3GPP TSG RAN WG1 Meeting #106bis-e R1-2109258

**e-Meeting, Oct. 11th – 19th, 2021**

**Source: Moderator (ZTE)**

Title: FL summary #1 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 above SRS enhancements submitted to RAN1#106bis-e [2]-[23].

# 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 | Huawei/HiSilicon, Futurewei (including collision between Rel-17 AP SRS with other UL channels/signals), ZTE, vivo, Lenovo/MotM, CATT, Xiaomi, Samsung, Intel, Nokia/NSB, Qualcomm, Ericsson, Apple (UE optional feature), NEC | * Rule 1 – Based on usage: Qualcomm, Nokia/NSB, Ericsson, vivo, Xiaomi, * Rule 2 – Based on set ID and CC ID: vivo, Xiaomi, Huawei/HiSilicon, ZTE, NEC * Rule 3 – Based on order of the triggering DCI: Lenovo/MotM, Samsung * Rule 4 – Based on type of the aperiodic SRS and the UL channel/signaling: Futurewei |
| Do not introduce new dropping rule | Spreadtrum, OPPO, CMCC, LGE, InterDigital |  |

Based on majority view, the following proposal is recommended by FL.

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

* *Select one or more of the following priority rules*
  + *Rule 1 – Based on usage*
  + *Rule 2 – Based on set ID and CC ID*
  + *Rule 3 – Based on order of the triggering DCI*
  + *Rule 4 – Based on type of the aperiodic SRS*
* *The new dropping rule is a UE optional feature*
* *FFS collision handling among Rel-17 flexible SRS and other UL channels/signals*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | Not support. Collision between aperiodic SRS resource sets is purely up to gNB scheduling. In Rel-16 LTE MIMO, RAN1 specified only aperiodic additional SRS (with maximum 13 symbols) and didn’t introduce priority rule between aperiodic SRSs, since triggering of aperiodic SRSs is controlled by gNB. It seems there is no clear motivation to introduce the priority rule at this stage. |
| InterDigital | We have a similar view as LG that gNB scheduler should take care of such collisions. |
| Huawei, HiSilicon | Support Rule-2. Only one meeting left for RAN1 in Rel-17 discussion, we prefer to conclude details in this meeting. Rule-1 is not clear for us and difficult to discuss which usage is priority, furthermore there is some case that the same AP-SRS is shared by multi-usages. Rule-2 seems a simple way, gNB can RRC configure different set ID/cc ID for the service to arrange the priority. |
| NEC | Support the proposal, and prefer Rule-2. |
| OPPO | Not support. We share similar view as LGE/InterDigital.  Based on Rel-17 mechanism, gNB can adjust three factors to control the target slot(s) for SRS transmission   * The slot for the DCI that triggers the SRS transmission * The legacy slot offset for each SRS resource set * The new available slot information indicated by the new configurable DCI filed   In this sense, gNB has quite good flexibility and can avoid the unintended collision by scheduling. |
| Samsung | We are supportive if gNB cannot solve collision by implementation. |
| vivo | We support the proposal from FL. |
| Lenovo/MotM | Support FL proposal. |
| Futurewei | Support, and support Rule-4. The idea is to be backward compatible as much as possible, and collision handling is needed only when there is new Rel-17 AP SRS. That is, new R17 AP SRSs have specific priorities relative to each other or to other transmissions (e.g., legacy SRS), but we do not need to introduce new priority / modify existing behaviors for legacy transmissions.  For the other rules, UE needs to follow two different behaviors and hence they are not preferred. |

### 2.1.2 Determination on the value of t

**DCI indication mechanism**

One essential issue to complete the Rel-17 mechanism of triggering offset determination is the bit width of the new DCI field the how to configure this mechanism. Two alternatives can be identified based on companies’ input as the following table.

Table 2-2

|  |  |
| --- | --- |
| **How to determine the bit width of the new SRS offset indication field (SOI)** | |
| Alternatives | Companies |
| Alt 1: Bit width of SOI depends on the maximum number of “t” values configured for any of the aperiodic SRS resource sets   * Candidate values of “t” include 0 * If no “t” value is configured in any resource set, follow Rel-15 approach to determine slot offset   + Otherwise, if no “t” value is configured for an aperiodic SRS resource set, t=0 is applied. | ZTE, LGE, Qualcomm, Samsung, vivo, NEC |
| Alt 2: Bit width of SOI depends on a new explicit RRC parameter   * Candidate values of this RRC parameter include 0 * If no “t” value is configured for an aperiodic resource set, and this parameter is configured, t=0 is applied * If this parameter is not configured, follow Rel-15 approach to determine slot offset | OPPO, CATT, Lenovo/MotM |

Since this is an essential component to complete this feature, companies are encouraged to share your views on the above two alternatives. The following is noted to understand better on the above two alternatives.

* Alt 1 does not require new RRC parameter compared to the current list.
* Alt 2 requires a new RRC parameter, and some rules are needed to align the new RRC parameter and the number of t values configured for each SRS resource set.

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | Support Alt 1 in principle. We think alt 1 is better mechanism with no additional RRC overhead. I think some modification is needed for Alt 1 as below.  Alt 1: Bit width of SOI depends on the maximum number of “t” values configured for any of the SRS resource sets which are associated with SRS trigger state(s)   * Candidate values of “t” include 0 * If no “t” value is configured, follow Rel-15 approach to determine slot offset |
| InterDigital | * We think this is over-optimization, t value should be always assumed 2 bits. * If the 2 bits is not configured, UE should fall back to Rel-15/16 procedure.     *FL’s response:*  To make the number of bits be always 2 bits is too restrictive in my view, considering sometimes gNB may not want to use all the 4 t values.  Further, even we follow your first bullet, the question is still there. “If the 2 bits is not configured” as in your second comment, what parameter is used to not to configure the two bits? So we have to make a decision between Alt 1 or Alt 2.  Last, your second bullet is not correct per previous agreement. Even the field does not exist in DCI, it does not just fall back to Rel-15. If there is one t value configured, UE still use the available slot based approach in Rel-17 to determine SRS slot without DCI indication of *t*. The following is from a previous agreement (see the Appendix for more details).  *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.* |
| Huawei, HiSilicon | Both Alt.1 and Alt.2 can work. For Alt.1, some clarification is needed for the case where only part of sets are configured with “t” value:  *If no “t” value is configured for an aperiodic SRS resource set and Rel-17 approach is used, t=0 is applied.* |
| NEC | Support Alt 1. |
| OPPO | Both alternatives can work. We prefer Alt.2 as Alt.2 is a clearer solution.  Regarding the Alt.2 summarized by FL, we suggest to remove the 1st sub-bullet “Candidate values of this RRC parameter include 0” as it is not needed  *FL’s response:*  To make Alt 2 work, my understanding is this bullet should exist. Copy the same response to IDC below.  Even the field does not exist in DCI, it does not just fall back to Rel-15. If there is one t value configured, UE still use the available slot based approach in Rel-17 to determine SRS slot without DCI indication of *t*. The following is from a previous agreement (see the Appendix for more details).  *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.* |
| Samsung | Support Alt.1 |
| vivo | Support Alt. 1 |
| Lenovo/MotM | Support Alt. 2 |
| Futurewei | Alt. 1, Alt. 2, and InterDigital’s fixed 2 bits all can work. Even if fixed 2 bits are used, the overhead is still very limited, and potential saving is quite marginal. In addition, fixed 2 bits maximize SRS triggering flexibility.  For Alt. 2, is it prohibited that the RRC configured bit width is 2 but all SRS resource sets have at most 1 or 2 offsets?  For the previous agreement, it describes one SRS resource set, but the bit width cannot be determined by only one SRS resource set. When a SRS resource set is configured with only one t but other sets have more, what should be the behavior for this SRS resource set? Options are:   * UE ignores the DCI field; OR * UE expects the DCI field indicates a value consistent with the RRC, otherwise treats it as an error case.   For all the potential designs, what if the DCI indicates a value even larger than the number of configured offsets for a set? |

## Flexible DCI format

**Re-purpose**

Based on the agreement of using DCI 0\_1/0\_2 to trigger SRS without data and without CSI request, companies propose the following schemes to repurpose unused fields in these DCI fields to indicate SRS parameters dynamically.

Table 2-3

|  |  |  |
| --- | --- | --- |
| **Repurpose unused fields in DCI format 0\_1/0\_2 without data and without CSI** | | |
| Categories | Detailed alternatives | Companies |
| CAT A (Time-domain parameters)   * 6 supporting companies: ZTE, Xiaomi, NTT DOCOMO, vivo, LGE, Futurewei * 1 company has concern | A-1: Indication of available slot position, i.e., the t values | ZTE, Xiaomi, NTT DOCOMO |
| A-2: Indication of slot offset | vivo |
| A-3: Indication of SRS symbol-level offset | Futurewei, LGE |
| A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting | Futurewei |
| Do not support this category | Intel |
| CAT B (Frequency-domain parameters)   * 5 supporting companies: Futurewei, Xiaomi, Qualcomm, CMCC, Intel * 1 company has concern | B-1: Indication of a group of CCs for SRS transmission | Futurewei, Xiaomi, Qualcomm |
| B-2: Indication of frequency domain resource in a BWP for SRS transmission | CMCC, LGE |
| B-3: Indication of whether DL/UL BWP is applied for SRS transmission | Intel |
| Do not support this category | vivo |
| CAT C (Power control parameters)   * 4 supporting companies: Futurewei, NTT DOCOMO, Qualcomm Huawei/HiSilicon * 2 companies have concern | C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’ | Futurewei, NTT DOCOMO, Qualcomm |
| C-2: Indication of open loop power control parameter e.g., p0. | Huawei/HiSilicon |
| Do not support this category | vivo, CMCC |
| CAT D (Spatial-domain parameters, i.e., indication of SRS port and beamforming)   * 1 company has concern | Re-purpose CSI-RS/TPMI indication to indicate SRS spatial-domain parameters |  |
| Do not support this category | CMCC |
| CAT E (Extend the number of DCI codepoints for aperiodic SRS trigger states)   * 5 supporting companies: Futurewei, Xiaomi, Intel, NTT DOCOMO, Nokia/NSB | Extend the number of DCI codepoints for aperiodic SRS trigger states | Futurewei, Xiaomi, Intel, NTT DOCOMO, Nokia/NSB |
| No or deprioritize | - | OPPO, Samsung, Apple, Lenovo/MotM |

It seems it is hard converge on this 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:*** *No consensus to support repurpose of DCI field(s) for SRS parameter indication in Rel-17.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | We support A-3 and B-2, but we are fine to deprioritize this issue for the sake of progress. |
| InterDigital | Support FL’s proposal. |
| Huawei, HiSilicon | Although we prefer to use the unused bits for more efficient power control, but we can accept no consensus in Rel-17. |
| NEC | Support the FL proposal. |
| OPPO | Support FL proposal |
| Samsung | Support FL proposal |
| Lenovo/MotM | Support FL proposal |
| Futurewei | We support a few categories. Given the current situation, we suggest to consider the following alternative to avoid wasting too many bit:  *Decide if the existing TPC command field, bandwidth part indicator field, and FDRA field in the DCI configured for data transmission apply to the AP SRS or not.* |

**Group-common DCI**

Another remaining issue is whether to enhance group-common DCI in addition. Companies’ views are summarized as follows.

Table 2-4

|  |  |  |
| --- | --- | --- |
| **Whether group-common DCI enhancement is supported additionally** | | |
| Alternatives | Number | Companies |
| Yes | 4 | Futurewei, vivo, Samsung, Qualcomm |
| No or deprioritize |  | Huawei/HiSilicon, Lenovo/MotM |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Not support. As we clarified before, group-common DCI is general used for group common related service. But for aperiodic SRS triggering, it is difficult to find the scenarios need group common triggering. |
| Samsung | Support the GC DCI based method as well. Group-common DCI also can handle DCI reduction which is key motivation for adopting flexible aperiodic SRS triggering. |
| Lenovo/MotM | Not support. We share similar view with Huawei. |
| Futurewei | Support GC DCI enhancement. At least the triggering offset can be easily supported in DCI 2\_3. |

## 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 2-7 summarizes companies’ views.

Table 2-5

|  |  |  |
| --- | --- | --- |
| **Whether to support specification enhancement on using SRS resources configured in SRS resource set with usage = “antennaSwitching” for codebook based UL transmission** | | |
|  | Number | 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 | 4 | vivo, NTT DOCOMO, Apple, Ericsson |
| Action 2: Add a RRC parameter to turn on/off the UE behavior in Action 1 | 4 | vivo, NTT DOCOMO, Apple, Ericsson |
| Action 3: Clarify same virtualization is used if SRS resource(s) for antenna switching also belong to a set for codebook | 2 | NTT DOCOMO, Ericsson |
| None of the above actions is needed |  | Huawei/HiSilicon, OPPO, Lenovo/MotM |

***FL proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Not necessary. SRS resource sharing can be already enabled from Rel-15 in implementation, while the same issue discussed in Rel-15. We cannot accept to introduce a new UE capability to enable/disable the existing implementation features. Virtualization is anyway based on UE side, which have concluded from Rel-15. |
| OPPO | As we discussed many meetings, this new feature is not needed as the similar functionality is enabled by Rle-15. |
| Lenovo/MotM | We still believe this feature can be implemented by Rel-15. |
| Futurewei | Not needed and Rel-15 works fine. |

## 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 2-6

|  |  |  |
| --- | --- | --- |
| **Update Tx/Rx antennas for SRS antenna switch in dynamic signaling** | | |
| Views | Companies | Further details |
| Clarify the interpretation of dynamic Tx/Rx antenna change first   * Int. 1: Change the number of antennas dynamically * Int. 2: Change the number of SRS ports dynamically but do no change the number of antennas | Futurewei | Futurewei requests to clarify this question first before discussing further details. |
| Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | Huawei/HiSilicon (MAC-CE for periodic/semi-persistent SRS, only for Rx), ZTE, Spreadtrum (MAC CE), vivo (MAC CE with enhancements on activation time), OPPO (MAC CE, applicable on all CCs in a frequency band, and need to clarify the number of Rx antennas for PDSCH), CATT (DCI based on SRS triggering states), Xiaomi, Samsung (MAC CE), Intel (DCI, no MAC CE), Ericsson (MAC CE), Qualcomm (MAC CE), Lenovo/MotM(MAC CE) | Applicable cases  Case 1: all of aperiodic, periodic and semi-persistent SRS   * Xiaomi   Case 2: only periodic or semi-persistent SRS   * Huawei/HiSilicon |
| Support UE reporting of the preferred antenna switching configuration | Yes: Xiaomi (MAC CE), Apple  No: Intel |  |

The following proposal is given based on majority view.

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

* *Applicable to at least one of the following two cases*
  + *Case 1: all of aperiodic, periodic and semi-persistent SRS*
  + *Case 2: only periodic or semi-persistent SRS*
* *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*
* *FFS whether DCI can be additional used to indicate the used antenna switching configuration*
* *FFS the application timing of the MAC CE activation*
* *Note: Any change on the configured number of Tx antennas in each SRS resource is precluded in either the gNB indication or UE reporting*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | We have following question. What is the condition for UE reportingof one preferred antenna switching configuration in MAC CE? |
| InterDigital | We have a similar view as Futurewei that we need further clarification on this feature.  Does “*Support UE reporting of one preferred antenna switching configuration in MAC CE*” mean xTyR configuration?  *FL’s response:*  I think so, but limited to the number of Rx antennas based on the last note. |
| Huawei, HiSilicon | General fine for us. One question is for UE to reporting preferred antenna switching, why not to use PUSCH, but use MAC-CE? |
| OPPO | Before we can go with any proposal, we firstly need to clarity the understanding on the “yR” receive antennas. Based on the discussions of last meeting, there are two interpretations:  1. It is only related to the “xTyR” antenna switching configuration, not related to the Rx antennas for data reception  2. It is implicitly indicating the Rx antennas for data reception  We need to have a common understanding what we want to do. |
| Samsung | Support FL proposal. Regarding the last FFS bullet with the application timing, we think the same MAC-CE activation time is enough. |
| vivo | From UE’s perspective, time slots for antenna switching resource(s) activation, i.e. required time for turning ON Rx front end, may be different across realistic UEs due to various capabilities. If MAC CE based flexible antenna switching feature is supported, application timing of the MAC CE should be also supported.  Thus, we propose modified version as below:  *Support gNB indicating the used SRS resources from the configured SRS resources in SRS resource set(s) for antenna switching via MAC CE.*   * *Applicable to at least one of the following two cases*   + *Case 1: all of aperiodic, periodic and semi-persistent SRS*   + *Case 2: only periodic or semi-persistent SRS* * *Support UE reporting of one preferred antenna switching configuration in MAC CE* * *Introduce additional time for application timing*   + *It can a UE capability.* * *The gNB indicated or UE reported antenna switching configuration belongs to the supported antenna switching reported by UE capability signaling* * *FFS whether DCI can be additional used to indicate the used antenna switching configuration* * *~~FFS the application timing of the MAC CE activation~~*   *Note: Any change on the configured number of Tx antennas in each SRS resource is precluded in either the gNB indication or UE reporting* |
| Lenovo/MotM | We agree with vivo’s view on the application timing on the MAC CE that additional time may be required for this feature. But we prefer to take it as an FFS:  We provide the following updated proposal based on vivo’s version:  *Updated proposal:*  *Support gNB indicating the used SRS resources from the configured SRS resources in SRS resource set(s) for antenna switching via MAC CE.*   * *Applicable to at least one of the following two cases*   + *Case 1: all of aperiodic, periodic and semi-persistent SRS*   + *Case 2: only periodic or semi-persistent SRS* * *Support UE reporting of one preferred antenna switching configuration in MAC CE* * *FFS: whether to introduce additional time for application timing of the MAC CE*    + *It can a UE capability if the additional time is required.* * *The gNB indicated or UE reported antenna switching configuration belongs to the supported antenna switching reported by UE capability signaling* * *FFS whether DCI can be additional used to indicate the used antenna switching configuration* * *~~FFS the application timing of the MAC CE activation~~*   *Note: Any change on the configured number of Tx antennas in each SRS resource is precluded in either the gNB indication or UE reporting* |
| Futurewei | We think the clarification we asked for should be resolved first. This is essentially also what OPPO is asking for. |

## Implicit determination of SRS parameters from data channel

Some companies propose to associate aperiodic SRS parameters (e.g., bandwidth) with scheduled data channel (e.g., PUSCH/PDSCH). The following summarizes companies’ views on this issue.

Table 2-7

|  |  |  |
| --- | --- | --- |
| **Implicit determination of SRS parameters from data channel** | | |
|  | Number | Companies |
| Inherit SRS parameters from data channel transmission parameters by associating them with co-scheduled PUSCH or PDSCH | 2 | LGE, Futurewei |

***FL proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | Support. |
| InterDigital | We believe this could be discussed later. |
| OPPO | Low priority |
| Futurewei | Support. We have shown high performance gains and answered other companies’ questions before. This seems to be a simple mechanism with good performance benefit and should be considered |

## 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 2-8

|  |  |  |
| --- | --- | --- |
| **Update of the association between trigger states and resource sets** | | |
|  | Number | Companies |
| Support to update the association between SRS trigger states and SRS resource sets via MAC CE | 2 | Lenovo/MotM, NTT DOCOMO |

***FL proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Not needed. |
| OPPO | Low priority |
| Lenovo/MotM | Support.  Additional triggering flexibility can be provided by employing this feature like aperiodic CSI-RS triggering. |

## Others

The following issues are discussed by one company.

|  |  |
| --- | --- |
| Extend the mechanism of indicating t for available slot to SRS triggered by group common DCI 2\_3 | Intel |
| Support single scheduling DCI to trigger simultaneous A-SRS transmission across multiple component carriers | Qualcomm |
| Updating the association between AP SRS resource sets and aperiodic SRS triggering states by MAC CE | Lenovo/MotM |
| Support to trigger aperiodic SRS by non-scheduled DCI format 1-1 and 1-2. | vivo |
| TPC command and BWP indication   * 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 |

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

|  |  |
| --- | --- |
| Companies | Views |
|  |  |
|  |  |
|  |  |

# Antenna switching up to 8Rx

## Extension for aperiodic SRS with <=4Rx

One FFS point is whether to support more values of N for aperiodic SRS with <=4Rx. Companies’ views are summarized as follows.

Table 3-1

|  |  |
| --- | --- |
| **Whether to support more N values for 1T4R, 2T4R, T=R and 1T2R cases** | |
|  | Companies |
| Yes | Huawei, CATT, Xiaomi, Nokia/NSB, Ericsson   * Support N=4 for 1T4R and N=2 for 1T2R/2T4R   CATT   * Support N=4 for 1T4R and N=2 for 1T2R/2T4R * Support one resource set for 1T4R if all the symbols in a slot can be used for SRS   Intel, ZTE, Qualcomm (Optional UE feature) |
| No or deprioritize | OPPO, Lenovo/MotM |

Given majority view expressed, the following FL proposal is recommended.

***FL Proposal:*** *For extension of antenna switching SRS configurations for <=4Rx, support N=4* *for 1T4R and N=2 for 1T2R/2T4R.*

* *The above extension is UE optional*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Support the proposal |
| OPPO | Not support. The benefit is not well justified  lack sufficient justifications:   * Rel-15/16 DCI based triggering has supported antenna switching of 1T2R/2T4R/1T4R with an efficient way. It is not clear why the network insists to use specific configuration(s) that is not suitable for it. One the other hand, even with such kind of specific configuration(s), network still has the flexibility to use periodic or semi-persistent antenna switching * The 2 UL symbols in special slots will be wasted.   + They can still be used for SRS associated with PUSCH (e.g., codebook-based PUSCH).   + They can be used for periodic and semi-persistent antenna switching. * Lager value of N means larger latency for antenna switching, which may lead to outdated channel state information * It will be difficult for UE to maintain phase continuity for the cases with larger value of N, e.g., due to the change of duplexing directions, or transmit power change. * As the penetration rate of 5G subscriber increases, only two symbols of the special slots for SRS will not be sufficient and then NW has to configure more symbols in some slots for SRS transmission. In this sense, the current configuration of antenna switching is future-proof. |
| Vivo | We are ok with the proposal |
| Lenovo/MotM | As the supporter pointed that this feature is useful for the special case that only two UL symbols in a slot, which means that at least 4 continuous slots are required for SRS transmission for DL channel estimation, we are not sure the estimated channel matrix is still effective. |

## Guard period

Companies discuss possible enhancements on guard symbols for antenna switching SRS. The proposed alternatives and companies’ positions are summarized as follows.

Table 3-2

|  |  |
| --- | --- |
| **Presence of guard symbols** | |
| Alternatives | Companies |
| Alt 1-0: Guard symbols are always-on, which is same as Rel-15 | Huawei/HiSilicon, OPPO, Xiaomi, MediaTek, Intel, Qualcomm |
| Alt 1-1: Guard symbols are configurable subject to UE capability | Spreadtrum, ZTE, vivo, CATT, CMCC, Samsung, NTT DOCOMO, Nokia/NSB, LGE, Ericsson, Lenovo/MotM |
| **Inter-slot guard symbols** | |
| Alternatives | Companies |
| 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 | Intel, Nokia/NSB |
| Alt 2-1: Introduce guard symbols between two sets mapped to consecutive slots | Huawei/HiSilicon (if the gap is larger than 2Y symbols, no scheduling restriction needs to be defined), Spreadtrum, ZTE (subject to gNB configuration and UE capability, only if UE is capable of transmitting SRS in all symbols in one slot), vivo, OPPO, CATT, CMCC, Xiaomi, Samsung, MediaTek, NTT DOCOMO, Ericsson (based on UE capability, and if two slots contain SRS resources in adjacent symbols), Qualcomm |

Based on companies’ input, it seems Alt 2-1 stands for majority view, and the situation of Alt 1-0 or 1-1 is not clear. Hence, FL recommends the following proposal.

***FL Proposal:*** *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 the minimum GP can be configurable subject to UE capability*
* *Whether this inter-set GP is needed for 4T6R can be discussed later per the decision on 4T6R configuration.*
* *Note: whether to define scheduling restriction on the symbols in-between the two resource sets is up to RAN4*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | Support the main bullet only (I think there is typo “exits”🡪”exists”). For the first subbulet, we think that the value of Y for intra-set and inter-set can be different since each set could be used for different UE panel. We’d like to suggest deleting the first subbullet and revising the second subbullet as follows:   * *FFS whether the minimum GP with regard to inter-resource and/or inter-resource set can be configurable subject to UE capability* |
| InterDigital | Support FL’s proposal. |
| Huawei, HiSilicon | There are two issues need to be clarified for the FL proposal:  For inter-slot case, even we define the minimum gap Y between two SRS sets, but if the interval between two SRS resource sets X is much bigger than Y, whether PUSCH transmission is disabled for the all X symbols following in the current spec?  For 4T6R, whether guard period is required, since two antennas switching in the 4Tx, seems no guard periodic is needed, since the 4Tx can be for simultaneous transmission. This case should be discussed later.  *FL’s response:*  For your first comment, isn’t whether to define scheduling restriction between the two resource sets up to RAN4? From RAN1 perspective, we just need to make sure there would be Y symbols in between two resource sets, but whether to define scheduling restriction should be discussed and determined in RAN4. One note is to clarify this.  For your second comment, one bullet is added to clarify the situation of 4T6R. |
| OPPO | Support FL proposal in principle |
| Samsung | Support the FL proposal aligned with a current specification. |
| vivo | Support the proposal from FL |
| Lenovo/MotM | Generally fine with the FL proposal.  We think the FFS point is also applicable for the guard symbols between different SRS resources. |

## 4T6R configurations

It has been agreed to support 4T6R antenna switching in Rel-17. Companies’ views on the detailed 4T6R configuration are summarized as follows.

Table 3-3

|  |  |  |
| --- | --- | --- |
| **4T6R SRS antenna switching configurations** | | |
| Alternatives | Companies | Further details |
| Alt 1: 4 + 2 | ZTE, CATT, CMCC, Samsung, Intel, Qualcomm, OPPO, Lenovo/MotM |  |
| Alt 2: 2 + 2 + 2 | Huawei/HiSilicon, InterDigital, CMCC, vivo | Huawei/HiSilicon:   * No guard symbols between the first two resources, * No guard symbols between the last two resources if the required number of guard symbols is 1, * Have 1 guard symbol if the required number of guard symbols is 2   InterDigital:   * No guard symbols between the first two resources, * No guard symbols between the last two resources |
| Alt 3: 4 + 4 | NEC, CMCC, Nokia/NSB, LGE |  |
| Alt 4: 4 + 4 + 4 | Ericsson, Qualcomm |  |
| Clarification on the notation:  means totally K resources are needed, where the k-th resource contains ports, 1<=k<=K.  Whether to distribute the K resources in one or more sets is to be discussed afterwards. | | |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | Support alt 3. |
| InterDigital | Support Alt2. This is the only alternative that required the least number of resources and at the same time supports an equal power across SRS resources. |
| Huawei, HiSilicon | Support Alt.2, i.e., 2+2+2, where guard period could be reduced.  For 4+2, there is some problems, such as power imbalance of the SRS transmission on different ports and different channel estimation on different ports. |
| NEC | Support Alt 3. Not quite understand alt 2, isn’t that 2T6R? |
| OPPO | Support Alt.1 |
| Samsung | Support Alt1 considering asymmetric structure. |
| Vivo | Support alt2 |
| Lenovo/MotM | Support Alt.1 |

## 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 | InterDigital, Qualcomm |
| Ericsson proposes to enhance this from a different angle: Support to report ∆TRxSRS = 0 dB as a UE capability (in RAN4) | Ericsson |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | We believe this issue needs to be addressed to prevent any distortion in the estimated DL CSI. |
| Huawei, HiSilicon | Not necessary at this stage. In RAN1, it is also difficult to discuss the values of insertion loss. |
| OPPO | Insertion loss is an RAN4 issue. |
| vivo | RAN1 doesn’t expertise, should be discussed in RAN4 first |

## 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 | LGE |
| 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 |

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

|  |  |
| --- | --- |
| Companies | Views |
|  |  |
|  |  |
|  |  |

# 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} * Fraunhofer IIS/Fraunhofer HHI: Support an additional PF value which is a multiple of 4 * Futurewei: 3, 8, 12, 16, and fractional numbers * Huawei/HiSilicon: Support 3 if is a multiple of 3 |
| Do not support additional PF values | * Intel, Ericsson |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | Support the proposal. |
| Huawei, HiSilicon | Since some bandwidth of SRS is multiple of 3, so it is make sense to include PF=3. |
| OPPO | Support FL proposal |
| Samsung | Support FL proposal. |
| vivo | Few more values should be supported in order for gNB to flexibly configure SRS parameters |
| Futurewei | Support more values and support dynamic indication of Pf. More Pf values and dynamic indication are needed for the flexibility required by coverage/capacity enhancements. gNB can already configure a wide range of SRS BW values. What additional benefit can the RPFS feature bring if only {2,4} are supported? |

### 4.1.2 Start RB location hopping

The remaining issues of start RB location hopping includes three aspects

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

Companies’ views on these three aspects are summarized as follows.

Table 4-2

|  |  |  |
| --- | --- | --- |
| **Detailed pattern for** | | |
| Views | | Companies |
| For PF = 2 | | |
| = {0, 1}, which is the only option | | Huawei/HiSilicon, ZTE, Futurewei, MediaTek, Apple, Qualcomm |
| For PF = 4 | | |
| Alt 1: = {0, 2, 1, 3} (Symmetric pattern, which is same as the legacy FH) | | Huawei/HiSilicon, ZTE, Lenovo, MediaTek, Qualcomm, LGE, NEC, OPPO |
| Alt 2: = {0, 1, 2, 3} (Increment pattern) | | Futurewei, vivo |
| Clarification on the notation:  means for the (n+k)-th legacy FH period, where k = {0, …, PF-1}, and n = {1, 2, 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 | Spreadtrum, CATT, MediaTek |
| Start RB location hopping is performed across SRS occasions in one legacy FH period | Ericsson |
| No or deprioritize | | vivo, OPPO, NTT DOCOMO, Lenovo/MotM |
| **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 |
| For aperiodic SRS, support start RB location hopping across repetition symbols for R>1 | | MediaTek, CATT |
| Start RB location hopping is not applicable on aperiodic SRS | | Intel, LGE |

At least the first issue (detailed pattern for ) is an essential component to complete this feature, FL encourages companies to share your views at least for the first issue. The following proposal is given based on the current majority view.

***FL Proposal:*** *For the detailed pattern of when start RB location is enabled, support the following*

* *For PF = 2, = {0, 1}*
* *For PF = 4, = {0, 2, 1, 3}*
* *Note: means for the (n+1)-th legacy FH period, where n = {0, 1, 2, 3, …}*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | Fine with the proposal.  Regarding Whether to support start RB location hopping within a legacy FH period, we prefer not to introduce it within FH period. Also, repetition(R>1) has its own motivation to achieve coverage gain, not hopping. |
| Huawei, HiSilicon | Generally fine for the proposal.  The notation is not clear, some confusion on (n+k), dose it means:“ means, for the (*n+1)*-th legacy FH period, ”?  *FL’s response:*  Yes, it means the same as in your comment. Use your suggestion as it looks simpler. |
| NEC | Fine with the proposal. |
| OPPO | Fine with the proposal |
| vivo | The mechanism should be agnostic to Pf values, in this sense we support Alt 2: = {0, 1, 2, 3} (Increment pattern) for Pf=4 which is aligned with Pf=2. Otherwise agreement on 4.1.1 should be made first. |
| Lenovo/MotM | Fine with the proposal. |
| Futurewei | It seems there is no technical motivation for {0,2,1,3}. It actually makes the implementation a little more complicated as an additional mapping is needed. |

### 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 4-3

|  |  |
| --- | --- |
| **Whether to restrict the applicable cases for RPFS** | |
| Views | Companies |
| Applicable for frequency hopping case only | vivo, OPPO, CMCC, Intel, Qualcomm |
| Applicable for both frequency hopping and non-frequency hopping cases | Huawei/HiSilicon, Futurewei, NEC, CATT, Lenovo/MotM |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | If it is applicable for both cases, dynamic indication of Pf and/or Kf should be supported to enhance signaling mechanism, because partial frequency sounding is already supported by RRC (re)configuration of SRS BW in non-frequency hopping case. |
| Huawei, HiSilicon | No need to add the restriction.  The benefits of partial sounding is for addressing SRS capacity for multiplexing UEs. Both hopping and non-hopping cases are with SRS capacity limitation. By the way, partial sounding for frequency hopping is more complicated than non-hopping case, so it not make sense support hopping case but not support non-hopping case. |
| NEC | Support to applicable for both frequency hopping and non-frequency hopping.  And considering 4.1.4, if number of RBs for partial sounding can be an integer value (either Alt 1 or Alt 2), more flexibility for configuration of sounding bandwidth can be achieved for both frequency and non-frequency hopping cases. |
| OPPO | For the non-frequency hopping cases, SRS transmitted at the fixed frequency position and the network can select suitable parameters and  are able to achieve the same purpose of RB-level partial frequency sounding. That is to say, RB-level partial frequency sounding cannot offer any new value compared to the current Rel-15 SRS design. |
| Vivo | Applicable for frequency hopping case only, the motivation of this feature is to allow power boosting and sweep the whole SRS bandwidth quickly. |
| Futurewei | Support both cases, and support dynamic indication of Pf and/or Kf. We are fine to tie these two together, e.g.:  *RPFS is applicable for both frequency hopping and non-frequency hopping cases if dynamic indication of* *Pf and/or Kf is supported.* |

### 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 4-4

|  |  |
| --- | --- |
| **Further restriction on the number of RBs for RPFS** | |
| Alternatives | Companies |
| Alt 1: is an integer value | ZTE, Huawei/HiSilicon, Futurewei, NEC, Ericsson |
| Alt 2: is an integer value with minimum value 4 | NEC, NTT DOCOMO |
| Alt 3: is a multiple of 4 | vivo, OPPO, CATT, Intel, Apple, LGE, Qualcomm |
| Alt 4: Round to a multiple of 4 in case of Alt 1 or Alt 2 | vivo, NEC (Starting RB index of the RBs in the RBs aligns with a multiple of 4), CATT |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | Alt 3 should be the baseline, for multiplexing not only between enhanced SRSs but also between enhanced SRS and legacy SRS, with less complexity. |
| Huawei, HiSilicon | We already agreed partial sounding is without new sequence length, which is equivalent of Alt.1 or 2. So, the additional restriction is not necessary. |
| NEC | We are fine with any alternatives except Alt 3.  If Alt 3 is agreed, there is no benefit for partial sounding, which is already supported by legacy Rel-15/16 scheme. |
| OPPO | We prefer Alt.3. In the current SRS design of Rel-15/16, an SRS resource is always transmitted to continuous frequency subband with multiple of 4 RBs. UE implementation is also optimized to match the configuration. |
| Samsung | Support Alt3. Since this issue has been discussed a number of meetings, if there is no consensus, the default option can be Alt3 which is a current specification. |
| Vivo | Support alt3 and 4 |
| Futurewei | Both Alt 1 and Alt 2 are generally acceptable. The only difference between them is about how to handle a resulting bandwidth less than 4 PRBs. We note that the actual limitation is not directly on the number of PRBs but on the minimum sequence length. So it seems Alt 1 together with the restriction that “SRS sequence shorter than the minimum length supported in the current specification is not pursued” is the best choice.  Alt 3 is very limiting, significantly restricting the potential PF values and usable SRS bandwidth configurations. Many of the SRS bandwidth values supported in the current standards cannot meet this requirement. Therefore, this is not preferred.  Alt 4 assumes that UE should transmit SRS with bandwidth values as multiples of 4 only. It is unclear why this restriction has to be imposed. This is not preferred at least from a futureproof or SRS flexibility perspective. |

### 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 4-5

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

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | Support dynamic indication for aperiodic SRS. |
| Huawei, HiSilicon | Not necessary. |
| Samsung | Do not support to use MAC CE or DCI to update |
| vivo | Do not support |
| Futurewei | Support dynamic indication for aperiodic SRS. |

## Comb-8

The only remaining issue for Comb 8 is the maximum supported number of CSs. Companies’ views are summarized as follows.

Table 4-6

|  |  |  |
| --- | --- | --- |
| **The maximum number of supported cyclic shifts** | | |
| Alternatives | Companies | Further details |
| Alt 1: The maximum number of CSs for Comb-8 is 6 | Huawei/HiSilicon, ZTE, Futurewei, Spreadtrum, vivo, OPPO, NEC, Samsung, Intel, Apple | Huawei/HiSilicon, ZTE, vivo, Samsung: 4 ports are supported using multiple comb offsets   * ZTE: Configure two comb offset values and two CS values * vivo: |
| 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 | Lenovo/MotM, CATT, MediaTek, Nokia/NSB, Ericsson, Qualcomm | Detailed rule when SRS sequence is shorter than max CS:   * Lenovo/MotM: Only the odd or the even CS values can be used * CATT: The minimum SRS bandwith is set to 8 PRBs for Comb-8 * MediaTek: The restriction is based on sequence length condition * Nokia/NSB: Use specific cyclic shift value combinations resulting short sequences * Ericsson: Prohibit the configuration of some cyclic shifts in the range [, ], and involve a mapping between port-specific cyclic shifts to the set of valid cyclic shifts * Qualcomm: It is up to gNB to proper configure the CSs (e.g., restrict some CSs configuration or use subset of CSs) |

Based on that the majority view is to support max CS = 6, and this is an essential component to complete comb-8, FL recommends the following.

***FL Proposal:*** *For comb-8 SRS in Rel-17, the maximum number of CSs is 6.*

* *Two comb offsets are used to carry 4 ports in this case, FFS details*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Support FL’s proposal. We do not see the necessity of introducing more than CS=6 in the real channels. |
| NEC | Support the proposal.  While we think the issue for maximum number of CSs should also be discussed in case of RB-level partial frequency sounding, and this can be discussed in section 4.1.  In current spec, the maximum number of CSs is determined based on the value of K\_TC, which is suitable for current SRS transmission band (a multiple of 4), while in Rel-17, the partial SRS transmission band may not be a multiple of 4 (depends on the output of 4.1.4), then determination of maximum number of CSs needs further discussion.  For example, in case of PF=2, K\_TC = 4, and the SRS band is configured as 4, then the partial SRS transmission band is 4/PF = 2, and the sequence length is actually 6, which we think is similar with comb-8 case. Maximum number of CSs should be 6 too. |
| OPPO | Support the principle |
| Samsung | Support FL proposal. |
| Vivo | Support FL proposal |
| Lenovo/MotM | The case that *SRS sequence is shorter than the maximum number of CSs* may also appear for the Rel-15 CS and Comb combination. For example, when the sounding band is 4 PRB with =2 and =4, the result SRS sequence length is 6 which is less than the supported =8. When the sounding band is 4 PRB with =4 and =2, the result SRS sequence length is 6 which is less than the supported =12. So, we prefer to have a unified solution to handle this problem. |
| Futurewei | Support |

## 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 |
|  |  |
|  |  |
|  |  |

# Conclusion

# 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  contiguous RBs in one OFDM symbol, where  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  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 modifications  An “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 RBs in the RBs is , 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: is an integer value   + Alt 2: is an integer value with minimum value 4   + Alt 3: is a multiple of 4   + Alt 4: Round 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- ZC sequence * Alt 2: Truncate from legacy length- 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 RBs in the RBs.   * For a given SRS transmission occasion, , 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 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, 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- 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 |

# References

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| --- | --- | --- | --- |
| [1] | RP-193133 | New WID: Further enhancements on MIMO for NR | Samsung |
| [2] | R1-2108761 | Enhancements on SRS in Rel-17 | Huawei, HiSilicon |
| [3] | R1-2108794 | Enhancements on SRS flexibility, coverage and capacity | FUTUREWEI |
| [4] | R1-2108813 | Further Details on SRS Enhancements | InterDigital, Inc. |
| [5] | [R1-2108875](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2108875.zip) | Enhancements on SRS flexibility, coverage and capacity | ZTE |
| [6] | R1-2108900 | Considerations on SRS enhancements | Spreadtrum Communications |
| [7] | [R1-2108956](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2108956.zip) | Further discussion on SRS enhancement | vivo |
| [8] | [R1-2109043](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2109043.zip) | Enhancements on SRS flexibility, coverage and capacity | OPPO |
| [9] | [R1-2109107](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2109107.zip) | Enhancements on SRS | Lenovo, Motorola Mobility |
| [10] | [R1-2109127](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2109127.zip) | Discussion on SRS enhancement | NEC |
| [11] | [R1-2109189](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2109189.zip) | Further details on SRS enhancement for Rel-17 | CATT |
| [12] | [R1-2109275](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2109275.zip) | Enhancements on SRS flexibility, coverage and capacity | CMCC |
| [13] | R1-2109353 | Enhancements on SRS for coverage and capacity | Fraunhofer IIS, Fraunhofer HHI |
| [14] | R1-2109383 | Discussion on SRS enhancements | Xiaomi |
| [15] | R1-2109473 | Enhancements on SRS | Samsung |
| [16] | R1-2109547 | Enhancements on SRS flexibility, coverage and capacity | MediaTek Inc. |
| [17] | R1-2109596 | Discussion on SRS enhancements | Intel Corporation |
| [18] | [R1-2109663](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2109663.zip) | Discussion on SRS enhancement | NTT DOCOMO, INC. |
| [19] | R1-2109875 | Enhancements on SRS flexibility, coverage and capacity | Nokia, Nokia Shanghai Bell |
| [20] | R1-2110018 | Views on Rel-17 SRS enhancement | Apple |
| [21] | R1-2110082 | Enhancements on SRS flexibility, coverage and capacity | LG Electronics |
| [22] | R1-2110121 | Remaining Issues for SRS | Ericsson |
| [23] | R1-2110170 | Enhancements on SRS flexibility, coverage and capacity | Qualcomm Incorporated |