**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. |

# 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. |

### 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. |

### 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 (7): ZTE, Spreadtrum, CMCC, NTT DOCOMO, Sharp, Intel, NEC
* 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. |

### 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 |

### 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.

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| **Company** | **View** |
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# 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.

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| **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. |

## 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.

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| **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. |

## 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.

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| **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. |

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

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| **Company** | **View** |
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# Conclusions

TBD

# References

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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.