**3GPP TSG-RAN WG4 Meeting # 97-e R4-201xxxx**

**Electronic Meeting, Nov. 2020**

**Agenda item:** 12.3.2.1.2, 12.3.2.1.3, 12.3.2.2.1, 12.3.2.2.2

**Source:** Moderator (Qualcomm Incorporated)

**Title:** Email discussion summary for [97e][136] NR\_RF\_FR2\_req\_enh2\_Part\_2

**Document for:** Information

# Introduction

*The topics for discussion are arranged per tables below.*

|  |  |  |
| --- | --- | --- |
| **FR2 Inter-band DLCA** | **bands in same frequency group** | **bands in different frequency groups** |
| *IBM* | *Topic #1* | *Not treated here* |
| *CBM* | *Not treated here* | *Topic #2* |

|  |  |
| --- | --- |
| **FR2 Inter-band ULCA** | **bands in same frequency group or in different frequency groups** |
| *IBM/CBM* | *Topic #3* |

# Topic #1: Inter-band DL CA: IBM for bands in same frequency group

*Agenda item 12.3.2.1.2*

## Companies’ contributions summary

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| --- | --- | --- | --- |
| **T-doc number** | **Title** | **Company** | **Proposals / Observations** |
| [**R4-2014233**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_97_e/Docs/R4-2014233.zip) | On the feasibility of IBM for FR2 inter-band CA within the same frequency group | Apple | * On collocation and non-collocation deployment scenarios   Observation 1: The cell size or coverage is similar for the bands within the same frequency group.  **Proposal 1: Operators’ inputs are needed if collocated deployment can be considered as typical scenario for FR2 inter-band CA within the same frequency group.**   * On the metric to evaluate the performance gain of IBM over CBM   **Proposal 2: Based on the assumption of collocated deployment, it should be evaluated on the probability that different beams can be selected with IBM for different bands within the same band group. This should be done with reasonable assumption of frequency separation/beam squint and codebook size (e.g. <64).**   * IBM and CBM from UE architecture perspective   Observation 2: Compared to CBM, IBM related cost, form factor and power consumption are expected to be higher. Meanwhile, IBM normally requires larger memory size, multiple BM processing engines and potentially longer BM processing delay.  **Proposal 3: The performance gain of IBM over CBM for FR2 inter-band CA within the same band group should be justified, considering the impact on cost, form factor, power consumption, memory size, # of BM engines and processing delay.** |
| [**R4-2014587**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_97_e/Docs/R4-2014587.zip) | On IBM feasibility for CA configurations within same frequency group | Intel Corporation | Observation: IBM can support non-collocated gNB deployments.  **Proposal: IBM is allowed to support inter-band DL CA within the same frequency group. The PSD imbalance level needs to be reduced or ΔRIB,P,n and ΔRIB,S,n are further relaxed. They are a function of frequency gap between upper channel edge of highest CC in lower band and lower channel edge of lowest CC in upper band.** |
| [**R4-2015873**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_97_e/Docs/R4-2015873.zip) | Views on Feasibility for CA configurations within same frequency group based on IBM | Sony, Ericsson | Observation 1: A CBM UE is assumed to support the co-located deployment scenarios. An IBM UE is assumed to support both co-located and non-co-located deployment scenarios.  Observation 2: Supporting IBM UE within the same band group can significantly improve network deployment flexibility.  Observation 3: From an RF viewpoint, supporting IBM within the same band group operation mainly requires separated phase shifters for each band but can provide a better performance comparing to the CBM UEs, which is a feasible solution for inter-band DL CA.  Observation 4: There is no protocol barrier for supporting IBM UEs within the same band group.  **Proposal 1: RAN4 conclude the IBM UEs are feasible for the DL inter-band CA within the same frequency group** |

## Open issues summary

*The primary goal of the study is to establish feasibility of IBM for inter-band CA across bands in the same frequency group. See thread #135 for ‘frequency group’ discussion..*

### Sub-topic 1-1

*On need for UEs to support non-co-located inter-band CA deployment for bands within the same frequency group:*

**Issue 1-1: Can** **co-located deployment be considered a typical scenario for FR2 inter-band CA within the same frequency group?**

### Sub-topic 1-2

*2 out of the 3 contributions have argued that IBM between bands in the same frequency group is feasible, while citing improved network performance, while the third contribution recommends that the performance gain of IBM over CBM in this context should be justified based on UE implementation-specific criteria. Should feasibility stop with network benefit if established, or should it also include UE implementation challenges?*

**Issue 1-2: Feasibility criteria for IBM for inter-band CA between bands in the same frequency group**

* Proposals
  + Option 1: Network benefit is enough
  + Option 2: Network benefit must be balanced with UE implementation challenges
  + Others

### Sub-topic 1-3

*Discussion on what parameters to study to quantify IBM benefit and UE implementation complexity.*

**Issue 1-3: Parameters to study on IBM benefit** **and UE implementation complexity**

## Companies views’ collection for 1st round

### Open issues

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| --- | --- | --- |
| **Issue** | **Options** | **Company Comments** |
| Issue 1-1: Can co-located deployment be considered a typical scenario for FR2 inter-band CA within the same frequency group? | (open discussion) | Intel: From UE perspective, co-located deployments are preferred in term of challenges from PSD imbalance and MRTD from bands in CA, regardless same frequency group or different frequency groups. But co-located deployment is expected to have smaller PSD imbalance and MRTD.  Verizon:  Yes, the co-located deployment should be considered for FR2 inter-band CA.  In actual deployments, it is highly possible to deploy the cell based on the spectrum. Both 28 and 39GHz carriers are possible to be implemented in either co-located or non-co-located in the network (gNB(s)) for high data throughput.  MediaTek: Agree. We think co-located deployment can be considered a typical scenario for FR2 inter-band CA within the same frequency group.  Apple: Considering similar coverage/propogation loss for the bands within the same frequency group, we think collocated deployment should be considered as typical scenario. Since collocation and non-collocation assumptions also concerns deployment cost, operators’ inputs are helpful.  The frequency separation between the 2 CCs within the same band group can be relatively close. The impact due to PSD difference from non-collocated deployment needs to be considered as the weak signal could be desensitized already at the UE receiver antenna.  Samsung: within same frequency group, co-located deployment scenario can be considered more typical than non-co-located deployment.  OPPO: Yes.  Ericsson: can be both collocation and non-collocation. Antenna colocation is not always possible (and not always due to technical issues).  Sony: we think both co-located and non-collocated can be deployed for the same frequency group, though it has been agreed that CBM UEs are assumed to support co-located scenario while IBM UEs can support both co-located and non-collocated.  vivo: Generally fine with this proposal. Still, BS deployment does not dependent on the frequency group, but is mainly related to BM type  Nokia: Both collocated and non-collocated deployments are possible. Also in case of collocation small PSD difference may not always realize in UE end due to reflections etc.  Xiaomi: Yes. co-located deployment should be considered a typical scenario for FR2 inter-band CA within the same frequency group. |
|  | Huawei: both collocated and non-collocated are possible. |
| Issue 1-2: Feasibility criteria for IBM for inter-band CA between bands in the same frequency group | (open discussion)  For example: network benefit, UE implementation challenges | Intel: Option 2. If non co-located deployments exist, IBM looks more reasonable.  Qualcomm: IBM is certainly implementable for multiple bands within the same frequency group, and we think there is network benefit to this implementation. The barriers to adoption of IBM for inter-CA between bands of the same frequency group are mostly related to design choice rather than physics impediment. Feasibility is therefore better left for individual UE vendors to decide for themselves. RAN4 need not debate preclusion of IBM in this context  Verizon: The IBM should be implemented for multiple bands to support both co-located and non-co-located inter-band CA.  For flexibility both UE and network deployments, it is possible to consider the IBM/CBM as a UE capability for the UE to select the preferred network. On the network side, the gNB should be able to configure the beam management based on the reported UE capability and availability of network resources.  MediaTek: We worry about the practical feasibility and cost.  Apple: We agree with Qualcomm that IBM is implementable. It is more about if the IBM gain over CBM can justify the implementation cost and complexity increase. If non-collocated deployment is considered for CA in the same frequency group, IBM has to be implemented. However, if collocated deployment is agreed as typical scenario, IBM gain over CBM should be investigated and justified.  Samsung: the most benefits for network is that non-co-located deployment is possible if IBM is allowed. It also offer UE flexibility to overcome beam squint effect and other disadvantage of CBM, though there will be increasing on cost and complexity. Freedom should be left to UE vendor to support IBM or CBM based on UE capability. we are also fine to study the IBM gain firstly.  OPPO: Option2. IBM is always can be implemented with high costs, the issue is mainly about whether IBM needs to be mandated or optionally supported by UE considering the outcome of issue 1-1. If colocation is assumed for intra-band group, then there is no need for UE to support IBM in intra band group, but this is up to UE maybe a capability can be defined.  Ericsson: IBM capable UEs would be able to handle different AoA in a non-collocated scenario for bands in the same FR2 range.  Sony: The IBM UE is feasible for the same frequency group. Allowing IBM UE for the same frequency group can significantly improve the network's deployment flexibility and provide a more robust performance since the AoAs of CCs may come from different directions due to the reflection or diffraction even under the co-located scenarios. In addition, we think the RAN1 spec already supports beam management per CC, and thus there is no protocol barrier  vivo: prefer option 2. For co-located deployment, the benefit of IBM should be considered based on CBM, because the CBM have obvious gain on saving cost and overhead. For non-co-located deployment, IBM may be the only choice for better performance.  Nokia: IBM should not be ruled out for CA configurations within same frequency group. It is up to UE vendor to decide BM type.  Xiaomi: Option 2. The IBM for same frequency group has high cost but not enough network benefit has shown.  Huawei: IBM should be the baseline. There is no performance degradation for IBM. Even UE use the same chain to receive 2 bands with collocated deploy, the MRTD decides there is unavoidable loss. |
| Issue 1-3: Parameters to study on IBM benefit and UE implementation complexity | (open discussion)  (metrics needed) | Intel: 1) minimum gap size between CCs from two bands 2) frequency separations within each bands 3) co-located or non co-located 4) beam squint, etc  Apple: agree with Intel’s proposal. Additionally, UE related complexity associated with IBM should be studied including UE architecture, beam management and RRM etc.  Samsung: generally agree with Intel and Apples proposals  For IBM benefit: spectrum utility; co-located or non-colocated; beam squint  For UE complexity: RF architecture; beam management; power consumption; cost etc.  OPPO: Depends on Issue 1-1, if colocation is assumed for intra-band group, then there is no need for UE to support IBM in intra band group. And it can be up to UE implementation decide.  vivo: Share previous views from Samsung.  Xiaomi: Agree with Intel especially the minimum gap size between CCs from same frequency group.  Huawei: from MRTD requirement, the performance compared with CBM, the adaptable scenarios. |

### CRs/TPs comments collection

*N/A.*

## Summary for 1st round

### Open issues

*Moderator tries to summarize discussion status for 1st round, list all the identified open issues and tentative agreements or candidate options and suggestion for 2nd round i.e. WF assignment.*

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|  | **Status summary** |
| Issue 1-1: Can co-located deployment be considered a typical scenario for FR2 inter-band CA within the same frequency group? | There is no consensus whether co-located deployment can be considered a typical scenario for FR2 inter-band CA within the same frequency group:   * Some companies felt non-co-located deployments are realistic   + Huawei, Verizon, Ericsson, Sony, Vivo, Nokia * Other companies felt co-located deployments should be considered typical   + MediaTek, Apple, Samsung, Oppo, Xiaomi * Some companies preferred co-located deployments in terms of impact to UE design:   + Intel, Apple   *Recommendations for 2nd round:*  Discussion on what a generalized deployment means from a UE perspective. For example: Does existing framework of IBM inter-CA requirements apply to band pairs in same frequency group? |
| Issue 1-2: Feasibility criteria for IBM for inter-band CA between bands in the same frequency group | There is consensus that IBM is implementable for FR2 inter-band CA within the same frequency group:   * Some companies felt feasibility should be left to UE vendor choice over concerns of cost and complexity. ‘Choice’ here refers to CBM declaration   + Qualcomm, Samsung, Mediatek, Oppo, Apple * One company recommended further study and justification for IBM if there was consensus in issue 1-1 (there was no consensus)   *Recommendations for 2nd round:*  Discussion on ‘IBM should be the baseline’ Can CBM be considered as an incapability signaling for the UE to use for certain allowed band combinations?*.* |
| Issue 1-3: Parameters to study on IBM benefit and UE implementation complexity | Many diverse ideas to evaluate IBM benefit.  *Recommendations for 2nd round:*  Continue discussion – what is preferred outcome of study? |

*Recommendations on WF/LS assignment*

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| --- | --- | --- | --- |
|  | **WF/LS t-doc Title** | **Assigned Company,**  **WF or LS lead** | **Notes** |
| #1 | On inter-band DL CA and UE BM type | Qualcomm | To capture consensus in 1st and 2nd discussion for all topics in this document |

### CRs/TPs

*N/A*

## Discussion on 2nd round (if applicable)

Due to overlap, a discussion topic from [135] have been brought over into this thread for further discussion.

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| **Issue** | **Options** | **Company Comments** |
| Continued Issue 1-1: Can co-located deployment be considered a typical scenario for FR2 inter-band CA within the same frequency group? | ~~Does existing framework of IBM inter-CA requirements apply to band pairs in same frequency group?~~ | (Being treated in [135], issue 2-2, see also ‘WF for Applicability of CBM/IBM for different CA’, Samsung) |
| Continued Issue 1-2: Feasibility criteria for IBM for inter-band CA between bands in the same frequency group | ~~Can IBM be considered baseline implementation and CBM as an incapability signaling for the UE to use for certain allowed band combinations?~~ | (Being treated in [135], issue 2-2, see also ‘WF for Applicability of CBM/IBM for different CA’, Samsung) |
| Continued Issue 1-3: Parameters to study on IBM benefit and UE implementation complexity | What should be outcome of study? | **Sony:** according to the input from operators in the 1st round discussion, the non-collocated deployment is a possible scenario. Therefore, it is clear that the benefit of supporting IBM is that non-collocated deployment can be facilitated. It can also be seen from the 1st round that IBM is at least a possible implementation, which can be up to the UE vendor to select whether or not to support it, and report capability IBM/CBM to the network.  It is not clear to us the necessity to associate the IBM benefit over CBM with any specific parameter and how this would affect the specification. Therefore, we suggest the study here can just focus on the requirement of IBM and CBM and how to differentiate them from the testing aspect.  Ericsson: non-collocation is also a likely scenario for bands within the same frequency group, operators cannot always collocate antennas even though the bands are in the same FR2 frequency range.  The minimum requirements for IBM should ensure that the UE is able to handle different AoA even though the current test regime is based on a single probe/direction. |
| Discussion on metrics for each parameter identified |  |
| **[135] Issue 4-3:** For FR2 inter-band CA within the same band group, the UE RF requirements are only defined based on cell co-location |  | **MediaTek**: Yes  **Sony:** As the non-collocated deployment scenario is also a possible deployment, we think it is too early to conclude that only the co-located case would be tested.  Whether to test co-located/non-collocated can be up to IBM or CBM UE rather than in the same or different frequency group in our understanding.  Ericsson: no. RF requirements only based on colocation would not ensure functionality in the field for non-collocation and may therefore impose a deployment restriction.  RAN4 should attempt at developing test cases for CBM/IBM for both collocation and non-colocation to increase flexibility for the network to configure a UE with a DL inter-band CA rather than focusing on the scope of requirements and ‘allowed’ BM capability reporting.  OPPO: Our preference is only define one of location scenario for requirement simplicity, and the co-location is preferred considering this is the most likely deployment for bands within the same freq group. If this is not agreeable, certain requirements from non co-location can also be considered as supplementary to verify the non co-location scenario. |

## Summary on 2nd round (if applicable)

*Moderator tries to summarize discussion status for 2nd round and provided recommendation on CRs/TPs/WFs/LSs Status update suggestion*

|  |  |
| --- | --- |
| **CR/TP/LS/WF number** | **T-doc Status update recommendation** |
| XXX | *Based on 2nd round of comments collection, moderator can recommend the next steps such as “agreeable”, “to be revised”* |

# Topic #2: Inter-band DL CA: CBM for bands across different frequency groups

*Agenda item 12.3.2.1.3*

## Companies’ contributions summary

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| **T-doc number** | **Title** | **Company** | **Proposals / Observations** |
| [**R4-2014232**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_97_e/Docs/R4-2014232.zip) | On the feasibility of CBM for FR2 inter-band CA cross different frequency groups | Apple | * On deployment scenarios   Observation 1: The cell size or coverage difference between 28GHz and 37GHz band group can be as large as 3 times based on free space path loss model. If n262 is considered, the corresponding difference can be even larger.  **Proposal 1: Operators’ inputs are needed if non-collocated deployment can be considered as typical scenario for FR2 inter-band CA between different frequency groups.**  Observation 2: On top of receiving time difference, non-collocated deployment can also impact CBM from the aspects of AGC, TPC due to different propagation loss and phase shifter setting due to the different orientation relative to UE.   * On MRTD   Observation 3: When MRTD is more than CP length in CBM, one slot per Rx beam switching can be interrupted on all CCs where the symbol boundry misalignment from the reference CC is more than CP. If PDCCH is interrupted, the corresponding impacts can last multiple slots.  Observation 4: When non-collocated scenario is assumed, it is infeasible to assume MRTD is less than CP length due to both TAE and propagation delay differences. The performance degradation due to Rx switch and the corresponding interruption can be quite significant.  Observation 5: When MRTD>CP, parallel RRM measurement on FR2 CC becomes questionable since beam switch may happen during the symbol duration.   * On frequency separation and beam squint   Observation 6: Substantial performance degradation is expected for CBM with FR2 inter-band CA between different frequency groups from the aspects of frequency separation and beam squint. |
| [**R4-2015874**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_97_e/Docs/R4-2015874.zip) | Views on Feasibility for CA configurations between different frequency groups based on CBM | Sony, Ericsson | Observation 1: A CBM UE is assumed to support the co-located deployment scenarios. An IBM UE is assumed to support both co-located and non-co-located deployment scenarios.  Observation 2: Supporting CBM UEs with different frequency groups can speed up the deployment of inter-band DL CA and save network resources since it does not require advanced phase shift networks on the UEs.  **Proposal 1: RAN4 concludes that CBM UEs are feasible for DL inter-band CA between the different frequency groups, at least for the co-located scenarios.** |

## Open issues summary

*The primary goal of the study is to establish feasibility of CBM for inter-band CA across bands across different frequency groups. See thread #135 for ‘frequency group’ discussion.*

### Sub-topic 2-1

*One contribution has pointed out that UEs that support CBM for bands across different frequency groups suffer from significant functionality impairments due to inability of networks to guarantee sub-CP MRTD and beam squint. Another points out that a UE design is physically possible and there is promise of reduced network overhead. It goes on to propose feasibility at least for co-located case.*

**Issue 2-1: Can non-co-located deployment be considered a typical scenario for FR2 inter-band CA between different frequency groups?**

### Sub-topic 2-2

*Discussion on CBM and MRTD > CP.*

**Issue 2-2: What performance criteria should be discussed to capture mid-symbol beam and AGC changes, and PDCCH interruption**

### Sub-topic 2-3

*Discussion on Beam Squint.*

**Issue 2-3: How would UE and network interact to compensate for beam squint in setting UL power per CC**

## Companies views’ collection for 1st round

### Open issues

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| **Issue** | **Options** | **Company Comments** |
| Issue 2-1: Can non-co-located deployment be considered a typical scenario for FR2 inter-band CA between different frequency groups? | (open discussion) | Verizon: In actual deployments, it is highly possible to deploy the cell based on the spectrum availabilities. In this scenario, both 28 and 39GHz carriers are possible to be implemented in either co-located or non-co-located in the network (gNB(s)) and the network should incorporate the functional modules of beam management. An IBM UE is assumed to support both co-located and non-co-located carriers in the deployment scenarios.  MediaTek: For different frequency groups, IBM is more made sense. Although IBM is not directly limit to non-co-located or co-located deployment scenarios, we think use “non-co-located” as starting point to discuss IBM requirement is made sense.  Apple: Considering the coverage gap between bands from different frequency groups, operators’ inputs are needed to understand the feasibility of collocated scenarios.  OPPO: Non collocated is ok as the typical scenario and in our understand this is more stringent scenario than collocated, therefore can be used to define requirements.  Ericsson: can be both collocation and non-collocation. Hence CBM capable UE may also be configured with CA even if the bands combined belong to different FR2 ranges.  Sony: Similar comments to Issue 1-1, both co-located and non-collocated scenarios are possible to our understanding.  Vivo: Even for inter-band CA between different frequency groups, co-located scenario still can be prioritized, though non-collocated is also possible. The performance of inter-band CA under non-co-located deployment may be poor due to the PSD imbalance.  Nokia: Both collocated and non-collocated deployments are possible.  Xiaomi: Both are possible.  Huawei: both are possible. |
| Issue 2-2: What performance criteria should be discussed to capture mid-symbol beam and AGC changes, and PDCCH interruption | (open discussion) | Qualcomm: In the short term, we can use REFSENS, but in the presence of PSD difference that is realistic in deployment scenarios. Unlike intra-band or intra-frequency group inter-band, even with co-located scenarios, beam squint and different propagation conditions will potentially cause significant PSD difference for inter-CA across different frequency groups.  In the long term, BB test methods may be developed to quantify a UE’s performance in response to beam changes and AGC activity.  Apple: Firstly, CBM related study should be prioritized for collocated scenario. With this, the corresponding PSD. difference, MRTD and beam squint effects can be decided. Based on these assumptions, the eventual throughtput performance loss matters. |
| Issue 2-3: How would UE and network interact to compensate for beam squint in setting UL power per CC | (open discussion) | Ericsson: the network might detect changes in the UL performance and reconfigure the UE if necessary. RAN4 minimum requirements do not cover all possible cases at any rate, should ensure baseline performance and functionality in the field.  Huawei: the beam squint may be calibrated by UE. However, gNB can make assistant. |

### CRs/TPs comments collection

*N/A.*

## Summary for 1st round

### Open issues

*Moderator tries to summarize discussion status for 1st round, list all the identified open issues and tentative agreements or candidate options and suggestion for 2nd round i.e. WF assignment.*

|  |  |
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|  | **Status summary** |
| Issue 2-1: Can non-co-located deployment be considered a typical scenario for FR2 inter-band CA between different frequency groups? | There is no consensus whether non-co-located deployment can be considered exclusively a typical scenario for FR2 inter-band CA between different frequency groups  There is consensus that both co-located and non-co-located deployments are possible for FR2 inter-band CA between different frequency groups |
| Issue 2-2: What performance criteria should be discussed to capture mid-symbol beam and AGC changes, and PDCCH interruption | *Recommendations for 2nd round:*  Discussion on what a generalized deployment means from a UE perspective. For example: Do we focus on co-located scenario for the sake of setting requirements? |
| Issue 2-3: How would UE and network interact to compensate for beam squint in setting UL power per CC | Network assistance available |

*Recommendations on WF/LS assignment*

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|  | **WF/LS t-doc Title** | **Assigned Company,**  **WF or LS lead** |
| #1 |  |  |

### CRs/TPs

*N/A*

## Discussion on 2nd round (if applicable)

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| --- | --- | --- |
| **Issue** | **Options** | **Company Comments** |
| Issue 2-2: What performance criteria should be discussed to capture mid-symbol beam and AGC changes, and PDCCH interruption | Do we focus on co-located scenario for the sake of setting requirements? | **Sony:** it is reasonable to only support co-located scenario for CBM UEs according to RAN4 previous agreement.  Ericsson: it is recognized that a power difference between CC can affect AGC performance in specific implementations. TPC is independent between CC; the minimum performance requirements for absolute power control can hardly be a design limitation (but the wide tolerances do have an impact on network performance).  The CBM is based on similar AoA for the CCs, which means that focus could be put on developing requirements relevant for co-location. This means that the MRTD can be expected to be up to 3 us.  Regarding MRTD, we note that BM can also be carried out when there is no DL data scheduled on one of the CCs and in the U-D switch. How often is BM carried out in relation to expected changes in the channel conditions?  What is the impact on the DL throughput due to PDCCH interruptions in case of non-collocation and an MRTD up to 3 us?  What is the time needed for BM (typically)?  Answers to these questions could assist in setting requirements. |
| (add lines to discuss other items) |  |

## Summary on 2nd round (if applicable)

*Moderator tries to summarize discussion status for 2nd round and provided recommendation on CRs/TPs/WFs/LSs Status update suggestion*

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| --- | --- |
| **CR/TP/LS/WF number** | **T-doc Status update recommendation** |
| XXX | *Based on 2nd round of comments collection, moderator can recommend the next steps such as “agreeable”, “to be revised”* |

# Topic #3: Inter-band UL CA

*Agenda Items 12.3.2.2.1, 12.3.2.2.2.*

## Companies’ contributions summary

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| **T-doc number** | **Title** | **Company** | **Proposals / Observations** |
| [**R4-2014715**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_97_e/Docs/R4-2014715.zip) | Inter-band UL CA for FR2 | Qualcomm Incorporated | Observation: (As listed in paper) issues to be discussed for inter-band UL CA …. the list of open items is long: |
| [**R4-2016086**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_97_e/Docs/R4-2016086.zip) | UL inter-band CA for different band group based on IBE | NTT DOCOMO INC. | **Proposal 1: For maximum TRP for FR2 UL inter-band CA, the sum of TRP from LB and HB shall not exceed maximum TRP associated with each power class, e.g., 23dBm for power class 2/3/4.**  **Proposal 2: For maximum peak EIRP for FR2 UL inter-band CA, it should be guaranteed that the sum of peak EIRP from LB and HB in any direction does not exceed the allowable level, e.g., 43dBm for PC 2/3/4.**  **Proposal 3: For FR2 UL inter-band CA, UE should meet minimum peak EIRP of LB and HB individually, and should meet common spherical coverage EIRP.**  **Proposal 4: UE should meet emission requirements of LB and HB under UL inter-band CA operation, respectively.** |
| Late additions due to submission under parent agenda item: | | | |
| [**R4-2014913**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_97_e/Docs/R4-2014913.zip) | Views on FR2 Inter-band UL CA | Apple Inc. | ***Proposal****: RAN4 to put off the inter-band UL CA requirements development until there is a clear or urgent demand on this feature.* |
| [**R4-2015328**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_97_e/Docs/R4-2015328.zip) | Discussion on FR2 inter-band UL CA | vivo | **Observation 1**: The inter-band UL CA that using CBM has similar problems with DL.  **Observation 2**: Currently there are some different possibilities of assumptions with the relationship between Fs,inter for UL and DL, which is:  **Option 1**: Fs,inter,UL =Fs,inter,DL=Fs,inter  **Option 2**: Fs,inter,UL ＜Fs,inter,DL or Fs,inter,UL ＞Fs,inter,DL  There would be some different CBM/IBM applicability for UL/DL in different cases.  **Proposal 1:** The frequency separation for inter-band UL CA (Fs,inter,UL) should be evaluated.  **Proposal 2:** The asymmetry of BM type between UL and DL need to be considered.  **Proposal 3:** The non-simultaneous transmission can be one of options for inter-band UL CA. |

## Open issues summary

### Sub-topic 3-1

*UE power class discussion. One contribution recommends per-UE applicability for TRP and EIRP limit.*

**Issue 3-1a: Do the power class requirements in TS38.101-2 v16.5 apply per UE or per band.**

**Issue 3-1b: Should there be regional requirements with NS in case of per UE?**

**Issue 3-1c: Per band spherical coverage and peak EIRP discussion**

### Sub-topic 3-2

*Configured power for inter-band UL CA:*

**Issue 3-2: If EIRP is shared in configured power formulation, what is the definition of shared EIRP**

### Sub-topic 3-3

*MPR and A-MPR:*

**Issue 3-3: Open discussion on impact of reverse IMDs and unequal PSDs**

### Sub-topic 3-4

*MPE:*

**Issue 3-4: Open discussion on P-MPR, PHR in context of UL in two bands**

### Sub-topic 3-5

*UE Capabilities:*

**Issue 3-5: Is CBM/IBM enough, or are new capabilities required?**

### Sub-topic 3-6

*Testability:*

**Issue 3-6: Is single AoA/AoD enough?**

### Sub-topic 3-7

*Emissions:*

**Issue 3-7: Can existing emissions limits in TS38.101-2 v16.5 be adopted as being applicable per UE?**

## Companies views’ collection for 1st round

### Open issues

|  |  |  |
| --- | --- | --- |
| **Issue** | **Options** | **Company Comments** |
| Issue 3-1a: Do the power class requirements in TS38.101-2 v16.5 apply per UE or per band. | (open discussion) | Intel: In Rel-15 and 16, only single CC UL and intra-band contiguous UL CA are considered. So V16.5 is per band and also per UE.  But for Rel-17 inter-band UL CA, the situation is a bit more complicated. We need further study how to define requirements for inter-band UL CA with 2 UL band active. It imposes challenge on UE design either per UE based or per band based. If per band based, simultaneous UL transmission over two bands will increase UE power consumption which is critical parameter is FR2. If per UE based, how to define/share EIRP and spherical coverage is not clear yet. It also not clear how to handle emission.  Qualcomm: The 23 dBm TRP limit was originally derived from co-existence considerations. In our view TRP is a per-band requirement.  Verizon: Per band!  MediaTek: Conceptually, our view is “Per UE“  Apple: Can be per band based. Our contribution R4-2014913 was not incluced. Can moderator please update the summary to include this contribution?  Samsung: power class requirements includes TRP, maxEIRP, min peak EIRP, etc. In our understanding, it is difficult to define TRP and maxEIRP requirements per-band. For min peak EIRP, there will be power splitting issue if the same PA is utilized, further study is needed.  OPPO: In our understanding, the max TRP/max peak EIRP is from regulation requirements and might be per-band defined but this needs clarification from regulations. And the min peak EIRP/CDF are defined by 3GPP which was per-band/per-UE defined in Rel-15/16, and in Rel-17 the inter-band UL CA introduced whether it is per-band or per-UE should be further evaluated since the concurrent Tx might have impact on the values especially for the CBM scenario.  vivo: in our understanding, max EIRP was derived for complying regulator, but the problem is we need to consider the beam directions at same time. It may be more reasonable apply the max EIRP on the overlapping area. For CBM, it is better to apply the requirement per UE, but for IBM it may be a table or formula based on the beam intersect area. So we think it should be studied further. The max TRP can be apply per band for limiting the interference.  Xiaomi: We believe the requirement should be per UE. And also as discussed in thread [135], we should consider TRP, max EIRP and min EIRP together.  Huawei: It depends on regulation requirement. Different regions seem have different requirement on TRP. RAN4 may need further discussion how to handle with the condition.  NTT DOCOMO, INC:  In our view, Max TRP and max EIRP should be carefully discussed considering how the current limit was derived. And we would like to know the impact caused by limitation of max TRP on minimum peak EIRP and spherical coverage EIRP. If UE do not use max level of TRP to achieve min peak EIRP and spherical EIRP, then the impact of limitation may be smaller. |
| Issue 3-1b: Should there be regional requirements with NS in case of per UE? | (open discussion) | Qualcomm: For regions that impose per UE limits, other limiting mechanisms can be discussed like Pmax or NS  OPPO: Per UE Situation needs to be further clarified like whether it was caused by regional regulations or other issues. |
| Issue 3-1c: Per band spherical coverage and peak EIRP discussion | (open discussion) | Intel: In general, it is reasonable to consider spherical coverage and peak EIRP per band based. But apparently, in UL CA case, it is challenging to deliver them on both bands simultaneously.  Qualcomm: This study will benefit from organization into CBM and IBM UEs  Verizon: Per band if it is possible, but a study is needed.  MediaTek: Maybe achieve the basic consensus on “per UE” or “per band” firstly, it would be helpful to converge each requirement.  Apple: Can be per band  Samsung: based on equal power splitting, per-band requirement is reasonable, and is also consistent with DL CA.  OPPO: Further evaluation is needed especially for the CBM cases.  vivo: per band for peak EIRP may be better, for ensuring the minimum performance. And for spherical coverage, it may be better to consider the requirement with EIS spherical coverage together to prevent mismatch.  Xiaomi: For EIRP we think per band is better.  Huawei: wait for conclusion on regulation requirement. |
| Issue 3-2: If EIRP is shared in configured power formulation, what is the definition of shared EIRP | (open discussion) | Intel: EIRP may be defined as per band based in configured power.  Apple: Maximum EIRP would depend on regulatory requirements as whether total power or power spectral density counts.  Samsung: peak EIRP at different direction can not be summed up.  Xiaomi: Based on some regulation of Wi-Fi, the EIRP are summed up directly without considering the directions. Hence we need to be really careful here and make enough communication with regulations about this shared EIRP definition. |
| Issue 3-3: impact of reverse IMDs and unequal PSDs | (open discussion) | Intel: The issue is more challenging for CBM Tx. Need further investigation.  Apple: How to characterize reverse isolation among PAs to evaluate the UL IMDs and its implication to out-of-band emissions could be rather challenging.  vivo: The impact of the reverse IMD may change dramatically under different scenarios. The same frequency group with CBM may be the worst case, the impact of different group with IBM may be minor. It may be an option to define the MPR base on band combination with different BM type. |
| Issue 3-4: P-MPR, PHR in context of UL in two bands | (open discussion) | Intel: It is depending on how to handle Tx requirements per band or per UE.  Apple: PHR can be per band. MPE is per UE.  vivo: similar problem with max EIRP, need more study |
| Issue 3-5: Is CBM/IBM enough, or are new capabilities required? | (open discussion) | Intel: Should be consistent with DL assumption  Apple: Same BM as with DL  Samsung: it is expected to be consistent with DL CA. |
| Is single AoA/AoD enough? | (open discussion) | Intel: Should be consistent with DL assumption  Apple: Same as with DL due to beam correspondence requirement.  Samsung: for RF requirements, single AoA is enough. |
| Can existing emissions limits in TS38.101-2 v16.5 be adopted as being applicable per UE | (open discussion) | Intel: Need further investigation.  Qualcomm: In our view regulatory-facing emissions limits are per UE (SEM, OBW, general spurious, additional requirements). Others like ACLR can be considered per band. FFS on co-existence requirements.  Verizon: this should be per UE.  Apple: Can be per band  Samsung: our initial understanding is per-UE emission limits, also open for further investigation.  Vivo: Share Qualcomm’s view. |

### CRs/TPs comments collection

*N/A.*

## Summary for 1st round

### Open issues

*Moderator tries to summarize discussion status for 1st round, list all the identified open issues and tentative agreements or candidate options and suggestion for 2nd round i.e. WF assignment.*

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| --- | --- |
|  | **Status summary** |
| Issue 3-1a: Do the power class requirements in TS38.101-2 v16.5 apply per UE or per band. | There is no consensus if power class requirements are per band or per UE. Needs further discussion  Multiple issues were raised. Further discussion needed |
| Issue 3-1b: Should there be regional requirements with NS in case of per UE? | One company suggested ‘For regions that impose per UE limits, other limiting mechanisms can be discussed like Pmax or NS’. Another company wanted clarification on source of per UE requirement |
| Issue 3-1c: Per band spherical coverage and peak EIRP discussion | Possible consensus is that peak EIRP and spherical coverage requirements will be specified per band.  Actual requirement values may depend on power splitting assumption and regulatory restrictions  Further discussion needed |
| Issue 3-2: If EIRP is shared in configured power formulation, what is the definition of shared EIRP | Multiple issues were raised. Further discussion needed |
| Issue 3-3: impact of reverse IMDs and unequal PSDs | Further discussion needed |
| Issue 3-4: P-MPR, PHR in context of UL in two bands | Further discussion needed |
| Issue 3-5: Is CBM/IBM enough, or are new capabilities required? | There seems to be consensus that UL and DL inter-band CA should share the same BM capability.  *Recommendations for 2nd round:*  Confirmation: the UE makes a single BM declaration for a band pair, and it applies to both for UL and DL |
| Issue 3-6: Is single AoA/AoD enough? | Consensus is that single AoA testing is enough |
| Issue 3-7: Can existing emissions limits in TS38.101-2 v16.5 be adopted as being applicable per UE | Further discussion needed |

*Suggestion on WF/LS assignment*

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| --- | --- | --- | --- |
|  | **WF/LS t-doc Title** | **Assigned Company,**  **WF or LS lead** | **notes** |
|  |  |  |  |

### CRs/TPs

*N/A*

## Discussion on 2nd round (if applicable)

Due to overlap with some issues discussed in this topic, some discussion topics from [135] have been brought over into this thread for further discussion.

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| **Issue** | **Options** | **Company Comments** |
| **[135] Issue 5-1:** **For maximum TRP for FR2 UL inter-band CA, the sum of TRP from LB and HB shall not exceed maximum TRP associated with each power class, e.g., 23dBm for power class 2/3/4.** | Proposals:   * Option 1: Yes the sum of TRP from LB and HB shall not exceed maximum TRP associated with each power class * Option 2: No there will not be such limitation * Option 3: option 2 + regional regulations shall be supported by NS or Pmax | **MediaTek**: Our view is “Option1”, that aligned general power class meaning in legacy in our understanding. Of course, the corresponding EIRP etc spec shall have corresponding modification.  **OPPO:** Option 3, restricting sum of TRP according to the power class in inter-band CA potentially will cause UE output power back off. The impact to the inter-band CA requirements need further study. Besides, for inter-band CA the output power are at different freq, need to understand better on the impact to Max TRP regulation which is probably based on per-band. |
| **[135] Issue 5-2: For maximum peak EIRP for FR2 UL inter-band CA, it should be guaranteed that the sum of peak EIRP from LB and HB in any direction does not exceed the allowable level, e.g., 43dBm for PC 2/3/4** | Proposals 5-2:   * Option 1: Yes it should be guaranteed that the sum of peak EIRP from LB and HB in any direction does not exceed the allowable level * Option 2: No there will not be such limitation * Option 3: Option 1 + regional regulations shall be supported by NS or Pmax | **MediaTek**: Our view is “Option1”, similar view as maximum TRP part.  **OPPO:** Option 3, restricting sum of peak EIRP according to the power class in inter-band CA potentially will cause UE output power back off. The impact to the inter-band CA requirements need further study. Besides, for inter-band CA the output power are at different freq, need to understand better on the impact to peak EIRP regulation which is probably based on per-band. |
| **[135] Issue 5-3: For FR2 UL inter-band CA, UE should meet minimum peak EIRP of LB and HB individually, and should meet common spherical coverage EIRP.** | Proposals:   * Option 1: Yes UE should meet minimum peak EIRP of LB and HB individually, and should meet common spherical coverage EIRP * Option 2: Needs more discussion | **MediaTek**: Our view is “Option2”, we shall finalize “max TRP” and “Max Peak EIRP” discussion firstly.  **OPPO**: Option 2, the minimum peak EIRP needs further clarification since in CBM there might be some relaxation; and whether to define common spherical coverage for CBM is still under discussion. |
| Issue 3-2: If EIRP is shared in configured power formulation, what is the definition of shared EIRP |  | **MediaTek**: our preliminary view is while each band has 3dB less power because of total TRP limitation, the corresponding individual EIRP shall have 3dB less requirement compared to non-UL-CA operation. |
| Issue 3-3: impact of reverse IMDs and unequal PSDs |  |  |
| Issue 3-4: P-MPR, PHR in context of UL in two bands |  |  |
| Issue 3-5: Is CBM/IBM enough, or are new capabilities required? |  |  |
| Issue 3-7: Can existing emissions limits in TS38.101-2 v16.5 be adopted as being applicable per UE  **[135] Issue 5-4: UE should meet emission requirements of LB and HB under UL inter-band CA operation, respectively** | Proposals:   * Option 1: UE meets emission requirements of LB and HB under UL inter-band CA operation, respectively i.e. both LB and HB meet own applicable requirements * Option 2: Needs more discussion * Option 3: UE meets SEM, general spurious (-13 dBm/ MHz) and SEM requirements on a per UE basis | **OPPO**: Option 2. Emission might needs to be summed from two bands since they are overlapped in freq domain. |
| Issue 3-8: Shall RAN4 put off development of inter-band UL CA requirements until there is a clear or urgent demand for this feature |  | **MediaTek**: Agree, after considering RAN4 loading.  **Sony:** we have no strong opinion. But from the efficient aspect, we think unless there is a clear demand, it might be more efficient for RAN4 focus on DL and finalize it first, and then start on UL.  Ericsson: yes, focus should be put on developing test cases for DL inter-band CA for which there are many outstanding issues.  OPPO: Ok with put off. This is market demand dependent. |

## Summary on 2nd round (if applicable)

*Moderator tries to summarize discussion status for 2nd round and provided recommendation on CRs/TPs/WFs/LSs Status update suggestion*

|  |  |
| --- | --- |
| **CR/TP/LS/WF number** | **T-doc Status update recommendation** |
| XXX | *Based on 2nd round of comments collection, moderator can recommend the next steps such as “agreeable”, “to be revised”* |

# Version

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| --- | --- |
| Filename: | Incorporates: |
| draftR4-2016638 | [topic136\_v0 Intel\_QC-Verizon\_mtk\_apple\_Samsung\_OPPO\_EAB\_Sony\_vivo\_Nokia\_Xiaomi\_HW\_DCM.docx](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_97_e/Inbox/Drafts/%5B97e%5D%5B136%5D%20NR_RF_FR2_req_enh2_Part_2/FirstRound/topic136_v0%20Intel_QC-Verizon_mtk_apple_Samsung_OPPO_EAB_Sony_vivo_Nokia_Xiaomi_HW_DCM.docx) |
| Added missing contributions from Apple and Vivo in topic #3 |
| R4-2016638 | Incorporated discussion topics from [135] |
| topic136\_rnd2 | R4-2016638 + removal of discussion topics that are duplicated from [135] |