3GPP TSG RAN WG1 Meeting #107-e R1-2112589

**e-Meeting, Nov. 11th – 19th, 2021**

**Source: Moderator (ZTE)**

Title: FL summary #2 on SRS enhancements

Agenda Item: 8.1.3

Document for: Discussion and Decision

# Introduction

In RAN#86, the Rel-17 WID of further enhancements on MIMO for NR is approved [1]. In the approved WID, a particular point is about SRS enhancements in terms of flexibility, coverage and capacity, targeting both FR1 and FR2. The detailed scope of the SRS enhancement is given as follows.

*3. Enhancement on SRS, targeting both FR1 and FR2:*

* 1. *Identify and specify enhancements on aperiodic SRS triggering to facilitate more flexible triggering and/or DCI overhead/usage reduction*
	2. *Specify SRS switching for up to 8 antennas (e.g., xTyR, x = {1, 2, 4} and y = {6, 8})*
	3. *Evaluate and, if needed, specify the following mechanism(s) to enhance SRS capacity and/or coverage: SRS time bundling, increased SRS repetition, partial sounding across frequency*

Previous RAN1 agreements on these SRS enhancements are given in Section 6.1.

In this contribution, we summarize companies’ views on the second-round email discussion in RAN1#107-e.

# Flexibility enhancements

## SRS triggering offset

### 2.1.1. Collision handling

One FFS point from RAN1#104e’s agreement on available slot definition is “rules to handle the case of multiple SRS resource sets with overlapping symbols and/or triggered by a same DCI”. Companies’ detailed views are given in the table below.

Table 2-1

|  |
| --- |
| **Collision handling** |
| Views | Companies | Priority rules |
| Introduce dropping rule when collision happens among aperiodic SRS resource sets | Intel, Xiaomi (UE optional), CMCC, Apple (UE optional), Nokia/NSB, Qualcomm, ZTE, Huawei/HiSilicon, Futurewei, Lenovo/MotM, Ericsson, vivo, Spreadtrum, CATT | * Rule 1 – Based on usage: Intel, CMCC, Nokia/NSB, Qualcomm, ZTE, Ericsson, vivo
* Rule 2 – Based on set ID and CC ID: Intel, CMCC, ZTE, Huawei/HiSilicon, Ericsson, vivo, Spreadtrum, CATT
* Rule 3 – Based on order of the triggering DCI: Lenovo/MotM, vivo
* Rule 4 – Based on type of the aperiodic SRS and the UL channel/signaling: Futurewei
 |
| Do not introduce new dropping rule | Samsung, OPPO, LG |  |

The majority of companies are positive to have dropping rule defined to handle this collision. Among all the proposed rules, the first two rules (usage and CC ID/set ID) attract the majority view. Based on majority view, the following proposal is recommended by FL.

***FL Proposal 2-1:*** *Introduce dropping rule when collision happens among multiple aperiodic SRS resource sets in a same CC or different CCs.*

* *Adopt the following* *priority rules (with priority level from high to low)*
	+ *Usage > CC ID > Set ID*
		- *For usages, priority order is AS > CB > NCB > BM*
		- *For CC ID/set ID, lower ID has higher priority than higher ID*
* *The new dropping rule is a UE optional feature*
	+ *UE will take collision as error case if UE does not support this feature*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | The proposal is updated based on the comments from Ericsson, Apple and VDF in the first round. Companies are encouraged to further check and share your views. |
| OPPO | No support since it is overkill. The benefits are not justified.  |
| DOCOMO | We are fine with the FL proposal 2-1.  |
| Ericsson | Support  |
| InterDigital | We have a question, if we agreed to have a rule, does UE send an indication to gNB that it has dropped an SRS transmission, or the assumption is that gNB woud know? If former, then shouldn’t we also discuss the need to have a drop-indication signal? If latter, then if gNB could realize that a drop has occurred, why it could not manage the collision in the first place? |
| Huawei, HiSilicon | Not support. The concern raised by many companies in last round on ‘usage’ as a dropping rule is not acceptable for us, which will restrict the scheduling in the practical use cases. The priority of different usages depend on the scenario, such as BM has higher priority in FR2 transmission, but DL CSI acquisition has higher priority in some cases for FR1. We support the dropping rule without usage, i.e., only with CC ID and Set ID. |
| Samsung | We this collision can be handled by implementation |
| MTK | We support to have dropping rule but are not totally convinced by the priority rule in proposal after reading other companies views. We also have some questions1. “*UE will take collision as error case if UE does not support this feature”* is that the same as UE does not expect collision will happen, which implies gNB will handle collision at first place?
2. Is this feature only to tolerate dynamic of “DCI flexible triggering” in R17? In other words, can UE support this feature if it doesn’t support DCI flexible triggering?
 |
| Futurewei | We only support collision handling involving R17 SRS with available slot offset, and leave SRS without available slot offset untouched. In our view:* R15/16 AP SRS has no collision handling.
* R17 introduces available slot offset to AP SRS, without changing R15/16 AP SRS.

So what is the motivation for introducing collision handling that will all AP SRS, regardless of with or without available slot offset? This would affect R15/16 behavior.With available slot offset, RAN1 agreed the following:*Note: Collision handling between the triggered SRS and any other UL channel/signal is performed after the determination of available slot.*This should be the basis of this discussion. |
| QC | We only support dropping rule for collision between SRS sets triggered by same DCI.  |
| Lenovo/MotM | We support to introduce collision handling rule at least for single CC case. As we commented in the 1st round, CB should have the same priority as NCB in this situation since only one of them can be configured in a CC. |
| Xiaomi | If no consensus, this issue can be deprioritized and handled by gNB scheduling.  |
| LGE | Not support. We don’t think dropping rule between aperiodic resources is necessary. |
| Intel | Support FL proposal.We think the case of multi-CC should be addressed, in which the collision happens more often. |
| Spreadtrum | Not support. The logic of mixing usage and ID is not clear. We think using CC ID/Set ID is enough for defining dropping rule. |
| vivo | Support FL proposal. In Rel-15/16, slot offset is RRC configured by gNB, collision can be avoided by gNB implementation. However, introduction of available slot offset for each SRS resource set separately, it would be very complexs and difficult for gNB to avoid collision if not impossible. Thus, legacy collision rule is not sufficient and it should be improved as a part of available slot offset enhancement. |
| CATT | We support introducing dropping rule but not see the necessity of combining Rule 1 and the Rule 2. We prefer Rule 2 with CC ID > set ID. |
| Nokia/NSB | We are fine with FL proposal 2-1. |

## Flexible DCI format

**Re-purpose**

It seems it is hard converge on this repurpose issue. Since we have discussed this issue for long time costing a lot of meeting resources, and companies’ interest on this has cooled down, the following conclusion is recommended by FL.

***FL Proposal 2-4:*** *No consensus to support repurpose of DCI field(s) for SRS parameter indication in Rel-17.*

Supported by InterDigital, NEC, Huawei/HiSilicon, QC, Lenovo/MotM, CATT, Xiaomi, Nokia/NSB, CMCC, Xiaomi

Concerned by Futurewei, NTT DCM, Intel

Since the view from Futurewei, NTT DCM and Intel in the first round is to focus on interpretation of the TPC command and BWP indicator when SRS is triggering without data and without CSI, FL suggests to also discuss the issue in Table 2-5 here to see whether we can identify any essential issue for completing this feature.

Table 2-5

|  |
| --- |
| **Interpretation of TPC command and BWP indicator in DCI 0\_1/0\_2 triggering SRS without data and without CSI** |
| Views | Companies |
| * For SRS triggered by DCI format 0\_1/0\_2 without scheduling PUSCH and without CSI Request, the existing TPC command carried by the DCI is used for the triggered SRS transmission.
* When SRS is triggered by DCI format 0\_1/0\_2 without scheduling PUSCH and without CSI Request, the existing BWP indicator field carried by the DCI could be used to switch the BWP for the triggered aperiodic SRS transmission.
 | Intel, Futurewei, NTT DCM |
| No need for discussion | Samsung, Huawei/HiSilicon, Qualcomm, Nokia/NSB, CMCC, CATT, OPPO |

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | Companies are suggested to share your views on FL proposal 2-4 and the issue in Table 2-5, esp. about whether you think the issue in Table 2-5 is essential. |
| OPPO | Support FL proposal 2-4No need to discuss the proposal in Table 2-5 |
| DOCOMO | For TPC command, in Rel-16, when A-SRS is triggered by a DCI with UL SCH scheduling, power control adjustment state for PUSCH is reused for the A-SRS. On the other hand, when A-SRS is triggered by a DCI 2\_3, which does not schedule data/CSI, the DCI also has TPC command field. We think, in case either UL SCH or CSI report is not scheduled in the DCI triggering Rel-17 enhanced A-SRS, the principle considered in DCI 2\_3 (indicating TPC command in DCI) should be followed. Thus, TPC command in DCI 0\_1/0\_2 without scheduling PUSCH and without CSI Request should be used for the triggered SRS transmission. |
| Ericsson | Support the enhancement proposed in Table 2-5.  |
| InterDigital | Support proposal 2-4. |
| Huawei, HiSilicon | Fine for FL proposal 2-4.  |
| Samsung | Support FL proposal 2-4No need to discuss the proposal in Table 2-5 |
| MTK | We think re-purpose DCI has benefits but consider the limited time in the last meeting, we are fine to deprioritize it.  |
| Futurewei | Agree with DOCOMO on TPC command. The spec impact is so small and the benefit is so clear, so we do not see why this should be dropped.For BWP indicator field and CIF, as we mentioned before, existing specs specify that they apply to SRS. We think this should be clarify to align companies’ understanding. Please let us know if we missed anything. |
| QC | Support FL proposal 2-4. |
| Lenovo/MotM | Support proposal 2-4. |
| Xiaomi | Support FL proposal 2-4 |
| LGE | OK with proposal 2-4. |
| Intel | Agree with the assessment from DoCoMo and Futurewei and support the enhancement in Table 2-5.Regarding BWP indicator and CIF field, do we have the same understanding on the UE behavior regarding these fields when aperiodic SRS is triggered by DCI 0\_10\_2 without scheduling data? |
| Spreadtrum | Support. |
| vivo | Support FL proposal 2-4 |
| CATT | Support proposal 2-4. The issues in Table 2-5 are not necessary. As we explained in the first round, BWP switching due to DCI triggering AP-SRS only may degrade the performance of PUSCH. It should be avoided. |
| Nokia/NSB | Support the enhancement proposed in Table 2-4. No need to discuss the proposal in Table 2-5. |

**Group-common DCI**

After first round discussion, the proponents want to focus on the enhancement to applying Rel-17 triggering offset enhancement to SRS triggered by GC DCI (format 2\_3). Hence FL suggests to focus on this to check whether companies think it is essential to Rel-17.

Table 2-4

|  |
| --- |
| **Whether the Rel-17 available slot offset enhancement is also applied on SRS triggered by GC DCI** |
| Alternatives | Companies |
| Yes (Rel-17 available slot offset enhancement applies for SRS triggered by GC DCI) | Qualcomm, Futurewei, Intel, Ericsson, Xiaomi |
| No (Rel-17 available slot offset enhancement does not applied for SRS triggered by GC DCI) | LG, Huawei/HiSilicon, CATT, Lenovo/MotM, OPPO |

***FL Proposal 2-5:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | Companies are encouraged to share your view on the above issue, including whether you think it is essential to Rel-17. |
| OPPO | Different UEs may be configured with different slot format. Thus, we doubt the benefits.  |
| Ericsson | Support the enhancement in Table 2-4.  |
| Huawei, HiSilicon | No. As we clarified before, available slot is for flexible AP-SRS triggering, group common DCI is not proper for AP-SRS triggering.  |
| Futurewei | Support |
| QC | Support |
| Lenovo/MotM | Not support since we fail to see the benefit. |
| Xiaomi | Support  |
| LGE | Similar view as OPPO, Huawei/HiSi, and Lenovo/MotM. |
| Intel | Support to apply available slot for DCI 2\_3. Otherwise, there is mixed operation of Rel-17 and Rel-15 behavior. |
| vivo | Support |
| CATT | Not support |
| Nokia/NSB | Low priority |

## Usage/overhead reduction

One remaining issue is whether to support specification enhancement on using SRS resources configured in SRS resource set with usage = “antennaSwitching” for codebook based UL transmission. Table 2-5 summarizes companies’ views.

Table 2-6

|  |
| --- |
| **Whether to support specification enhancement on using SRS resources configured in SRS resource set with usage = “antennaSwitching” for codebook based UL transmission** |
|  | Companies |
| Action 1: Add a UE capability to ensure same virtualization if SRS resource(s) for antenna switching also belong to a set for codebook | Apple, NTT DOCOMO, Ericsson |
| Action 2: Add a RRC parameter to turn on/off the UE behavior in Action 1 | Apple, NTT DOCOMO, Ericsson |
| Action 3: Clarify same virtualization is used if SRS resource(s) for antenna switching also belong to a set for codebook | NTT DOCOMO, Ericsson |
| None of the above actions is needed | Futurewei, Huawei/HiSilicon, Lenovo/MotM |

***FL proposal 2-7:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| DOCOMO | We support to either of the three actions.  |
| Ericsson | Support Action 1+2+3 to introduce SRS resource usage sharing in NR to reduce SRS overhead when using massive MIMO in TDD deployments.  |
| Huawei, HiSilicon | Not necessary. SRS resource sharing is already supported in Rel-15. |
| Futurewei | Not needed. |
| Lenovo/MotM | Not needed. |
| CATT | Usage sharing is helpful in overhead reduction. Support Action 1+2 and Action 3. |

## Flexible antenna switching

Multiple companies discuss the issue of indicating the number of antennas to support more flexible antenna switching in dynamic signaling. Their views are summarized in the following table.

Table 2-7

|  |
| --- |
| **Update Tx/Rx antennas for SRS antenna switch in dynamic signaling** |
| Views | Companies | Further details |
| Clarify that it changes the number of SRS ports dynamically but does not change the real number of Tx/Rx antennas | Futurewei, OPPO |  |
| Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | Intel, Xiaomi, Samsung, Nokia/NSB, Qualcomm, Futurewei, Lenovo/MotM, Ericsson, vivo, Spreadtrum, CATT, OPPO | MAC CE:* Xiaomi, Samsung, Nokia/NSB, Qualcomm, Ericsson, vivo (with new activation timing), Spreadtrum, OPPO

DCI:* CATT, Intel
 |
| Support UE reporting of the preferred antenna switching configuration | Yes: Xiaomi (MAC CE), AppleNo: Intel, Futurewei |  |

The following proposal is given based on majority view.

***FL proposal 2-8:*** *Support gNB indicating the used SRS resources from the configured SRS resources in SRS resource set(s) for antenna switching via MAC CE.*

* *Support UE reporting of one preferred antenna switching configuration in MAC CE*
* *The gNB indicated or UE reported antenna switching configuration belongs to the supported antenna switching reported by UE capability signaling*
* *A new application timing of the MAC CE activation is introduced for this purpose*
* *Note1: Any change on the configured number of Tx antennas in each SRS resource is precluded in either the gNB indication or UE reporting*
* *Note2: This feature is not related to the Rx antennas for DL reception.*

Some issues to be discussed

* Whether Note1 should be kept
	+ Remove: IDC
	+ Not to remove: Huawei/HiSilicon
* Whether a new application timing is needed
	+ Yes: vivo
	+ No: Samsung, QC, CMCC, Futurewei, Lenovo/MotM, OPPO
* Whether to change MAC CE to DCI
	+ Yes: Intel, CATT

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | Note2 is added per OPPO and Xiaomi’s comments. Feel free to share your further views esp. on the above three issues. |
| OPPO | Note 1: Dynamic turn-on / turn-off of Tx antenna is more useful from the perspective of power consumption. However, the current proposal is not sufficient for Tx antennas adaptation. Thus, we support to keep Note 1 to avoid some potential issue on UE implementation. We expect to specify a complete solution for Tx antenna adaptation in future. New application timing: NoWhether to change MAC CE to DCI: MAC CENote 2: Support |
| DOCOMO | Question: if we have both Note 1 and Note 2, what is the new result by the gNB indication? We understood that this proposal is to intend to change the number of Tx and/or Rx for DL CSI acquisition dynamically based on the discussion so far. It seems to us that when we have both Note 1 and Note 2, it would not be possible to change either Tx or Rx. In this case, what can be changed per gNB indication? Is it correct that only SRS resource for antenna switching can be changed per MAC CE when both Notes are agreed?  |
| Ericsson | We have the same question as DOCOMO. What does “is not related” mean in Note 2? The whole purpose New application timing: NoWhether to change MAC CE to DCI: MAC CE (also support DCI)It should also be noted that the network can ignore the preferred antenna switching reported by the UE.  |
| Huawei, HiSilicon | FL’s proposal is generally fine for us. For Note1, it is essential for the proposal. For the third issue, not agree to use DCI. From the discussion before, the proponents mentioned the benefit is for power and resource saving. So, we do not think it is necessary to use DCI for dynamically changing the Rx number. By the way, we propose to restrict the type of SRS to periodic and semi-persistent SRS. For AP-SRS, only once transmission, no any benefit on power/resource saving. |
| MTK | Same questions as DOCOMO/Ericsson.  |
| Futurewei | We understand the intention of Note 2 but the term may need improvement, such as “*This feature is related to only sounding and does not affect the Rx antennas for DL reception*”.We still have concern about the usefulness of UE reporting one preferred antenna configuration. Note 1 is needed; Tx switching has not been fully discussed.New application timing is not needed.Open to use DCI, but there is not enough time to complete this. |
| QC | In our views, this proposal is for the adaptation of xTyR SRS antenna switching configuration and not related to UE adaptation of actual Rx antennas. It is like a fallback or a downgrade of SRS configuration to get partial spatial DL channel. We support Note 1 and Note 2. Not okay with new application timing.*This also should be UE optional feature.*  |
| Lenovo/MotM | Same questions as DOCOMO and Ericsson. |
| Xiaomi | Fine with FL’s proposal. Similar views with QC/Futurewei/Oppo on Note1/Note 2 that this feature is not to change the Tx or Rx antennas, but to change the antenna switching configuration that can achieve partial sounding to save SRS resources. Also fine with Futurewei’s wording for Note 2.For UE reporting, UE can help get a more accurate DL measurement of which set of antenna ports having poor channel conditions that may not need to be sounded by the NW or the set of ports having nearly equal performance as full reception compared to full sounding in order to save SRS resources. And some reasons only UE knows, eg. UE having power saving mode on, or some antennas used for other RAT, or some antennas not working (eg.CPE devices…), and this information of preferred xTyR can be used to assist the scheduling of partial sounding of each UE for the NW.  |
| Intel | Do not support the FL proposal.1. For aperiodic SRS, the DCI based solution should be supported, which is more important. Introducing MAC-CE to indicate some resources just introduce additional signaling overhead and is not be sufficient to satisfy the timing of aperiodic SRS.The switching between xTyR could be achieved by associating different trigger state with the aperiodic SRS resource sets for corresponding xTyR. For example, trigger state #1 could be associated with SRS set #A for 2T4R, and trigger state #2 could be associated with SRS set #B for 1T2R.The spec impact is much less and there is no need to introduce new DCI field.2. For periodic SRS, we don’t see the need to have MAC-CE based solution at all. The RRC reconfiguration is sufficient.3. Regarding semi-persistent SRS, it has been agreed that two semi-persistent SRS resource sets could be supported. Therefore, the existing MAC-CE to activate/deactivate semi-persistent SRS can be used to enable flexible switching between xTyR.For example, the UE could be configured with one semi-persistent resource set for 2T4R and another semi-persistent SRS resource set for 1T2R. In this way, the gNB can use the existing MAC-CE to activate corresponding semi-persistent SRS resource set for 1T2R or 2T4R operation.With the existing MAC-CE, there is no need to introduce additional application timing for MAC-CE activation.Comparing with introducing new MAC-CE, re-using the existing MAC-CE is the simplest way and has minimum spec impact. In addition, re-using the existing MAC-CE can also support changing the number of ports of SRS.4. Regarding the UE reporting of preferred antenna switching configuration via MAC-CE, what’s the condition to trigger the reporting and how often to report it?5. Some company mentioned the proposal is for power saving, but the proposal doesn’t allow to change the number of Tx. We really doubt on the benefit for power saving, since the Tx consume more power than Rx.6. Given this is the last meeting, we think we should go with the way with less spec impact.Therefore, we have the following proposal:***Proposal:**** *For antenna switching with aperiodic SRS, DCI is used to switch between different xTyR*
	+ *The aperiodic SRS resource sets for different xTyR are associated with different trigger state*
	+ *No new DCI field is needed*
 |
| Spreadtrum | We are fine with FL proposal. |
| vivo | We think flexible antenna switching impacts on current MAC CE application timing, if MAC CE signaling is supported for dynamic indication additional timing relaxation should be considered. Otherwise, we don’t support the whole proposal.Assume a UE with below RF architecture-A supports (2T4R-1T4R-1T2R).**RF architecture-A**If the UE has been configured 1T2R by RRC, 1T2R switching to 1T4R in by MAC CE in current timing could be sufficient in above figure.However, assume RF architecture-B that a UE only supports 1T4R-1T2R, and due to power restriction, 2T4R is not supported.**RF architecture-B**Similarly, UE has been configured 1T2R by RRC. If the UE receives an activation command to 1T4R, as a consequence, Tx chain 2 will be activated after HARQ-ACK transmission corresponding to the MAC CE, and the activation time for achieving 1T4R in this architecture is much larger than that of in RF architecture-B.There are variety of UE RF implementations, and for certain implementation extra timing relaxation is necessary. Thus, we support to keep new application time and which could be a UE capability.  |
| CATT | Similar view as Intel that DCI based solution should be supported. Intel’s proposal is acceptable to us. |
| Nokia/NSB | Agree with Docomo and Ericsson that further clarification is needed when both Note 1 and 2 are applied.Regarding to new application timing, we do not see need for itWhether to change MAC CE to DCI: MAC CEShare the same view as Ericsson, even though the UE may recommend antenna switching configuration, the network has always a control determine the indicated one.  |

## Update of the association between trigger states and resource sets

Several companies discuss the issue of using MAC CE to update the association between SRS trigger states and SRS resource sets. Companies’ views are summarized in the following table

Table 2-9

|  |
| --- |
| **Update of the association between trigger states and resource sets** |
|  | Companies |
| Support to update the association between SRS trigger states and SRS resource sets via MAC CE | NTT DCM, Lenovo/MotM, Ericsson, Nokia/NSB |
| Not needed | Huawei/HiSilicon, OPPO, CMCC, Samsung, Intel |

***FL proposal 2-10:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | Companies are encouraged to share your further views, esp. on whether this issue is essential for Rel-17 completion. |
| OPPO | No. We don’t see the benefit.  |
| DOCOMO | We support to update the association between SRS trigger states and SRS resource sets via MAC CE |
| Ericsson | Support |
| Huawei, HiSilicon | No, we do not think introducing additional MAC-CE is necessary. |
| Samsung |  Not needed |
| Lenovo/MotM | Support to provide flexibility when more AP SRS resources are configured. |
| Intel | Low priority |
| vivo | Not needed |
| Nokia/NSB | Support to update the association between SRS triggering states and SRS resource sets via MAC |

## Others

The following issues are discussed by a small number of companies.

|  |  |
| --- | --- |
| The FDRA field in a DCI can apply to the triggered aperiodic SRS resource set*.* | LGE, Futurewei |
| Support single scheduling DCI to trigger simultaneous A-SRS transmission across multiple component carriers | Qualcomm |
| Support to trigger aperiodic SRS by non-scheduled DCI format 1-1 and 1-2. | Vivo, LGE, Futurewei |
| Support DCI format 0\_1 and 0\_2 to trigger aperiodic SRS without data but with a non-zero “CSI request” where the associated “reportQuantity” in CSI-ReportConfig set to “none” for all CSI report(s) triggered by "CSI request" in this DCI format 0\_1 or 0\_2. | CATT, Futurewei |

Companies’ further views on the above issues are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | This part is kept in case we miss anything essential for Rel-17 completion. |
| CATT | AP-SRS triggering with DCI format 0\_1/0\_2 without PUSCH scheduling and without CSI request is supported. It is natural to support AP-SRS triggering with DCI format 0\_1/0\_2 without data but with a non-zero "CSI request" where the associated "reportQuantity" in *CSI-ReportConfig* set to "none" for all CSI report(s) triggered by "CSI request" in this DCI format 0\_1 or 0\_2. |
|  |  |

# Antenna switching up to 8Rx

## Guard period

**Presence of GP**

Companies discuss possible enhancements on the presence of guard symbols for antenna switching SRS. The proposed alternatives and companies’ positions until the first round are summarized as follows.

Table 3-1

|  |
| --- |
| **Presence of guard symbols** |
| Alternatives | Companies |
| Alt 1-0: Guard symbols are always-on, which is same as Rel-15 | Intel, Xiaomi, Qualcomm, Huawei/HiSilicon, OPPO, MediaTek |
| Alt 1-1: Guard symbols are configurable subject to UE capability | Nokia/NSB, ZTE, CMCC, Samsung, NTT DCM, vivo, CATT, LG, Ericsson, InterDigital, Lenovo/MotM |

***FL Proposal 3-1:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support Alt 1-0 which is aligned with RAN4 LS. Without new input from RAN4, RAN1 should stick to the existing design. |
| DOCOMO | Support Alt 1-1.  |
| Ericsson | Support Alt 1-1 to make NR AS as flexible as LTE AS.  |
| InterDigital | Support Alt 1-1 |
| Huawei, HiSilicon | Support Alt 1-0. Rel-15 conclusion for guard symbol should be used unless a new performance metric is agreed for antenna switching time in RAN 4. |
| Samsung | Support Alt 1-1. |
| MTK | Support Alt 1-0 |
| QC | Support Alt 1-0.One note: per earlier RAN1 agreement, Rel-15 behavior is baseline if none of the enhancement is agreed. **Agreement*** On the presence of guard symbols in Rel-17 for SRS antenna switching, down-select one of the following
	+ Alt 1-0: Guard symbols are always-on, which is same as Rel-15
	+ Alt 1-1: Guard symbols are configurable subject to UE capability
* On whether to introduce guard symbols between SRS resource sets for antenna switching, down-select one of the following
	+ Alt 2-0: Do not introduce guard symbols between SRS resource sets, i.e., guard symbols only appears between SRS resources in a resource set
	+ Alt 2-1: Introduce guard symbols between two sets mapped to consecutive slots
* Note: Rel-15 guard period symbols are supported if none of the above enhancements is agreed
 |
| Lenovo/MotM | Support Alt 1-1. |
| Xiaomi | Support Alt.1-0 |
| LGE | Support Alt 1-1 to save unnecessary overhead of guard symbol. |
| Intel | Support Alt 1-0. Also agree with QC that following previous agreement, Rel-15 scheme should be supported if there is no consensus. |
| vivo | Support Alt 1-1. |
| CATT | Support Alt 1-1 to avoid unnecessary overhead and transmission latency of SRS. |
| Nokia/NSB | Support Alt 1-1.  |

**Remaining issue of inter-set GP**

One FFS point for inter-set GP is how/whether to handle the case where the interval between SRS resource sets is larger than Y.

Table 3-2

|  |
| --- |
| **How/whether to handle the case where the interval between SRS resource sets is larger than Y** |
| Alternatives | Companies |
| Alt 1: UL/DL signals are allowed to be transmitted in the interval between SRS resource sets for antenna switching when the interval is larger than Y symbols, i.e., no scheduling restriction | Huawei/HiSilicon, NTT DOCOMO |
| Alt 2: If the interval between two SRS resource sets for antenna switching is larger than Y symbols, the position of guard period for scheduling restriction is the last Y symbols of the interval. | CATT |
| Alt 3: If the interval between two SRS resource sets for antenna switching is larger than Y symbols, the position of guard period for scheduling restriction is the first Y symbols of the interval | OPPO |
| No need to handle this case | Qualcomm, Intel, LGE |

***FL Proposal 3-2 (conclusion):*** *If the interval between SRS resource sets is larger than Y, there is no scheduling restriction.*

Supported by Huawei/HiSilicon, NTT DCM, Ericsson, Lenovo/MotM, Xiaomi, Nokia/NSB, vivo

Concerned by OPPO, QC, LGE, Intel, CATT

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | To avoid mis-understanding, FL would like to check whether the proposed conclusion from HW in the first round is okay to companies. @Qualcomm, @Intel, when you said there is no need to handle this case, do you mean all the symbols (which is larger than Y) in the interval is used for scheduling restriction, or there is no scheduling restriction in the interval as the conclusion says.  |
| OPPO | We are ok to not handle this case, but not support the conclusion, since it will have some impact on RAN4 requirement.  |
| DOCOMO | We think the following text in R1-2112483 (the latest draft CR for 38.214) needs to be revised if we agree no scheduling restriction is needed. Thus, we believe FL Proposal 3-2 should be Agreement, not Conclusion. === Section 6.2.1.2 in 38.214 (in R1-2112483) ===The UE is configured with a guard period of Y symbols, in which the UE does not transmit any other signal, in the case the SRS resources of a set are transmitted in the same slot. The guard period is in-between the SRS resources of the set. For two SRS resource sets of an antenna switching located in two consecutive slots, if UE is capable of transmitting SRS in all symbols in one slot, a guard period of Y symbols exists between the last OFDM symbol occupied by the SRS resource set in the first slot and the first OFDM symbol occupied by the SRS resource set in the second slot. |
| Ericsson | Agree with conclusion/agreement.  |
| Huawei, HiSilicon | Support FL proposal. We do think clarifying the behavior when the interval between SRS resource sets is large than Y and reaching a consensus are essential to the completion of Rel-17 aperiodic antenna switching. Otherwise, it seems a spec hole for scheduling, where gNB does not know whether UE understand there could be data in the interval or not. Considering that the gap between two SRS resource sets on consecutive slots could be more than 20 symbols, we believe allowing signal transmission in the interval between two SRS resource sets when the interval is larger than Y symbols following similar principle of Rel-15 1T4R is reasonable.To OPPO, if no conclusion or agreement, then could you explain how to understand the symbols between two SRS resource sets which is large than Y, are them for data scheduling or not? Anyway, we need a clear understanding for the issue.To DCM, both conclusion and agreement are fine, the intention is to address the existed issue. The current draft version of spec is not clear for data scheduling, so we need to address the issue. |
| QC | @FL: Yes, gNB should do proper scheduling and RRC configuration to make sure that the minimum guard symbol exists between the two sets. Similar behavior of Rel-15 should be kept on UE behavior. No need to discuss scheduling restriction. |
| Lenovo/MotM | We support to have a conclusion for a clear understanding on those symbols. |
| Xiaomi | Fine with FL proposal |
| LGE | We have similar view with QC that no need to discuss scheduling restriction. There is no scheduling restriction for (first symbol of) second slot right after antenna switching SRS resource in the last symbol of first slot, in legacy behavior. |
| Intel | @FL, we think this could be up to gNB implementation. There is no need to have such conclusion. |
| Spreadtrum | Support FL proposal |
| vivo | No need to handle this case but we can live with the conclusion. |
| CATT | Not support the proposal. It is our view that if the interval between SRS resource sets is larger than Y, scheduling of DL signals/other UL signals in the interval should be allowed. However, “there is no scheduling restriction” is not correct. In the interval, at least Y symbols should be reserved to be guard period and cannot be scheduled with signals, isn’t it? |
| Nokia/NSB | Agree with Docomo that the Proposal 3-2 should be Agreement, not Conclusion.  |
| Huawei, HiSilicon2 | @QC, LGE: In Rel-15, there is no GP defined between two SRS resource sets, which means there is no need to discuss any scheduling restriction. However, since GP has been introduced between two SRS resource sets in Rel-17, the behavior should be clarified as an agreement or a conclusion to ensure the completeness of spec.@Intel: In our opinion, up to gNB implementation means no scheduling restriction, which is aligned with the FL proposal.@CATT: If the interval between SRS resource sets is larger than Y, the most straightforward way is to follow the design principle of 1T4R in Rel-15, where there doesn’t exist any scheduling restriction on the interval.If no any conclusion/agreement, how can UE to understand the gNB’s implementation? UE will be confused whether there is data on the symbols. |
| QC2 | Yes, there should be scheduling restriction between the two sets regardless of the length of the guard period. gNB by proper configuration and scheduling should make sure that minimum guard period exits and avoids unnecessary large guard period.  |

## 4T6R configurations

The situation of this issue is summarized as following.

***FL Proposal 3-3A:*** *For 4T6R configuration, support two SRS resources with 4 ports in one resource and 2 ports in another resource.*

* *The two resources are distributed in 1 or 2 sets for aperiodic SRS*

Supported by Intel, Xiaomi, CMCC, NEC, Samsung, NTT DCM, Qualcomm, ZTE, CATT, OPPO, LG, Apple

Other alternatives:

|  |  |
| --- | --- |
| Alt 2-1: 2 + 2 + 2* No guard symbols exist between the 1st and the 2nd transmission. Y guard symbol(s) exist between 2nd and 3rd transmission, where Y is same as the value defined in the current specification for different SCSs
 | vivo |
| Alt 2-2: 2+2+2* For SCS=15, 30 and 60KHz: No guard symbols exist
* For SCS=120 KHz: No guard symbols exist between the 1st and the 2nd transmission, and 1 guard symbol exists between the 2nd and 3rd transmission
 | CMCC (1st), Nokia/NSB, InterDigital, Huawei/HiSilicon, Ericsson, Spreadtrum |

Given the above situation, FL suggests the following compromised proposal to move forward.

***FL Proposal 3-3B:*** *On SRS configuration for 4T6R, gNB can configure one of the following two configurations to UE subject to UE’s capability*

* *Alt 1: 4+2*
	+ *The two resources are distributed in 1 or 2 sets for aperiodic SRS*
* *Alt 2: 2+2+2,*
	+ *For SCS=15, 30 and 60KHz: No guard symbols exist*
	+ *For SCS=120 KHz: No guard symbols exist between the 1st and the 2nd transmission, and 1 guard symbol exists between the 2nd and 3rd transmission*
	+ *The three resources are contained in 1 set for aperiodic SRS*
* *Note: For UEs supporting 4T6R, whether Alt 1 or Alt 2 is mandatory can be discussed in UE capability session*

Supported by NTT DCM, Ericsson, InterDigital, Huawei/HiSilicon, Nokia/NSB

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | Companies are encouraged to share your view on FL proposal 3-3B.  |
| OPPO | Not support Alt.2 due to the concern on the guard period.One more question for Alt.2: How to differentiate Alt.2 and 2T6R?  |
| DOCOMO | We are generally supportive of such compromised direction, but isn’t it RAN4’s responsibility to determine whether it is possible to have 1) no guard symbol for SCS = 15, 30, 60 kHz and 2) only 1 guard symbol between 2nd and 3rd transmission in case of 120 kHz SCS? If this is correct understanding, we think an LS to ask it to RAN4 would be necessary, and the detail of Alt 2 depends on its reply.  |
| Ericsson | Support introduction of a UE capability, but I wonder if we only need a UE capability for Alt.2, where Alt.1 is the default? All 6R UE should be able to support Alt.1, while support for Alt.2 is more advanced (but also gives benefits). Also, the proposal is a compromise, not compromised, right 😉 |
| InterDigital | Our preference is Alt2, as we have argued before, we see performance issues dure to power imbalance with Alt1, however for the progress we could support FL proposal. |
| Huawei, HiSilicon | Support Alt.2.To OPPO, why we need to differentiate Alt.2 and 2T6R? It is not design principle. Actually, Alt.2 is without GP in the 4T6R case, but GP is required for 2T6R.We have strong concern on Alt.1 for the issues on power imbalance and coverage loss for 3dB as we mentioned in last rounds feedback. But we are willing to compromise in the last meeting. |
| Samsung | Support Alt.1. |
| Futurewei | Support Alt. 2 and have concerns on Alt. 1. |
| QC | Support Alt 1. We have strong concerns on Alt 2 without guard symbols between the SRS resources.  |
| Lenovo/MotM | We share the same comment on the 1st sub-bullet of Alt2 since it is not aligned with Rel-15 spec. Alternatively, guard symbol(s) can be configured according to UE capability reporting. |
| Xiaomi | Support Alt.1 |
| LGE | Support Alt 1 only. We don’t think that the UE capability is needed for some part(4T6R configuration) of specific UE behavior(antenna switching). Also, regarding no guard symbol between SRS resources, we need opinion from RAN4. |
| Intel | We still don’t understand the motivation to have Alt 2 (3 SRS resources, 2+2+2).As we commented in previous round, the power imbalance also exists for Alt 2, for example, if the UE PA architecture is [23 23 23 17] dBm.Regarding supporting both configuration of Alt 1 and Alt 2, this is over complicated design.Therefore, we only support FL Proposal 3-3A and do not support FL Proposal 3-3B. |
| *FL* | The current situation is summarized as above. Still, the majority of companies support 3-3A. Given we need to complete 4T6R in this meeting, I’d like to encourage companies to be more flexible on 3-3A given this is the majority view. |
| vivo | We can accept Alt 2. We believe UE can achieve antenna switching with no guard symbol between 1st and 2nd transmission, but we doubt only 1 guard symbol between the 2nd and 3rd transmission is sufficient. Thus, share similar view with DOCOMO, it should be check with RAN 4 to confirm guard symbol length between 2nd and 3rd transmission. |
| CATT | Support Alt 1. |
| Nokia/NSB | Support FL’s proposal. However, similar to Ericsson, we would like to get further clarification why Alt 2 is only subject to UE capability and Alt 1 not? |
| *FL* | The proposal is updated based on the comments from Ericsson and Nokia. Alt 1 is made as a basic feature for 4T6R UEs while Alt 2 is optional. Hope this can be a better compromise for Alt 1 proponents to accept.  |
| Huawei, HiSilicon2 | Do NOT support proposal 3-3A and the revised 3-3B. We really concerns on 4+2 for power imbalance and 3dB coverage loss.@Intel, the power imbalance problem exists in any antenna architectures for 4+2. Your mentioned issue is for antenna architectures that no proper for 4T6R antenna switching. There exists many cases such as 17+17+17+23, how can 4+2 antenna switching structure deals with this? What we mentioned power imbalance is due to the 3dB power difference between 4-port resource and 2-port resource because of the antenna switching structure, but in RAN4 definition only 3dB gap is allowed for power class 3. Then, how can guarantee there is no insertion loss for antenna switching? |
| *FL* | 3-3B is updated to leave the discussion of mandatory/optional to UE feature session. Now I believe we have stable versions for these two proposals. We will decide 3-3A or 3-3B in the GTW. |
| QC2 | We don’t support Alt 2 unless there is guard period between the SRS resources. Few comments.* Even for legacy devices there is power imbalance between SRS ports due to UE RFFE losses, power amplifier mismatch. As commented earlier, RAN4 specification for this power imbalance can be large up to 7.5dB.
* In addition, using two SRS sets for Alt 1 and do proper configuration of power control parameters, all ports can be sounded with equal power.
* Also, using 2T instead of 4T will underutilize UE maximum TxPower. For example, if we have 4 PAs sized 17dBm each, then maximum Tx Power is 20 dBm with Alt 2. However, Alt 1 can deliver 23 dBm.
* Alt 2 can’t accommodate SRS resource sharing between CB and AS.
* Above all, we don’t think that Alt 2 is feasible neither practical solution.
 |
| vivo | We don’t support to introduce UE capability for this different configuration, we still have concern on 3-3A. |

## Insertion loss compensation

Some companies discussed possible enhancements to compensate the insertion loss cause by antenna switching, especially when the number of switches is large. Companies’ views are summarized as follows.

Table 3-4

|  |
| --- |
| **Insertion loss compensation** |
| Views | Companies |
| Support UE capability reporting of power offset across antenna ports in different SRS resources for insertion loss compensation in DL CSI acquisition | Qualcomm, InterDigital |
| Ericsson proposes to enhance this from a different angle: Support to report ∆TRxSRS = 0 dB as a UE capability (in RAN4) | Ericsson |
| Not needed | Huawei/HiSilicon, OPPO, CMCC |

***FL Proposal 3-4:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | Companies are suggested to share your further views esp. on whether you think it is essential for Rel-17 completion.  |
| OPPO | It is RAN4 issue |
| DOCOMO | Let us repeat our question in the 1st round:* Why is such report, which is NOT supported in Rel-15/16, necessary here in Rel-17? Although we read QC tdoc, we are still struggling to understand why introductions of new Tx-Rx combination results in this proposal.
* What is the impact in RAN1 specification by having this report?
 |
| Ericsson | To DOCOMO, it is necessary since the problem has been observed rather recently by field operations, where we observe that the SRS power between different SRS ports can vary by a huge amount, and this makes reciprocity based operation in TDD deployments for such UEs have poor performance. In Rel.15,16 it was too early to make such observation. I don’t think there is impact to RAN1 spec, it is more information to the network whether this UE can be scheduled in MU-MIMO or not. If SRS measurements are unreliable for reciprocity based operation, then the UE needs to be removed from the candidate pool of MU-MIMO UEs. Note that this is a critical issue for TDD operators using massive MIMO in their deployments and it needs to be enhanced as soon as possible.  |
| Huawei, HiSilicon | No, we do not think this is essential for Rel-17 completion. |
| QC | @DCOCOM:The impact of insertion loss or power mismatch between SRS ports largely affect reciprocity-based DL precoding as this power offset between antennas is only for UL channel and not for the DL channel. This power delta between SRS ports will get worse for 6Rx and 8Rx devices with 1T or 2T as more RF switches are needed to route the signal from the Tx chains/PAs to physical antennas. gNB knowledge of the power offset is very useful to get better estimate of the DL channel from the UL SRS. |
| LGE | It is more likely RAN4 issue. |
| vivo | It should be discussed in RAN 4. |
| Nokia/NSB | We share the same concern as Ericsson and QC regarding to negative impact of power imbalance between UL SRS antenna ports to the performance of reciprocity based DL MU-MIMO precoding w/ 6 RX and 8 RX UEs. From our perspective, this should be discussed in RAN4.  |

## Others

The following issues are discussed by one or two companies.

|  |  |
| --- | --- |
| A 6Rx can report a capability of two, four or six layers of maximum number of DL MMO layers. And 8Rx UE can report a capability of two, four, six or eight layers of maximum number of DL MMO layer. | Qualcomm |
| Consider multi-panel Ues for antenna switching. | Vivo |
| For antenna switching across multiple slots, restrict that the slots are contiguous or within a given period | LG |
| Support antenna switching configuration for mTRP* Two periodic/semi-persistent SRS resource sets for antenna switching in multi-TRP
* The number of aperiodic SRS resource sets in single TRP is K, then number of aperiodic SRS resource sets for xTyR in multi-TRP should be 2\*K
 | Intel, vivo |
| Clarify how UE should handle OFDM symbols including potential guard period(s) associated with UL SRS antenna switching configuration between non-consecutive UL SRS symbols | Nokia/NSB |
| Support simple indication (e.g. RRC) in Rel-17 whether antenna correspondence holds or not between UL SRS transmission and DL DMRS reception | Nokia/NSB |
| Support N=1 for 1T4R aperiodic SRS | CATT |

Companies’ further views on the above issues are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | This part is kept in case we miss anything essential for Rel-17 completion. |
| CATT | Since N=1 SRS resource set for aperiodic SRS configuration is supported for 1T6R and 1T8R, it is natural to support N = 1for 1T4R. |
| Ericsson | Support N=1 for 1T4R aperiodic SRS as proposed by CATT |

# Coverage and capacity enhancements

## RB-level partial frequency sounding (RPFS)

This section summarizes companies’ views on remaining issues for RPFS.

### 4.1.1 PF values

Companies discuss details about additional values for PF. Companies’ views are summarized as follows.

Table 4-1

|  |
| --- |
| **Additional PF values** |
| Values | Companies |
| Support additional PF values | * vivo: Support {3, 8, 12}
* Futurewei: 3, 8, 12, 16, and fractional numbers
* Huawei/HiSilicon: Support 3 if $m\_{SRS, B\_{SRS}}$ is a multiple of 3
 |
| Do not support additional PF values  | Intel, CMCC, OPPO |

For PF values, given there is no consensus on whether and how to support PF values other than {2, 4}, FL recommends the following.

***FL Proposal 4-1:*** *No consensus to support PF values other than {2, 4} for RPFS in Rel-17.*

Supported by Intel, CMCC, OPPO, LGE, NEC, Samsung, Ericsson, Qualcomm, Lenovo/MotM, CATT, Spreadtrum, Xiaomi, Nokia/NSB, Apple, Huawei/HiSilicon,

Add more P\_F values: Futurewei, NTT DCM

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| DOCOMO | Still we believe it should be supported. If Alt 1 is taken in FL Proposal 4-5 (we think that is what no consensus there means), we do not see an issue for introducing larger value(s) for P\_F.  |
| Ericsson | OK  |
| Huawei, HiSilicon | Fine for FL proposal 4-1. Although we think introducing 3 can bring some benefit in some scenarios, here for the sake of progress we can accept the proposal. |
| Samsung | Support FL proposal |
| MTK | Fine with FL proposal |
| Futurewei | Agree with DOCOMO. |
| QC | Support the FL proposal.  |
| Xiaomi | Support the FL proposal.  |
| LGE | Support the FL proposal. |
| Intel | Ok with FL proposal |
| Spreadtrum | Support the FL proposal. |
| vivo | For the sake of progress, we can live with the proposal. |
| CATT | Support the FL proposal. |
| Nokia/NSB | Support FL proposal. |

### 4.1.2 Start RB location hopping

The remaining issues of start RB location hopping includes three aspects

* Whether to extend start RB location hopping to aperiodic SRS
* Whether to support start RB location hopping within a legacy FH period

**Whether to extend start RB location hopping to aperiodic SRS**

Based on the first-round discussion, the following two options are selected for further discussion as they are supported by more companies.

Table 4-2

|  |
| --- |
| **Whether to extend start RB location hopping to aperiodic SRS** |
| Views | Companies |
| For aperiodic SRS, support same start RB location hopping approach as for P/SP SRS | ZTE, Huawei/HiSilicon, Ericsson, Futurewei, LGE, NEC, Qualcomm, MediaTek, Xiaomi, CMCC, NTT DCM, OPPO |
| Start RB location hopping is not applicable on aperiodic SRS |  vivo |

Based on majority view, the following proposal is given.

***FL Proposal 4-2:*** *For aperiodic SRS, support same start RB location hopping approach as for P/SP SRS.*

Supported by ZTE, Huawei/HiSilicon, Ericsson, Futurewei, LGE, NEC, Qualcomm, Xiaomi, CMCC, NTT DCM, OPPO, vivo, Nokia/NSB, Lenovo/MotM

Support to apply start RB hopping on aperiodic SRS but prefer a different pattern: MediaTek, Intel

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | FL encourages companies to share your view about the two options in the above table 4-2, and whether proposal 4-2 is acceptable. |
| OPPO | Although we doubt the benefit, we can live with it if majority companies support it.  |
| DOCOMO | We are fine with FL Proposal 4-2.  |
| Ericsson | Support. A-SRS is the cornerstone of massive MIMO for TDD in high load.  |
| Huawei, HiSilicon | Support FL proposal 4-2. Extending start RB location hopping to aperiodic SRS can be useful when there is more than one FH period for aperiodic SRS. |
| MTK | Support apply to A-SRS. We don’t agree to have sentence “*same start RB location hopping approach as for P/SP SRS*”, which means in the same way as in inter legacy FH period, right? This should be the separate topic discussed in the next.  |
| Futurewei | Support |
| QC | Support extension of P/SP startRB hopping to AP SRS when more than one legacy FH exits within the slot |
| Lenovo/MotM | We support apply start RB location hopping to AP-SRS but the hopping pattern should be discussed separately. |
| Xiaomi | Support the FL proposal.  |
| LGE | We don’t have strong view, but if supported, the existing start RB index hopping pattern is sufficient. And, we think start RB index indication via triggering DCI can be considered, since full partial band hopping is impossible in some cases with less SRS symbols within a slot. |
| Intel | We are still not clear about the benefit. But if most companies support, we could be open.Several points to clarify.1. Similar view as MTK, the same start RB hopping as P/SP SRS is not needed. This should be the next level details.2. What’s the repetition factor? Does it apply to R=1 or R>1 or both? |
| *FL* | It seems most of the companies are okay to extend start RB hopping to aperiodic SRS. @Intel, @MTK, @Lenovo,Given this is already the last meeting, to have a different pattern agreed within the last a few days is nearly impossible. Is this proposal acceptable to you given there is super majority view?On the question from Intel, the current proposal applies on both R=1 and R>1. As long as there is multiple legacy hopping periods, the existing start RB hopping mechanism can be applied. The spec impact is just to add a column for aperiodic SRS in the first row of Table 6.4.1.4.3-3 in 211. |
| vivo | Although we still think benefit is not clear, for the sake of progress, we can accept above proposal on the condition that the sentence of “same start RB location hopping approach” is kept.  |
| Nokia/NSB | For the sake of progress, we are fine with FL Proposal 4-2. |

**Whether to support start RB location hopping within a legacy FH period**

Companies’ views on this aspect are summarized as follows.

Table 4-3

|  |
| --- |
| **Whether to support start RB location hopping within a legacy FH period** |
| Views | Companies |
| Yes | Start RB location hopping is performed across repetition symbols in one SRS resource when R>1 | MediaTek, Spreadtrum |
| Start RB location hopping is performed across SRS occasions in one legacy FH period | CATT |
| No or deprioritize | NTT DCM, Huawei/HiSilicon, vivo, OPPO, LGE |

***FL Proposal 4-3:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Not necessary |
| Huawei, HiSilicon | Not necessary. We think this is not essential for Rel-17 completion. |
| MTK | Support start RB location hopping within a legacy FH period when R>1 |
| Futurewei | Can deprioritize  |
| Xiaomi | Not necessary |
| LGE | Prefer to deprioritize. |
| vivo | Not needed. |
| CATT | We can support the start RB location hopping is performed across SRS occasions in one legacy FH period or repetition symbols in one SRS resource when R>1. One benefit is that the whole bandwidth can be sounded in one FP period, which helps to improve the channel estimation accuracy and avoid interpolation calculation at UE side. |

### 4.1.3 Applicable cases

Some companies discuss whether to restrict RPFS applicable to FH enabled case only. Companies’ views are summarized as follows.

Table 4-4

|  |
| --- |
| **Whether to restrict the applicable cases for RPFS** |
| Views | Companies |
| Applicable for frequency hopping case only | Intel, CMCC, Qualcomm, OPPO, vivo, Xiaomi |
| Applicable for both frequency hopping and non-frequency hopping cases | NEC, ZTE, Futurewei, CATT, LGE, Spreadtrum, Ericsson, Huawei/HiSilicon, Lenovo/MotM, NTT DCM, Nokia/NSB |

***FL Proposal 4-4:*** *No consensus to restrict the applicable case of RPFS to FH only*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | FL suggests to conclude with the above proposal, which reflects the status of the discussion. |
| OPPO | Support for frequency hopping case only. For non-hopping cases, the current spec can achieve the same purpose.  |
| DOCOMO | Fine with the FL Proposal 4-4  |
| Ericsson | Support the conclusion of no consensus.  |
| Huawei, HiSilicon | Support FL proposal. |
| Samsung | Support FL’s proposal |
| MTK | Support FL’s proposal |
| Futurewei | Support both FH and non-FH.What is the spec impact of the FL proposal? Is RPFS applicable to non-FH or not? It is unclear to us as the previous agreement had only “FFS it is applicable to frequency hopping and non-frequency hopping”. |
| QC | We still think it is redundant solution for non-hopping case.  |
| Xiaomi | Ok with a conclusion |
| Intel | Do not support the proposal.We think the partial sounding is applicable for frequency hopping only. |
| vivo | Support for frequency hopping case only. |
| CATT | Support the proposal. |
| Nokia/NSB | Fine with the FL Proposal 4-4 (conclusion). |
| OPPO2 | We haven’t agreed any scenario where *RPFS* is applicable so far. Does FL’s proposal intend to not support RPFS anymore? By reading all comments, our impression is that:* + Consensus on frequency hopping case
	+ No consensus on non-frequency hopping case
 |
| *FL* | @Futurewei, @OPPO,My understanding of this proposed conclusion is it does not have any specification impact. The spec can be kept as it is. |

### 4.1.4 Further restriction on the number of RBs

One remaining issue is whether to further restrict the number of RBs for SRS transmission in RPFS. Companies’ views are summarized as follows.

Table 4-5

|  |
| --- |
| **Further restriction on the number of RBs for RPFS** |
| Alternatives | Companies |
| Alt 1: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ is an integer value | NEC, ZTE, Futurewei, Ericsson, Huawei/HiSilicon, MediaTek |
| Alt 2: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ is an integer value with minimum value 4 | NEC, NTT DCM, Nokia/NSB, MediaTek, Lenovo/MotM |
| Alt 3: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is a multiple of 4 | Intel, Samsung, Apple, Nokia/NSB, Qualcomm, vivo, OPPO, LG |
| Alt 4: Round $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ to a multiple of 4 in case of Alt 1 or Alt 2 | NEC, Qualcomm, vivo, CATT |

***FL Proposal 4-5:*** *No consensus to have further restriction on the number of RBs for RPFS in Rel-17.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | FL suggests to conclude with the above proposal, which reflects the status of the discussion. |
| OPPO | Alt.3 for the better support of mulitplexing with legacy UEs and improve the efficency of SRS resource. |
| DOCOMO | Our understanding is that no consensus here means RAN1 automatically supports Alt 1. Is it correct?  |
| Ericsson | Support Alt.1 |
| Huawei, HiSilicon | Support FL proposal. The additional restriction is not necessary. To DCM, yes, Alt.1 is already supported in previous agreement. |
| Samsung | Shared same view as OPPO |
| Futurewei | Support. |
| QC | We have raised some concerns on Alt 1 in the previous round of discussion:1. Orthogonality of SRS sequences when SRS sequence is not integer number of maxCS for PF=2,4.
2. Multiplexing with legacy UEs.
3. MPR issues for 1,2,3 RBs especially at edge of the band.
 |
| Lenovo/MotM | If wo don’t restrict the minimum value of $\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$, additional discussion is required on how to handle the case when the resulted SRS sequence length is less than the Max #CS for Comb 2 and Comb 4. |
| Xiaomi | Multiplexing with legacy UEs would be an issue. |
| LGE | If there is no consensus, Alt 3 should be the baseline since the minimum SRS subband size is 4 RBs in legacy behavior. We also agree with OPPO, Samsung, and QC that it is better for multiplexing between legacy SRS and Rel-17 SRS. |
| Intel | We think Alt 3 should be supported.In RAN1 #104-e meeting, we agreed that for partial sounding, “No new sequence including length is introduced”.Other Alternatives will generate new sequence and change our previous agreement. |
| vivo | Support Alt 3 or Alt 4. And if no consensus to support Alt 1/2/4, Alt 3 should be the default. |
| CATT | We have similar concerns with QC. |
| Nokia/NSB | Support Alt.2 or Alt. 3. |
| Ericsson | As we have iterated many times, Alt2,3 and 4 provides very slight difference to what can be achieved with legacy SRS configuration. To QC, we need further restrictions in some cases to maintain orthogonality.  |
| Huawei, HiSilicon2 | @QC: following are the responses to your concerns.**Answer 1:** The orthogonality for different UEs can be handled by gNB implementation. Taking Comb 4 with *Max\_CS* of 12 and SRS sequence length of 6 as an example, gNB can allocate even CSs (i.e., 0, 2, 4, 6, 8, 10) to different UEs to ensure orthogonality. For the orthogonality of multi-CSs in a UE, at least 2 CSs are orthogonal for each comb for length 6 or multiple 6. So, there is no issue for the case of port number is 1 or 2 with different CSs. And also no issue for the port number is 4 if the sequence length is multiple of 4. The only case is for the 4-port and the sequence length is multiple of 6 but not multiple of 4. The issue in the case could be addressed with the agreed working assumption for Comb-8 with CS=6 (with more general description with *Max\_CS* instead of 6, *K\_TC* instead of 8), where 4 orthogonal ports for a UE is realized with 2 Combs and each Comb with 2 orthogonal CSs: * + *Port 0 and Port 2 locate in n\_CS and (n\_CS + Max\_CS/2) mod Max\_CS in comb offset k\_TC respectively.*
	+ *Port 1 and Port 3 locate in n\_CS and (n\_CS + Max\_CS/2) mod Max\_CS in comb offset (k\_TC + K\_TC/2) mod K\_TC, respectively.*

**Answer 2:** The multiplexing issue is not due to the length of sequence, but it is indeed due to the agreed sequence generation for partial sounding. We raised the same issue and propose using truncated sequence generation to address the issue. If I remember correctly, QC insisted to using new sequence generation for partial sounding, which is difficult to multiplex with legacy UE in the previous meetings. Now, it only can be multiplexed by FDM or TDM.**Answer 3:** We do not understand why to discuss MPR issue here. MPR is guaranteed by RAN4 with transmit power limitation and duty cycle no matter how many RBs in scheduling. @Intel: The agreement “No new sequence length is introduced” means length is 6 or multiple 6. It is already a restriction for partial sounding configuration, which is the reason why we say no need further restrictions. With the previous agreement for no new sequence length, it means when comb-2 configured, then any integer number of RB is allowed for partial sounding. But if Comb-4 or 8 configured, then multiple of two or four RBs is required for partial sounding. |
| QC2 | Thanks for the responses by Huawei and Ericsson! Is the common understanding this restriction is done by gNB implementation? Regarding the MPR for <4RBs, the power back-off will take away the coverage gain (PSD boost). In addition, based on Huawei’s earlier results in tdoc (**R1-2102338**), there was no gain for PFS $\leq $4RBsChart, bar chart  Description automatically generatedFigure 8. Performance comparison of legacy SRS and partial SRS for 4RBs hopping bandwidth |

### 4.1.5 Dynamic signaling to determine PF and kF

It has been agreed that RRC signaling is used to indicate PF and kF. The following is to discuss whether more dynamic signaling, e.g., MAC CE or DCI can also be used to update these two values.

Table 4-6

|  |
| --- |
| **Signaling to determine PF and kF** |
| Alternatives | Companies |
| Use MAC CE to update P\_F and/or k\_F | CMCC, NTT DCM, Lenovo/MotM, CATT, Futurewei |
| Use DCI to indicate P\_F and/or k\_F | Lenovo/MotM, CATT, LG, Futurewei, LGE |
| Do not support to use MAC CE or DCI | Samsung, Nokia/NSB, Qualcomm, vivo, Spreadtrum, Ericsson, OPPO, Intel |

***FL Proposal 4-6:*** *No consensus to use MAC CE or DCI to update P\_F and/or k\_F in Rel-17*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | FL suggests to conclude with the above proposal, which reflects the status of the discussion. |
| OPPO | No need to support MAC-CE or DCI  |
| DOCOMO | Proper value for P\_F depends on some aspects which could be dynamically changed, e.g. pathloss. Therefore, we still believe the use of MAC CE to update P\_F is essential to make RPFS work, especially for periodic/semi-persistent SRS.  |
| Ericsson | Support the conclusion |
| Huawei, HiSilicon | Support FL proposal. |
| Samsung | Support FL’s proposal |
| Futurewei | Agree with DOCOMO. |
| QC | Support FL proposal. |
| Xiaomi | Support FL proposal. |
| LGE | At least, we think dynamic start RB index indication for aperiodic SRS can be considered, since full partial band hopping is impossible in some cases with less SRS symbols within a slot. |
| Intel | Support FL proposal |
| Spreadtrum | Support FL proposal |
| vivo | Support FL proposal. |
| CATT | Considering the flexibility, we support MAC CE or DCI to indicate P\_F and/or k\_F.  |
| Nokia/NSB | Support FL’s proposal. |

## Comb-8

The remaining issues for Comb 8 includes

* For the supported Max CS = 6, how 4 ports are supported.
* Whether to support Max CS = 12

### 4.2.1 How to support 4 ports when Max CS = 6

***FL Proposal 4-7 (Working assumption):*** *To support 4 ports with Max CS = 6,*

* *Port 0 and Port 2 locate in n\_CS and (n\_CS+3) mod 6 in comb offset k\_TC, respectively.*
* *Port 1 and Port 3 locate in n\_CS and (n\_CS+3) mod 6 in comb offset (k\_TC + 4) mod 8, respectively.*
* *Note: n\_CS and k\_TC are the configured CS and comb offset values.*
* *Note: This working assumption can be revisited if Max CS = 12 is agreed.*

Supported by Samsung, ZTE, vivo, Huawei/HiSilicon, Lenovo/MotM, MediaTek, NTT DOCOMO, Intel, OPPO, Futurewei, Apple

Another alternative: Allow 4 CSs for each comb offset to support 4 ports

Supported by Ericsson

This is just a place holder. We will try to address this issue in email first.

### 4.2.2 Whether to support Max CS = 12

Companies’ views on this aspect are summarized as follows.

Table 4-8

|  |
| --- |
| **Whether to support Max CS = 12** |
| Alternatives | Companies |
| Yes | NEC (when the sequence length is 12), NTT DCM, Nokia/NSB, Qualcomm, MediaTek, Lenovo/MotM, Ericsson, CATT, Intel |
| No | Samsung, Huawei/HiSilicon, Spreadtrum, Futurewei, vivo, OPPO, Spreadtrum, CMCC |

***FL Proposal 4-8:*** *No consensus to support Max CS = 12 for comb-8 in Rel-17.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | FL suggests to conclude with the above proposal, which reflects the status of the discussion. |
| OPPO | Support the conclusion |
| DOCOMO | Seeing some evaluation results by companies which show the feasibility and benefit of 12 CS, we prefer to support max. 12 CS.  |
| Ericsson | Support 12 CS.  |
| Huawei, HiSilicon | Support FL proposal. We do not see the benefits shown in practical scenarios for supporting 12 CSs. Actually it is easy to get the result in analysis that the practical channels are difficult to support Comb-8+12 CSs as details discussed in our Tdoc. |
| Samsung | Support FL’s proposal |
| MTK | Support 12 CS. |
| Futurewei | Support |
| QC | Support 12 CS |
| Lenovo/MotM | Support 12 CS. |
| Intel | Fine to support Max CS=12. |
| Spreadtrum | Support FL proposal |
| vivo | Support FL’s proposal |
| CATT | Support 12 CS. |
| Nokia/NSB | Support 12 CS.  |

## Others

The following issue is discussed by one companies.

|  |  |
| --- | --- |
| Support different repetition factors/SRS bandwidths for different symbols within one SRS resource | Nokia/NSB |
| Support to use RRC, MAC CE and DCI to indicate the Comb number and offset | Futurewei |

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| *FL* | This part is kept in case we miss anything essential for Rel-17 completion. |
|  |  |
|  |  |

# Conclusion

The following proposals are recommended at least for the GTW discussion.

**Star RB location hopping for aperiodic SRS**

***FL Proposal 4-2:*** *For aperiodic SRS, support same start RB location hopping approach as for P/SP SRS.*

Supported by ZTE, Huawei/HiSilicon, Ericsson, Futurewei, LGE, NEC, Qualcomm, Xiaomi, CMCC, NTT DCM, OPPO, vivo, Nokia/NSB, Lenovo/MotM

Support to apply start RB hopping on aperiodic SRS but prefer a different pattern: MediaTek, Intel

**4T6R configuration**

***FL Proposal 3-3A:*** *For 4T6R configuration, support two SRS resources with 4 ports in one resource and 2 ports in another resource.*

* *The two resources are distributed in 1 or 2 sets for aperiodic SRS*

Supported by Intel, Xiaomi, CMCC, NEC, Samsung, NTT DCM, Qualcomm, ZTE, CATT, OPPO, LG, Apple

***FL Proposal 3-3B:*** *On SRS configuration for 4T6R, gNB can configure one of the following two configurations to UE subject to UE’s capability*

* *Alt 1: 4+2*
	+ *The two resources are distributed in 1 or 2 sets for aperiodic SRS*
* *Alt 2: 2+2+2,*
	+ *For SCS=15, 30 and 60KHz: No guard symbols exist*
	+ *For SCS=120 KHz: No guard symbols exist between the 1st and the 2nd transmission, and 1 guard symbol exists between the 2nd and 3rd transmission*
	+ *The three resources are contained in 1 set for aperiodic SRS*
* *Note: For UEs supporting 4T6R, whether Alt 1 or Alt 2 is mandatory can be discussed in UE capability session*

Supported by NTT DCM, Ericsson, InterDigital, Huawei/HiSilicon, Nokia/NSB

**Further restriction on the number of RBs for RPFS**

|  |  |
| --- | --- |
| Alternatives | Companies |
| Alt 1: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ is an integer value | NEC, ZTE, Futurewei, Ericsson, Huawei/HiSilicon, MediaTek |
| Alt 2: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ is an integer value with minimum value 4 | NEC, NTT DCM, Nokia/NSB, MediaTek, Lenovo/MotM |
| Alt 3: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is a multiple of 4 | Intel, Samsung, Apple, Nokia/NSB, Qualcomm, vivo, OPPO, LG |
| Alt 4: Round $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ to a multiple of 4 in case of Alt 1 or Alt 2 | NEC, Qualcomm, vivo, CATT |

***FL Proposal 4-5:*** *No consensus to have further restriction on the number of RBs for RPFS in Rel-17.*

**Whether to support Max CS = 12**

|  |  |
| --- | --- |
| Alternatives | Companies |
| Yes | NEC (when the sequence length is 12), NTT DCM, Nokia/NSB, Qualcomm, MediaTek, Lenovo/MotM, Ericsson, CATT, Intel |
| No | Samsung, Huawei/HiSilicon, Spreadtrum, Futurewei, vivo, OPPO, Spreadtrum, CMCC |

***FL Proposal 4-8:*** *No consensus to support Max CS = 12 for comb-8 in Rel-17.*

# Appendix

## Previous agreements

Table 6-1

|  |
| --- |
| **RAN1#102e****Agreement**Enhance the determination of aperiodic SRS triggering offset, with at least one of the following alternatives* + Alt 1: Delay the SRS transmission to an available slot later than the triggering offset defined in current specification, including possible re-definition of the triggering offset
	+ Alt 2: Indicate triggering offset in DCI explicitly or implicitly
	+ Alt 3: Update triggering offset in MAC CE
	+ Further consideration aspects may include the cost v.s. the total combinations PDCCH and SRS locations for gNB to choose, DCI overhead, multi-UE SRS multiplexing, CA aspect, whether to have multiple opportunities to transmit SRS, etc.

**Agreement**Study the following two alternatives in the scope to enhance at least one DCI format for aperiodic SRS triggering * + Alt 1: Use UE-specific DCI, e.g., extending DCI 0\_1 without uplink data and without CSI
	+ Alt 2: Use group-common DCI, e.g., extending DCI 2\_3 for cases other than carrier switching
	+ Further consideration aspects may include simultaneous or CC-specific SRS triggering for multiple CCs, dynamic indication of SRS frequency resources, etc..

**Agreement**For SRS overhead reduction, study reusing same resources among multiple usages, at least for “codebook” and “antenna switching”. Study aspects include* + Whether implementation approach based on legacy SRS configuration is sufficient
		- If not, and if there are benefits other than RRC overhead reduction, study further on the case that antenna switching and PUSCH have different number of Tx antennas, whether UL BWP for different SRS usages is the same or different, whether and how to ensure UE to use same virtualization, the set of applicable usages, UE implementation complexity and overhead, etc..

**Agreement**For SRS antenna switching up to 8Rx, study the configuration of {1T6R, 1T8R, 2T6R, 2T8R, 4T6R, 4T8R}.* + Study points may include CSI latency, performance considering aspects like insertion loss, use cases, antenna structure, UE power saving, SRS resource configuration, etc..

**Agreement**For SRS coverage/capacity enhancements, evaluate and, if needed, specify one or more from three categories based on the following definition. * + Class 1 (Time bundling): Utilize relationship among two or more occasions of one or more SRS resources in one or more slots to enable joint processing within time domain.
		- Study aspects include the issue of phase discontinuity, interruption of SRS transmission by other UL signals, etc..
	+ Class 2 (Increase repetition): Change the legacy SRS pattern in one resource and one occasion from time domain by increasing SRS symbols for repetition.
		- Study aspects include to use TD-OCC to compensate the negative impact on SRS capacity, inter-cell interference randomization, whether these SRS symbols are in one slot or consecutive slots, etc..
	+ Class 3 (Partial frequency sounding): Support more flexibility on SRS frequency resources to allow SRS transmission on partial frequency resources within the legacy SRS frequency resources.
		- Study aspects include the partial frequency resources are with RB level or subcarrier level (e.g., larger comb, partial bandwidth), PAPR issue, etc..

**RAN1#103e****Agreement**A given aperiodic SRS resource set is transmitted in the (t+1)-th available slot counting from a reference slot, where t is indicated from DCI, or RRC (if only one value of t is configured in RRC), and the candidate values of t at least include 0. Adopt at least one of the following options for the reference slot.* Opt. 1: Reference slot is the slot with the triggering DCI.
* Opt. 2: Reference slot is the slot indicated by the legacy triggering offset.
* FFS the detailed definition of “available slot” considering UE processing complexity and timeline to determine available slot, potential co-existence with collision handling, etc., e.g.,
	+ Based on only RRC configuration, “available slot” is the slot satisfying: there are UL or flexible symbol(s) for the time-domain location(s) for all the SRS resources in the resource set and it satisfies the minimum timing requirement between triggering PDCCH and all the SRS resources in the resource set
* FFS explicit or implicit indication of t
* FFS whether updating candidate triggering offsets in MAC CE may be beneficial

**Agreement**Support at least DCI 0\_1 and 0\_2 to trigger aperiodic SRS without data and without CSI.* FFS whether/how to re-purpose the unused fields, e.g., the triggering offset(s) and the frequency resources for triggering A-SRS on one or more component carriers, SFI-index, etc.
* FFS UL/DL DCI with data for aperiodic SRS
* FFS group common DCI

**Agreement**In Rel-17 SRS coverage and capacity enhancement, support at least one scheme from Class 2 and Class 3, and deprioritize Class 1.* Note: Extensions of Rel-15/16 frequency hopping are included in Classes 2 and 3, e.g. where UE hops once per symbol within a Rel-17 SRS resource.

**Agreement**Candidate schemes for Class 2:* Scheme 2-0: Increase the number of repetition symbols in one slot
* Scheme 2-1: Inter-slot repetition on consecutive symbols or non-consecutive symbols across slots
* Scheme 2-2: Repetition with TD-OCC
* Scheme 2-3: Repetition with CS hopping

Candidate schemes for Class 3:* Scheme 3-1: RB-level partial frequency sounding
* Scheme 3-2: Subcarrier-level partial frequency sounding
* Scheme 3-3: Subband-level partial frequency sounding
* Scheme 3-4: Partial-frequency sounding schemes assisted with CSI-RS, where SRS is transmitted in a subset of RBs of the original SRS frequency resource
* Scheme 3-5: Dynamic change of SRS bandwidth with RB-level subband size scaling
* Note: Consider issues like gNB receiver complexity, PAPR, etc., with above schemes
* Note: Joint operation between Class 2 and Class 3 schemes can be considered

**Agreement**For antenna switching up to 8Rx, support SRS resource configurations for {1T6R, 1T8R, 2T6R, 2T8R, [4T6R], 4T8R}.**RAN1#104e****Agreement**For Rel-17 SRS capacity and coverage enhancement, support the following* Increase the maximum number of repetition symbols in one slot and one SRS resource to S
	+ Support at least one S value from {8, 10, 12, 14}
		- FFS other candidate values
* Support to transmit SRS only in $\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ contiguous RBs in one OFDM symbol, where$m\_{SRS,B\_{SRS}}$  indicates the number of RBs configured by BSRS and CSRS
	+ Support at least one PF value from {2, [3], 4, 8}
		- FFS other candidate values, e.g., non-integer values for PF
	+ Note: SRS sequence shorter than the minimum length supported in the current specification is not pursued.
	+ No new sequence including length is introduced
	+ FFS it is applicable to frequency hopping and non-frequency hopping
	+ FFS detailed signaling mechanism to determine PF and the location of the $\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ RBs
* Support Comb 8
	+ Note: SRS sequence shorter than the minimum length supported in the current specification is not pursued.
* FFS whether and if needed, how to use harmonized approach to define the three supported schemes
* Note: other schemes for SRS capacity and coverage enhancements are not supported in Rel-17.

**Agreement*** For aperiodic antenna switching SRS, support to configure N <=N\_max resource sets, where totally K resources are distributed in the N resource sets flexibly based on RRC configuration.
	+ For 1T6R, K=6, N\_max = [4], and each resource has 1 port.
	+ For 1T8R, K=8, N\_max = [4], and each resource has 1 port.
	+ For 2T6R, K=3, N\_max = [3], and each resource has 2 ports.
	+ For 2T8R, K=4, N\_max = [4], and each resource has 2 ports.
	+ (Working Assumption) For 4T8R, K=2, N\_max = [2], and each resource has 4 ports.
	+ FFS the number of supported candidate values of N for each xTyR.
* FFS extension to increase N\_max for 1T4R, 2T4R, T=R and 1T2R cases for aperiodic, periodic and semi-persistent SRS resources
* FFS the number of resources and resource sets for semi-persistent and periodic antenna switching SRS
* Note: SRS could be transmitted over the last 6 OFDM symbols, or over any OFDM symbols within the slot subject to UE capability.

**Agreement**Further study whether and if needed, how to achieve further enhancements on aperiodic SRS triggering and resource management based on repurposing unused fields in DCI format 0\_1/0\_2 without data and without CSI. Consider the following examples* CAT A: Time-domain parameters
	+ A-1: Indication of available slot position, i.e., the t values
	+ A-2: Indication of slot offset
	+ A-3: Indication of SRS symbol-level offset
	+ A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting
* CAT B: Frequency-domain parameters
	+ B-1: Indication of a group of CCs for SRS transmission
	+ B-2: Indication of frequency domain resource in a BWP for SRS transmission
	+ B-3: Indication of whether DL/UL BWP is applied for SRS transmission
* CAT C: Power control parameters
	+ C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’
		- FFS impact on power control, impact from triggering a group of CCs for SRS
	+ C-2: Indication of open loop power control parameter e.g., p0.
* CAT D: Spatial-domain parameters, i.e., indication of SRS port and beamforming
* CAT E: Extend the number of DCI codepoints for aperiodic SRS trigger states
* Other examples are not precluded

**Agreement**A list of t values is configured in RRC for each SRS resource set. Adopt at least one of the following for DCI indication of t.* In DCI format 0\_1/0\_2 without data and without CSI request,
	+ Alt 1-1: Reuse the same scheme used for DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH
	+ Alt 1-2: Re-purpose unused DCI field to indicate t
	+ Alt 1-3: t is indicated by a configurable DCI field, where the DCI field may contain bits from unused fields and additional bits configured by gNB
		- FFS design details with other potential field(s)
	+ FFS: whether t can be slot offset
* In DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH
	+ Alt 2-1: t is indicated by adding a new configurable DCI field
	+ Alt 2-2: t is indicated without adding DCI payload
* Note: The size of DCI payload does not change dynamically
* Note: RAN1 should strive for unified solution for different DCI formats.
* FFS: The number of RRC configured t values per SRS resource set and DCI bit field size.

**Agreement**Confirm the following working assumption with modificationsAn “available slot” is a slot satisfying there are UL or flexible symbol(s) for the time-domain location(s) for all the SRS resources in the resource set and it satisfies UE capability on the minimum timing requirement between triggering PDCCH and all the SRS resources in the resource set.* From the first symbol carrying the SRS request DCI and the last symbol of the triggered SRS resource set, UE does not expect to receive SFI indication, UL cancellation indication or dynamic scheduling of DL channel/signal(s) on flexible symbol(s) that may change the determination of “available slot”.
* Note: Collision handling between the triggered SRS and any other UL channel/signal is performed after the determination of available slot.
* FFS: Rules to handle the case of multiple SRS resource sets with overlapping symbols and/or triggered by a same DCI

**RAN1#104bis-e****Agreement**For increased repetition in Rel-17, support the following N\_symbol (number of OFDM symbols in one SRS resource) and R (repetition factor) values* N\_symbol = 8, R = {1, 2, 4, 8}
* N\_symbol = 12, R = {1, 2, [3], 4, 6, 12}
* FFS the following configurations
	+ N\_symbol = 10, R = {1, 2, 5, 10}
	+ N\_symbol = 14, R = {1, 2, 7, 14}
* FFS options to reduce SRS BW for R>1

**Agreement**On aperiodic SRS configuration for antenna switching with > 4Rx, support the following N\_max values* 1T6R: N\_max = 3
* 1T8R: N\_max = 4
* 2T6R: N\_max = 3
* 2T8R: N\_max = 4
* [4T8R: N\_max = 2]
* The support of N\_max value does not imply the support of N value that is smaller than N\_max. This is FFS.
* FFS whether further enhancement for single-DCI or multi-DCI based MTRP is needed

**Agreement**For RB-level partial frequency sounding (RPFS) in Rel-17* The start RB index of the $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ RBs in the $m\_{SRS, B\_{SRS}}$ RBs is $N\_{offset}=\frac{k\_{F}}{P\_{F}}m\_{SRS, B\_{SRS}}$, where kF = {0, …, PF-1}
	+ FFS support start RB location (Noffset) hopping in different SRS occasions, symbols or frequency hopping periods, and if supported, detailed hopping pattern
* Support to determine PF and Noffset at least via RRC configuration per SRS resource.
	+ FFS whether to introduce DCI and/or MAC CE in addition

**Working Assumption**For DCI indication of “t” in Rel-17 SRS triggering offset enhancement* For both DCI that schedules a PDSCH/PUSCH and DCI 0\_1/0\_2 without data and without CSI request
	+ t is indicated by adding a new configurable DCI field (up to 2 bits)
		- Applies only when there are multiple candidate values of t configured
	+ No further enhancement to indicate “t” for DCI 0\_1/0\_2 without data and without CSI request at least when the new DCI field is configured

**Agreement**On supported values of N for Rel-17 aperiodic SRS antenna switching with >4Rx, down-select at least one of the following alternatives in RAN1#105e* Alt 1: All the non-zero integer values <= N\_max are supported for N
* Alt 2: Support N=N\_max only
* Alt 3: Support specific N values <= N\_max
* FFS whether different alternatives may be selected for the same xTyR configuration subject to the UE capability on maximum number of symbols that can be used for SRS in a slot
* FFS: whether different alternatives may be selected for different xTyR configuration

**Agreement**Study the maximum number of cyclic shifts for Comb-8 in Rel-17, with the following alternatives as starting points* Alt 1: The maximum number of CSs for Comb-8 is 6
* Alt 2: The maximum number of CSs for Comb-8 is 12, and introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs

**Agreement*** Up to 4 “t” values can be configured per SRS resource set.

**Agreement*** For RPFS in Rel-17, support PF = {2, 4}.
* FFS 3, 8, 12, 16 or fractional numbers
* Support at least one of the following alternatives (to be decided in RAN1#105-e)
	+ Alt 1: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is an integer value
	+ Alt 2: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is an integer value with minimum value 4
	+ Alt 3: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is a multiple of 4
	+ Alt 4: Round $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ to a multiple of 4 in case of Alt 1 or Alt 2

**Agreement**On aperiodic SRS configuration for antenna switching with 4T8R, support N\_max = 2**Agreement**For RPFS SRS in Rel-17, adopt one of the following alternatives for sequence generation, where no new sequence length other than the ones supported in the current spec is introduced (to be decided in RAN1#105-e)* Alt 1: Generate length- $\frac{12}{Comb⋅P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{\frac{12}{P\_{F}}m\_{SRS, B\_{SRS}}}{Comb}$ ZC sequence
* Alt 2: Truncate from legacy length-$\frac{12}{Comb}m\_{SRS, B\_{SRS}}$$\frac{12⋅m\_{SRS, B\_{SRS}}}{Comb}$ sequence according to the location of RPFS SRS

**Agreement**For antenna switching, support one of the following * Alt 1: Support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS
* Alt 2: Support up to two semi-persistent SRS resource sets in addition to a periodic SRS resource set
	+ Note: the two SP-SRS resource sets are not activated at the same time.
* FFS whether further enhancement for single-DCI or multi-DCI based MTRP is needed
* FFS whether configurations on SRS repetitions have impact
* FFS relevant UE capability design

**RAN1#106-e****Agreement**Confirm the following WA:For DCI indication of “t” in Rel-17 SRS triggering offset enhancement* For both DCI that schedules a PDSCH/PUSCH and DCI 0\_1/0\_2 without data and without CSI request
	+ t is indicated by adding a new configurable DCI field (up to 2 bits)
		- Applies only when there are multiple   candidate values of t configured
	+ No further enhancement to indicate “t” for DCI 0\_1/0\_2 without data and without CSI request at least when the new DCI field is configured

**Agreement**Support start RB location (Noffset) hopping in different SRS frequency hopping periods for RPFS and at least periodic/semi-persistent SRS, where Noffset is the start RB index of the $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ RBs in the $m\_{SRS, B\_{SRS}}$ RBs.* For a given SRS transmission occasion, $N\_{offset}=\frac{\left(k\_{F}+k\_{hopping}\right) mod P\_{F}}{P\_{F}}m\_{SRS, B\_{SRS}}$ , where khopping is same for all SRS occasions within a legacy FH period but changes across legacy FH periods, kF and PF are at least configured by RRC signaling (kF = {0, 1, …, PF-1}).
* Support at least one pattern for khopping in time domain, FFS detailed pattern
* Note: the legacy FH period is the period to sound the full SRS hopping bandwidth across the different subbands of $m\_{SRS, B\_{SRS}}$ RBs each.
* This start RB location hopping is enabled or disabled by RRC signaling.
* FFS whether MAC CE or DCI can be additionally used
* When this start RB location hopping is disabled,$k\_{hopping}$ khopping is fixed to be 0 for all SRS symbols
* This start RB location hopping is UE optional.
* FFS whether start RB location hopping is also applicable on SRS occasion(s) within one FH period (e.g., when R>1) and/or on aperiodic SRS, if so, how

**Agreement**For aperiodic xTyR antenna switching SRS, where xTyR is from {1T6R, 1T8R, 2T6R, 2T8R, 4T8R}, support all the non-zero integer values N<=N\_max except N=1 for 1T8R * For each xTyR configuration, UE does not expect multiple SRS resource sets are configured or triggered in one slot
* UE does not expect that the OFDM symbols contained in one SRS resource set exceed UE capability on which OFDM symbols can be used for SRS taking guard period into account

**Agreement**Support Opt. 2: Reference slot is the slot indicated by the legacy triggering offset.* If DCI is transmitted in slot n, and k is the legacy triggering offset, reference slot is slot n+k.
* Note: the legacy triggering offset can be 0, if slotOffset is absent.

**Conclusion**MAC CE for t value update in Rel-17 is not supported.**Agreement**For antenna switching SRS, support maximum one SRS resource set for periodic SRS and maximum 2 SRS resource sets for semi-persistent SRS.* Note: the two SP-SRS resource sets are not activated at the same time
* For xTyR where y>4, if UE does NOT support this feature, support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS
* Applies for all supported xTyR where y<=8
* For each xTyR antenna switching (except for 4T6R if supported), each periodic or semi-persistent resource set contains y/x resources.

This feature is UE optional: For UEs that do not support this feature, follow Rel-15 on the number of resource sets for periodic and semi-persistent SRS**Agreement*** Support 4T6R SRS antenna switching in Rel-17.

**Agreement**For RPFS SRS sequence generation, support * Alt 1: Generate length-$\frac{\frac{12}{P\_{F}}m\_{SRS, B\_{SRS}}}{Comb}$ ZC sequence.

**Agreement**For SRS increased repetitions in Rel-17, support the following configurations, and no other values are supported.* (N\_symbol, R) = {(8, 1), (8, 2), (8, 4), (8, 8), (12, 1), (12, 2), (12, 3), (12, 4), (12, 6), (12, 12), (10, 1), (10, 2), (10, 5), (10,10), (14, 1), (14, 2), (14, 7), (14, 14)}
* Note: N\_symbol SRS symbols are adjacent in a slot.

**Agreement*** On the presence of guard symbols in Rel-17 for SRS antenna switching, down-select one of the following
	+ Alt 1-0: Guard symbols are always-on, which is same as Rel-15
	+ Alt 1-1: Guard symbols are configurable subject to UE capability
* On whether to introduce guard symbols between SRS resource sets for antenna switching, down-select one of the following
	+ Alt 2-0: Do not introduce guard symbols between SRS resource sets, i.e., guard symbols only appears between SRS resources in a resource set
	+ Alt 2-1: Introduce guard symbols between two sets mapped to consecutive slots
* Note: Rel-15 guard period symbols are supported if none of the above enhancements is agreed

**Agreement**For Comb-8 SRS in Rel-17, down-select one of the following in RAN1#106bis-e* Alt 1: The maximum number of CSs for Comb-8 is 6
* Alt 2: The maximum number of CSs for Comb-8 is 12, and introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs

**RAN1#106bis-e****Agreement**For two SRS resource sets of an xTyR antenna switching located in two consecutive slots, if UE is capable of transmitting SRS in all symbols in one slot, a minimum gap period of Y symbols exists between the last OFDM symbol occupied by the SRS resource set in the first slot and the first OFDM symbol occupied by the SRS resource set in the second slot* The value of Y is same as the inter-resource GP defined in Rel-15
* FFS: Whether or not the minimum GP exists can be RRC configurable subject to UE capability
* Whether this inter-set GP is needed for 4T6R can be discussed later per the decision on 4T6R configuration.
* FFS: How/Whether to handle the case where the interval between SRS resource sets is larger than Y

**Agreement**For the detailed pattern of $k\_{hopping}$ when start RB location hopping across legacy FH periods is enabled, support the following* For PF = 2, $k\_{hopping}$ = {0, 1}
* For PF = 4, $k\_{hopping}$ = {0, 2, 1, 3}
* Note: $k\_{hopping}=\{x\_{0},\cdots x\_{P\_{F}-1}\}$ means $k\_{hopping}=x\_{n mod P\_{F}}$ for the (n+1)-th legacy FH period, where n = {0, 1, 2, 3, …}

**Agreement**Bit width of SOI depends on the maximum number of “t” values configured for any of the aperiodic SRS resource sets (FFS: across all CCs or across a CC/BWP)* The SOI field is 0 bit if the maximum number of ‘t’ values is one
* If at least one resource set has “t” configured
	+ For the resource sets with “t” value configured, each of them is configured with K values of “t”, where 1<=K<=4
	+ t=0 applies for the resource set(s) without “t” configured in RRC
* If none of the resource sets is configured with “t” values, follow Rel-15 approach to determine slot offset

**Agreement**For comb-8 SRS in Rel-17, the maximum number of CSs is 6.* FFS: Whether a maximum number of 12 CSs is supported

**Agreement**For extension of aperiodic antenna switching SRS configurations for <=4Rx, support N=4 for 1T4R and N=2 for 1T2R/2T4R.* The above extension is UE optional

**Agreement**On SRS configuration for 4T6R, select at least one from the following three alternatives in RAN1#107e* Alt 1: 4 + 2
* Alt 2: 2+2+2
	+ Alt 2-1:
		- No guard symbols exist between the 1st and the 2nd transmission. Y guard symbol(s) exist between 2nd and 3rd transmission, where Y is same as the value defined in the current specification for different SCSs
	+ Alt 2-2:
		- For SCS=15, 30 and 60KHz: No guard symbols exist
		- For SCS=120 KHz: No guard symbols exist between the 1st  and the 2nd transmission, and 1 guard symbol exists between the 2nd and 3rd transmission
* Clarification on the notation: $x\_{1}+\cdots +x\_{K}$ means totally K resources are needed, where the k-th resource contains $x\_{k}$ ports, 1<=k<=K
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# References

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| --- | --- | --- | --- |
| [1] | RP-193133 | New WID: Further enhancements on MIMO for NR | Samsung |
| [2] | [R1-2110766](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110766.zip) | Remaining Details on SRS Enhancements | InterDigital, Inc. |
| [3] | [R1-2110786](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110786.zip) | Enhancements on SRS in Rel-17 | Huawei, HiSilicon |
| [4] | [R1-2110882](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110882.zip) | Enhancements on SRS flexibility, coverage and capacity | FUTUREWEI |
| [5] | [R1-2110936](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110936.zip) | Enhancements on SRS | Lenovo, Motorola Mobility |
| [6] | [R1-2110947](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110947.zip) | Finalizing SRS  | Ericsson |
| [7] | [R1-2110953](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110953.zip) | Enhancements on SRS flexibility, coverage and capacity | ZTE |
| [8] | [R1-2110995](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110995.zip) | Remaining issues on SRS enhancement | vivo |
| [9] | [R1-2111089](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111089.zip) | Considerations on SRS enhancements | Spreadtrum Communications |
| [10] | [R1-2111226](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111226.zip) | Remaining issues on SRS enhancement | CATT |
| [11] | [R1-2111284](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111284.zip) | Enhancements on SRS flexibility, coverage and capacity | OPPO |
| [12] | [R1-2111458](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111458.zip) | Enhancements on SRS flexibility, coverage and capacity | LG Electronics |
| [13] | [R1-2111481](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111481.zip) | Discussion on SRS enhancements | Intel Corporation |
| [14] | [R1-2111545](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111545.zip) | Discussion on SRS enhancements | Xiaomi |
| [15] | [R1-2111602](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111602.zip) | Enhancements on SRS flexibility, coverage and capacity | CMCC |
| [16] | [R1-2111688](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111688.zip) | Discussion on SRS enhancement | NEC |
| [17] | [R1-2111722](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111722.zip) | Enhancements on SRS | Samsung |
| [18] | [R1-2111858](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111858.zip) | Views on Rel-17 SRS enhancement | Apple |
| [19] | [R1-2112094](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112094.zip) | Discussion on SRS enhancement | NTT DOCOMO, INC. |
| [20] | [R1-2112181](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112181.zip) | Enhancements on SRS flexibility, coverage and capacity | Nokia, Nokia Shanghai Bell |
| [21] | [R1-2112201](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112201.zip) | Enhancements on SRS flexibility, coverage and capacity | Qualcomm Incorporated |
| [22] | [R1-2112280](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112280.zip) | Enhancements on SRS flexibility, coverage and capacity | MediaTek Inc. |