**3GPP TSG-RAN WG4 Meeting # 104-e R4-22**

**Electronic Meeting, 15– 26 August, 2022**

**Agenda item:** 11.4.3

**Source:** Moderator (Huawei, HiSilicon)

**Title:** Email discussion summary for [104-e][314] FS\_NR\_BS\_RF\_evo

**Document for:** Information

# Introduction

This email thread discuss the SI on NR BS RF requirement evolution. The contributions are in agenda 11.4, which includes:

* Topic #1: General aspects
* Topic #2: Investigation of mmWave multi-band BS

# Topic #1: General aspects

## Companies’ contributions summary

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| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| [**R4-2212496**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2212496.zip) | Huawei, HiSilicon | Work plan on NR BS RF requirement evolution |
| [**R4-2212497**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2212497.zip) | Huawei, HiSilicon | TR skeleton for NR mmWave MB-BS |

## Open issues summary

*Before e-Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

### Sub-topic 1 –General aspects

**Issue 1-1: work plan**

* Proposal:

Following work plan is proposed for the SI.

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| **3GPP Meeting** | **TU** | **Task** |
| RAN4#104 | 0.5 | Work kick-off   * Discussion on the work plan/agreement * Discussion on the TR skeleton/agreement * Early study on the feasibility |
| RAN4#104bis | 0.5 | * Continue the feasibility study   + BS architectures   + Wideband RF   + Wideband antenna * Early discussion on if FR1 multi-band methods are re-usable for FR2 * Early discussion on the definition of FR2 multi-band BS |
| RAN4#105 | 0.5 | * Continue the feasibility study * Continue the discussion on if FR1 multi-band methods are re-usable for FR2 * Continue the discussion on the definition of FR2 multi-band BS * Discussion on if FR1 exceptions are acceptable for FR2 * Study on other RF requirements if any |
| RAN4#106 | 0.5 | * Conclude the feasibility study * Conclude the definition of FR2 multi-band BS * Conclude whether to reuse FR1 multi-band methods * Conclude whether to reuse FR1 exceptions * Continue study on other RF requirements if any |
| RAN4#106bis | 0.5 | * Continue study on the remaining issues for RF requirements |
| RAN4#107 | 0.5 | * Conclude the discussion on RF requirements * Conclude the SI * Finalize the TR |

* Recommended WF
  + Discuss and agree on the work plan

**Issue 1-2: TR skeleton**

* Proposals: R4-2212497
* Recommended WF
  + Comments collection and agree on the TR skeleton

## Companies views’ collection for 1st round

### Open issues

**Collection of comments:**

**Issue 1-1: work plan**

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| **Company** | **Comments** |
| Nokia | *No need to say 'Continue the feasibility study' as this is a SI so study should continue till the SI is complete or stopped, also no need to say 'Early'.* |
| Qualcomm | Replace “Early study on the feasibility” with “Preliminary feasibility”.  Replace “Early discussion on if FR1 multi-band methods are re-usable for FR2” with “Assess the applicability of FR1 multi-band methods to FR2” |
| Huawei | We do not have strong view on the wording and ok to update |

**Issue 1-2: TR skeleton (R4-2212497)**

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| **Company** | **Comments** |
| Nokia | *To align with SID, clause should contains two subclauses: 5.1) Wideband RF architectures, and 5.2) Wideband antenna architecture.* |
| Qualcomm | proposed scope: “*The present document is the Technical Report for the Study Item on BS RF requirement evolution dealing with FR2 multi-band BS deployments*.” |
| Huawei | To Nokia: ok to have the two sub-clauses in clause 5  To Qualcomm: ok with the proposed change on the scope. |
| Ericsson | Section 6 seems to pre-suppose re-use of FR1 requirements/methods/excemptions in some way. Quite likely that is needed but an additional section is needed like “FR2 specific multi-band requirements”. Alternatively, remove the sub-heading structure until later in the SI for now (add later). |

## 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** |
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*Suggestion on WF/LS assignment*

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

## Discussion on 2nd round (if applicable)

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| **Issues** | **Company Comments** |
|  | Company A:  Company B: |
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## 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** |
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# Topic #2: Investigation of mmWave multi-band BS

## Companies’ contributions summary

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| **T-doc number** | **Company** | **Proposals / Observations** |
| [R4-2211658](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211658.zip) | CATT | General consideration on mmWave multi-band BS |
| [R4-2211775](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211775.zip) | Huawei, Hisilicon | General consideration on mmWave multi-band BS |
| [R4-2211811](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211811.zip) | Nokia, Nokia Shanghai Bell | Proposals on topics for investigation of mmWave multi-band BS |
| [R4-2211812](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211812.zip) | Nokia, Nokia Shanghai Bell | Discussion on possible issues on performance of wideband RF and antenna architectures |
| [R4-2212622](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2212622.zip) | Ericsson | Multi-band BS in mm wave |
| [R4-2213700](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2213700.zip) | ZTE Corporation | Discussion on FR2 multi-band operation |

## Open issues summary

*Before e-Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

### Sub-topic 2 –Investigation of mmWave multi-band BS

**Issue 2-1: FR1 multi-band BS methods and exceptions**

* Proposals:

The following topics should be considered for investigation of FR2 multi-band BS:

1) Additional declarations for FR2 multi-band BS

2) The applicability of multi-band requirements

3) OTA transmitter OFF power

4) OTA Adjacent Channel Leakage Power Ratio (ACLR)

5) OTA operating band unwanted emissions

6) OTA transmitter spurious emissions

7) OTA adjacent channel selectivity

8) OTA in-band blocking

9) OTA out-of-band blocking

10) OTA receiver spurious emissions

11) OTA receiver intermodulation

* Recommended WF
  + Discuss whether the proposal is agreeable

**Issue 2-2: Definition of FR2 multi-band BS**

* Proposals:
  + **Option 1:**

**Definition of FR2 multi-band BS:**

BS type 2-O may be capable of supporting operation in multiple operating bands with one of the following implementations at the radiated interface boundary:

- All RIBs are single-band RIBs.

- All RIBs are multi-band RIBs.

- A combination of single-band RIBs and multi-band RIBs provides support of the BS type 2-O capability of operation in multiple operating bands.

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| **multi-band RIB:** *operating band* specific RIB associated with a transmitter or receiver that is characterized by the ability to process two or more carriers in common active RF components simultaneously, where at least one carrier is configured at a different *operating band* than the other carrier(s) and where this different *operating band* is not a *sub-band* or *superseding-band* of another supported *operating band*.  **single-band RIB:** *operating band* specific RIB supporting operation either in a single *operating band* only, or in multiple *operating bands* but does not meet the conditions for a *multi-band RIB*. |

* + **Option 2:** 
    - To revisit the definition of multi-band BS for FR2, based on the following scenarios.

1) Multi-band transmitter and/or receiver with common active RF components

2) Single-band transmitter and receiver

3) Configurable BS for different bands with the same hardware

4) BS covers full-band or sub-band of band A and band B

5) BS covers consecutive spectrums with different band number, for example, n258+n261

6) BS covers overlapping spectrums with different band number, for example, n258+n257

* Recommended WF
  + Discuss on the options

**Issue 2-3: Feasibility of FR2 multi-band BS**

* Observations/proposals on feasibility study from contributions:

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| **T-doc number** | **Company** | **Proposals / Observations** |
| [R4-2211658](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211658.zip) | CATT | **Observation 1: Multi-band AA (Antenna Array) with common radiated element with 19.5% FBW in 26+28 GHz combinations is feasible.**  **Observation 2: Multi-band AA (Antenna Array) with common radiated element with 19.5% FBW in frequency range 24-29 GHz which includes n257/n258/n261, or with 26.3% FBW in frequency range 37-48 GHz which includes n260/n259/n262 is feasible.**  **Observation 3: Multi-band AA (Antenna Array) with common radiated element with higher than 40.6% FBW in 28+39 GHz, 26+40 GHz, and 28+40 GHz combinations is not feasible.**  **Observation 4: It is possible to use multiple separate single-band AAs (Antenna Array) for ultra-wide band combination, for example, one single-band AA is for frequency range 24-29 GHz which includes n257/n258/n261, and another single-band AA is for frequency range 37-48 GHz which includes n260/n259/n262.** |
| [R4-2211775](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211775.zip) | Huawei, Hisilicon | **Proposal 3: FR2 multi-band BS has several key technical challenges including wideband RF front-end and wideband antenna. Companies are encouraged to provide the evaluations on the feasibility study.** |
| [R4-2211812](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211812.zip) | Nokia, Nokia Shanghai Bell | **1) If the supported radio bandwidth is wide**  **a. the lowest operating band may suffer degradation in directivity.**  **b. the highest operating band may have limited steerable angle (not to create grating lobes).**  **c. directivity variation between bands may be large which impacts to power accuracy requirements.**  **2) Concurrent beamforming for all operating bands at the same time instance is not possible for RF architecture adopting frequency-invariable-control phase shifters.**  **3) There are options to enable concurrent beamforming for all operating bands at the same time instance for RF architectures adopting phase shifters. However, the definitions of a BS that may be capable of supporting operation in multiple operating bands may not sufficiently cover all possible architectures and thus RF requirements.** |
| [R4-2212622](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2212622.zip) | Ericsson | **Observation 3: The following requirements need to be studied for considering very wide bandwidth multiband FR2:**   * **EIRP accuracy** * **EVM** * **ACLR and OBUE** * **Spurious emissions** * **RX sensitivity** * **Demodulation requirements** * **In-band blocking** * **RX IM**   **Observation 4: For supporting multiple bandwidths based on separate panels per band, most likely no change to the single band requirements is needed.**  **Observation 5: For consecutive and non-overlapping bands, the maximum expected BW IBW should be clarified. Then, the need for any adjustments to requirements based on a wider IBW should be considered.** |
| [R4-2213700](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2213700.zip) | ZTE Corporation | **Observation 2: for multi-band operation across different frequency group, it is challenging to support by the same power amplifier or driver amplifier.**  **Proposal 1: for multi-band operation in FR2, n257+n261 should be excluded which is not aligned with multi-band RIB definition.**  **Observation 3: for multi-band operation of example band combination** 26+28 GHz: n258 + n261 **it seems feasible to support by the same power amplifier or driver amplifier.** |

* Recommended WF
  + It is the first time for the SI and the proposals on the feasibility study are diverse. For 1st round moderator suggests to collect comments for the observations/proposals from companies’ contributions.

## Companies views’ collection for 1st round

### Open issues

**Collection of comments:**

**To Sub-topic 2**

**Issue 2-1: FR1 multi-band BS methods and exceptions**

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| **Company** | **Comments** |
| Nokia | *OK with the list as a starting point.* |
| Qualcomm | Agree on the proposed preliminary list. |
| Huawei | agree |
| Samsung | Agree with the list as starting point for further study |
| CATT | OK with it being a starting point. |
| Ericsson | The list is OK, but if the scope is to consider extremely large bandwidths then the list should not only be restricted to the requirements that are impacted in FR1. Suggest to add that other requirements alterations specific to FR2 for multiband should be investigated.  (It may be that once the scope of how much bandwidth is covered is clearer then indeed only the requirements that are also multiband for FR1 are impacted, but we should not jump to that conclusion too quickly). |

**Issue 2-2: Definition of multi-band BS**

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| **Company** | **Comments** |
| Nokia | *On option 1, there is no need to define multi-band BS, multi-band RIB currently defined in FR1 can be reused in FR2.*  *On option 2, the scenarios listed are similar to what had been considered for MB-MSR, the only difference is the requirements for MB-MSR are defined at connector not RIB, also these scenarios are similar to what need to be considered in FR1 where multi-band RIB is already defined.* |
| Qualcomm | Current definition of multi-band RIB should suffice for the definition of multi-band BS. |
| Huawei | On option 1, we need to investigate if the definition of multi-band RIB can be re-used for FR2.  On option 2, there are some scenarios which may not studied in FR1 MB-MSR, e.g. scenario 3 ~6. Hence we suggest to study these scenarios from OTA RIB perspective. |
| Samsung | It’s premature to agree on option 1 at this meeting before extensive study. We prefer to have further study based on option 2. |
| CATT | To respond to Nokia’s comment: We didn’t intend or propose to define multi-band BS. It should be “multi-band capable BS” which is used in TS 38.104. Our understanding is that current definition for BS type 1-O is general enough, so we think option 1(or the multi-band definition for type 1-O) can be the starting point to further check. We would like to know what the concern is based on option 2. Does the current definition can’t support any of the scenarios listed? |
| Ericsson | Option 1: If all RIBs are single band RIBs then the BS is a single band BS per RIB according to FR1 definitions. It could be discussed whether there is any reason for FR2 to define a BS supporting only single band RIBs as multi-band, but so far we did not see a motivation to change from FR1.  Option 2 seems OK. |

**Issue 2-3: Feasibility of FR2 multi-band BS**

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| **Tdoc number** | **Comments collection** |
| [R4-2211658](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211658.zip) CATT | Nokia:  On multi-band BS definition, AA may also use active RF components like PA for multi-band processing, so multi-band BS definition is not independent of AA.  On band combination feasibility, would it be possible for n260+n261 (28+39GHz) combination (with BWP=37%)? If maximum radio bandwidth is smaller than 27500-40000Mhz (i.e., not cover full band of A and/or B), then BWP may be smaller than 35% which is within the limit of ultra-wide band. (35% follows analysis in the paper) |
| Huawei: if our understanding is correct, the FBW limit in the standard YD/T 2867-2015 is applicable for FR1 passive antenna. For FR2 AAS, the limit might be different which need further study. The two aspects frequency ranges and active RF components should also be considered. |
| CATT: Thanks for the comment. The analysis in our contribution is a preliminary study. Agree that more study can be conducted in future meetings. |
| Ericsson:  Regarding the feasibility study, as a first step it might be good to decide whether the SI should really consider a wideband implementation covering 28-40GHz, or whether the SI should rather conclude that such an implementation is not feasible and/or does not have obvious benefits in the current timeframe and so is ruled out of the study. Making such a decision would simplify the consideration on which requirements to study. In general we tend to believe that such a bandwidth is not feasible.  Then as a next step we could discuss the expected widest bandwidth to be covered. As well as the antenna array, the efficiency of wideband PAs etc. should be considered, and whether locking analogue beamforming over all of the bands is desirable. |
|  |
| [R4-2211775](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211775.zip) Huawei | Nokia:  On multi-band BS definition, the scenarios listed under proposal 1 are similar to what had been considered for MB-MSR, the only difference is the requirements for MB-MSR are defined at connector not RIB, also these scenarios are similar to what need to be considered in FR1 where multi-band RIB is already defined.  On technical challenge, phase shifters and beamforming architectures also need to be considered. |
| Qualcomm:  Based on [5] in the paper, can one conclude that FR1 multi-band methods are re-usable for FR2? Table 2.3-1 simply presents the changes needs to apply the affected requirements to FR2. |
| Samsung: in general we agree with the proposals in this contribution to kick off the study on FR2 multi-band capable gNB. |
| Ericsson: Regarding the architectures, it may be difficult to route the PA output through different filters and antenna arrays in an efficient manner at mm wave frequencies. Then if the same array is used for the full range indeed it will not be optimal for some part of the range. |
|  |
| [R4-2211812](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2211812.zip)  Nokia | Qualcomm:  Assuming the patterns provided in Figure 2.2.2-1 are based on the M.2101 AAS model, should not it be band agnostic? The boresight offset axis that we get is due to the offset in the phase shifters. With proper hybrid BF architectures (multiple phase shifters).  Assuming that one may consider splitting the antenna array to smaller sub-arrays, each to address a given single band, would there be spatial isolation considered in such case to avoid the inter-subarrays leakage? |
| Huawei: in addition to the phase shifter, are there other techniques applicable to FR2 MB BS, e.g. real time delay line? |
| Samsung: as pointed in this contribution and above comments the further study on implementation solutions together with feasibility/challenge to support FR2 MB BS is needed before we conclude on the definition. |
| Ericsson: In general we agree with the observations. We think that 28-40GHz should be ruled out because a wideband array cannot be constructed, PA efficiency too low etc.. Then for other combinations, indeed factors such as wideband PA efficiency, feasibility and performance of phase shifters, implications of beam management on the BS side etc. need to be considered. |
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| [R4-2212622](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2212622.zip) Ericsson | Nokia:  On observation 5, IBW is similar to the current 'total radio bandwidth' declaration for MB-MSR. |
| Huawei: agree with observation 3. On observation 4, we may need to study if single band requirement is enough multi-band operation, and whether multi-band test is needed. On observation 5, will the non-contiguous requirement be applied? |
| Samsung: for EIRP accuracy, EVM and sensitivity, which are not included in subtopic 2-1 explicitly since it’s based on FR1 methodology, we also share the same view that further review is need. We also would like to study further on the validity on statement in observation 4 and 5. |
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| [R4-2213700](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_104-e/Docs/R4-2213700.zip)  ZTE Corporation | Nokia:  On multi-band operation, multi-band BS can transmit to different UEs for both bands, so no need to couple the discussion with UE inter-band CA requirements.  On proposal 1, n257+n261 combination is not listed as example band in the SID. |
| Huawei: as discussed in Issue 2-2, we may need further study on whether to reuse the definition of multi-band RIB for FR2. |
| Ericsson: We should not mix up multi-band BS (which is transmitting multiple carriers from the same wideband radio on the BS side) with CA (which is transmitting / receiving multiple carriers at the same UE on the UE side) |
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## 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** |
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*Suggestion on WF/LS assignment*

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|  | **WF/LS t-doc Title** | **Assigned Company,**  **WF or LS lead** |
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## Discussion on 2nd round (if applicable)

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| **Issues** | **Company Comments** |
|  | Company A:  Company B: |
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## 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** |
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# Recommendations for Tdocs

## 1st round

**New tdocs**

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| **Title** | **Source** | **Comments** |
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**Existing tdocs**

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| --- | --- | --- | --- | --- |
| **Tdoc number** | **Title** | **Source** | **Recommendation** | **Comments** |
| R4-210xxxx | CR on … | XXX | Agreeable, Revised, Merged, Postponed, Not Pursued |  |
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Notes:

1. Please include the summary of recommendations for all tdocs across all sub-topics incl. existing and new tdocs.
2. For the Recommendation column please include one of the following:
   1. CRs/TPs: Agreeable, Revised, Merged, Postponed, Not Pursued
   2. Other documents: Agreeable, Revised, Noted
3. For new LS documents, please include information on To/Cc WGs in the comments column
4. Do not include hyper-links in the documents

## 2nd round

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| **Tdoc number** | **Title** | **Source** | **Recommendation** | **Comments** |
| R4-210xxxx | CR on … | XXX | Agreeable, Revised, Merged, Postponed, Not Pursued |  |
| R4-210xxxx | WF on … | YYY | Agreeable, Revised, Noted |  |
| R4-210xxxx | LS on … | ZZZ | Agreeable, Revised, Noted |  |
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Notes:

1. Please include the summary of recommendations for all tdocs across all sub-topics.
2. For the Recommendation column please include one of the following:
   1. CRs/TPs: Agreeable, Revised, Merged, Postponed, Not Pursued
   2. Other documents: Agreeable, Revised, Noted
3. Do not include hyper-links in the documents

# Annex

Contact information

|  |  |  |
| --- | --- | --- |
| **Company** | **Name** | **Email address** |
| Nokia | Man Hung Ng | man\_hung.ng@nokia.com |
| Samsung | Yankun Li | Yankun.li@samsung.com |
| CATT | Huiping Shan | shanhuiping@catt.cn |
|  |  |  |

Note:

1. Please add your contact information in above table once you make comments on this email thread.
2. If multiple delegates from the same company make comments on single email thread, please add you name as suffix after company name when make comments i.e. Company A (XX, XX)