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Interference between three systems sharing a frequency channel 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 situation:

- 3 systems share a channel in 3.65GHz;
- One of the systems is 802.11y based, the others are 802.16e - OFDMA based
- 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.

The computations (see fig.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:

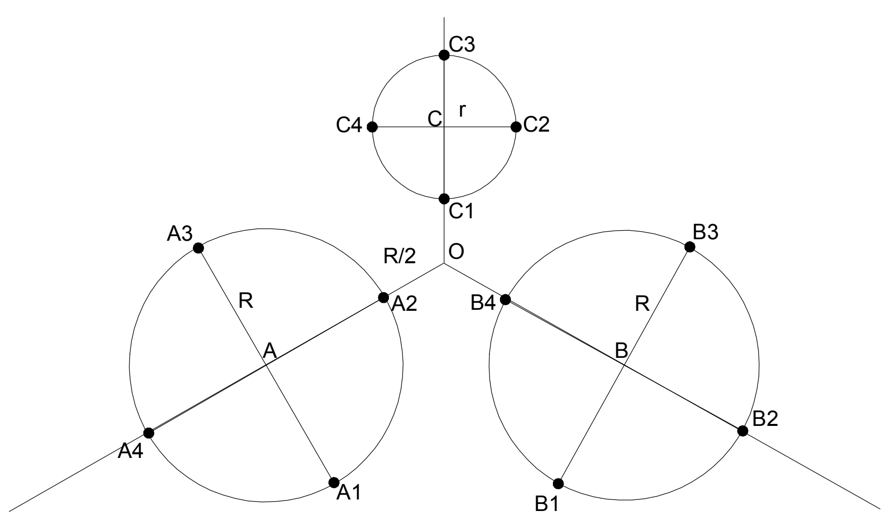

Fig. 1 Geometry

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

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/MS 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 realistic for the Base Station. System 4 reflects a 802.11 system having a Base Station parameters in line with the market offering for large area deployments in 5GHz.

	System type 1		System type 2		System type 3		System type 4	
	BS to outdoor 802.16 OFDMA PHY		**BS to outdoo r 802.16 OFDM PHY**		**BS to outdoo r 802.11 v1**		**BS to outdoo r 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.

	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

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)	SNIR	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)	SNIR	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.

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)	SNIR	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:

$$SNR - SNIR = 8 - (-5.52) = 13.52.$$

The new cell size becomes:

$$R' = Inv\_Dual\_slope\ (SysGain - SNR + SNIR) = 125 - 13.5 = Inv\_Dual\_slope\ (111.5) = 2.46km.$$

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)	SNIR	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.

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

Element in system A	I+N (dBm)	SNIR	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.

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.

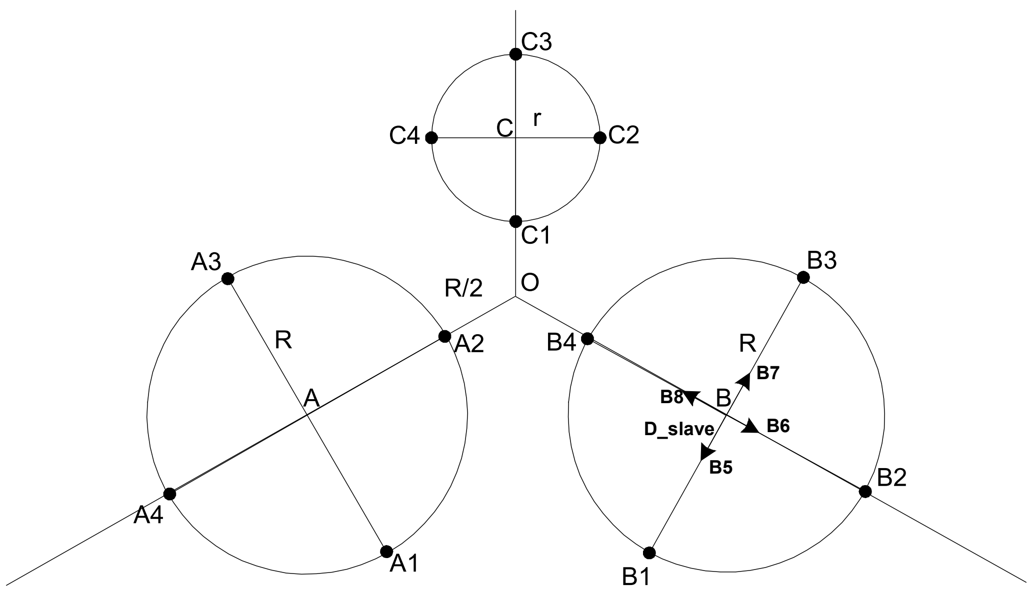

Fig 2 Slave subscriber stations in System B

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)	SNIR	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 SNIR, as shown below:

Element in system B	I+N (dBm)	SNIR	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)	SNIR	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)	SNIR	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

Regarding the use of the Shared Frames, there are a number of cases based on the reciprocal power reduction of the Base Stations.

t.b.c

6.4 Adjacent Channel Interference

t.b.c.