**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. |

# 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. |

### 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.**

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| **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? |

### 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.**

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| **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. |

### 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.**

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| **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. |

### 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. |

# 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. |

## 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. |

## 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. |

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

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

# Conclusions

TBD

# References

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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.
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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.