1. Adjacent band co-existence study between MFCN in 3400-3800 MHz and LAN in 3800-4200 MHz

Study is using for both WBB MP and MFCN the non sub array model.

* 1. Introduction

The MFCN frequency band 3.4-3.8 GHz was defined by ETSI in the European Harmonised Standard EN 301 908-24 through two notes (Note 4 and Note 5) below the Table 1-2 referring to the frequency band n77 (3300-4200 MHz) and n78 (3300-3800 MHz).

Note 4: In Europe, according to [i.24] and [i.8], radio equipment in band n77 operates between 3400 MHz and 3800 MHz (FDL\_low = 3400 MHz and FDL\_high = 3800 MHz).

Note 5: In Europe, according to [i.24] and [ i.8], radio equipment in band n78 operates between 3400 MHz and 3800 MHz (FDL\_low = 3400 MHz and FDL\_high = 3800 MHz).

The frequency band 3800-4200 MHz is not covered as an independent frequency band in the European Harmonised standard EN 301 908-24.

In this document, it is assumed that 3800-4200 MHz is an independent frequency band when defining the out of band emission mask and the receiver blocking mask, the spurious emissions is defined as 40 MHz away from the band edge, the in-band blocking and out of band blocking are also defined relative to the band edge 3800 MHz and 4200 MHz.

* 1. Analysis of Interference from LAN to MFCN
     1. Interference from outdoor LAN Small cell to MFCN Macro cell
        1. Simulation assumptions and scenario

As shown in Figure 1 and Figure 2, two cases are considered:

1. unsynchronised operation between MFCN and LAN without guard band;
2. unsynchronised operation with a guard band of 60 MHz.

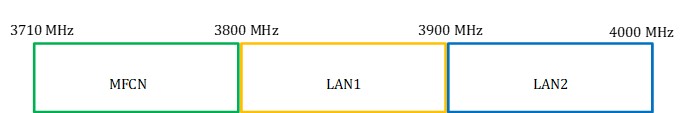


Figure 1: Unsynchronised operation without guard band

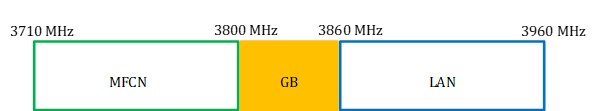


Figure 2: Unsynchronised operation with a guard band of 60 MHz

Two co-existence scenarios are studied, as shown in Figure 3 and Figure 4 :

1. Scenario: LAN outdoor Small cell is in the middle of MFCN 5G NR macro cell;
2. Scenario 2: MFCN Macro cell 5G NR BS is at the LAN outdoor small cell coverage edge.

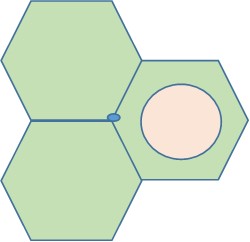


Figure 3: Scenario\_1 – LAN outdoor Small cell is in the middle of MFCN 5G NR Macro cell

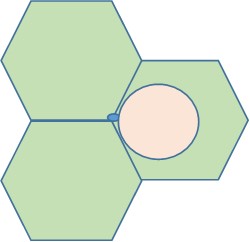


Figure 4: Scenario\_2 – MFCN Macro cell 5G NR BS is at the LAN outdoor Small cell coverage edge

The LAN BS (Medium Range BS) emission mask is plotted in Figure 5.

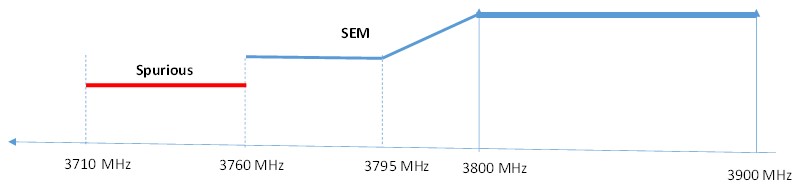


Figure 5: LAN BS Tx mask

The MFCN 5G NR BS (wide area BS) is illustrated in Figure 6.

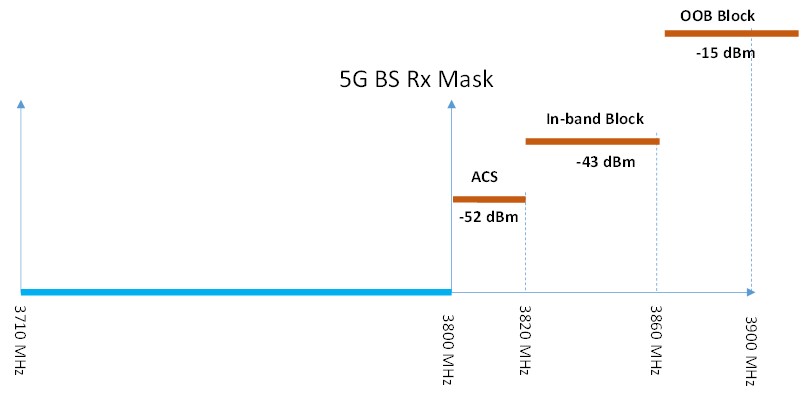


Figure 6: MFCN 5G NR BS Rx mask

The system parameters and deployment assumptions used in the simulations are summarized in Table 1.

Table 1: System parameters and deployment assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | MFCN 5G NR BS | LAN1 BS | LAN2 BS |
| Centre Frequency (MHz) | 3755 | 3850 | 3950 |
| Channel bandwidth (MHz) | 90 | 100 | 100 |
| BS Tx Power (EIRP dBm) | 75 (120 W) | 50, 45, 40, 35, 30 | 49, 45, 40, 35, 30 |
| 5G BS AAS antenna | 8x12 |  |  |
| Element gain (dBi) | 7.1 |  |  |
| 5G BS antenna height (m) | 25 |  |  |
| 5G BS antenna downtilt (°) | 6 |  |  |
| H/V element spacing | 0.5 for H  0.7 for V |  |  |
| Emission Mask | 3800-3840 MHz: SEM  Above 3840 MHz: -30 dBm/MHz |  |  |
| BS Rx mask | 3800-3820 MHz: ACS  3820-3880 MHz: in-band blocking  3880-4000 MHz: out of band blocking |  |  |
| LAN BS Tx mask |  |  | SEM |
| LAN BS Rx mask |  |  | ACS,  in-band blocking,  out of band blocking |
| BS antenna pattens | ITU-R M.2101 for AAS Macro cell BS  ITU-R F.1336 for non-AAS outdoor Small cell BS  Omni for indoor | ITU-R F.1336 for non-AAS outdoor Small cell BS  Omni for indoor | |
| LAN BS antenna height (m) |  | 6 for outdoor  3 for indoor | |
| LAN BS antenna downtilt (°) | -6 for Macro cell  0 for Small cell | 0 | |
| BS noise figure (dB) | 3 | 8 for MR BS  11 for LA BS | |
| Cell range (m) | 400 | 100 m for outdoor Small cell  50 m for indoor Small cell | |

Table 2: 5G NR BS Tx mask from 0 to 40 MHz (120 W Tx Power)

|  |  |  |  |
| --- | --- | --- | --- |
| Frequency offset of measurement filter ‑3dB point, Δf | Frequency offset of measurement filter centre frequency, f\_offset | *Basic limits* | Measurement bandwidth |
| 0 MHz ≤ Δf < 5 MHz | 0.05 MHz ≤ f\_offset < 5.05 MHz |  | 100 kHz |
| 5 MHz ≤ Δf < min(10 MHz, Δfmax) | 5.05 MHz ≤ f\_offset < min(10.05 MHz, f\_offsetmax) | -14 dBm | 100 kHz |
| 10 MHz ≤ Δf ≤ Δfmax | 10.5 MHz ≤ f\_offset < f\_offsetmax | -15 dBm | 1 MHz |

Table 3: 5G NR (LAN) Medium Range BS Tx Mask

|  |  |  |  |
| --- | --- | --- | --- |
| Frequency offset of measurement filter ‑3dB point, Δf | Frequency offset of measurement filter centre frequency, f\_offset | *Basic limits* | Measurement bandwidth |
| 0 MHz ≤ Δf < 5 MHz | 0.05 MHz ≤ f\_offset < 5.05 MHz |  | 100 kHz |
| 5 MHz ≤ Δf < min(10 MHz, Δfmax) | 5.05 MHz ≤ f\_offset < min(10.05 MHz, f\_offsetmax) | Prated,x - 60dB | 100 kHz |
| 10 MHz ≤ Δf ≤ Δfmax | 10.05 MHz ≤ f\_offset < f\_offsetmax | Min(Prated,x - 60dB, -25dBm) (Note 3) | 100 kHz |

Table 4: Propagation models used in the simulations

|  |  |
| --- | --- |
| Scenario | Propagation model |
| MFCN Macro cell BS to UE | 3GPP TR38.901 Path Loss Model: UMa, LOS Probabilities |
| LAN Small cell BS to UE | 3GPP TR38.901 Path Loss Model: UMi, LOS Probabilities |
| LAN BS to MFCN BS | 3GPP TR38.901 Path Loss Model: UMa, LOS Probabilities |
| LAN BS to MFCN Micro cell BS | 3GPP TR38.901 Path Loss Model: UMi, LOS Probabilities |

* + - 1. Simulation results
         1. Simulation results for the scenario\_1

The simulation scenario\_1 (as shown in Figure 7) results are given in Table 5.

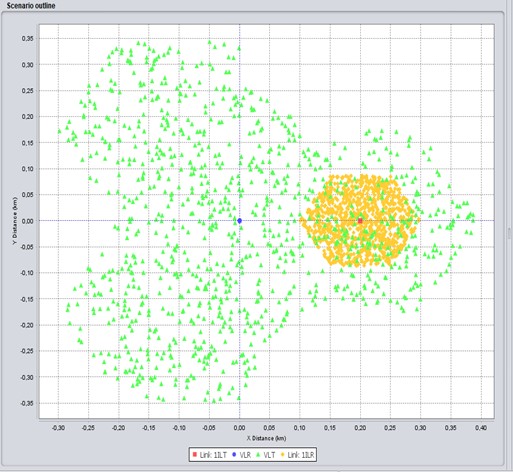


Figure 7: Simulation secnario\_1

Table 5: Simulation results (LAN cell radius 100 m in middle 5G Macro cell with BS antenna at 6 m height )

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| LAN BS Tx Power (EIRP dBm) | LAN 3800-3900 MHz | | | LAN 3900-4000 MHz  LAN 3860-3960 MHz | | |
|  | I\_unwanted | I\_blocking | TP loss | I\_unwanted | I\_blocking | TP loss |
| 50 | -83.6 | -71.9 | 30.674% | -105.2 | -122.3 | 2.268% |
| 45 | -89.3 | -77.6 | 23.201% | -110.2 | -127.3 | 1.277% |
| 40 | -93.7 | -82.1 | 17.095% |  |  |  |
| 35 | -98.9 | -87.2 | 12.331% |  |  |  |
| 30 | -103.8 | -92.1 | 8.379% |  |  |  |
| 25 | -109.0 | -97.4 | 5.381% |  |  |  |

From the simulation results in the Table 5, it can be seen that the unsynchronised LAN operation in 3800-3900 MHz create an MFCN 5G NR UL throughput loss more than 5% even with a transmitting power of 25 dBm EIRP, the limiting factor is the blocking effect.

The MFCN 5G NR UL throughput loss from the unsynchronised operation of LAN above 3860 MHz at EIRP <=50 dBm is below 3%.

Figure 8 below shows the MFCN 5G NR UL throughput loss as function of LAN BS antenna height for LAB BS EIRP=45 dBm. It can be seen at LAN BS antenna height of 20 m, MFCN 5G NR BS suffers the more interference from LAN BS.

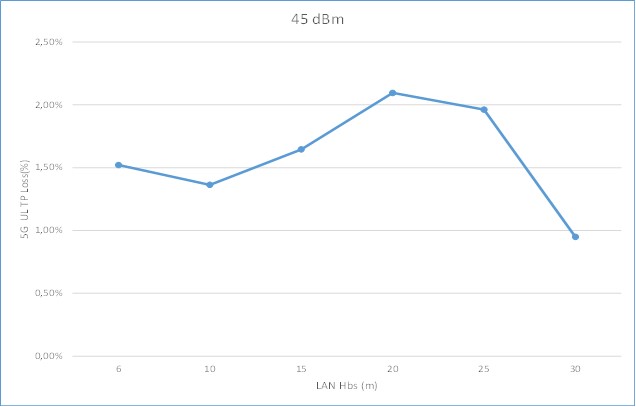


Figure 8: MFCN 5G BS UL TP loss vs LAN BS antenna height

* + - * 1. Simulation results for the scenario\_2

The simulation scenario\_2 (as shown in Figure 9) results are given in Table 6.

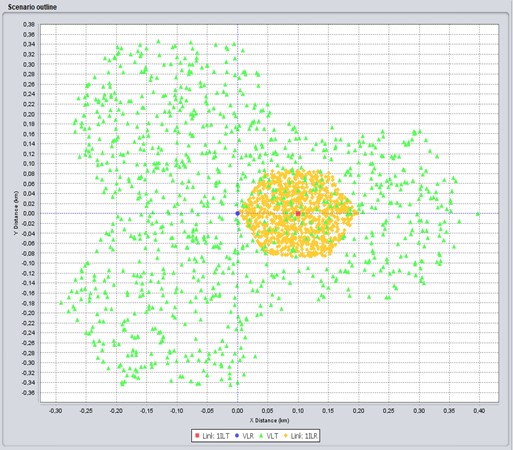


Figure 9: Simulation secnario\_2

Table 6: Simulation results (LAN cell radius 100 m in middle 5G Macro cell with BS antenna at 6 m height)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| LAN BS Tx Power (EIRP dBm) | LAN 3800-3900 MHz | | | LAN 3900-4000 MHz  LAN 3860-3960 MHz | | |
|  | I\_unwanted | I\_blocking | TP loss | I\_unwanted | I\_blocking | TP loss |
| 50 | -77.3 | -65.7 | 45.34% | -97.8 | -114.9 | 4.822% |
| 45 | -82.2 | -70.6 | 35.902% | -103.1 | -120.2 | 2.597% |
| 40 | -87.1 | -75.5 | 27.715% | -107.7 | -124.9 | 1.724% |
| 35 | -91.9 | -80.2 | 20.523% |  |  |  |
| 30 | -97.2 | -85.5 | 14.094% |  |  |  |
| 25 | -101.8 | -90.1 | 9.803% |  |  |  |
| 20 | -107.1 | -95.4 | 6.166% |  |  |  |
| 15 | -111.9 | -100.2 | 3.901% |  |  |  |

From the simulation results in the Table 6 for the scenario\_2, it can be seen that the unsynchronised LAN operation in 3800-3900 MHz create an MFCN 5G NR UL throughput loss more than 5% even with a transmitting power of 20 dBm EIRP, the limiting factor is the blocking effect.

The MFCN 5G NR UL throughput loss from the unsynchronised operation of LAN above 3860 MHz at EIRP <=40 dBm is below 2%.

Figure 10 below shows the MFCN 5G NR UL throughput loss as function of LAN BS antenna height for LAB BS EIRP=40, 35, 30 dBm. It can be seen at LAN BS antenna height of 20 m, MFCN 5G NR BS suffers the more interference from LAN BS.

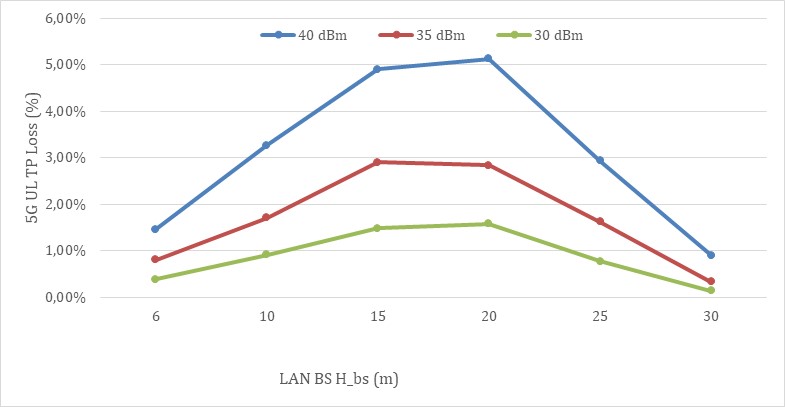


Figure 10: MFCN 5G BS UL TP loss vs LAN BS antenna height

* + - 1. Summary

The simulation results for the unsynchronised operation between LAN BS and MFCN 5G NR BS show that:

* Co-existence is difficult for LAN operation in the frequency range 3800-3900 MHz, the limiting factor is the MFCN 5G NR BS receiver blocking;
* Co-existence is possible for LAN operation above 3860 MHz under the condition of LAN BS emission power limit EIRP <=35 dBm.
  + 1. Interference from indoor LAN Smallcell to MFCN Macrocell
       1. Simulation scenario and assumptions

The simulation scenario is illustrated in Figure 11 below.

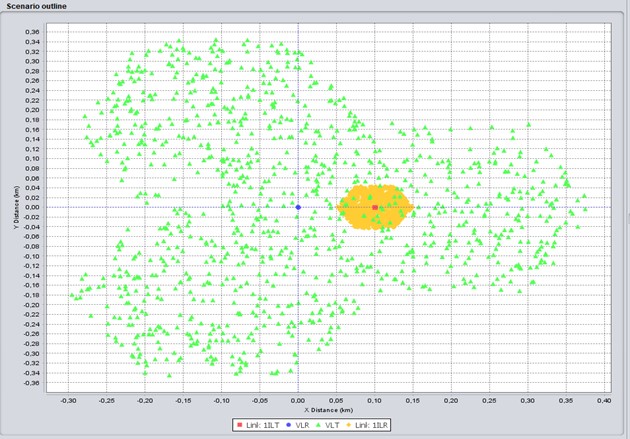


Figure 11: Simulation scenario between LAN indoor Small cell and outdoor MFCN 5G NR Macro cell

For LAN indoor Small cell, it is assumed that LAN BS antenna height is at 3 m, an omni antenna with a gain of 3 dBi. The cell radius is 50 m, the separation distance between LAN indoor Small cell BS and the MFCN 5G NR BS is 100 m. Wall penetration loss is 15 dB with a standard deviation of 5 dB. LAN indoor Small cell follows a distribution as below:

* 40% ground floor;
* 30% 1st floor;
* 20% 2nd floor;
* 10% 3rd floor.
  + - 1. Simulation results

The simulation results for LAN indoor Small cell unsynchronised operation in 3800-3900 MHz are given in Table 7.

Table 7: Simulation results for the co-existence between MFCN Macro cell and LAN indoor Small cell

|  |  |  |  |
| --- | --- | --- | --- |
| LAN BS Tx Power (EIRP dBm) | Indoor LAN 3800-3900 MHz | | |
|  | I\_unwanted | I\_blocking | TP loss |
| 50 | -90.4 | -78.7 | 22.257% |
| 45 | -95.6 | -84.0 | 16.078% |
| 40 | -100.3 | -88.7 | 11.551% |
| 35 | -105.8 | -94.2 | 7.737% |
| 30 | -110.5 | -98.8 | 4.805% |
| 25 | -115.4 | -103.7 | 3.07% |
| 20 | -120.5 | -108.8 | 1.691% |

The simulation results in the Table 7 show that when a LAN indoor Small cell is at EIRP<=20 dBm, the MFCN 5G NR BS located at 100 m away has an UL throughput loss less than 2%.

* + - 1. Summary

The simulation results show for the case of unsynchronised operation between LAN indoor Small cell and MFCN 5G NR Macro cell, MFCN UL throughput loss is less than 2% with LAN indoor Smallcell BS EIRP<=20 dBm.

* + 1. Outdoor LAN Small cell to outdoor MFCN Small cell
       1. Simulation scenarios and assumptions

In the simulations, two scenarios are considered:

1. Scenario\_1: face-to-Face at 100 m separation, as shown in Figure 12.

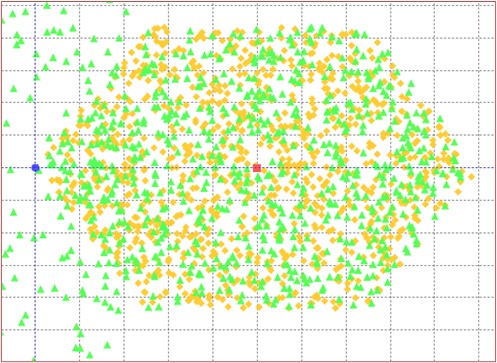


Figure 12: Scenario\_1, face-to-face

1. Scenario\_2: 50 m/50 m separation, as shown in Figure 13.

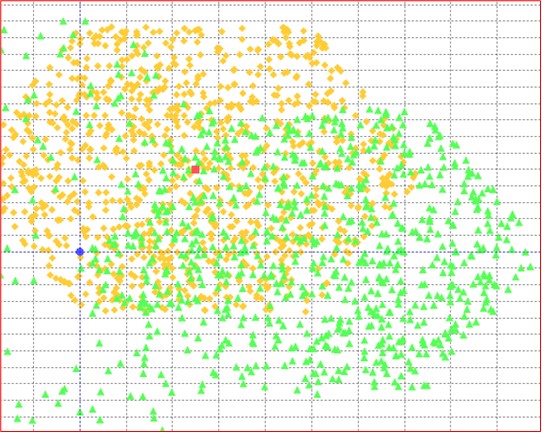


Figure 13: Scenario\_2, 50 m/50 m separations

It is assumed 5G BS Medium Range BS has a noise figure NF=8 dB, panel antenna with Gain=9 dBi

* + - 1. Simulation results
         1. Simulation results for the scenario\_1

The simulation results for the scenario\_1 are given in Table 8.

Table 8: Simulation results for the scenario\_1

|  |  |  |  |
| --- | --- | --- | --- |
| LAN BS Tx Power (dBm) | Scenario\_1 | | |
|  | I\_unwanted (dBm) | I\_blocking (dBm) | UL TP loss (%) |
| 40 | -91.7 | -103.9 | 14.544 |
| 35 | -96.8 | -109 | 6.009 |
| 30 | -101.7 | -113.9 | 2.326 |

From the Table 8, it can be seen that MFCN Small cell UL throughput loss is below 3% when the LAN outdoor Small cell BS EIRP is less than 30 dBm.

* + - * 1. Simulation results for the scenario\_2

The simulation results for the scenario\_2 are given in Table 9.

Table 9: Simulation results for the scenario\_2

|  |  |  |  |
| --- | --- | --- | --- |
| LAN BS Tx Power (dBm) | Scenario\_1 | | |
|  | I\_unwanted (dBm) | I\_blocking (dBm) | UL TP loss (%) |
| 40 | -94.2 | -106.3 | 9.345 |
| 35 | -99.1 | -111.3 | 3.669 |
| 30 | -104.1 | -116.3 | 1.487 |

From the Table 9, it can be seen that MFCN Small cell UL throughput loss is below 2% when the LAN outdoor Small cell BS EIRP is less than 30 dBm.

* + - 1. Summary

The simulation results show that in case LAN outdoor Small cell BS EIRP is limited to 30 dBm, the MFCN outdoor Small cell UL throughput loss is less than 3%.

* 1. Analysis of interference from MFCN to LAN
     1. Interference from MFCN Macro cell to outdoor LAN Small cell
        1. Simulation scenarios & assumptions

5G NR Macrocell BS emission mask is plotted in Figure 14.

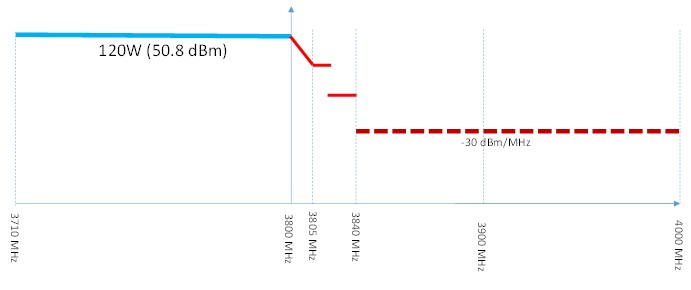


Figure 14: 5G NR BS Tx mask (Wide area BS)

LAN Medium range BS receiver mask is illustrated in Figure 15.

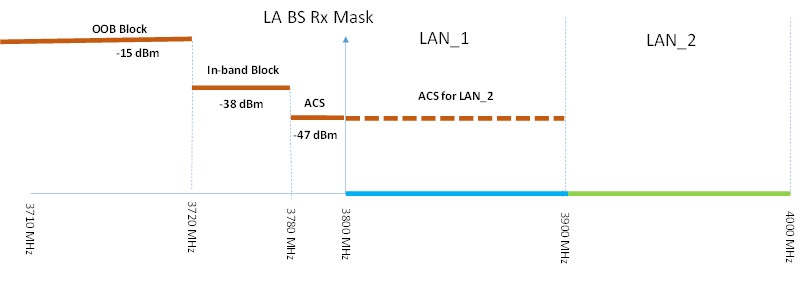


Figure 15: LAN Small cell BS Rx mask (Medium Range BS)

It is assumed LAN outdoor Small cell BS has a noise figure NF=8 dB, with a directional antenna with gain of 6 dBi.

Two scenarios are simulated:

1. Scenario\_1: 200m separation between MFCN 5G NR BS and LAN outdoor Small cell BS;
2. Scenario\_2: 100m separation between MFCN 5G NR BS and LAN outdoor Small cell BS.
   * + 1. Simulation results

Simulation results for the scenario\_1

Simulation scenario\_1 is illustrated in Figure 16. The simulation results are plotted in Figure 17 for different LAN outdoor Small cell BS antenna heights.

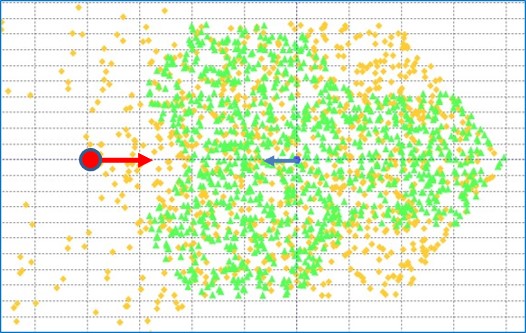


Figure 16: Scenario\_1, 200 m separation distance

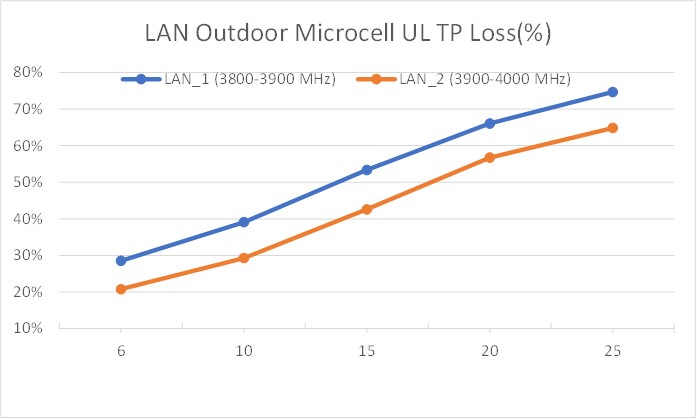


Figure 17: LAN outdoor Small cell UL TP loss

Simulation results for the scenario\_2

Simulation scenario\_2 is illustrated in Figure 18. The simulation results are plotted in Figure 19 for different LAN outdoor Small cell BS antenna heights.

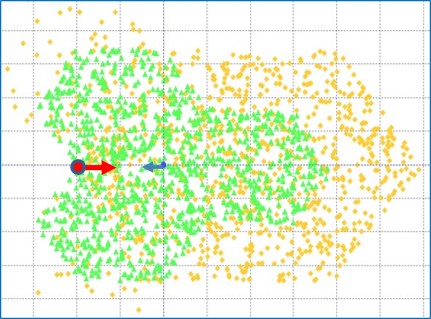


Figure 18: Scenario\_2, 100 m separation distance

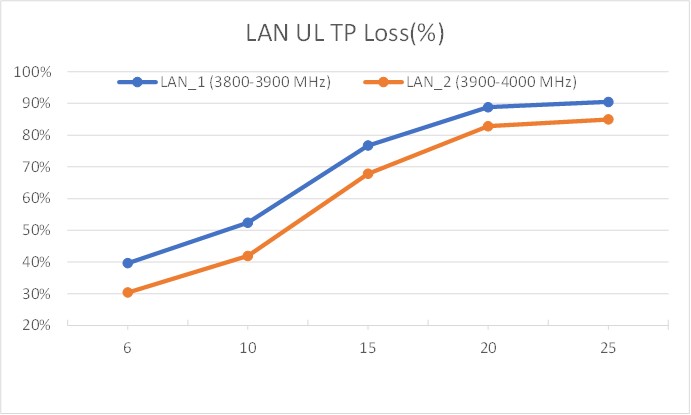


Figure 19: LAN outdoor Small cell UL TP loss

* + - 1. Summary

The simulation results show that LAN outdoor Small cell uplink throughput loss can vary from 30% to 90% depending on the LAN Small cell BS antenna height and the separation distance. The limiting factor is the LAN BS receiver blocking. A guard band does not help much and is not sufficient.

* + 1. Interference from MFCN Macrocell to indoor LAN Smallcell
       1. Simulation scenarios & assumptions

Local area BS is used for Indoor LAN Small cell. It is assumed that the local area BS for LAN indoor Small cell has a noise figure of 11 dB. An omni-directional antenna of 3 dBi gain is used for indoor LAN Small cell.

Local area BS receiver mask is plotted in Figure 20.

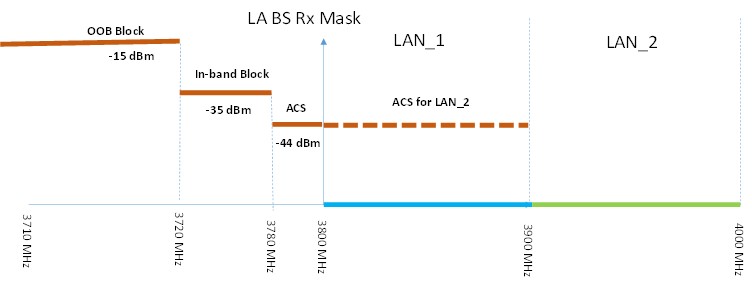


Figure 20: Local area BS receiver blocking mask

5G NR UE emission mask is plotted in Figure 21.

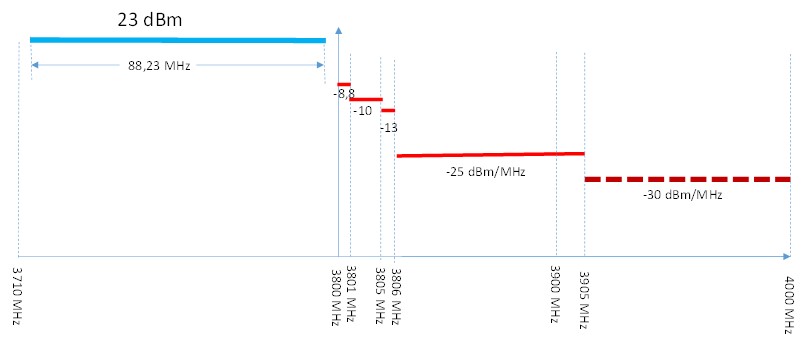


Figure 21: 5G NR UE Tx mask

The simulation scenario is illustrated in Figure 22. In the simulation with SEAMCAT, the 5G NR UE is generated within the same area of the LAN indoor Small cell coverage area. 15 dB wall loss is used in the simulation.

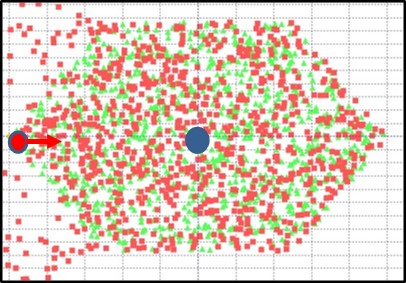


Figure 22: Simulation scenario for interference from MFCN Macro cell to LAN indoor Small cell

* + - 1. Simulation results

LAN indoor Small cell UL throughput loss caused by interference from outdoor Macro cell BS and by interference from 5G NR UE connecting to the outdoor Macro cell BS are simulated. The simulation results are given in Table 10.

Table 10: LAN indoor Small cell UL TP loss

|  |  |  |  |
| --- | --- | --- | --- |
| Interferer | I\_unwanted | I\_blocking | UL TP loss (%) |
| 5G NR UE (UL) | -107.6 | -114.4 | 3.861% |
| 5G NR BS (DL) | -113.2 | -91.8 | 24.197% |

The simulation results show that:

* Interference from indoor 5G UE connecting to outdoor Macro cell 5G BS to indoor LAN BS does not appear as a big issue;
* Interference from outdoor Macro cell 5G BS to indoor LAN BS is still a problem.
  + - 1. Summary
  1. Synchronisation and Semi-synchronisation
     1. Synchronisation

The simulation results presented in section A1.2 and A1.3 show that the co-existence between MFCN 5G NR in 3710-3800 MHz and Local area network in 3800-4200 MHz is not easy when they are not synchronised. In particular the interference from MFCN 5G NR Macro cell to LAN outdoor Small cells. A guard band does not help much.

The synchronisation can be a solution to ensure the co-existence between MFCN 5G NR and Local Area Network. The synchronisation needs

1. Common phase clock reference;
2. Compatible frame structure
   * 1. Semi-synchronisation

Usually MFCN 5G NR network has more downlink data capacity than UL, the DL/UL ratio is usually 75% / 25%. Some applications of local area network may require more UL data capacity. As described in ECC Report 296, the semi-synchronisation could be a solution for Local Area Network where it needs more UL data capacity under condition of tolerating some UL interference:

* *"DL to UL modifications": the default DL transmission direction in the flexible part is modified into UL*
* *From BS-BS interference perspective, the network that modifies the default DL into UL will not interfere with the other network(s) but it will receive additional interference from the other network(s);*

In case Local area network use this *"DL to UL modifications"* semi-synchronisation,the LANUL throughput loss (%) will be

TP\_loss = TP\_loss1 \* P2

Where:

* TP\_loss1 is the simulated LAN UL TP Loss for unsynchronised case;
* P2 is the collision probability

For example, at 6 m LAN BS antenna height, the simulated LAN UL throughput loss for the second channel 3900-4000 MHz is TP\_loss1 = 30%, if the *"DL to UL modifications"* semi-synchronisation is used, the resultant LAN UL throughput loss for different UL/DL ratios are given in the Table 11 below.

Table 11: LAN UL TP loss when using semi-synchronisation

|  |  |  |  |
| --- | --- | --- | --- |
| 5G NR DL/UL ratio | 75% / 25% | 75% / 25% | 75% / 25% |
| LAN DL/UL ratio | 75% / 25% | 50% / 50% | 25% / 75% |
| DL to UL collision probability | 0% | 25% | 50% |
| LAN UL TP Loss | 0% | 7.5% | 15% |

* 1. Conclusions

Based on the simulation results and the analysis, the following conclusions can be made:

1. When the Local Area Network operating in 3800-4200 MHz is not synchronised with MFCN 5G NR in 3400-3800 MHz, the technical conditions for protecting MFCN UL are:
2. a guard band of 60 MHz (3800-3860 MHz);
3. LAN BS transmit power EIRP<=30 dBm/100 MHz for both outdoor and indoor Small cell deployment.

But the interference from MFCN 5G NR to LAN uplink is a problem due to LAN BS receiver blocking characteristics. The possible solution is to define a more robust LAN BS receiver blocking performance in the future harmonised standard.

1. Synchronisation between MFCN 5G NR in 3400-3800 MHz and Local Area Network in 3800-4200 MHz is a good solution to ensure the co-existence:
2. Common phase clock reference
3. Compatible frame structure
4. The possible constraint may be the DL / UL ratio for some LAN applications, in case LAN needs more UL data capacity, the “DL to UL modification” semi-synchronisation as described in the ECC Report 296 can be considered as a possible solution.
5. The European harmonised standard for the MFCN 5G NR BS EN 301 908-24 is not yet officially published. This standard includes the European MFCN frequency band 3400-3800 MHz but does not cover the frequency band 3800-4200 MHz band. The frequency band 3800-4200 MHz and some technical conditions, e.g., BS receiver blocking performance, based on ECC PT1 study, need to be included in the future European harmonised standard.