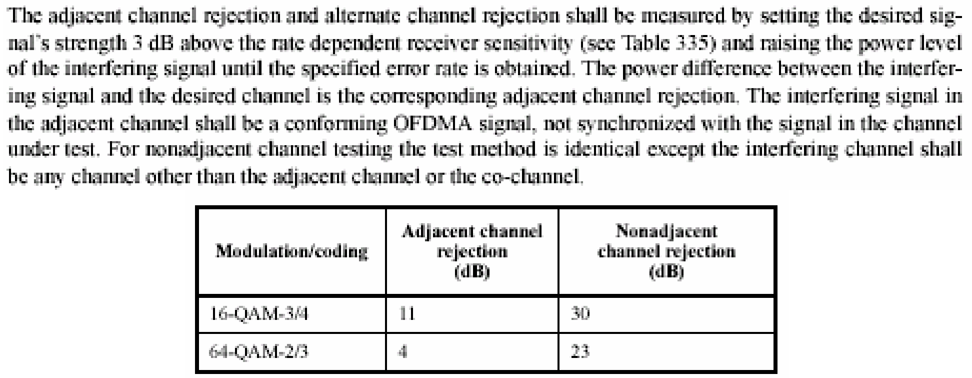


Table 84—Rate-dependent parameters

Data rate (Mbit/s)	Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

7.4 OFDMA adjacent channel rejection

The standard indicates the adjacent channel rejection at higher rates, as follows:



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 335) 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.

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

Based on the SNR values, the adjacent and non-adjacent channel rejection can be extrapolated as shown in the following Table, based on the relations below, for example for translation to QPSK1/2:

$ACI = ACI_{16QAM3/4} + (SNR_{16QAM3/4} – SNR_{QPSK1/2}) = 11 + (14 - 5) = 20dB$, for the first adjacent channel;

$ACI_{2nd} = ACI_{2nd16QAM3/4} + (SNR_{16QAM3/4} – SNR_{QPSK1/2}) = 30 + (14 - 5) = 39dB$, for the second adjacent channel.

The 802.16-OFDMA rejection value is better than the 802.11a rejection at the same modulation by 7, resp. 10dB. However, the interfering signal was considered to have OFDMA masks, and not 802.11a masks.

Inter 802.16 systems adjacent channel rejection

Modulation/coding	Adjacent channel rejection (dB)	Alternate channel rejection (dB)
QPSK-1/2 rep 4	26	45
QPSK-1/2 rep 2	23	42
QPSK-1/2	20	39
QPSK 3/4	17	36
16QAM 1/2	14.5	33.5

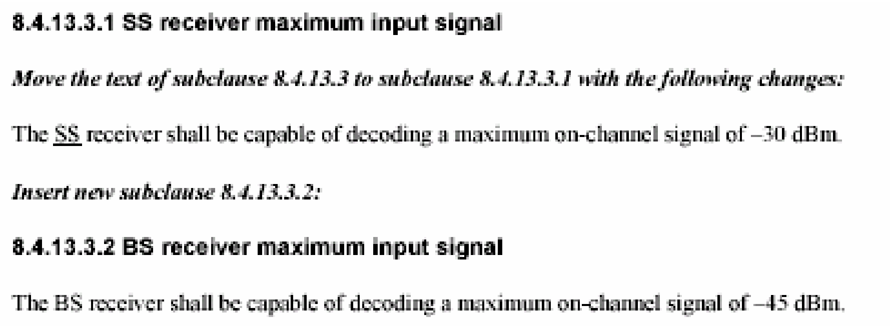
Taking into consideration that the 802.11a mask it is worse by aprox. 4db, we will use in our estimations the modified values, as shown below:

Table 802.16 - OFDMA – adjacent channel rejection of 802.11a

Modulation/coding	Adjacent channel rejection (dB)	Alternate channel rejection (dB)
QPSK-1/2 rep 4	22	41
QPSK-1/2 rep 2	19	38
QPSK-1/2	16	35
QPSK 3/4	13	32
16QAM 1/2	10.5	29.5

7.5 Receiver blocking

The 802.16e-2005 requirement is:



8.4.13.3.1 SS receiver maximum input signal

Move the text of subclause 8.4.13.3 to subclause 8.4.13.3.1 with the following changes:

The SS receiver shall be capable of decoding a maximum on-channel signal of –30 dBm.

Insert new subclause 8.4.13.3.2:

8.4.13.3.2 BS receiver maximum input signal

The BS receiver shall be capable of decoding a maximum on-channel signal of –45 dBm.

7.6 Adjacent channel RSL degradation

The degradation of the RSL is given in dB by the difference between $(I+N)_{dBm}$ and $N_{dBm.}$
The relation for translating the power into the adjacent channel in co-channel power is:

$$\mathbf{TF = SNR + impl\_loss + ACI}$$

where:
TF – translation factor (dB)
Impl_loss – implementation loss.

For the 802.16, OFDMA PHY, results TF=27dB. Incase of interference from an 802.11a system, TF becomes 23dB.

7.7 Scenarios for the calculation of the adjacent channel interference

We limit our calculations to the case of an 802.16 victim system. The 802.16 system is implementing the OFDMA-PHY, while the 802.11 system is implementing the OFDM PHY. The other system parameters are those in Table 1.

The geometry for a 802.11 transmitter creating interference to an 802.16 receiver is shown below. It is assumed that d varies, from almost co-location to high distances.

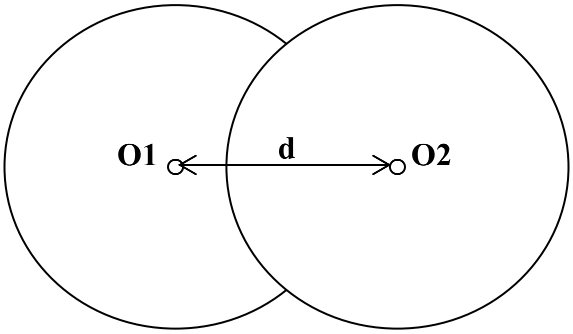


Fig 2 Geometry for adjacent channel interference

7.7.1 802.11 BS to 802.16 SS/MSS interference

The following table shows the degradation due to 802.11 BS to 802.16 SS interference. The yellow color indicates receiver blocking situation. Note that the interference-free cell size was calculated as 9.98km.

Distance between 802.11 BS and 802.16 SS/MS	Interference in the adjacent channel (dBm)	Interference translated into channel (dBm)	I+N (dBm)	RSL degradation (dB)	New cell size at QPSK3/4 (km)	New cell size at QPSK1/2 (km)
10	-14.65	-37.65	-37.6458	56.34	0.02	0.03
20	-20.67	-43.67	-43.6664	50.32	0.04	0.05
50	-28.63	-51.63	-51.625	42.36	0.09	0.13
100	-34.65	-57.65	-57.6448	36.34	0.18	0.25
185	-39.99	-62.99	-62.9858	31.00	0.33	0.47
500	-48.63	-71.63	-71.6001	22.39	0.89	1.26
1000	-54.65	-77.65	-77.5462	16.44	1.76	2.49
2000	-60.67	-83.67	-83.2809	10.71	3.41	4.82
5000	-68.63	-91.63	-89.6382	4.35	7.09	9.24
10000	-76.04	-99.04	-92.8085	1.18	9.33	11.08

7.7.2 802.11BS to 802.16 - BS interference

Distance between 802.11 BS and 802.16 BS	Interference in the adjacent channel (dBm)	Interference translated into channel (dBm)	I+N (dBm)	RSL degradation (dB)	New cell size at QPSK3/4 (km)	New cell size at QPSK1/2 (km)
10	-14.65	-37.65	-37.6459	58.34	0.01	0.02
20	-20.67	-43.67	-43.6664	52.32	0.03	0.04
50	-28.63	-51.63	-51.6251	44.36	0.07	0.10
100	-34.65	-57.65	-57.6452	38.34	0.14	0.20
325	-44.88	-67.88	-67.8768	28.11	0.46	0.65
500	-48.63	-71.63	-71.6094	24.38	0.71	1.00
1000	-54.65	-77.65	-77.5827	18.41	1.41	1.99
2000	-60.67	-83.67	-83.4193	12.57	2.75	3.89
5000	-68.63	-91.63	-90.2706	5.72	6.06	8.54
10000	-74.65	-97.65	-93.729	2.26	8.76	10.42

7.8 BS to BS interference in 2nd adjacent channel

Distance between 802.11 BS and 802.16 BS	Interference in the alternate channel (dBm)	Interference translated into channel (dBm)	I+N (dBm)	RSL degradation (dB)	New cell size at QPSK3/4 (km)	New cell size at QPSK1/2 (km)
10	-14.65	-56.65	-56.6454	39.34	0.13	0.18
20	-20.67	-62.67	-62.6644	33.33	0.25	0.36
50	-28.63	-70.63	-70.6126	25.38	0.63	0.89
100	-34.65	-76.65	-76.5956	19.39	1.25	1.77
325	-44.88	-86.88	-86.3803	9.61	3.87	5.47
500	-48.63	-90.63	-89.5168	6.47	5.55	7.84
1000	-54.65	-96.65	-93.2951	2.69	8.55	10.16
2000	-60.67	-102.67	-95.1441	0.85	9.51	11.30
5000	-68.63	-110.63	-95.8429	0.15	9.90	11.76
10000	-74.65	-116.65	-95.9525	0.04	9.96	11.84

7.9 Adjacent channel interference – conclusions

The above results show that 802.11 and 802.16 systems cannot coexist in adjacent channels, in the same area:

- both the SS and BS suffer from blocking up to high distances (> 50m for SS and > 300m for BS);
- when the adjacent channel interference is below the blocking levels, is producing a drastic cell size degradation
- Even at level signals above the blocking level the cell size degradation is not acceptable
- A spare channel between systems will improve (but not resolve) the situation – considering 3 channels/system results that the channel size shall be max. 7MHz;

- The only solution to improve / resolve the blocking situation is to isolate the two types of systems in time, by applying the Coexistence Frame
- The coexistence Frame needs to be restructured such that the separation in time will extend its applicability to separation of 802.11 technology from 802.16 technology in adjacent channels as well.

8 Conclusions

The "energy detection" is not suitable for large cell deployments, due to the fact that the energy sensing is done at too high levels. In order to avoid creating harmful interference to the 802.16 technology and destroy its cell size, 802.11y has two possible alternatives:

- reduce the "energy detect threshold" around the 802.16 sensitivity level for BPSK ½, or -92dBm
  - if this is the preferred way, the level needs to be more accurately calculated
- implement the separation in time (see more details in [1]) by:
  - Synchronizing the Base Stations with the absolute time
  - Implementing the Quiet periods with the parameters in [1]
  - Change the Time Unit from 1024 to 1000.

9 References

[1] Mariana Goldhamer - IEEE C802.16h-07/024 - Scheduling of Quiet Periods and Extended Quiet Periods in 802.11;
[2] IEEE Wireless LAN Edition; Standards Information Network; IEEE Press A compilation based on IEEE Std 802.11TM-1999 (R2003) and its amendments

[3]IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 5: Spectrum and Transmit Power Management Extensions in the 5 GHz band in Europe

[4] IEEE P802.11-REVma™/D8.09.0 - (Revision of IEEE Std 802.11-1999) – Draft Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications

[5] IEEE STD 802.16-2004

[6] IEEE Std 802.16e™-2005 and IEEE Std 802.16™-2004/Cor1-2005

[7] IEEE P802.16h/D2, January 2007