**3GPP TSG RAN WG1 Meeting #109-e R1-22xxxxx**

**e-Meeting, May 9 – 20, 2022**

**Agenda Item: 9.1.3.2**

**Source: Moderator (Futurewei)**

**Title: FL Summary #1 on SRS enhancements**

**Document for: Discussion and decision**

# Introduction

In RAN#94-e, a new Work Item for Rel-18 on “MIMO Evolution for Downlink and Uplink” was approved, and the motivations, scopes, and objectives were agreed in [1]. Among the objectives, the underlined in the following are related to SRS enhancements, mainly in the aspects of SRS for TDD Coherent Joint Transmission (CJT or C-JT) and 8 Tx operation:

1. Study, and if justified, specify enhancements of CSI acquisition for Coherent-JT targeting FR1 and up to 4 TRPs, assuming ideal backhaul and synchronization as well as the same number of antenna ports across TRPs, as follows:
   * Rel-16/17 Type-II codebook refinement for CJT mTRP targeting FDD and its associated CSI reporting, taking into account throughput-overhead trade-off
   * SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS capacity enhancement and/or interference randomization, with the constraints that 1) without consuming additional resources for SRS; 2) reuse existing SRS comb structure; 3) without new SRS root sequences
   * Note: the maximum number of CSI-RS ports per resource remains the same as in Rel-17, i.e. 32
2. Study, and if justified, specify UL DMRS, SRS, SRI, and TPMI (including codebook) enhancements to enable 8 Tx UL operation to support 4 and more layers per UE in UL targeting CPE/FWA/vehicle/Industrial devices
   * Note: Potential restrictions on the scope of this objective (including coherence assumption, full/non-full power modes) will be identified as part of the study.

23 contributions [3-25] have been submitted to Agenda Item 9.1.3.2 of RAN1#109-e on SRS Enhancements targeting TDD CJT and 8 Tx operations. Views from these contributions are summarized in this document. Further inputs from any company are also collected in this document.

# EVM

As advised by the WI rapporteur in the work plan [2], we should aim at finalizing EVM discussions during this meeting. Several companies pointed out that a wide variety of SRS EVMs have already been established in previous releases (the latest being Rel-17) and they can be generally reused, at least as a starting point. To facilitate the progress, the group should focus on only additional EVMs that require RAN1 agreement, if any. Please provide inputs to the following questions:

* Q1: Is there a need for agreeing on EVM in addition to existing SRS EVMs in RAN1?
* Q2: If the answer to Q1 is “Yes”, please elaborate: in SRS for TDD CJT and/or in 8 Tx SRS; link-level simulation and/or system-level simulation; etc.

Note that answering “No” to Q1 does not preclude any future decision making based on evaluation results for any specific enhancement proposal, and companies are encouraged to provide evaluation results with any previously agreed SRS EVMs as they see fit.

Companies’ views on the above are collected as follows.

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| --- | --- |
| **Company** | **View** |
| Apple | * Q1: We are open for additional EVM if necessary. But we are wondering which EVM should be assumed, Rel-17 one? |
| QC | * Q1: From our point of view, evaluations are certainly needed depending on the scheme under discussion. However, agreeing to additional EVM at this point may not be needed. |
| Intel | We think the Rel-17 EVM can be used. But we are open on additional EVM setting. |
| Samsung | Q1: We are open to discuss. We think that Rel-17 SRS can be a starting point. |
| OPPO | Q1: Yes.  Q2: At least antenna configuration for evaluation of 8 Tx SRS is needed for LLS. In Rel-17, we only have 2/4 Tx in uplink. Other Rel-17 EVM can be reused. |
| MediaTek | Q1: In our opinion Rel-17 can be used as a starting point. However, additional configuration may be required based on the outcome of agreed schemes, for example as OPPO mentioned above we may need to extend Rel-17 EVM to 8 TX depending on the decision on WID objective 5. |
| Lenovo | Q1: We think that evaluation assumptions from Rel-17 SRS can serve as a starting point for discussing EVM with SRS enhancement for CJT. We are open for additional EVM. |
| Huawei, HiSilicon | Q1: Yes.  Q2: In SRS for TDD CJT, both LLS and SLS should be considered.  Considering that the R17 SRS EVM only focus on the sTRP scenario, additional EVMs are certainly needed for R18 TDD CJT scenario, in which the SRS is received by both the serving cell and the coordinated cell(s). To accurately reflect the interference situation faced by CJT, following factors should be considered:  For LLS, the core issue is interference signal modeling. In terms of the large-scale modeling, according to the power-imbalance issue shown in many companies’ contribution, it is reasonable to assume that the power of intra-cluster interference is xdB larger than the target SRS signal, where x can be randomly chosen from a certain range, e.g., {3, 6, 9}. The power of inter-cluster interference can be ydB larger than the target SRS signal, where y can be randomly chosen from a certain range, e.g., {-3, 0, 3}. The delay spread can be 100/300/1000ns. In terms of the number of inter-/intra-cluster interference, any reasonable assumption that can fully embody the severe interference circumstance under CJT is not precluded.  For SLS, real SRS channel estimation should be considered. |
| ZTE | Q1: We think the Rel-17 EVM can be used. |
| vivo | Q1: Support Rel-17 EVM as a start point. |
| KDDI | Q1: Yes.  Q2: Antenna configuration for evaluation of 8Tx SRS is needed for both LLS and SLS. We need antenna configuration for 8 antennas to evaluate 8Tx SRS. |
| Ericson | Q1: Rel-17 EVM can be a starting point. We are open to further refinements of the EVM assumption. |
| Nokia/NSB | We share the same view with Ericsson. |

## FL update

Thank you all for the useful inputs.

**Regarding a starting point of EVM**:

Based on the above inputs, the FL has the following suggestions:

* Most companies are fine with reusing Rel-17 EVM. Agreed Rel-17 EVM can be used, especially Rel-17 SRS EVM. Some Rel-17 EVM examples are provided in Appendix 1 for reference.
* Furthermore, any Rel-18 EVM, if agreed and relevant, can also be used. For example, Rel-18 FDD CJT have just been agreed in agenda item 9.1.2; see Appendix 2 for reference. The relevant parts can be adopted for TDD CJT when properly combined with SRS EVM.
  + A merged version of the relevant agreed R17 SRS EVM and R18 CJT EVMs for TDD CJT SLS is provided in Appendix 3, which can be used as a starting point for TDD CJT SLS.
  + A straightforward adaptation of the relevant agreed R17 SRS EVM and R18 CJT EVMs for TDD CJT LLS is provided in Appendix 4, which can be used as a starting point for TDD CJT LLS.
  + Other new agreements from Rel-18 can also be adopted as needed, and any new additions to Appendix 3 and Appendix 4 can also be discussed and adopted as needed.
* Agreed EVM earlier than Rel-17, if relevant, is not precluded.
* For 8 Tx UE antenna configuration and CJT SRS power imbalance modeling, please see below for further discussions.
* It is strongly encouraged that companies clearly indicate the simulation assumptions when submitting results, especially if different from the starting point.

The following proposal is suggested.

**Proposal 2-1: For SRS EVM, adopt combined relevant parts from Rel-17 SRS EVM and Rel-18 FDD CJT EVM as starting point**

* **Details are provided in Appendix 3 for system-level simulations**
* **Details are provided in Appendix 4 for link-level simulations.**

Companies’ views on the proposals are collected as follows.

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| --- | --- |
| **Company** | **View** |
| Apple | OK in general. Do we need another EVM for 8Tx SRS? |
| DOCOMO | Ok with Proposal 2-1. |
| CATT | Is this proposal for Rel-18 FDD CJT EVM only? The scenarios and targeted devices are different for Rel-18 UL 8Tx and Rel-18 FDD CJT, therefore the Rel-18 UL 8Tx EVM in AI 9.1.4.2 shall be considered as a reference for Rel-18 8Tx SRS EVM. |
| OPPO | We agree with CATT that for evaluation of 8Tx SRS, the EVM in 9.1.4.2 should be the baseline similar to Rel-18 FDD C-JT EVM. |
| ZTE | Support Proposal 2-1. |
| Nokia/NSB | We are fine with Proposal 2-1. |
| FL | @Apple @CATT @OPPO: For 8 Tx SRS EVM, my understanding is that Rel-17 SRS EVM and the content in Proposal 2-2 are sufficient. Please also note that Proposal 2-2 allows EVM outcomes from other agenda items to be incorporated for 8 Tx SRS EVM. Sorry if I was not making this clear. |
| Huawei, HiSilicon | Fine with FL’s proposal. Some further comments are listed below:  **For SLS,** since it is hard for a simple modeling to fully embody the channel estimation improvement brought by interference randomization and capacity enhancement, real SRS channel estimation can be considered:   |  |  | | --- | --- | | SRS modeling for UL channel estimation | Companies to state the used SRS periodicity; Companies to state the SRS channel estimation modeling (e.g., real channel estimation based on sequence generation.) Number of ports = 2 or 4; Tx power = 23 dBm; |   **For LLS,** since the TRP selection is based on RSRP, there exists power difference between TRPs for SRS reception in practical scenarios. Considering that the range of RSRP difference is generally -10dB~10dB, we prefer to add the following:   |  |  | | --- | --- | | Scenarios | N\_TRP (#TRPs): 2, 3, 4;  Difference between received power for SRS at different TRPs can be chosen from -10dB ~ 10dB; | |
| Samsung | Support Proposal 2-1. Regarding Huawei’s example on channel estimation, we think that the original wording seems enough. Also, difference between received power can be discussed in section 3.1.1. |

**Regarding UE 8 Tx antenna configuration EVM**:

@OPPO @MediaTek @KDDI: Thank you for the good suggestions, and we agree this is worth discussion. It seems other than the 8 Tx antenna configuration, all existing SRS EVM can be reused. A few points follow for the 8 Tx antenna configuration:

* Though 8 Tx antenna configuration EVM has not been discussed before, 8 Rx antenna configuration EVM (including 8 Rx ports or 8 Rx elements) has been discussed and agreed from previous releases. Some examples are provided in Appendix 4. These may be adapted as a starting point for 8 Tx SRS EVM.
* 4 Tx EVM has been agreed before. Some of them may be extended to 8 Tx in a straightforward manner. For example, for 4 Tx of (1,2,2; 1,1; 1,2), (dH, dV) = (0.5, 0.5)λ, it may be extended to 8 Tx of (2,2,2; 1,1; 2,2), (dH, dV) = (0.5, 0.5)λ or 8 Tx of (1,4,2; 1,1; 1,4), (dH, dV) = (0.5, 0.5)λ.
* 8 Tx EVM is under discussion in several ongoing agenda items (e.g., 9.1.4.1, 9.1.4.2). Those do not preclude any discussion of 8 Tx SRS EVM in this agenda item; in the meantime, the group may try to avoid duplicated effort if possible.
* Given the above, the FL suggests using 8 Tx of (2,2,2; 1,1; 2,2), (dH, dV) = (0.5, 0.5)λ or 8 Tx of (1,4,2; 1,1; 1,4), (dH, dV) = (0.5, 0.5)λ as a starting point for 8 Tx SRS evaluations to avoid any delay. There can be many different UE antenna configurations for 8 Tx, and they can be discussed and alignment with other agenda items can also be made.

The following proposal is suggested.

**Proposal 2-2: For 8 Tx SRS, a starting point of UE antenna configurations can be:**

* **(M, N, P; Mg,Ng; Mp, Np) = (2,2,2; 1,1; 2,2), (dH, dV) = (0.5, 0.5)λ, or**
* **(M, N, P; Mg,Ng; Mp, Np) = (1,4,2; 1,1; 1,4), (dH, dV) = (0.5, 0.5)λ.**
* **FFS other 8 Tx UE antenna configuration and alignment with outcomes from other agenda items.**

Companies’ views on the proposal are collected as follows.

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| --- | --- |
| **Company** | **View** |
| Apple | We think the following antenna architecture should be included:   * **(M, N, P; Mg,Ng; Mp, Np) = (1,2,2; 1,2; 1,2), (dH, dV) = (0.5, 0.5)λ, or** * **(M, N, P; Mg,Ng; Mp, Np) = (1,1,2; 1,4; 1,1), (dH, dV) = (0.5, 0.5)λ.** |
| CATT | OK with the proposal. |
| OPPO | Support. |
| ZTE | Support |
| FL | @Apple: It seems the suggested has either 4 Tx ports or 2 Tx ports, rather than 8 Tx ports. Maybe you used Mp and Np for each panel? Our understanding is that Mp and Np are for all panels. Please correct me if I am wrong.  Also the suggested are for multiple UE panels, which may need some alignment with other agenda items. For simplicity, maybe the starting point can be for 1 UE panel, and more complicated antenna configurations can be used optionally, or included if companies agree.  @All: Please feel free to comment on Apple’s suggestion. |
| Huawei, HiSilicon | Fine with FL’s proposal. |

**Regarding CJT SRS power imbalance related EVM**:

@Huawei, HiSilicon: Thank you for the detailed suggestion.

This issue is related to Sec. 3.1.1. As you may see, indeed a number of companies have similar views, but a few companies are still trying to fully understand the problem. The FL suggests further discussion in Sec. 3.1.1, and then revisit necessary EVM based on the outcome. As long as the power imbalance issue is not precluded in RAN1, companies can feel free to submit evaluation results with power imbalance.

Nevertheless, since EVM for this issue is brought up here and other companies have not expressed their views, companies can provide input on EVM for this issue in the table below.

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| --- | --- |
| **Company** | **View** |
| Huawei, HiSilicon | As we’ve discussed above, since the TRP selection is based on RSRP, there exists power difference between TRPs for SRS reception in practical scenarios. As a result, the received power for SRS at different TRPs may be assumed as different in EVM as shown below:   |  |  | | --- | --- | | Scenarios | N\_TRP (#TRPs): 2, 3, 4;  Difference between received power for SRS at different TRPs can be chosen from -10dB ~ 10dB; | |
|  |  |

# SRS enhancements to manage inter-TRP cross-SRS interference targeting TDD CJT

## High-level scope, key issues, and clarifications

Discussions on high-level scope, key issues that may need to be resolved before discussing potential enhancements, and clarifications, if any, are provided in this subsection. Possible enhancements are discussed in the next subsection.

### Inter-TRP cross-SRS interference issues at a “non-targeted TRP”

Several companies (Futurewei, Huawei, HiSilicon, Ericsson, ZTE, InterDigital, Samsung, Qualcomm) mentioned an issue of severe cross-SRS interference related to SRS received power imbalance at a TRP. For example, Ericsson illustrated a near-far problem caused by TDD CJT UE which may significantly degrade SRS-based channel estimation. In addition, ZTE and InterDigital described an issue of SRS transmission spatial filtering, and Futurewei described a timing offset issue. All these issues are closely related and are due to that the SRS transmission is targeting TRP 1 (in terms of its transmission power, spatial filter, and TA) but is also utilized by TRP 2 for CSI acquisition; here TRP 2 is loosely referred to as a “non-targeted TRP” for convenience.

To enable SRS-based CSI acquisition at a “non-targeted TRP”, standard-transparent approaches and/or standardized approaches may be possible. Depending on whether standardized approaches for SRS-based CSI acquisition at a “non-targeted TRP” are to be considered or not in Rel-18, the potential enhancements could be different. For example, if this issue is considered as severe and companies agree to address this issue, then this WI can specify solutions to resolve this issue. However, if this issue is considered as severe but no agreement on addressing this issue is achieved, then generally per-TRP sounding will be required for TDD CJT, which may impact SRS overhead, cross-SRS interference, DL CJT operation/performance, and potential enhancements in this WI. Further discussions are therefore needed.

Please provide inputs to the following questions:

* Q1: Do you agree that the “non-targeted TRP” further exacerbates the inter-TRP cross-SRS interference issue? If the answer is “No”, any argument you can provide to help resolve the above concerns would be appreciated.
* Q2: If the answer to Q1 is “Yes”, do you support to consider potential solutions that may require standard support in the present WI of Rel-18? If you support so, please specify on which aspect (e.g., power imbalance, spatial filter, and TA offset) Rel-18 should work on. If you do not support to address the issue in this WI, please outline your general view on possible alternative directions (e.g., enhancements only targeting per-TRP sounding in this WI of Rel-18).

Companies’ views on the above are collected as follows.

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| --- | --- |
| **Company** | **View** |
| Apple | Q1: We think more study is needed. Doesn’t this interference to non-targeted TRP issue exist for all UL channels? We think it is more reasonable to provide justification on how critical this issue is. |
| DOCOMO | Q1: Yes, but less significant than the issues captured in section 3.2, i.e. common issues for both target TRP and non-target TRP.  Q2: Yes at least for power imbalance. Regarding the other factors (e.g., spatial filter, and TA offset), we can be open at this stage but they should have lower priority than the issues in 3.2. They could be further considered after the issues in 3.2. |
| InterDigital | Q1: Yes.  Q2: We think this WI should address at least the issues on power imbalance and spatial filter considering the SRS is targeting two TRPs where the precoder for CJT is determined across non-co-located antenna ports. |
| QC | Q1: The aspect on spatial filter is not clear as this item is for FR1. Also, in terms of TA difference, we do not envision TA-related enhancements in this AI (it can be addressed by network implementation to ensure TA is good enough from both TRPs’ reception).  Q2: Overall, we think the baseline assumption should be that one SRS transmission is received by multiple TRPs (in the CJT cluster). While we agree with the power imbalance issue mentioned by Ericsson (and open to solutions whether they are spec-transparent or not), we think further evaluations are needed as TRP-specific SRS will result in double the overhead, and the interference issue would be worsened. Then, if enhancements are needed, it should still be with the assumption that one SRS resource is received by multiple TRPs in FR1. |
| Intel | Q1: We can study further, but we think that issues in Section 3.2 should be prioritized. |
| Samsung | Q1. The issues on both non-targeted and target TRPs can be further studied. We understand the intention, but the terminology ‘Non-targeted TRP’ may cause misunderstanding.  Q2. We are opened for all factors (power imbalance, spatial filter, TA offset) which can be further studied, but if we need to down select, at least power imbalance issue would be firstly discussed. This is because we are not sure whether spatial filter and TA offset can be included the scope of this agenda item or not. |
| Nokia/NSB | Q1: Yes, to reduce UL SRS resource overhead and latency, it is beneficial to consider ways to handle interference at non-targeted TRPs.  Q2: Yes, power imbalance between different TRPs is one important aspect to be considered. |
| OPPO | Q1: We also think the inter-TRP cross-SRS interference already exists in previous release. For power imbalance and TA offset, similar issues also occur in LTE. For SRS detection in a non-targeted TRP, interference randomization or orthogonal SRS between TRPs may be needed compared to Rel-17.  Q2: It should be first justified that current SRS including SRS enhancement in Rel-17 cannot satisfy the interference/capacity requirement of inter-TRP SRS transmission. If yes, we are open to introduce enhancement in Rel-18. |
| MediaTek | Q1: Section 3.2 should be prioritized, however, we are open to further study this issue. |
| Lenovo | Q1: Yes, we share the similar view on inter-TRP cross SRS interference issue in our contribution. We think the severeness for the issue may be related with application scenario, UE number and SRS configuration, etc.  Q2: Yes, we are open for discussing potential solutions. For power imbalance, it is an important aspect to be considered. Moreover, we think SRS coordination schemes guaranteeing orthogonality also can be considered if inter cell CJT is in the scope of this study/work item. |
| CMCC | Q1: Yes, we are open to discuss this issue. However, Sec 3.2 should be prioritized.  Q2: For this issue, at least the impact of power imbalance should be considered. However, we are not clear about the aspect of spatial filter, since this AI is targeting FR1 as described in the R18 WID. |
| Xiaomi | Q1: Yes  Q2: Yes. But section 3.2 should be studied with high priority. We can further study the impact of power imbalance, spatial filter, and TA offset with low priority. |
| Huawei, HiSilicon | Q1: Yes.  Q2: Yes. As shown in our contribution, power imbalance issue will lead to poor SRS channel estimation quality and should be treated as high priority.  In terms of the TRP-specific SRS, although we are not here to strongly preclude it, considering the potential increase of SRS overhead and interference level, we still think the SRS measurement hypothesis should be “one SRS transmission is received by multiple TRPs”. |
| LGE | Q1: It seems that the issue is not clear yet and further clarification on the issue is needed. We also think section 3.2 should be prioritized. |
| ZTE | Q1: Yes . We agree with Moderator that first we need to clarify that which schemes among TRP common SRS and TRP-Specific SRS should be supported for CJT. Specifically,the target receivers of one TRP common SRS are multiple TRPs and the target receiver of one TRP-Specific SRS is one TRP. In CJT case, the UE needs to transmit SRS to more than one TRPs using TRP common SRS or TRP-Specific SRS, so both of the two schemes will exacerbate the inter-TRP cross SRS interference issue. There is power imbalance issue for both of the two schemes. Compared with per TRP SRS, the TRP common SRS can save the UE power and reduce interference because UE just needs to transmits one SRS resource. So we support TRP common SRS should be enhanced for CJT transmission.  Q2: To support TRP common SRS, the Tx power and spatial relation/precoding of one SRS resource can be based on multiple CSI-RS resources from multiple TRPs. The TA enhancement can be with lower priority because we think the one SRS resource can be received by each CJT TRPs within CP. In addition, TA enhancement is being discussed in AI 9.1.1.2 |
| Sharp | Q1: Yes, we are OK to discuss this issue. However, Section 3.2 should be prioritized. |
| Spreadtrum | Q1: Open for further study on this issue.  Q2: At least TRP-specific SRS could be a baseline, and further study the impact of non-TRP-specific SRS. |
| CATT | Q1: Yes.  Standard-transparent solutions shall be prioritized and well studied. |
| Vivo | Q1: Prefer to further study this issue.  Q2: One SRS transmission received by multiple TRPs can be prioritized. |
| Ericsson | Q1: Yes  Q2: As discussed in our contribution, there will be a power offset and timing offset at the non-targeted TRP. The impact on performance of these offsets should be studied and, if necessary, potential solutions could be standardized. |

#### FL update

Thank you all for the useful inputs.

**Power imbalance issue**:

Companies’ views:

* Prioritize enhancements in Sec. 3.2: DOCOMO, Intel, MediaTek, CMCC, Xiaomi, Sharp. (Some companies are open to study this issue.)
* One SRS processed by multiple TRPs with potential power imbalance is needed for CJT and will be studied: InterDigital, QC, Samsung, Nokia/NSB, Lenovo, Huawei, HiSilicon, ZTE, vivo

Based on the inputs, the FL has the following analysis:

* Note that regarding the case of one SRS sent by a UE and used by multiple TRPs for channel estimation, where the pathlosses between the UE and the TRPs have only small differences, it can already be supported for CJT based on network implementation, though with narrower use cases, e.g., the UE has to have similar distances to the TRPs. Therefore, only if one SRS is sent by a UE and used by multiple TRPs and the pathlosses between the UE and the TRPs have large differences, the above issue needs to be studied.

If one SRS utilized by multiple TRPs is not allowed, then TDD CJT will be based on TRP-specific SRS. With up to 4 TRPs for CJT, the SRS overhead, cross-SRS interference, and UE power consumption will be very high. Additionally, if TRP-specific sounding is supported for CJT, the UE may need to maintain up to 4 sets of SRS transmission parameters (e.g., power control settings, TA settings), which has not been supported. Thus, TRP-specific sounding is not a preferred solution.

* Therefore, it is suggested to study this case of one SRS utilized by multiple TRPs at least if the power balance is not small.

@Apple @OPPO @LGE: Inter-TRP cross-SRS interference with power imbalance at a TRP is not a new issue, but that the interfering SRS also needs to be used for channel estimation at the TRP seems new. The root cause is that, in order to reduce the SRS overhead and interference in CJT cases, one SRS is sent for channel estimation for multiple TRPs. Several companies pointed this out in their contributions (with nice illustrations and greater details) and in above inputs, so please refer to them for the details.

@CATT: your position is not too clear, but please feel free to elaborate if needed.

**Spatial filtering issue:**

@InterDigital @ZTE: This issue is related to the precoded SRS for DL CSI acquisition, which will be discussed in more detail in Sec. 3.2.2.

**TA issue:**

Some companies are open to study this, but some other companies suggest that the TA offset between SRSs at a TRP may not be a big issue if they are small relative to the CP length, even if all the SRSs with some arrival timing differences are to be used for channel estimation. In addition, some believe this can be addressed by implementation. It seems this issue does not require further study.

A proposal is provided for further discussion of the power imbalance issue.

**Proposal 3.1.1: Study the case where one SRS sent by a UE is utilized by multiple TRPs for channel estimation, and the pathlosses between the UE and the TRPs differ by at least x dB**

* FFS x
* FFS potential enhancements such as SRS power control enhancements.

Companies’ views can be provided in below table.

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| **Company** | **View** |
| Apple | We would like to understand whether it is for SRS capacity enhancement or interference randomization? According to the WID, it seems we would not do anything beyond the two areas. |
| DOCOMO | First, we are not sure what the motivation of proposal would be. Does it intend to clarify the case to be studied regarding SRS transmission to non-target TRP? If so, since x is still FFS above, we think the proposal 3.1.1 may not give us more clarity than where we are now.  In our understanding, normally CJT is performed for a UE when RSRP from coherent multiple TRPs are within a certain threshold (e.g. up to 3 dB). This may be configurable in actual implementation, but we do not think it would be realistic to assume larger value for x.  Or does x value intend to observe a range of x which is problematic for SRS toward non-target TRP? Anyway, we think typical x value(s) should be identified more clearly even at this stage.  Based on above, we would like to suggest considering an typical value for x. one possibility is 3 for x, but we would be open to discuss. |
| CATT | To elaborate our view, when we consider standard support to solve the issue, we should keep in mind that there are also standard-transparent solutions to solve the issue. Standardized solutions should provide justifiable over standard-transparent solutions. |
| OPPO | We agree with DOCOMO that a small value of x (e.g. 3dB) would be more reasonable. Companies who propose a larger value of x should justify that C-JT can provide significant gain with the value, which is not expected by us. |
| ZTE | Support the Proposal 3.1.1. From our perspective, x can belong to the set of {3db, 6dB} . |
| Nokia/NSB | Agree with Docomo that motivation of the proposal should be further clarified. In general, we support to study further SRS transmission to non-target TRP. |
| FL | @All: Please note that this proposal is about “study the case” to fully understand it via simulations or analysis, not about providing enhancements yet. It has impact on SRS performance and also TDD CJT performance, so it may be worth investigating. For example, a small x value limits the CJT use cases but ensures good SRS performance, and a large x value is less limiting for CJT use cases but may degrade SRS performance. Thus, it may be a meaningful study to simulate x = {3, 6, 9} dB. Anyway more inputs are welcome. |
| Huawei, HiSilicon | Regarding the first sub-bullet, considering that in practical scenarios, such as C-RAN deployment, there exists non-negligible probability that the power difference is larger than 10dB, here we suggest the power difference being chosen from -10dB~10dB.  Regarding the second sub-bullet, we think the discussion of potential enhancements should be in the WID scope. |
| Samsung | Support the proposal 3.1.1 and we are fine 3 dB and 6 dB for x, which were also used for Rel-17 PDCCH/PUSCH/PUCCH repetition. also, we think that we can carefully consider the scope of WID. |

### Others

Any other views on high-level scope, key issues that may need to be resolved before discussing potential enhancements, and clarifications, if any, can be provided in below table.

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| --- | --- |
| **Company** | **View** |
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## Potential enhancements for SRS capacity enhancements and/or interference randomization

We roughly categorize the potential enhancements for SRS capacity enhancements and/or interference randomization according to: 1) Resource mapping with randomized or new patterns in time/frequency/sequence/etc. domains; 2) Capacity enhancements and/or overhead reduction; and 3) Extensions of Rel-17 partial frequency sounding. The three categories are *not meant to be strict or limiting*. For example, some partial frequency sounding related enhancements may also belong to 1) or 2), but for the ease of discussion, they are all put in 3), which should not affect the technical discussions. In addition, any other potential enhancements can also be considered.

### Resource mapping with randomized or new patterns in time/frequency/sequence/etc. domains

Various companies have proposed enhancements for SRS interference randomization, such as several hopping techniques, randomizing / changing the existing resource mapping / transmission parameters for SRS, enhancing the signaling for more flexible SRS transmission, etc. A short summary is as follows.

* Randomized / new frequency-domain resource mapping (9): ZTE, Xiaomi (FDM via cell ID), Samsung (different bandwidths for different FH symbols), Ericsson/Apple/Qualcomm (comb hopping), NTT DOCOMO, CMCC, InterDigital,
* Randomized / new code-domain resource mapping
  + Cyclic shift (6): Futurewei, Huawei, HiSilicon, Ericsson, Spreadtrum, NTT DOCOMO,
  + Sequence (7): Futurewei, ZTE, CMCC, Qualcomm, Spreadtrum (per TRP hopping), NTT DOCOMO, InterDigital (low correlation)
* Enhanced signaling for flexible SRS transmission (4): InterDigital (triggering), Samsung (dynamic PC signaling), NTT DOCOMO (dynamic time/frequency resources, hopping, sequence/sequence group, comb, cyclic shift; also based on slot/symbol/TRP), Qualcomm (based on MU / scheduling / DL traffic for AP/SP SRS)

Based on the above summary, the FL suggests companies to consider and provide views on the following high-level proposal:

**Proposal 3.2.1: Study at least the following for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS interference randomization**

* **Randomized / new frequency-domain resource mapping for SRS transmission**
* **Randomized / new code-domain resource mapping for SRS transmission**
* **Enhanced signaling for flexible SRS transmission.**

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | We suggest we have a more detailed proposal for each study point. Current formulation looks to redesign the whole SRS resource mapping operation. |
| DOCOMO | We think it might be good to add some examples provided by companies to make the target a bit clearer, thus suggest updating as follows:  **Proposal 3.2.1 (proposed by DOCOMO): Study at least the following for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS interference randomization**   * **Randomized / new frequency-domain resource mapping for SRS transmission**   + **E.g. FH with non-uniform bandwidth, comb hopping** * **Randomized / new code-domain resource mapping for SRS transmission**   + **E.g. cyclic shift hopping/randomization, sequence hopping/randomization** * **Enhanced signaling for flexible SRS transmission.**   + **E.g. dynamic update of SRS parameters** |
| InterDigital | OK with the proposal, we also support studying dynamic updates of SRS parameters. |
| QC | Agree with Apple that candidate schemes to be studied need to be more concrete and detailed. Otherwise, the chance of converging in future meetings would become lower. In addition, we have the following comments:   * Our proposal in the domain of transmitting / not transmitting (Pseudo-random muting of SRS) is not captured. * The last bullet belongs to capacity enhancements as it is not clear how it can randomize interference. |
| Intel | Version from DOCOMO is better with added examples. OK to study. |
| Samsung | Support in principle at this early stage of Rel-18, and we are also fine for Docomo’s elaboration to capture some examples for each sub-bullet. |
| Nokia/NSB | We share the same view as Apple that current proposal requires a redesign of legacy UL SRS, especially randomized/new frequency-domain resource mapping part. Therefore, we prefer to focus more on randomized/new code-domain resource mapping for SRS. |
| OPPO | Fine with the study with detail. |
| MediaTek | We are fine with considering the top two solutions with the examples provided by DOCOMO, i.e.:   * **Randomized / new frequency-domain resource mapping for SRS transmission**   + **E.g. FH with non-uniform bandwidth, comb hopping** * **Randomized / new code-domain resource mapping for SRS transmission**   + **E.g. cyclic shift hopping/randomization, sequence hopping/randomization** |
| Lenovo | We are fine with either the proposal for studying SRS interference randomization schemes in high level or Docomo’s updated version with more detail information. |
| CMCC | We support FL’s proposal in principle and Docomo’s more detailed version with some examples for each sub bullet is also fine for us. |
| Xiaomi | We are fine with the proposal and Docomo’s updated version. |
| Huawei, HiSilicon | Support the first two sub-bullet in FL’s proposal and also fine with corresponding detailed version.  The third sub-bullet can be moved to 3.2.2 for further discussion. |
| LGE | Support in principle. |
| ZTE | We agree with the suggestion from DOCOMO to add some examples to make the discussion clear and concentrated. So we give our additional examples based on DOCOMO’s version  **Proposal 3.2.1 (proposed by DOCOMO): Study at least the following for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS interference randomization**   * **Randomized / new frequency-domain resource mapping for SRS transmission**   + **E.g. FH with non-uniform bandwidth, comb hopping**   + **E.g.non-uniform frequency hopping pattern across different hopping periods during each of which the entire bandwidth of  is sounded once.** * **Randomized / new code-domain resource mapping for SRS transmission**   + **E.g. cyclic shift hopping/randomization, sequence hopping/randomization**   + **E.g. C\_init can be based on slot index, u and v can be based on frame index besides slot and symbol index** * **Enhanced signaling for flexible SRS transmission.**   + **E.g. dynamic update of SRS parameters** |
| Sharp | We are fine with the proposal. |
| Spreadtrum | Fine with FL’s proposal. |
| CATT | Fine with MTK’s updated proposal. |
| vivo | Fine with DOCOMO’s updating. |
| Ericsson | We also prefer a proposal with a bit more specific examples. The first two sub-bullets in the version submitted by DOCOMO look good to us.  The third sub-bullet can be moved to section 3.2.2 as suggested by some other companies. Does this third sub-bullet only include dynamic update of SRS parameters? or does it include both (1) dynamic update of SRS parameters and triggering enhancements to indicate one of multiple candidate SRS configurations? |

#### FL update

It seems most companies are fine with the proposal except for the last bullet, though some companies asked for more details while some other companies supported this to be high-level at this early stage. In any case, we can see if the update along the line of Docomo and ZTE is acceptable, but instead of listing very specific techniques as examples, it may be a better idea to list the general next-level techniques. For example, rather than listing FH with non-uniform bandwidth which is very specific, we can list further enhancements to frequency hopping which may include a category of potential enhancements.

@QC @MediaTek @Huawei, HiSilicon @CATT @Ericsson: For the 3rd bullet, based on the FL’s understanding, it can be also helpful to achieve interference randomization via dynamic update of SRS parameters. For example, Docomo described in their contribution that “To avoid continuous serious inter-TRP interference on SRS measurement, how to achieve interference randomization for SRS transmission should be studied. The interference randomization can be considered in terms of time, frequency or sequence domain. For example, dynamic update of SRS resource parameters, such as time/frequency resource allocation, hopping, sequence group number, sequency number, comb, CS, etc., can be beneficial to randomize the interference in time, frequency, or sequence domain.” In other words, a dynamic signaling can inform the UE to send SRS with a different hopping pattern or frequency-domain resource allocation, which can add flexibility rather than transmitting SRS with only pre-configured pattern (even if it is pseudo-random). You are also correct that it may also increase SRS capacity, but as mentioned above, the categorization is not meant to be strict or limiting. So we suggest to keep the discussion here, but if the group agrees, we can either move to capacity enhancements or create a new category if there is sufficient interest. Further details of the 3rd bullet can be explained by proponents.

@QC: For the domain of transmitting / not transmitting (Pseudo-random muting of SRS), please check if the updated summary is fine and if you think it is ok to capture in “new frequency-domain resource allocation based on network-provided parameters” in below proposal. That is, some SRS REs can be muted based on, e.g., the OFDM symbol number, etc.

**Proposal 3.2.1-1: Study at least the following for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS interference randomization**

* **Randomized / new frequency-domain resource mapping for SRS transmission**
  + **E.g., further enhancements to frequency hopping, comb hopping,** **new frequency-domain resource allocation based on network-provided parameters**
* **Randomized / new code-domain resource mapping for SRS transmission**
  + **E.g., cyclic shift hopping/randomization, sequence hopping/randomization, new code-domain parameter mapping based on system parameters**
* **FFS: Enhanced signaling for flexible SRS transmission**
  + **E.g., dynamic update of SRS parameters**

Companies’ views can be provided in below table.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | We also think the last FFS should be removed, as it looks to be out of scope. |
| DOCOMO | Support |
| OPPO | Though we think dynamic update of SRS parameters can help to reduce the inter-TRP cross-SRS interference, we don’t think it can be so-called interference randomization. Maybe there are different understanding among companies. We can accept it as FFS. |
| ZTE | Support |
| Nokia/NSB | We support the first two bullets in the proposal. However, the last FFS bullet can be done after SRS interference randomization scheme(s) has been agreed. |
| FL | Since this proposal has “Study at least …”, regardless of whether the last bullet is included or not in this proposal, proponents and opponents can always discuss it at least at early stage of the release. |
| Huawei, HiSilicon | In the second sub-sub-bullet, we propose to add one more example, which can also achieve code domain interference randomization:  **SRS Sequence for each hop is from a long SRS sequence** |
| Samsung | Support Proposal 3.2.1-1 and also fine for FFS since it is not clear whether it is out-of-scope or not as FL mentioned it can be helpful for interference randomization. Anyway it can be captured as FFS. |

### Capacity enhancements and/or overhead reduction

SRS enhancements to increase the SRS capacity (allowing more resources for SRS transmissions), reduce the SRS overhead, and/or increase the SRS multiplexing (with the same UE or multiple UEs, with other SRS or non-SRS, preferably orthogonal), have been proposed and are summarized as follows.

* TD OCC (8): ZTE, Spreadtrum, CMCC, NTT DOCOMO, Sharp, Intel, NEC, Lenovo
* Increase cyclic shift maximum (6): Futurewei, Spreadtrum, Xiaomi, Apple, NTT DOCOMO, NEC
* Beamformed SRS for CSI acquisition (3): Huawei, HiSilicon (spatial domain capacity enhancement), ZTE (beamformed based on multiple CSI-RS)

The following high-level proposal is suggested and companies’ views are welcome.

**Proposal 3.2.2: Study at least the following for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS capacity enhancements and/or overhead reduction**

* **SRS TD OCC**
* **Increasing the maximum number of cyclic shifts**
* **Beamformed SRS for DL CSI acquisition.**

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | We would like understand what “beamformed SRS” means. Currently UE is allowed to apply antenna virtualization and analog beamforming (FR2 only). Does it mean to introduce spatial relation for FR1? |
| DOCOMO | We are fine with the Proposal 3.2.2. Note that our understanding of “study” is that we can study even whether to have specification impact at least for the captured direction. |
| NEC | We support TD-OCC and increasing maximum number of CS. |
| InterDigital | OK with the proposal. |
| QC | Our following proposals, which can help in SRS efficiency / capacity are not captured:   * **Configuration of (sequence index within a group) per SRS resource.** * **Configuration of cyclic shift per SRS port per SRS resource.**   For the first bullet, the benefit is to increase the number of SRS sequences that can be assigned (from already defined sequences). For the second bullet, the benefit is more efficient assignment of cyclic shift in case of multiple UEs.  In addition, as mentioned in the previous section, enhanced signaling for flexible SRS transmission belong to this category (and not randomization). |
| Intel | OK with studying the first two cases.  Not sure what the third sub-bullet implies w.r.t. SRS capacity enhancement. |
| Samsung | We can live with the Proposal 3.2.2 at this early stage, but the necessity of capacity enhancement especially using a time-domain component (new dimension for capacity enhancement on SRS) and whether increased maximum number of CS is needed or not should be carefully evaluated/considered.  BTW, more elaboration on beamformed SRS from proponents would be helpful for better understanding.  Also, Proposal 3.2.3 below can be included in 3.2.2 as well, for capacity enhancement. |
| Nokia/NSB | Agree with Apple that it remains unclear what “beamformed SRS” means.  We are fine to study the option where maximum number of cyclic shifts is increased. |
| OPPO | Though we think more CSs and beamformed SRS are helpless for SRS capability due to the restriction on narrow applicable scenarios, we are fine to study them at this stage. |
| MediaTek | OK with studying the top two cases. It is unclear to us what is meant by beamformed SRS, especially in FR1. |
| Lenovo | We are fine with the proposal for studying schemes for SRS capacity enhancements and/or overhead reduction. For beamformed SRS, more explanation or details will be helpful for further discussion. |
| CMCC | Support the proposal at this early stage.  For the “BF SRS”, maybe more elaboration is needed for better understanding and discussion. |
| Xiaomi | For SRS TD OCC, it has been discussed during Rel-17 SRS coverage and capacity enhancement, and the scheme is not specified. It is not clear why we should discussed again. |
| Huawei, HiSilicon | For the second sub-bullet, we think increasing the maximum number of cyclic shifts should be carefully evaluated, taking the practical application scenario and higher requirements on CSI precision proposed by CJT into consideration. As an alternative, other potential design that can effectively increase the supported number of cyclic shifts should not be precluded. Thus we suggest updating as follows:   * **Increasing the maximum number of cyclic shifts**   + **Other potential design that can effectively increase the supported number of cyclic shifts should not be precluded**   For the third sub-bullet, here more elaboration on beamformed SRS is given:  In current spec, the total port number of SRS for DL CSI acquisition is the same as the number of UE receiving antennas. For beamformed SRS, through proper precoding, the total SRS port number can be reduced to the PDSCH layer number, while the channel information required for DL precoding can be obtained. By this means, the SRS capacity can be effectively improved. One possible precoder for beamformed SRS is the U matrix corresponding to the SVD of DL CJT channel. In order to obtain that U matrix, multiple CSI-RS resources are needed, which is not supported in the current spec. Hope this makes the beamformed SRS clearer to companies. |
| LGE | The meaning of beamformed SRS is also unclear to us as well. |
| ZTE | OK with the proposal. Based on confusion about beamformed SRS raised other companies, we propose to give more examples for the last bullet as shown in following updated proposal:  **Proposal 3.2.2: Study at least the following for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS capacity enhancements and/or overhead reduction**   * **SRS TD OCC** * **Increasing the maximum number of cyclic shifts** * **Beamformed SRS for DL CSI acquisition.**   + **E.g. the precoding of SRS for antenna switching can be based on multiple CSI-RS resources each of which from one TRP respectively.**   @Apple, Intel, Samsung, Nokia, MediaTek, Lenovo CMCC, Huawei and LGE, thanks for your discussion about beamformed SRS. From our perspective, the beam formed SRS for CJT can reduce interference, save UE power, have no impact on getting the down link CJT precoding and reduce the number of transmitted SRS ports especially when the beam of SRS is based on multiple CSI-RSs from multiple TRPs with CJT assumption. |
| Sharp | We are fine with the proposal. |
| Spreadtrum | We are fine for FL’s proposals except the third bullet. More explanations on beamformed SRS should be studied. |
| CATT | Fine with studying the first two solutions. |
| vivo | Fine with the proposal. |
| Ericsson | Regarding the beamformed SRS explanation from HW and ZTE, seems like CSI-RS resources from different TRPs is needed. We are not sure if such enhancment is within the scope of this SRS WID objective.  We think partial frequency sounding proposals in section 3.2.3 may be merged in here as it seems to belong to this category. |

#### FL update

Most companies are generally fine with this proposal, except for the beamformed SRS sub-bullet. Note that studying a technique does not ensure that technique to be specified.

**Regarding “beamformed SRS”:**

Several companies explained beamformed SRS in their contributions and above inputs. Please refer to these discussions for details. Moreover, below is the FL’s understanding:

* In existing specs, DL CSI acquisition based on SRS supports non-precoded SRS with usage “antennaSwitching”.
* Proponents of “beamformed SRS” proposed to support precoded SRS for DL CSI acquisition. This is new.
* It may be a bit clearer if the term “precoded SRS” is used, as the UE precoding action is similar to NCB SRS. For example, 214 has “For non-codebook based transmission, the UE can calculate the precoder used for the transmission of SRS based on measurement of an associated NZP CSI-RS resource.”
* The benefit of precoded SRS for capacity enhancements seems quite obvious (e.g., transmitting a 4-port SRS vs a 1-port SRS after precoding), but further discussion can be provided as several companies are still trying to understand this. We can consider it as FFS at this point.

**@**Huawei, HiSilicon: the suggested cyclic shift part is not too clear. Can you please elaborate?

@ZTE: your suggest addition can be discussed in the next step if companies gain a better understanding of the precoded SRS.

**Proposal 3.2.2-1: Study at least the following for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS capacity enhancements and/or overhead reduction**

* **SRS TD OCC**
* **Increasing the maximum number of cyclic shifts**
* **FFS: Precoded SRS for DL CSI acquisition.**

Companies’ views can be provided in below table.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | OK |
| DOCOMO | The main bullet clearly says “Study at least”. Therefore, having “FFS” in the candidate technologies doesn’t make much sense to us. It rather looks making the formulation more complex. We would suggest removing the wording “FFS:”. |
| CATT | SRS for DL CSI acquisition assumes same transmit and receive filters are used at the UE side. This basically requires that UE’s Rx and Tx chains are well calibrated. If not calibrated, reciprocity error would make estimated channel from useless for deriving DL precoding. Few UEs are capable of reciprocal operation. We could hardly find any usage if this feature is specified.  Another problem relates to the issue discussed in section 3.1.1. For C-JT operation, UE’s Rx filter for receiving signals from coordinated TRPs shall be the same. When UE transmits the SRS precoded with a same Tx filter towards multiple TRPs, the received quality at those TRPs cannot be guaranteed. The interference situation would be made even more complicated.  As a summary, we don’t think precoded SRS is worthy of further study. |
| OPPO | We also think the applicable scenarios of precoded SRS is very corner. It can be studied with low priority. |
| ZTE | Thanks Moderator’s concern for our suggestion on beamformed SRS. We agree to replace beamformed SRS with precoded SRS.  We have same concern as DOCOMO. Can the FFS in the last bullet be deleted ? Then it can be studied/discussed sufficiently especially at the early stage especially it is very suitable for CJT case from our perspective. Thanks a lot.  @CATT, thank for your discussion. When a UE can get precoding of an non codebook SRS based on associated-CSI-RS, the UE can get precoding of an SRS for antenna switching based on CSI-RS. In addition, the same TX filter of one SRS port can be a vector of U of svd result of the downlink CJT channel, then the vector is towards each of the CJT TRPs. The SRS can be received with high power by each of the CJT TRPs. So we think the precoding SRS is an potential candidate for SRS enhancement for CJT, which is worth further studying. |
| Nokia/NSB | We are fine with the proposal. |
| FL | Since this proposal has “Study at least …”, regardless of whether the last bullet is included or not in this proposal, proponents and opponents can always discuss it at least at early stage of the release. |
| Huawei, HiSilicon | Thanks FL for the detailed explanation and hope this can help companies comprehend the conception of beamformed SRS profoundly.  In terms of the “FFS” in the third sub-bullet, we also think it should be removed. Several companies including FL have already clearly showed the benefit of beamformed SRS in terms of capacity enhancement. Furthermore, it is for study, we could include potential techniques and study their benefits.  @FL: Following is the further elaboration. As we discussed above, taking the practical application scenario and higher requirements on CSI precision proposed by CJT into consideration, we worry that further increasing the maximum number of cyclic shifts may destroy the orthogonality seriously and do harm to the system performance. As we all know, the cyclic shift is achieved by linear phase rotation in frequency domain, then nonlinear phase rotation which has the potential to address above concern and enhance the capacity simultaneously can also be studied. One possible way to realize nonlinear phase rotation in frequency domain is multiplying mask sequence to the legacy SRS sequence. In order to avoid ambiguity, here we suggest to add one sub-bullet:   * **Multiplying mask sequence to the legacy SRS sequence**   @CATT: Thanks for your discussion.  Regarding the first problem, since reciprocity is a normal assumption for TDD system, we wonder why beamformed SRS will extraordinarily suffer from its absence.  Regarding the second problem, in fact the received quality of beamformed SRS at serving/coordinated TRPs is greater than or at least similar to the received quality of non-beamformed SRS owing to the beamforming gain. |
| Samsung | We can live with the proposal. As other companies mentioned, we also think that beamformed SRS seems not appropriate on this AI. Hence we are also fine with deleting the last bullet and focus on studying two bullets. |

### Extensions of Rel-17 partial frequency sounding

Partial frequency sounding, in particular RB-based partial frequency sounding (RPFS), was discussed in Enhancements on SRS flexibility, coverage and capacity for Rel-17 FeMIMO, and some features in this category have been supported, which can increase the SRS capacity and randomize cross-SRS interference. The following companies proposed enhancements along this line:

* Partial sounding (6): Futurewei, Xiaomi, NTT DOCOMO, Nokia, Nokia Shanghai Bell, InterDigital,

The following proposal is suggested. Any views can be provided in the table below.

**Proposal 3.2.3: Study partial frequency sounding extensions for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS capacity enhancements and/or interference randomization.**

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | Can we have some examples on the potential extensions to be studied? Since this was discussed in R17, I guess we would not have duplicated discussion in R18. |
| DOCOMO | Similar to Proposal 3.2.1, some examples can be added here. We would suggest the following:  **Proposal 3.2.3: Study partial frequency sounding extensions for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS capacity enhancements and/or interference randomization.**   * **E.g. larger partial frequency sounding factor** |
| NEC | We also think potential extensions should be listed for study. And we think Rel-17 partial frequency sounding is limited, which should be further enhanced, for example, maximum number of CS (at least for K\_TC=2) should be enhanced for capacity. |
| InterDigital | OK with proposal. RPFS Rel-17 enhancements can be taken as baseline and further enhancements studied for the mTRP scenario. |
| QC | Given there were extensively discussed in Rel-17, we share the same view as Apple that duplicate discussions may not be needed in Rel-18. If a specific enhancement is relevant to the Rel-18 WID/objective, the potential enhancements can be listed as part of the previous two proposals. |
| Intel | DOCOMO’s version with example is clearer. OK to study but with lower priority than issues in 3.2.1 and 3.2.2 |
| Samsung | We are fine with studying further on RPFS, but it can be included in the Proposal 3.2.2 as well since it is mainly for SRS capacity enhancement. We are also fine with low priority on this issue. |
| Nokia/NSB | Share the same with Apple that to study potential extensions for capacity enhancements further details are needed. For example, increasing the maximum number of cyclic shifts up to 12 should be considered. |
| OPPO | We also think this enhancement can be studied with low priority. |
| MediaTek | Agree with Apple’s comment. Only potential enhancements/extensions to Rel-17 partial frequency sounding should be considered. Example provided by DOCOMO is fine with us. |
| Lenovo | We think partial frequency sounding schemes is one kind of schemes for SRS capacity enhancement. So they can be discussed together in 3.2.2. Since partial frequency sounding schemes are specified/discussed in Rel-17, more details on extension schemes are helpful for further discussion. |
| CMCC | It seems the extension of partial frequency sounding is mainly related to SRS capacity enhancement, this scheme could be included in Proposal 3.2.2. |
| Xiaomi | Support the proposal. Docomo’s updated version is fine to us. |
| Huawei, HiSilicon | OK to study but with low priority considering the higher requirements on CSI precision proposed by CJT. |
| LGE | Support in principle. |
| ZTE | Agree with DOCOMO’s suggestion to add more examples to make it clear. So we provide our example based on DOCOMO’s version as shown in the following updated proposal.  **Proposal 3.2.3: Study partial frequency sounding extensions for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS capacity enhancements and/or interference randomization.**   * **E.g. larger partial frequency sounding factor** * **E.g. partial frequency sounding on other bandwidth corresponding to , besides the last bandwidth  which is supported in Rel-17.** |
| Sharp | We think this issue has low priority. |
| Spreadtrum | Support to study this issue with low priority. |
| CATT | Partial frequency sounding has been studied extensively in Rel-17. It shall be given low priority in Rel-18 if we are going to study it at all. |
| Vivo | We think this issue should be studied with low priority, since partial frequency sounding has been discussed in the whole Rel-17. |
| Ericsson | Study with lower priority. We think this should be moved into section 3.2.2. Not sure if it needs a dedicated section. |

#### FL update

A few general observations and comments:

* Rel-17 partial frequency sounding introduced not only a PF factor but also a starting RB location hopping with hopping sequences (an optional feature). Therefore, it can enhance the SRS capacity and, if enabled, the starting RB hopping can randomize cross-SRS interference. A few other potential enhancements were also discussed (but not agreed) in Rel-17 which may have further interference randomization benefits, such as DCI indication of partial sounding parameters. Hope this clarifies why partial sounding may be considered as a separate category. However if deemed necessary by the group we can re-categorize it into 3.2.1 and/or 3.2.2.
* A few companies suggested deprioritizing this. However, 6 companies proposed to further study this. Maybe this does not have to be precluded at least at the first meeting.

@ZTE: the example you added is not very clear. Could you please elaborate?

**Proposal 3.2.3-1: Study partial frequency sounding extensions for SRS enhancement to manage inter-TRP cross-SRS interference targeting TDD CJT via SRS capacity enhancements and/or interference randomization.**

* **E.g., larger partial frequency sounding factor, starting RB location hopping enhancements**

Companies’ views can be provided in below table.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | We think this should be with low priority as partial frequency sounding has already been widely discussion during R17. |
| DOCOMO | support |
| CATT | Prefer to deprioritize this proposal. |
| OPPO | We also think this should be deprioritized. |
| ZTE | Thank moderator for paying notation on our example. Our example is shown as following Fig. The bandwidth marked with yellow will not be sounded. The bandwidth transmitted on each hopping occasion is with red.    The gNB can get the frequency domain component of downlink precoding based on the channel on the sounded bandwidth. In addition, the total number of occasions to sound the entire bandwidth corresponding to bhop can be reduced compared with Rel-17 partial sounding. |
| Nokia/NSB | We are fine with the proposal. |
| Huawei, HiSilicon | OK with FL’s proposal. |
| Samsung | Despite of FL’s explanation, we cannot figure out why RPFS is specially considered as separate proposal. It can be included in other proposals. Also, we are fine with deprioritizing this issue. |

### Others

Some views were described by one or two companies, e.g., Lenovo discussed S-DCI based SRS enhancement and antenna port switching, CMCC proposed to also consider 8 Tx for the TDD CJT feature, etc. The FL suggests companies provide highlights (in a few words) of their additional proposals followed by some short descriptions in the table below. All companies can express their views on these proposals.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia/NSB | To reduced UL SRS resource overhead and transmission latency related to antenna switching with CJT, support UL SRS xTyR antenna switching configurations with 4 > UL TX antenna ports, for example xTyR. Where x = {6,8} and y = {6, 8}. |
| Lenovo | The application scenario for TDD CJT can be clarified, which is useful for EVM and discussion on enhanced schemes. For example, we want to clarify whether inter-cell CJT is in the scope of study. |

#### FL update

@Nokia/NSB: This should be within scope of the WI, and it may be considered after the 8 Tx SRS discussion becomes a bit more clear. Other companies’ views on this are also welcome.

@Lenovo: There seems to be no conclusion precluding inter-cell CJT. Alignment with the FDD CJT can be made, and if needed, conclusion on this issue can also be made in this agenda item. Other companies’ views on this are also welcome.

# SRS enhancements targeting 8 Tx operation

It is well known that increasing UE Tx antenna ports can significantly improve various performance metrics for UL/DL transmissions. 8 Tx transmissions can be feasible for at least CPE/FWA/vehicle/industrial devices and hence can be beneficial.

## Discussion on scope for 8 Tx SRS

Discussions on high-level scope, key issues that may need to be resolved before discussing potential enhancements, and clarifications, if any, are provided in this subsection. Possible enhancements are discussed in the next subsection.

SRS enhancements targeting 8 Tx will be considered in the present agenda item. Related to 8Tx SRS, in parallel in RAN1, agenda item 9.1.3.1 covers “Increased number of orthogonal DMRS ports; Including increasing orthogonal DMRS ports for UL/DL MU-MIMO and 8 Tx UL SU-MIMO”, and agenda item 9.1.4.2 covers “SRI/TPMI enhancement for enabling 8 TX UL transmission; To support up to 4 or more layers per UE in UL targeting CPE/FWA/vehicle/industrial devices”.

Regarding their relationship, the FL has the following general views:

* Avoid duplicated effort across the agenda items as much as possible.
* If a specific SRS enhancement in this agenda item depends on the outcome of other agenda items, the possible ways are
  + Waiting for the other agenda items to provide sufficient inputs to this agenda item for 8 Tx SRS design; AND/OR
  + The 8 Tx SRS design in this agenda item should be flexible/general enough to accommodate or be consistent with at least typical/possible designs/outcomes of the other agenda items.

Please share your view on the scope, any potential high-level issues, and the above bullet points below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | We think we can start the work for 8Tx SRS |
| DOCOMO | We agree that it would be good to avoid duplicated efforts in general. Also agree that whether to support UL with more than 4 layers is still under discussion.  However, we think it would also be good to pursue some progress in this agenda even at this stage to have efficient progress. For example, by conditioning based on whether to support 8-layer UL (e.g. consider to have “if 8-layer UL is supported” in agreements, or just to make it as WA), we can clarify RAN1 direction on SRS enhancement to support 8-layer UL “if needed”.  Also, we are not quite sure if we need to follow the progress in 9.1.3.1 (DMRS). Even in legacy NR, design/usage of DMRS and SRS are different. |
| NEC | We also think we can start the work. |
| InterDigital | Both items can work in parallel with clearly defined boundaries on the scope. |
| QC | Thank FL sharing the view on this topic.  We think RAN1 can start to work on 8 Tx SRS, in parallel with 9.1.4.2. We agree that in 9.1.4.2, whether support >4 layers is still opening. But that openness seems not stopping RAN1 to specify 8 Tx SRS, because when for 8 Tx with <=4 layers, 8 ports SRS is needed.  Regarding the parallelism with 9.1.3.1 (DMRS), we have similar view as DOCOMO. We don’t see issue to stop RAN1 to work on these two sub-agenda in parallel. |
| Intel | Generally fine to avoid duplicate efforts across agenda items.  We think the work on 8Tx SRS can start. |
| Samsung | We can start SRS 8TX. |
| Nokia/NSB | Share same view with FL an Docomo that duplication of efforts should be avoided. On the other hand, for the sake of progress, we could follow the Docomo’s proposal on conditioning to enable the start of 8 TX SRS work. |
| OPPO | We think RAN1 can start the work via listing the candidate solutions. Even more than 4 layers are not supported, 8 Tx SRS is still needed. |
| MediaTek | In our opinion we can start the work for 8TX SRS. |
| Lenovo | We also think we can start our work for 8Tx SRS |
| CMCC | Regarding the parallelism with 9.1.3.1 (DMRS), we have similar view as DOCOMO and QC. We don’t see the impact to start SRS discussion before 9.1.3.1.  Regarding the parallelism with 9.1.4.3, we agree that whether to support UL with more than 4 layers is still under discussion. We can start 8 Tx SRS enhancement with the assumption of supporting more than 4 layers. Or else, we can start the discussion of 8 Tx SRS design that has no relationship with whether more than 4 layers is supported or not, such as antenna switching for 8 Tx UE. |
| CEWiT | By making sure it is consistent with the outcomes of other overlapping agenda items, we can parallely start the 8TX SRS work. |
| Xiaomi | In our opinion, we can start 8TX SRS. |
| Ericsson | We can start the work targeting 8 Tx SRS. |
| Huawei, HiSilicon | We think RAN1 can start work on 8TX SRS.  Regarding the parallelism with 9.1.4.3, we hold same view with CMCC. |
| LGE | Agree with other companies that we can start working on 8Tx SRS regardless of supporting >4 layers with 8Tx. |
| ZTE | We can start out work for SRS 8TX. |
| Sharp | We are fine with avoidance of duplicate discussion.  Design of 8Tx SRS can be discussed. |
| Spreadtrum | We can start the study of 8Tx SRS in parallel. |
| CATT | It is our view that enhancement for SRS is needed if UL 8Tx is supported, no matter whether more than 4 layers is supported or not. Therefore we can start the work. |
| Vivo | We can start to discuss SRS with 8 ports parallelly. |
| KDDI | We think that we can start work on 8Tx SRS although the EVM should be consistent with other agendas. |

#### FL update

Thank you all for the support. A couple of comments:

* All companies support to work on 8 Tx SRS. A proposal is provided below.
* The general view on the relation between this agenda item and the others seems to be acceptable to all companies. We can consider this high-level discussion is closed and no agreement is needed.

The following proposal is suggested.

**Proposal 4.1: Support 8 Tx SRS in Rel-18.**

Please indicate if you support this proposal in below table.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | Suggest changing the proposal as follows:  **Support 8 Tx SRS for codebook and antenna switching in Rel-18.** |
| DOCOMO | The term “8 Tx SRS” is not very clear to us. Does it imply 8-port SRS? If so, looking at views from companies, we understand it may or may not be 8-port SRS in a SRS symbol.  Also, although we are supportive, we are not sure if all companies really support it. We think it would be good to start working on 8Tx SRS now, but it doesn’t necessarily mean Rel-18 NR supports 8-port SRS, which may be interpreted from the current proposal. Replacing “Support” with “Study” may be better. |
| CATT | Support. |
| OPPO | We intend to agree with DOCMO. Instead of current proposal 4.1, listing the possible solutions to support 8 ports SRS for further study is more meaningful. |
| ZTE | Support |
| Nokia/NSB | Agree with Docomo that it would be good to clarify proposal to be UL SRS with simultaneous 8 TX antenna ports. In general, if simultaneous 8TX antenna port will be specified, the specification support should not be limited to a certain usage type but should applied to all UL SRS usages, i.e. BM, NCB, CB, AS |
| FL | This may be a good place to discuss and align the understanding of what “8 Tx SRS” means, while discussing enhancements in the next subsection in the meantime.  The WID uses “8 Tx UL operation”. The FL’s understanding is that the UE has 8 Tx ports “physically” (as in CB and AS) and is capable of transmitting with all 8 “physical” Tx ports simultaneously. The 8 “physical” Tx ports may be virtualized into up to 8 Tx ports (as in NCB and BM). Specifically for NCB, 8 virtualized Tx ports should be possible.  @All: Please share your understanding on “8 Tx SRS”. |
| Huawei, HiSilicon | Support FL’s proposal and agree with FL’s understanding on “8 Tx SRS”. |
| Samsung | Similar view with OPPO, Docomo, and Nokia. “Study” seems valid for the proposal in this stage. |
| QC | Our view of 8 Tx is UE has 8 SRS ports for CB/NCB PUSCH Tx, just like Rel-15 has 4 SRS ports for CB/NCB PUSCH. There can be more than 8 physical antenna/ Tx ports equipped on UE. One SRS ports maybe implemented by virtualization including multiple physical antenna/Tx ports, which is by UE implementation and transparent to spec. The point is the # SRS ports seeing by spec is 8 for both CB and NCB. Regarding how many physical antenna/Tx ports UE has, it does not matter.  So we suggest to update the FL proposal as  **Proposal 4.1: Support 8 ports SRS in Rel-18 for both codebook based and noncodebook based PUSCH.** |

## Potential enhancements: 8Tx SRS parameters and design factors

Based on the contributions submitted for 8 Tx SRS, almost all companies have discussed at least some of the aspects below, summarized in terms of SRS key parameters and key design factors.

* **Key parameters**: number of SRS resource sets, the number of SRS resources, the number of ports per resource, the number of OFDM symbols, the allowed configurations for comb / comb shifts / cyclic shifts, number of simultaneous ports/resources/set per OFDM symbol

Note that there are a large number of design parameters for 8 Tx SRS and the parameters are intertwined. For example, the number of ports per resource can impact the number of SRS resource sets and the number of SRS resources. Companies generally have different preferences on how to set these parameters. A possible starting point may be to discuss one parameter first, e.g., the maximum number of SRS resource sets for 8 Tx SRS, which seems to be 2 based on the submitted contributions and existing standards for AS/CB/NCB.

* **Key factors**:
  + Hardware/device constraints:
    - UE capabilities, UE architecture, antenna conditions (types, installation), SRS transmission power maximum due to UE/regulation limitations, etc.
  + Operating conditions:
    - Usages (AS/CB/NCB/BM), resource types (P/SP/AP)
  + Objectives:
    - Positive impact or reduced negative impact on: gNB configuration flexibility, latency, multiplexing, overhead, coverage, hopping, backward/forward compatibility

The following proposal is suggested.

**Proposal 4.2: For SRS enhancements to enable 8 Tx UL operation to support 4 and more layers per UE in UL targeting CPE/FWA/vehicle/Industrial devices, study aspects include**

* **Design parameters, including number of SRS resource sets, number of SRS resources, number of ports per resource, number of OFDM symbols, the allowed configurations for comb / comb shifts / cyclic shifts, number of simultaneous ports / resources / resource sets per OFDM symbol**
  + **The maximum number of SRS resource sets for 8 Tx SRS is 2 for AS/CB/NCB**

Companies are welcome to share views in below table.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | OK with the proposal in principle. For maximum number of SRS resource sets, we suggest we clarify this number for each case, e.g. for sTRP case, this number should still be 1.  In addition, do we consider to list potential options to support 8 Tx SRS for further study? |
| DOCOMO | We support Proposal 4.2. |
| NEC | We are fine with the proposal. And we support to design 8-port SRS. For a UE supporting 4 or more layers UL transmission, 8-port SRS should be supported, and we think at least this should be discussed firstly. |
| InterDigital | OK with proposal. |
| QC | Thank FL for providing the proposal. We are fine with the most part of the proposal, except the last sub-bullet “The maximum number of SRS resource sets for 8 Tx SRS is 2 for AS/CB/NCB”.  We don’t agree with that part is not because we have a strong opinion to support or not support it. We just don’t want to exclude the possibility to support more than 2 SRS resource sets, e.g., 4 SRS resource sets, at this very early stage of Rel-18 without even study on the feasibility of it. Furthermore, AS/CB/NCB could potentially support different max # SRS resource sets.  In summary, we are fine with the proposal with the last sub-bullet removed.  **Proposal 4.2: For SRS enhancements to enable 8 Tx UL operation to support 4 and more layers per UE in UL targeting CPE/FWA/vehicle/Industrial devices, study aspects include**   * **Design parameters, including number of SRS resource sets, number of SRS resources, number of ports per resource, number of OFDM symbols, the allowed configurations for comb / comb shifts / cyclic shifts, number of simultaneous ports / resources / resource sets per OFDM symbol**   + **~~The maximum number of SRS resource sets for 8 Tx SRS is 2 for AS/CB/NCB~~** |
| Intel | What does it mean by ‘number of simultaneous ports / resources / resource sets per OFDM symbol’? Clarification is needed.  In addition, we don’t think the sub-bullet on the maximum number of SRS resource sets is 2 is needed. |
| Samsung | Support in principle, and we think that the maximum number of SRS resource sets in the last sub-sub-bullet should be included in design parameters mentioned in the first sub-bullet. |
| Nokia/NSB | We are fine with FL’s proposal. |
| OPPO | We are fine with the proposal without the sub-bullet. |
| MediaTek | We support in principle. We believe, limiting max number of SRS resource set as this stage is not needed. |
| Lenovo | We are general fine with the proposal in principle.  However, we think the partial frequency sounding factor introduced in Rel-17 should also be included in the design parameters. |
| CMCC | We are fine with most part of the proposal, except the last sub-bullet “The maximum number of SRS resource sets for 8 Tx SRS is 2 for AS/CB/NCB”.  We support the maximum number of SRS resource sets for M-TRP is 2. However, for single-TRP transmission, it is too early to increase the number of SRS resource sets without any further study. |
| CEWiT | We are fine with FL’s proposal, except for the sub-bullet which we think is unnecessary |
| Xiaomi | We are generally fine with the proposal in principle, and we also think limiting max number of SRS resource set at this stage is not needed. |
| Ericsson | We are in general fine with the proposal. Maybe we could propose these more specific direction to start with.  For antenna switching, study whether to support 8T8R.  For 8-port SRS, study whether to support 8 ports in a single resource using  1 OFDM symbol  2 OFDM symbols |
| Huawei, HiSilicon | Fine with FL’s proposal except for the sub-sub-bullet.  Such limitation may not be necessary at this stage. |
| LGE | We support the proposal in principle. We also prefer to remove the last bullet for the maximum number of SRS resource sets. |
| ZTE | We support FL’s proposal except the sub-bullet with the same view from QC. In addition, we agree with FL’s suggestion to discuss some parameters first. We recommend the maximal number of ports in one SRS resource can be first studied because it will impact the direction of enhancement of other parameters. So we propose following proposal:  **Proposal 4.2: For SRS enhancements to enable 8 Tx UL operation to support 4 and more layers per UE in UL targeting CPE/FWA/vehicle/Industrial devices, study aspects include**   * **Design parameters, including number of SRS resource sets, number of SRS resources, number of ports per resource, number of OFDM symbols, the allowed configurations for comb / comb shifts / cyclic shifts, number of simultaneous ports / resources / resource sets per OFDM symbol**   **- The maximum number of SRS ports of one SRS resource can be discussed firstly.**  **~~The maximum number of SRS resource sets for 8 Tx SRS is 2 for AS/CB/NCB~~** |
| Sharp | We are fine with the FL’s proposal. |
| Spreadtrum | Fine with FL’s proposal. |
| CATT | Fine with the proposal in principle. However, for the sub bullet for the maximum number of SRS resource sets, does 2 means 2 for S-TRP is supported? It is our view that whether 2 SRS resource sets shall be supported for S-TRP transmission depends on the design of 8 SRS ports. If 8-port SRS resource is supported, it is questionable why supporting 2 SRS resource sets is needed.  Maybe we can start to discuss which candidate solutions can be considered, e.g. whether enhancement for 8-port SRS resource can be a candidate or not, whether facilitate 8 SRS ports by combining multiple SRS resources can be a candidate or not, etc. |
| vivo | Support the proposal without the sub-bullet.  We think that the mentioned 2 SRS resource sets in the sub-bullet is used to combine 8 ports for SRS. It is not associated with the indication for MTRP or STRP. However, we think it is too early to restrict the maximum number of SRS resource sets. |
| KDDI | We support the FL’s proposal 4.2. |

#### FL update

Thank you all for the useful discussions. A couple of comments:

* All companies are fine with the proposal except for the sub-sub-bullet. Some companies suggested that the maximum number of SRS resource sets is still a design parameter to be decided. This is reflected in the updated proposal below.
* As described before, most of the parameters are intertwined. To have the first crack, the group may decide which parameter is to be agreed on first. Based on the inputs, the first parameter or parameter combination to be agreed on may be down-selected from:
  + Deciding whether to support 8 ports in one resource on 1 or 2 OFDM symbols. (Ericssion, ZTE, CATT)
  + Deciding the maximum number of SRS resource sets, which is closely related to factors such as S-TRP / M-TRP, SRS usages, etc. (Original intention of Proposal 4.2 and supported by a few companies)

The outcome of either option may be equivalent.

@Intel: “number of simultaneous ports / resources / resource sets per OFDM symbol” can be a design parameter, and it can be related to UE antenna configurations. For example, Ericsson described that an 8-port resource may be on 1 OFDM symbol or 2. Even if the UE is capable of transmitting all 8 ports on 1 OFDM symbol, there may be some limitations such as the maximum transmission power.

@Lenovo: Partial sounding extension to 8 Tx SRS is within the scope. If any standard support is needed, it can be discussed when 8 Tx SRS is supported.

**Proposal 4.2-1: For SRS enhancements to enable 8 Tx UL operation to support 4 and more layers per UE in UL targeting CPE/FWA/vehicle/Industrial devices, study aspects include**

* **Design parameters, including the maximum number of SRS resource sets, number of SRS resource sets, number of SRS resources, number of ports per resource, number of OFDM symbols, the allowed configurations for comb / comb shifts / cyclic shifts, number of simultaneous ports / resources / resource sets per OFDM symbol**
* **For the next decision point, study**
  + **Whether to support 8 ports in one resource on 1 or 2 OFDM symbols**
  + **The maximum number of SRS resource sets.**

Please provide your input in below table.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | OK |
| DOCOMO | Support the proposal in general. Meanwhile, we think CB and non-CB should be decoupled for further discussion. We would suggest clarifying that point.  **Proposal 4.2-1 (updated by DOCOMO): For SRS enhancements to enable 8 Tx UL operation to support 4 and more layers per UE in UL targeting CPE/FWA/vehicle/Industrial devices, study, for each of CB-based and NCB-based transmission, aspects include**   * **Design parameters, including the maximum number of SRS resource sets, number of SRS resource sets, number of SRS resources, number of ports per resource, number of OFDM symbols, the allowed configurations for comb / comb shifts / cyclic shifts, number of simultaneous ports / resources / resource sets per OFDM symbol** * **For the next decision point, study**   + **Whether to support 8 ports in one resource on 1 or 2 OFDM symbols (for CB-based transmission only)**   + **The maximum number of SRS resource sets.** |
| CATT | Besides the solution of facilitating 8 SRS ports by design 8-port SRS resource, another solution proposed by companies is facilitating 8 SRS ports through multiple 2-/4-port SRS resources. Therefore we propose to change the proposal as follows:  **Proposal 4.2-1: For SRS enhancements to enable 8 Tx UL operation to support 4 and more layers per UE in UL targeting CPE/FWA/vehicle/Industrial devices, study aspects include**   * **Design parameters, including the maximum number of SRS resource sets, number of SRS resource sets, number of SRS resources, number of ports per resource, number of OFDM symbols, the allowed configurations for comb / comb shifts / cyclic shifts, number of simultaneous ports / resources / resource sets per OFDM symbol** * **For the next decision point, study**   + **Whether to support 8 ports in one resource on 1 or 2 OFDM symbols**   + **Whether to support 8 ports through multiple SRS resources**   **The maximum number of SRS resource sets.** |
| OPPO | We are generally fine with the proposal. However, “Whether to support 8 ports in one resource on 1 or 2 OFDM symbols” is only for CB based and “The maximum number of SRS resource sets.” is only for NCB based. |
| ZTE | We support the proposal 4.2-1 in principle except that we recommend the word of ‘on 1 or 2 OFDM symbols’ in the first bullet to be deleted. Thanks a lot |
| Nokia/NSB | In general, we are fine with proposal. However, it would be good to clarify what is the UL SRS with 8TX antenna ports when two symbols are configured (4 TX UL SRS?) |
| FL | The intention is to discuss different usages separately whenever needed. This also applies to other design factors as list above, such as resource types, UE capabilities, etc.  @DOCOMO: It seems at least AS-based transmission can also be included. Also for NCB, up to 8 ports (including 8 ports) may not be precluded.  @CATT: The added sub-bullet seems to be included in the existing sub-bullet already. The existing sub-bullet states “whether to support 8 ports in one resource”, the outcomes may be (a) “support 8 ports in one resource”, (b) “support 8 ports in multiple resources”, and (a)+(b). Please check.  Further discussions are welcome. |
| Huawei, HiSilicon | Support FL’s proposal. |
| Samsung | Support in principle. In order to study separately for each usage, we suggest the following modification.   * **For the next decision point, study, for each usage**   + **Whether to support 8 ports in one resource on 1 or 2 OFDM symbols**   + **The maximum number of SRS resource sets.** |
| QC | Support FL proposal in general. Docomo’s update looks good to us. |

## Others

A few issues are discussed by one or two companies.

* Issue 1: PAPR issue for 4-port SRS due to the same cyclic shift on an OFDM symbol: NEC
* Issue 2: Non-uniform cyclic shifts for comb 4/8: Ericsson
* ~~Issue 3:~~ Min SRS sequence length is 6 (limiting max cyclic shifts to be 6) ~~To discuss the cyclic shift configuration for 8-port SRS: Intel~~
* Issue 4: xTyR for antenna switching, where x = {6,8} and y = {6, 8}: Nokia, Nokia Shanghai Bell

The first 3 issues exist from previous releases. For the last one, it seems most other companies intend to consider only 8T8R for DL CSI acquisition in Rel-18. Please provide your view on the above issues, e.g., whether the issues should be considered in R18 work (without affecting legacy designs) or they could be addressed in implementation, etc.

|  |  |
| --- | --- |
| **Company** | **View** |
| DOCOMO | * Issue 1: Agree with FL that it exists even in past releases. Thus it should be deprioritized. * Issue 2: Agree with FL that it exists even in past releases. Thus it should be deprioritized. * Issue 3: Agree with FL that it exists even in past releases. Thus it should be deprioritized. * Issue 4: It would be straightforward to consider 6T6R and 8T8R at first. Support of e.g. 6T8R is non-essential. Rel-17 NR already supports many of the antenna switching configurations needed for more than 4 Rx. |
| NEC | * Issue 1: this issue only exist in Rel-17, in Rel-15 and 16, the CS values are different for Res with different comb offset values. We think this should be enhanced. If companies don’t prefer this, at least we should consider PAPR issue for 8-port SRS design. * Issue 4: it seems 8T8R is enough. In WID, there is no mentioning of 6Tx. |
| QC | * Issue 4: We support to discuss this issue. |
| Intel | Our proposal is not correctly captured. Issue 3 is corrected. |
| Samsung | * Issue 1,2,3: These issues should be deprioritized. * Issue 4: Based on WID, 8T8R should be enough, 6T is clearly out-of-scope. |
| Nokia/NSB | * Issue 1: Share the same view with DCM * Issue 2: Share the same view with DCM * Issue 3: Share the same view with DCM * Issue 4: when considering SRS support for 8TX, it would be natural to consider also support for 6TX and 8 TX SRS antenna switching xTyR configurations including also x = {6,8} and y = {6, 8}: |
| OPPO | * We also think 6T6R is out of scope. |
| MTK | * We support further discussion for Issue 4 |
| CMCC | * Issue 1,2,3: These issues should be deprioritized. * Issue 4: Support. At least 8T8R for antenna switching should be designed. Besides, whether downgrading configuration of SRS for antenna switching will be considered for 8T8R UE can be studied. For example, whether the SRS configurations for 4T8R or 4T4R can be also configured for 8T8R UE to reduce the potential high overhead of SRS resources and facilitate high UE power efficiency. |
| CEWiT | * Issue 4: Based on our understanding of the WID, 6Tx is not in scope and 8T8R should be sufficient. |
| Xiaomi | Issue 3: this can be part of the detailed enhancement discussion.  Issue 4: we support further discussion on 6/8Tx for AS SRS. |
| Ericsson | We’d like to clarify that in our contribution, we’ve listed Issue 2 as non-preferred solution. We support Issue 4. |
| Huawei, HiSilicon | - Issue 4: 6Tx is not in scope. |
| ZTE | We support further discussion for Issue 4 with x=y=8. |
| Intel2 | We found the cyclic shift configuration is covered in Proposal 4.2. Issue 3 can be removed from others.  Issue 4: 6Tx is not in scope. |
| CATT | Issue 4: We are open to discuss whether 8T8R is supported in Rel-18. |
| vivo | Issue 1,2,3 should be deprioritized.  Issue 4: This observation focuses on the enhancement on uplink transmission, i.e., PUSCH. Antenna switching is used for downlink transmission. Thus, it seems not in scope to discuss it. |

#### FL update

Thank you all for the support. A couple of comments:

* It seems that Issues 1~3 do not require any effort at least at this stage.
* For Issue 4, several companies pointed that this it is out of scope. After checking the WID, this seems to be the case. Can proponents provide justification why this is within the scope of the WID?

The FL suggests moving forward with 8T8R for antenna switching.

**Proposal 4.3: Support 8T8R for SRS with usage antennaSwitching.**

Please provide your input in below table.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | OK |
| DOCOMO | Similar to 4-1, we think it may be premature to say “support” for this. Whether UE support 8-layer UL or not seems dependent on 9.1.4.2. |
| CATT | Support. If UL 8Tx is supported, it is nature to support 8T8R to improve the efficiency of DL CSI acquisition, as well as reduce the latency for DL CSI acquisition. For example, if 8T8R is not supported, a UE capable of UL 8Tx may report capability of 4T8R, then two 4-port SRS resources is needed to facilitate 8Rx CSI acquisition, with a 1/2-symbol GP in between the SRS resources. If 8T8R is supported, only one SRS resource is needed, at least the OFDM symbol(s) for GP can be saved (whether the OFDM symbols for SRS resource can be saved or not depends on the design of 8 ports SRS). |
| OPPO | We agree with DOCOMO. 8T8R can be supported only if 8 Tx SRS is supported firstly. |
| ZTE | Support |
| Nokia/NSB | In general, we support FL’s proposal. However, we would like to add one bullet into proposal:  FFS: xTyR for antenna switching where x = {6} and y = {6, 8}.  From our perspective, it would be natural to provide specification support also for 6 TX antenna ports. As a result of this, Rel-18 specification could provide better support for different vendor specific UE implementations for targeted CPE/FWA/vehicle/industrial devices. |
| Huawei, HiSilicon | Fine with FL’s proposal. |
| Samsung | We are fine with 8T8R only, but “Study” can be used for now, not “Support” |

Any other potential enhancement or view can be provided in below table.

|  |  |
| --- | --- |
| **Company** | **View** |
|  |  |
|  |  |

# Conclusions

TBD

# References

1. RP-213598, New WID: MIMO Evolution for Downlink and Uplink, Samsung (Moderator), RAN#94-e.
2. R1-2203886, Work plan for Rel-18 Evolved MIMO, Samsung, RAN1#109-e.
3. R1-2203066, SRS enhancements for TDD CJT and 8TX operation, FUTUREWEI, RAN1#109-e.
4. R1-2203153, SRS enhancement for TDD CJT and 8 TX operation in Rel-18, Huawei, HiSilicon, RAN1#109-e.
5. R1-2203230, On SRS enhancements targeting TDD CJT and 8 TX operation, Ericsson, RAN1#109-e.
6. R1-2203267, SRS enhancement targeting TDD CJT and 8 TX operation, ZTE, RAN1#109-e.
7. R1-2203324, Discussion on SRS enhancement targeting TDD CJT and 8 TX operation, Spreadtrum Communications, RAN1#109-e.
8. R1-2203382, Enhanced SRS Operation, InterDigital, Inc., RAN1#109-e.
9. R1-2203445, On SRS enhancement, CATT, RAN1#109-e.
10. R1-2203545, Views on SRS enhancement, vivo, RAN1#109-e.
11. R1-2203685, Discussion on SRS enhancement, NEC, RAN1#109-e.
12. R1-2203707, Views on SRS enhancement targeting 8 TX operation, KDDI Corporation, RAN1#109-e.
13. R1-2203797, Discussion on SRS enhancements, xiaomi, RAN1#109-e.
14. R1-2203892, Views on SRS enhancements, Samsung, RAN1#109-e.
15. R1-2203957, SRS enhancement targeting TDD CJT and 8 TX operation, OPPO, RAN1#109-e.
16. R1-2204145, SRS enhancement targeting TDD CJT and 8 TX operation, LG Electronics, RAN1#109-e.
17. R1-2204166, Discussion of SRS enhancement, Lenovo, RAN1#109-e.
18. R1-2204233, Views on Rel-18 MIMO SRS enhancement, Apple, RAN1#109-e.
19. R1-2204291, Discussion on SRS enhancement targeting TDD CJT and 8 TX operation, CMCC, RAN1#109-e.
20. R1-2204371, Discussion on SRS enhancement, NTT DOCOMO, INC., RAN1#109-e.
21. R1-2204510, SRS enhancement targeting TDD CJT and 8 TX operation, Sharp, RAN1#109-e.
22. R1-2204542, SRS enhancement for TDD CJT and 8Tx operation, Nokia, Nokia Shanghai Bell, RAN1#109-e.
23. R1-2204749, Discussion on SRS Enhancements for 8Tx Operation, CEWiT, RAN1#109-e.
24. R1-2204789, Discussion on SRS enhancement in Rel-18, Intel Corporation, RAN1#109-e.
25. R1-2205018, SRS enhancement for TDD CJT and 8 Tx operation, Qualcomm Incorporated, RAN1#109-e.

# Appendix

## Appendix 1: R17 SRS EVM examples

(Tables are truncated for brevity):

***Agreement***

*Adopt the following LLS assumptions at least for SRS enhancements on coverage/capacity in Rel-17.*

|  |  |
| --- | --- |
| ***Parameter*** | ***Value*** |
| *Metric* | *UL/DL BLER or throughput*  *Note: Other metrics like MSE can be considered optionally.* |
| *Baseline* | *Rel-15 SRS. Companies to state the detailed configuration used as baseline scheme.*  *Note: It has been agreed that FG 10-11 can be applied on licensed band. If no further restriction on the usage of FG 10-11 is agreed in Rel-16, it can be included in baseline.* |
| *Carrier frequency, SCS, System BW* | *FR1: 3.5GHz, 30kHz, 20, 40 or 100 MHz as baseline, 4GHz can be optionally used*  *FR2: 30 GHz, 120kHz* |
| *Channel model* | *CDL-B or CDL-C in TR 38.901 with 30ns or 300ns delay spread as baseline for MU-MIMO and SU-MIMO*  *Note: Other delay spread is not precluded.*  *Note: Simulation using TDL-A with 30ns or 300ns for MU-MIMO is not precluded.*  *Companies to state whether angle scaling is performed, and if so, the desired angle spread and mean angle.* |
| *UE speed* | *3km/h , 30km/h or 120km/h* |
| *Number of UE antennas* | *1T4R, 2T4R or 4T4R* |
| *Number of gNB antennas* | *32T32R or 64T64R* |
| *UE antenna configuration* | *FR1: omni as baseline*   * *Companies are not precluded to simulate directional antennas for 4Tx*   *FR2: directional* |

***Agreement***

*Adopt the following SLS assumptions at least for SRS capacity enhancements in Rel-17.*

|  |  |
| --- | --- |
| ***Parameter*** | ***Value*** |
| *Metric* | *DL throughput* |
| *Baseline* | *Rel-15 SRS. Companies to state the detailed configuration used as baseline scheme.*  *Note: It has been agreed that FG 10-11 can be applied on licensed band. If no further restriction on the usage of FG 10-11 is agreed in Rel-16, it can be included in baseline.* |
| *SRS error modelling* | *Table A.1-2 of TR 36.897*  *Δ=9 dB is assumed for baseline. Companies to state the detailed SRS configuration if it is different from baseline.*  *Note: The phase coherency model in LLS assumptions can be considered additionally.* |
| *SRS periodicity* | *Companies to state the simulated SRS periodicity.*  *Note: SRS triggering may be aperiodic* |
| *Carrier frequency, SCS and system bandwidth* | *3.5GHz, 30KHz and 20MHz/40MHz/100MHz as baseline* |
| *Number of gNB antennas* | *(M, N, P, Mg,Ng; Mp, Np) = (8,8,2,1,1,4,8). (dH,dV) = (0.5, 0.8)λ* |
| *Number of UE antennas* | *1T4R, 2T4R or 4T4R*  *Omni antennas are used as baseline. Companies are not precluded to simulate directional antennas for 4Tx.* |

## Appendix 2: R18 FDD CJT EVM

***Agreement Proposal 4.A:***

*On Rel-18 CSI enhancement EVM for SLS, use the attached excel spreadsheet “EVM CSI V03” (in /tsg\_ran/WG1\_RL1/TSGR1\_109-e/Inbox/drafts/9.1.2/ROUND 1)*

(Details skipped for brevity; see also approved tdoc R1-2205289)

## Appendix 3: R18 TDD CJT EVM

|  |  |  |  |
| --- | --- | --- | --- |
| Rel-18 SLS Assumptions for TDD CJT SRS | | | |
| Parameter | | | Value |
| Duplex, Waveform | | | TDD, OFDM |
| Multiple access | | | OFDMA |
| Scenario | | | |  | | --- | | Companies can simulate from the following 2 layouts.   1) Outdoor (typical 57-sector, or 21-sector, SLS):  OptionA: 1 TRP per sector, 3 sectors per site. N\_TRP (#TRPs): 2, 3, 4 (N\_TRP is semi-statically chosen based on, e.g. RSRP). The N\_TRP TRPs can be selected either only from the same site (intra-site - limited to 3 TRPs), or also from other sites (inter-site) - company should describe what is assumed   OptionB: N\_TRP co-located (at BS) panels per sector - companies describe how the panels are (azimuthally) oriented  - Dense Urban (macro only) 200m ISD or Urban Macro 500m ISD        2) Indoor Hotspot:  model in TS 38.802 - N\_TRP (#TRPs): 2, 3, 4 (N\_TRP is semi-statically chosen based on, e.g. RSRP)  **Outdoor OptA** | |
| Frequency Range | | | FR1 only, 3.5GHz |
| Inter-BS (site) distance | | | Outdoor: 200m or 500m Indoor Hotspot: per TS 38.802 |
| Channel generation model | | | According to the TR 38.901   Difference in propagation delays between UE and N\_TRP TRPs is taken into account in the composite Channel Impulse Response (CIR) for CJT. Otherwise, company should state if per-TRP delay offset (to "zero") is performed in the simulation.  Per WID, ideal synchronization and backhaul should be assumed.  Optionally, companies may present results with phase/frequency error and should state the assumed frequency error models and values. |
| Antenna setup and port layouts at gNB | | | - 8 ports: (4,4,2,1,1,1,4), (dH,dV) = (0.5, 0.8)λ - 16 ports: (8,4,2,1,1,2,4), (dH,dV) = (0.5, 0.8)λ - 32 ports: (8,8,2,1,1,2,8), (dH,dV) = (0.5, 0.8)λ  - 64 ports: (8,8,2,1,1,4,8), (dH,dV) = (0.5, 0.8)λ  Total #ports = N\_TRP x {8,16,32,64} |
| Antenna setup and port layouts at UE | | | 4RX: (1,2,2,1,1,1,2), (dH,dV) = (0.5, 0.5)λ for rank > 2 |
| BS Tx power | | | Dense Urban or Urban Macro: - Per TRP: 44 dBm for 20MHz, 47dBm for 40MHz, 51dBm for 100MHz Indoor: per TRP 24dBm |
| BS antenna height | | | Depending on scenarios (cf. table A.2.1-1 of TS 38.802): DU (25m), UMa (25m), Indoor Hotspot (3m) |
| UE antenna height & gain | | | Follow TR36.873 |
| UE receiver noise figure | | | 9dB |
| Modulation | | | Up to 256QAM |
| Coding on PDSCH | | | LDPC Max code-block size=8448bit |
| Numerology | Slot/non-slot | 14 OFDM symbol slot | |
| SCS | 30kHz | |
| Number of RBs | | 52RB for 20MHz, 104RB for 40MHz, 272RB for 100MHz | |
| Frame structure | | DSUDD, or companies to state the used frame structure | |
| MIMO scheme | | SU/MU-MIMO with rank adaptation is a baseline  For low RU, SU-MIMO or SU/MU-MIMO with rank adaptation are assumed  For medium/high RU, SU/MU-MIMO with rank adaptation is assumed | |
| MIMO layers | | For all evaluation, companies to provide the assumption on the maximum MU layers | |
| Overhead | | Companies shall provide the downlink overhead assumption | |
| Traffic model | | FTP 1 or FTP 3 with 20%, 50% or 70% traffic load | |
| UE distribution | | According to TS 38.802 - DU and UMa: 80% indoor (3km/h), 20% outdoor (30km/h)  - Indoor Hotspot: 100% indoor (3km/h) | |
| UE receiver | | MMSE-IRC as the baseline receiver | |
| DL Channel estimation | | Realistic | |
| Evaluation Metric | | DL throughput | |
| Baseline for performance evaluation | | R17 SRS design | |
| SRS modeling for UL channel estimation | | Companies to state the used SRS periodicity. Companies to state the SRS channel estimation modeling  Number of ports = 2 or 4 Tx power = 23 dBm | |

## Appendix 4: R18 TDD CJT EVM for LLS

|  |  |
| --- | --- |
| Rel-18 LLS Assumptions for TDD CJT SRS | |
| Parameter | Value |
| Scenario | N\_TRP (#TRPs): 2, 3, 4 |
| Carrier frequency and subcarrier spacing | 3.5 GHz with 30 kHz SCS |
| System bandwidth | 20MHz, 40MHz, 100MHz |
| Channel model | CDL-B or CDL-C in TR 38.901 with 30ns or 300ns delay spread as baseline for MU-MIMO and SU-MIMO  Note: Other delay spread is not precluded.   Difference in propagation delays between UE and N\_TRP TRPs is taken into account in the composite Channel Impulse Response (CIR) for CJT. Otherwise, company should state if per-TRP delay offset (to "zero") is performed in the simulation.  Per WID, ideal synchronization and backhaul should be assumed.  Optionally, companies may present results with phase/frequency error and should state the assumed frequency error models and values. |
| UE velocity | 3km/h |
| Antennas at UE | 1T4R, 2T4R, 4T4R |
| Antennas at gNB | 64 ports: (8,8,2,1,1,4,8), (dH,dV) = (0.5, 0.8)λ  32 ports: (8,8,2,1,1,2,8), (dH,dV) = (0.5, 0.8)λ  16 ports: (8,4,2,1,1,2,4), (dH,dV) = (0.5, 0.8)λ |
| Rank and MCS | Rank/MCS can be adaptive or fixed. |
| Evaluation metrics | MSE, BLER or throughput |
| Baseline | R17 SRS design |
| Precoding granularity | Fixed: 2, 4 or wideband for DL, wideband for UL. |
| SRS configurations | Companies to state the used SRS periodicity. Frequency hopping：Companies to state whether SRS frequency hopping is enabled and the hopping pattern if so. |
| DL SNR | Companies to state the used difference between DL SNR and UL SNR |

## Appendix 5: Other R17 EVM examples related to SRS

Previous EVM examples with 8 Rx or 4 Tx:

*Agreements****:****For FR2, UE antenna parameters for XR/CG evaluations are as follows.*

* *Option 1 (Follow Rel-17 evaluation methodology for FeMIMO in R1-2007151)*
  + *(M, N, P)=(1, 4, 2), 3 panels (left, right, top)*
* *Option 2 (from TR 38.802 – developed in Rel-14)*
  + *4Tx/4Rx: (M, N, P, Mg, Ng; Mp, Np) = (2,4,2,1,2;1,2), (dH,dV) = (0.5, 0.5)λ, the polarization angles are 0° and 90°*

*Company to report the UE antenna parameters for XR/CG evaluation.*

*Other UE antenna parameters can also be optionally evaluated.*

***Agreement***

*The EVM assumptions in Section 4 (except for Proposal 2 and 4) in R1-2006973 for Rel-17 CSI enhancements are agreed.*

***Proposal: For EVM for FDD CSI enhancement in Rel-17, following SLS parameter are used:***

|  |  |
| --- | --- |
| ***Parameter*** | ***Value*** |
| *Duplex, Waveform* | *FDD (TDD is not precluded), OFDM* |
| *Multiple access* | *OFDMA* |
| *Scenario* | *Dense Urban (Macro only) is a baseline.*  *Other scenarios (e.g. UMi@4GHz 2GHz, Urban Macro) are not precluded.* |
| *Frequency Range* | *FR1 only, 2GHz with duplexing gap of 200MHz between DL and UL, optional for 4GHz* |
| *Inter-BS distance* | *200m* |
| *Antenna setup and port layouts at gNB* | *Companies need to report which option(s) are used between*   * *32 ports: (8,8,2,1,1,2,8), (dH,dV) = (0.5, 0.8)λ* * *16 ports: (8,4,2,1,1,2,4), (dH,dV) = (0.5, 0.8)λ*   *Other configurations are not precluded.* |
| *Antenna setup and port layouts at UE* | *4RX: (1,2,2,1,1,1,2), (dH,dV) = (0.5, 0.5)λ for rank > 2*  *2RX: (1,1,2,1,1,1,1), (dH,dV) = (0.5, 0.5)λ for (rank 1,2)*  *Other configuration is not precluded.* |

***Agreement***

*The three proposals on R1-2007151 on the evaluation methodology for multi-beam enhancement are agreed.*

***Proposal 2:*** *The simulation assumptions are given below. Items that are the same as what has been agreed in Rel.16 are in green*

*Table 1 Baseline assumptions for SLS: common for intra-cell mobility and MPE/MP-UE*

|  |  |
| --- | --- |
| ***Parameters*** | ***Values*** |
| *Frequency Range* | *FR2 @ 30 GHz,*   * *SCS: 120 kHz* * *BW: 80 MHz* |
| *Transmission Power* | *Maximum Power and Maximum EIRP for base station and UE as given by corresponding scenario in 38.802 (Table A.2.1-1 and Table A.2.1-2)* |
| *BS Antenna Configuration* | *(M, N, P, Mg, Ng) = (4, 8, 2, 2, 2). (dV, dH) = (0.5, 0.5) λ. (dg,V, dg,H) = (2.0, 4.0) λ*  *Companies to explain TXRU weights mapping.*  *Companies to explain beam selection.*  *Companies to explain number of BS beams* |
| *BS Antenna radiation pattern* | *TR 38.802 Table A.2.1-6, Table A.2.1-7* |
| *UE Antenna Configuration* | *Number/location of panels: 3 panels (left, right, and back)*  *Panel structure: 1x4x2 or (M, N, P) = (1, 4, 2), dH = 0.5 λ*  *Companies to explain TXRU weights mapping.*  *Companies to explain beam and panel selection.*  *Companies to explain number of UE beams* |
| *UE Antenna radiation pattern* | *TR 38.802 Table A.2.1-8, Table A.2.1-10* |
| *Beam correspondence* | *Companies to explain beam correspondence assumptions (in accordance to the two types agreed in RAN4)* |