# Semi-Synchronized Operation

ECC Report 296 [1] has studied a toolbox for coexistence of MFCNs in synchronised, unsynchronised, and semi-synchronised operation in 3400-3800 MHz. Those studies are also relevant for the work on the least restrictive conditions for WBB LMP in 3800-4200 MHz. To enable a more flexible duplex operation for WBB LMP local networks, a synchronised operation with MFCN networks below 3800 MHz is not desired. Most studies submitted so far have therefore focused on unsynchronised operation between MFCN networks below 3800 MHz and WBB LMP above 3800 MHz, which is naturally the preferred option in terms of flexibility. Semi-synchronised operation could be an appealing option for some outdoor deployment scenarios when unsynchronised operation might not be feasible.

Semi-synchronised operation, which was studied in detail in ECC Report 296 [1], corresponds to the case where part of the frame is aligned with the frame structure of the MFCN network, while the remaining portion of the frame deviates from the frame structure of the MCFN network and is consistent with unsynchronised operation. This enables a trade-off between flexibility and additional cross interference. To enable semi- synchronised operation between WBB LMP and MFCN in the same coverage area/region, WBB LMP should use:

* The same phase clock reference as the MFCN network, as for synchronised operation;
* Partial frame alignment: the default frame structure should follow the frame structure of the adjacent channel MFCN, as for synchronised operation (for which UL/DL directions are defined across the whole frame). Modifications of DL/UL directions compared to the default frame structure are allowed for some specific slots.

The approach could be implemented with either one of the other frame structures recommended by ECC, cf. ECC/REC/(20)03, which are referred to as default frame structure in the following.

In this contribution, we focus on a specific sub-case of semi-synchronised operations, in which DL to UL modifications are allowed, as depicted in Figure 1. This case is especially interesting for those scenarios where WBB LMP networks require more UL resources than those available in the frame structure of the MFCN network. In the case of semi-synchronised operation with DL to UL modifications, only the default DL transmission direction in the default frame structure may be modified into UL. As a result, if DL to UL modifications are only performed by the WBB LMP networks, MFCN below 3800 MHz will not receive additional BS-to-BS cross interference from the WBB LMP network. While semi-synchronised operation is also possible employing UL to DL modifications, this case is not considered in this contribution since this would cause additional BS-to-BS cross interference from the WBB LMP network to MFCN below 3800 MHz.

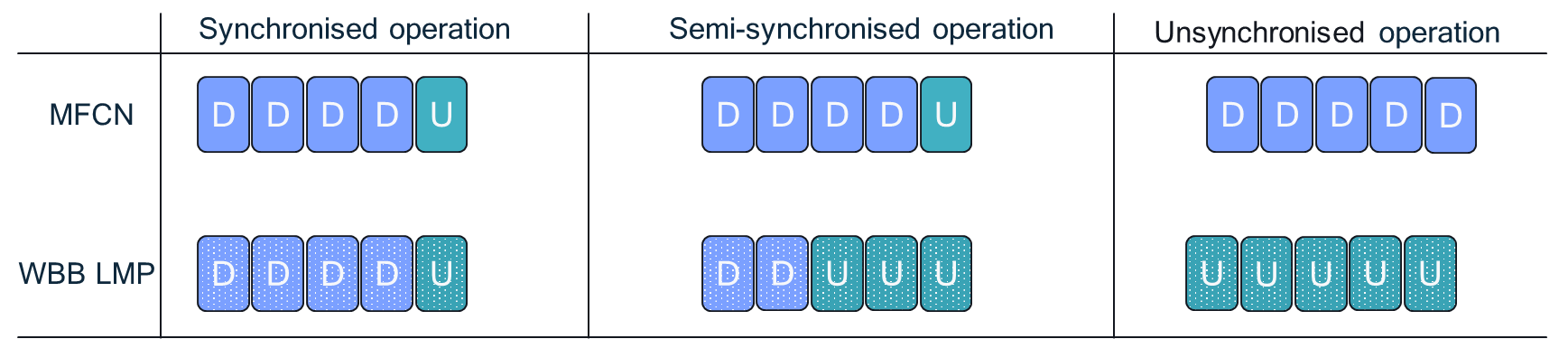


Figure 1: Different synchronization options

From the perspective of flexibility for local network deployments unsynchronised operation is usually the preferred option. However, for some cases, especially if the required separation distance for unsynchronised operation is a challenge, synchronisation is necessary. For those cases, additional frame structure flexibility is achieved by employing semi-synchronised operation.

The benefits of semi-synchronised operation with DL to UL modifications compared to unsynchronised operation are as follows:

* The BEM below 3800 MHz will be identical to synchronised operation;
* The separation distance to MFCN can be significantly reduced (see simulation results below);

Compared to synchronised operation the benefit is the possibility to employ more UL resources than provided by the frame structure of the MFCN network below 3800 MHz.

It should be noted that semi-synchronisation is realized the same way as synchronised operation and simply requires setting the corresponding network parameters related to the DL to UL modifications in the frame structure of the WBB LMP.

# Simulation Results

## Investigated Scenarios

Table 1

Table 1: Investigated scenarios

|  |  |  |  |
| --- | --- | --- | --- |
| # | Aggressor | Victim | Propagation assumptions |
| 1 | Outdoor 5G MFCN, AAS, 20m height, EIRP= 76dBm | Outdoor WBB LP BS, non-AAS, 10m height, EIRP = 31 dBm | Urban, no clutter and clutter at receiver side |
| 2 | Outdoor 5G MFCN, AAS, 25m height, EIRP= 76dBm | Outdoor WBB LP BS, non-AAS, 10m height, EIRP = 31 dBm | Rural, no clutter and clutter at receiver side |
| 3 | Outdoor 5G MFCN, AAS, 20m height, EIRP= 76dBm | Outdoor WBB MP BS, AAS, 15m height, EIRP = 49 dBm | Urban, no clutter and clutter at receiver side |
| 4 | Outdoor 5G MFCN, AAS, 25m height, EIRP= 76dBm | Outdoor WBB MP BS, AAS, 15m height, EIRP = 49 dBm | Rural, no clutter and clutter at receiver side |

The following parameters have been chosen for the WBB LMP:

* Bandwidth of WBB LMP: 100 MHz
* BS TDD activity factor (DL percentage): 50%
* Network loading factor: 100% (for a single base station)
* Indoor/outdoor percentage: 100% outdoor, 0% indoor (worst case)
* Antenna array configuration (Row × Column): 4 x 4 elements, non-subarray
* Non-AAS BS downtilt (degrees): 0
* Receiver mask according to Table 2.

Table 2: Receiver mask LMP WBB BS

|  |  |  |
| --- | --- | --- |
| Frequency offset | Low Power (Attenuation) | Medium Power (Attenuation) |
| 3800-3780 MHz | 32.2 dB | 32.2 dB |
| 3780-3740 MHz | 41.2 dB | 42.2 dB |
| Below 3740 MHz | 61.2 dB | 64.2 dB |

Table 3 summarizes the propagation model used for the BS-to-BS link.

Table 3: Propagation model for the BS-to-BS link

|  |  |  |
| --- | --- | --- |
| Case | Urban | Rural |
| Both ends above clutters | ITU-R P.452 50% of time, without clutter loss | |
| One end above clutters and one end within clutters | ITU-R P.452 50% of time, with ITU-R P.2108 fixed clutter loss corresponding to 50% locations applied to one end. | ITU-R P.1546 Land Rural 50% of time |

The simulations are performed with one aggressor and one victim BS. For the MFCN network and the WBB MP network with AAS antennas a single cell Tri-Sector (3GPP) cell layout is assumed. For the WBB LP network with non-AAS a single sector single omni-cell network is assumed, with the non-AAS antenna main beam pointing directly towards the aggressor MFCN BS.

For the links within each network the propagation models according to Table 4 are used.

Table 4: Propagation model for links within each network

|  |  |  |
| --- | --- | --- |
| Case | Urban | Rural |
| MFCN network | 3GPP TR38.901 Path Loss Model, UMa, LOS probabilities | 3GPP TR38.901 Path Loss Model, RMa, LOS probabilities |
| WBB LP | 3GPP TR38.901 Path Loss Model, Umi-Street Canyon, LOS probabilities | 3GPP TR38.901 Path Loss Model, RMa, LOS probabilities |
| WBB MP | 3GPP TR38.901 Path Loss Model, UMa, LOS probabilities | 3GPP TR38.901 Path Loss Model, RMa, LOS probabilities |

To consider the worst case, only outdoor deployment of the BSs is considered. Furthermore, for the non-AAS case the WBB LMP BS is directly pointing at the MFCN BS.

## Separation Distance Improvement

To investigate the separation distance improvement, semi-synchronised operation with DL to UL modifications is considered assuming 25% of the frame structure is modified from DL to UL, which means that the remaining 75% of the frame structure are synchronised with the frame structure of the MCFN network below 3800 MHz. Since semi-synchronised operation with DL to UL modification is used, only the WBB LMP network is considered as a victim.

### Scenario 1 WBB LP BS Non-AAS, urban

|  |  |
| --- | --- |
| A graph of a line graph  Description automatically generated  a) No clutter loss | A graph of a network  Description automatically generated  b) Clutter at receiver side |

Figure 2: Simulation results scenario 1, no clutter and clutter at receiver side

According to Figure 2, 51% and 27% reduction of the separation distance, for no-clutter and clutter at the receiver side, respectively, can be achieved by employing semi-synchronised operation instead of unsynchronised operation.

### Scenario 2 WBB LP BS Non-AAS, Rural

|  |  |
| --- | --- |
| A graph of a line graph  Description automatically generated  a) No clutter loss | A graph of a network  Description automatically generated  b) Clutter at receiver side |

Figure 3: Simulation results scenario 2, no clutter and clutter at receiver side

According to Figure 3, 47% and 30% reduction of the separation distance, for no-clutter and clutter at the receiver side, respectively, can be achieved by employing semi-synchronised operation instead of unsynchronised operation.

### Scenario 3 WBB MP BS AAS, urban

|  |  |
| --- | --- |
| A graph of a network  Description automatically generated  a) No clutter loss | A graph of a network  Description automatically generatedb) Clutter at receiver side |

Figure 4: Simulation results scenario 3, no clutter and clutter at receiver side

According to Figure 4, 76% and approx. 50% reduction of the separation distance, for no-clutter and clutter at the receiver side, respectively, can be achieved by employing semi-synchronised operation instead of unsynchronised operation.

### Scenario 4 WBB MP BS AAS, Rural

|  |  |
| --- | --- |
| A graph of a line graph  Description automatically generated  a) No clutter loss | A graph of a network  Description automatically generatedb) Clutter at receiver side |

Figure 5: Simulation results scenario 4, no clutter and clutter at receiver side

According to Figure 5, 72% and 49% reduction of the separation distance, for no-clutter and clutter at the receiver side, respectively, can be achieved by employing semi-synchronised operation instead of unsynchronised operation.

Table 5: Reduction of the separation distance, with semi-synchronised operation with 25% of the frame structure modified from DL to UL, compared to unsynchronised operation to achieve 5% average UL TP loss

|  |  |  |  |
| --- | --- | --- | --- |
| # | Description | No clutter | Clutter at receiver side |
| 1 | WBB LP BS Non-AAS, urban | 51% | 27% |
| 2 | WBB LP BS Non-AAS, rural | 47% | 30% |
| 3 | WBB LP BS AAS, urban | 76% | approx. 50% |
| 4 | WBB LP BS AAS, rural | 72% | 49% |

Table 5 summarizes the reduction of the separation distance to achieve an average UL throughput (TP) loss of 5% in the WBB LMP network for different scenarios compared to unsynchronised operation. For no clutter loss the reduction of the separation distance is between 47% and 76%, while for clutter at the receiver side a reduction of the separation distance by 27% to 50% can be achieved.

## Interference Level Improvement

To consider semi-synchronised operation for the regulatory toolbox, a method is needed to express the capability of the victim system to withstand larger interference from the aggressor network achieved by semi-synchronised operation compared to unsynchronised operation as a tolerable interference margin improvement. This improvement depends on the percentage of slots of the frame structure that are synchronised and reflects that the victim WBB LMP network can tolerate higher interference levels from the MFCN network below 3800 MHz, while still maintaining an average TP loss of 5%. As a reference for each scenario, the separation distance is fixed to the distance required to achieve a TP loss of 5% in the WBB LMP network due to BS-to-BS interference from the MFCN network below 3800 MHz. The I/N value for unsynchronised operation is used as a reference and the tolerable interference margin is obtained by simulations. In those simulations, for different percentages of synchronised slots, while keeping the distance to the interfering MFCN network fixed, the power of the aggressor MFCN base station is varied until the LMP WBB victim experiences an average UL TP loss of 5%.

Table 6: Tolerable interference margin in dB compared to unsynchronised operation for semi-synchronised operation depending on the percentage of synchronised slots for different scenarios

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Tolerable interference margin in dB | | | |
| % synchronised slots | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
| **0** | 0.0 | 0.0 | 0.0 | 0.0 |
| **10** | 0.5 | 0.5 | 0.8 | 0.7 |
| **20** | 1.1 | 1.1 | 1.6 | 1.5 |
| **30** | 1.8 | 1.7 | 2.7 | 2.4 |
| **40** | 2.5 | 2.4 | 4.0 | 3.6 |
| **50** | 3.5 | 3.4 | 5.6 | 5.0 |
| **60** | 4.7 | 4.5 | 7.9 | 7.0 |
| **70** | 6.4 | 6.0 | 11.4 | 10.1 |
| **80** | 9.2 | 8.4 | 18.4 | 16.2 |
| **90** | 15.9 | 14.1 | 34.0 | 32.9 |

The simulation results for the Tolerable interference margin are summarized in Table 6 for the scenarios given in Table 1. Scenarios 1 and 2 reflect a WBB LP BS, with 31 dBm EIRP and non-AAS, while scenarios 3 and 4 reflect a WBB MP BS, with 49 dBm EIRP and AAS. The difference between both scenarios for WBB LP BS and WBB MP BS, respectively, are that the scenarios 1 and 3 use an urban propagation model, while scenarios 2 and 4 use a rural propagation model.

It is observed from the results in Table 6 that the higher the percentage of synchronized slots used for semi-synchronized operation, the higher the Tolerable interference margin compared to unsynchronized operation. For cases where 70% or more of the frame are synchronized, which corresponds to, e.g., modifying 3 slots from DL to UL, an Tolerable interference margin of about 6 or 10 dB are achieved for non-AAS LP and AAS MP, respectively.

Note that the difference between the propagation models is mainly visible for cases where most of the slots are synchronized with the frame structure of the MFCN network below 3800 MHz. To simplify the application of the table above and to avoid having a dependency on the environment model (urban vs. rural), it is proposed that moving forward the results for rural are used. This provides the minimum Tolerable interference margin for each percentage of synchronized slots. Therefore, for non-AAS low power WBB base stations scenario 2 is used as a reference while for AAS medium-power base stations scenario 4 is used as a reference.

Table 7: Tolerable interference margin in dB compared to unsynchronized operation for semi-synchronized operation depending on the percentage of synchronized slots for different scenarios

|  |  |  |  |
| --- | --- | --- | --- |
|  | Tolerable interference margin in dB (Note 1) | | |
| % synchronized slots | Non-AAS LP | AAS MP | Non-AAS MP |
| **0** | 0.0 | 0.0 | 0.0 |
| **10** | 0.5 | 0.7 | 0.6 |
| **20** | 1.1 | 1.5 | 1.2 |
| **30** | 1.7 | 2.4 | 2.0 |
| **40** | 2.4 | 3.6 | 2.9 |
| **50** | 3.4 | 5.0 | 4.1 |
| **60** | 4.5 | 7.0 | 5.6 |
| **70** | 6.0 | 10.1 | 7.8 |
| **80** | 8.4 | 16.2 | 11.6 |
| **90** | 14.1 | 32.9 | 20.3 |
| Note 1: Tolerable interference margin of semi-synchronized operation compared to unsynchronized operation in dB depending on the percentage of slots synchronized with the MFCN network below 3800 MHz. | | | |

Table 7 summarises the proposed Tolerable interference margin in dB depending on the percentage of synchronized slots for low and medium power WBB networks. For completeness, in case AAS BS will not be allowed in the regulation, also simulation results for medium power WBB networks with non-AAS have been added, which were obtained by replacing the AAS antennas with non-AAS antennas for the WBB MP network in scenario 4. Comparing the I/N improvements between AAS and non-AAS for MP and 90% synchronized slots, the Tolerable interference margin increases by more than 12 dB when employing AAS, which shows that due to the adaptive antenna concept and the pointing of the beams the interference can be further reduced compared to non-AAS.

In summary, by using the Tolerable interference margin in Table 7 the I/N thresholds for semi-synchronized operation can be obtained for LP and MP WBB networks depending on the percentage of DL to UL modifications and using the I/N threshold for unsynchronized operation as a reference.

# Proposal for the Regulatory Conditions

Note, that WBB LMP networks using semi-synchronised operation with DL to UL modifications will experience the same BS-to-BS cross-interference as unsynchronised operation in those parts of the frame where DL to UL modifications are applied. Therefore, in case WBB LMP network operators prefer to also protect the modified parts of the frame, regulation should provide them with the freedom to apply the interference thresholds of unsynchronised operation. Even though this would increase the required separation distance, still the operation of MFCN below 3800 MHz will be fully protected.

For semi-synchronised operation the I/N thresholds can be relaxed by considering the tolerable interference margin in accordance with Table 7, depending on the percentage of DL to UL modifications.

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## Examples for Recommended Frame Structures

ECC/REC/(20)03 defines two recommended frame structures for MFCN below 3800 MHz, denoted as Frame A and B, respectively. Examples for semi-synchronised operation, employing only DL to UL modifications, with both recommended frame structures are denoted in Figure 6. The figure is using the notation from ECC/REC/(20)03, with D = Downlink slot; S = Special slot; U = Uplink slot. For each of the examples the percentage of slots synchronised with the recommended frame structure is denoted. This shows that for Frame A, only 80% and 60% synchronised slots are possible. For Frame B, 90%, 80%, 70%, 60%, 50% and 40% synchronised slots are possible.



Figure 6: Recommended frame structures according to ECC/REC/(20)03 and examples of potential semi-synchronised frame structures with DL to UL modifications

# Conclusions

Unsynchronised operation is the best option to achieve flexibility for WBB LMP since it does not impose constraints on synchronization with existing networks operating below 3800 MHz. If in some specific deployment scenarios, the cross interference generated by the unsynchronised WBB LMP networks is not acceptable, semi-synchronised operations would allow to achieve a trade-off between flexibility and additional cross interference. In this contribution, we focused on the case in which DL to UL modifications compared to a common default frame are applied in the WBB LMP, thus not creating additional BS-to-BS cross interference to the adjacent MFCN network. The simulations analyse the UL performance degradation perceived at the WBB LMP network and, in particular, the required separation distances between WBB LMP and MFCN networks to meet the target performance criteria. Results showed that the separation distance can be significantly reduced, while still operating without a guard band.

With respect to the regulatory conditions for semi-synchronised operation with DL to UL modifications, it is recommended that the BEM below 3800 MHz should be identical to synchronised operation. The I/N threshold for coordination with MFCN below 3800 MHz can be obtained by considering the tolerable interference margin from Table 7 relative to the I/N threshold for unsynchronised operation. Based on the results presented in this paper, we propose to add the results from this paper into the ECC Report and consider semi-synchronised operation of WBB LMP and MFCN as one option of the toolbox for WBB LMP networks in 3800-4200 MHz under development in the CEPT Report.

# References

1. [ECC Report 296](https://docdb.cept.org/document/9067): “National synchronisation regulatory framework options in 3400-3800 MHz: a toolbox for coexistence of MFCNs in synchronised, unsynchronised and semi-synchronised operation in 3400-3800 MHz”