3GPP TSG RAN WG1 Meeting #107-e R1-2110964

**e-Meeting, Nov. 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#107-e [2]-[22].

# 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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | We are on the fence for this issue. We see some value by considering some dropping rules, however at the same time we understand the position of companies who think this is not necessary and can be avoided by gNB. |
| Futurewei | RAN1 had the following agreement before:  **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*   So the group already agreed that collision handling is needed for SRS using the available slot mechanism, unless a collision never happens for such a SRS. If a collision never happens, the only implication is that the gNB is not allowed to overwrite any previous decisions, even when the gNB needs to do so to respond to some new events. Therefore, we think the group should stick with the previous agreement and provide the gNB with the flexibility via collision handling.  We also understand there is limited time for this WI. Based on the previous agreement, we do not have to design collision handling for general SRS transmissions, but only for cases involving SRS using the available slot mechanism.  So our suggestion is:  *Introduce dropping rule when collision happens among an aperiodic SRS resource set configured with available slot offset and other transmission(s) in a same CC or different CCs.*   * *The new dropping rule is a UE optional feature*   Further details can be discussed. |
| LGE | We don’t think that dropping rule is necessary. It is purely up to gNB scheduling.  Regarding the collision between Rel-17 SRS and the other transmission(s), legacy rule should be fine. |
| NEC | We think priority rule based on CC/set ID is enough.  While if majority supports the proposal, we are fine. |
| vivo | Support the FL proposal |
| Samsung | We think gNB can handle the collision. Hence we don’t think this is not needed. |
| Huawei, HiSilicon | Not support. One unified dropping rule based on usage is not reasonable since the priority of different usage 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. So, the dropping rule only based on CC ID/set ID is sufficient, and gNB can flexibly arrange the priority for usages by configuring CC ID/set ID. |
| Ericsson | Support first bullet, however, we need some clarification how this can be an optional feature? What is the behaviour when collisions occurs for a UE that do not support collisions? |

### 2.1.2 Remaining issues of the Rel-17 mechanism in CA case

The remaining issues to complete the Rel-17 mechanism of triggering offset determination in CA case includes the bit width of the SOI field when multiple CCs/BWPs are configured and the definition of reference slot when *caOffset* is configured.

Table 2-2

|  |  |  |
| --- | --- | --- |
| **Bit width of SOI when multiple CCs/BWPs are configured** | | |
| Alternatives | Companies | Further details |
| Alt 1: SOI bit width depends on the maximum number of “t” values configured for any of the aperiodic SRS resource sets across all BWPs within one CC | Qualcomm, CATT |  |
| Alt 2: SOI bit width depends on the maximum number of t values configured for the resource sets in the BWP where the DCI is received | ZTE, OPPO | * ZTE: Use padding or truncation approach when the maximum number of t values configured for resource sets in the indicated BWP does not equal to the DCI BWP * OPPO: if the number (X) of configured “t” values is less than the number (Y) that can be indicated by this new DCI field, when one of the largest (Y-X) codepoints is indicated by the new DCI field, the slot for the transmission of this triggered SRS resource is determined by Rel-15/16 mechanism |
| Alt 3: SOI bit width depends on the maximum number of t values configured for all the resource sets across all BWPs in all CCs. | Huawei/HiSilicon, Futurewei, vivo |  |
| **Reference slot when *caOffset* is configured** | | |
| Views | Companies | |
| When *ca-SlotOffset* is configured, reference slot to use the Rel-17 mechanism to determine the SRS offset is slot, where , , and are determined by *ca-SlotOffset* configurations of the PDCCH carrier and SRS carrier. | ZTE, Huawei/HiSilicon, Futurewei | |

For the first issue, FL believes a simple solution is sufficient to handle this case. Hence the following is recommended.

***FL Proposal 2-2:*** *SOI bit width depends on the maximum number of t values configured for all the resource sets across all configured BWPs in all configured CCs.*

For the second issue, the specification needs a solution to support the Rel-17 mechanism when *ca-SlotOffset* is configured. Hence FL suggests the following proposal.

***FL Proposal 2-3:*** *When ca-SlotOffset is configured, reference slot to use the Rel-17 mechanism for determining the SRS offset is slot , where , , and are determined by ca-SlotOffset configurations of the PDCCH carrier and SRS carrier.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support Proposal 2-2. |
| Futurewei | Support both proposals. |
| LGE | For Proposal 2-2, we suggest to add “within a cell group” at the end of the sentence. And, we have one clarification question on the proposal. The maximum number of configured t values (within a CC/BWP) can be different across different CCs/BWPs?  ***FL Proposal 2-2:*** *SOI bit width depends on the maximum number of t values configured for all the resource sets across all configured BWPs in all configured CCs within a cell group.*  For Proposal 2-3, the parameter name should be revised as “*ca-SlotOffset*” |
| NEC | We are fine with the proposals. |
| vivo | Support the FL proposal |
| Samsung | Support the FL proposal. |
| Huawei, HiSilicon | Support both proposals. |
| Ericsson | Support both proposals |

## 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)   * Supported by 4 companies * 1 company has concern | A-1: Indication of available slot position, i.e., the t values | Xiaomi, NTT DOCOMO |
| A-2: Indication of slot offset | vivo |
| A-3: Indication of SRS symbol-level offset | Futurewei |
| 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)   * Supported by 3 companies | B-1: Indication of a group of CCs for SRS transmission | Xiaomi, Futurewei |
| 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 | Intel |
| Do not support this category |  |
| CAT C (Power control parameters)   * Supported by 2 companies * 2 companies have concern | C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’ | NTT DOCOMO, Futurewei |
| C-2: Indication of open loop power control parameter e.g., p0. |  |
| Do not support this category | CMCC, vivo |
| CAT D (Spatial-domain parameters, i.e., indication of SRS port and beamforming) | 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)   * Supported by 5 companies | Extend the number of DCI codepoints for aperiodic SRS trigger states | Intel, Xiaomi, NTT DCM, Nokia/NSB, Futurewei |
| No or deprioritize | - | Samsung, Apple, Qualcomm, ZTE, OPPO |

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 2-4:*** *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 |
| InterDigital | Support FL proposal |
| Futurewei | We still think this can be beneficial. For the remaining of the WI, we hope to discuss repurposing/reusing as much as time allows, such as the TPC field discussed below. |
| NEC | Support the proposal. |
| Huawei, HiSilicon | Fine for the proposal. |

**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 | Companies |
| Yes | Samsung, Qualcomm, vivo, Futurewei |
| No or deprioritize |  |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | Added our support in above table. We also support GC DCI enhancement. At least it is straightforward to introduce available slot offset for GC DCI. |
| LGE | We are not sure it is really needed at this late stage. |
| Huawei, HiSilicon | Not necessary. Group-common DCI is generally used for group common related service. For aperiodic SRS triggering, it is difficult to find the scenarios where group common triggering is needed. |

**TPC command and BWP indication**

Companies would like to clarify or enhance the interpretation of TPC command and BWP indicator in DCI 0\_1/0\_2 triggering SRS without data and without CSI.

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 |

***FL proposal 2-6:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | We think CIF and BWP indicator fields should apply to the SRS, which is covered in existing spec:  TS 38.213  If a UE is configured with *CrossCarrierSchedulingConfig* for a serving cell the carrier indicator field value corresponds to the value indicated by *CrossCarrierSchedulingConfig.*  *…*  If a bandwidth part indicator field is configured in a DCI format, the bandwidth part indicator field value indicates the active DL BWP, from the configured DL BWP set, for DL receptions as described in [5, TS 38.212]. If a bandwidth part indicator field is configured in a DCI format, the bandwidth part indicator field value indicates the active UL BWP, from the configured UL BWP set, for UL transmissions as described in [5, TS 38.212]. If a bandwidth part indicator field is configured in a DCI format and indicates an UL BWP or a DL BWP different from the active UL BWP or DL BWP, respectively, the UE shall  … - set the active UL BWP or DL BWP to the UL BWP or DL BWP indicated by the bandwidth part indicator in the DCI format  For the TPC command field, it is not covered in existing spec but this enhancement is simple and beneficial. We support to use the TPC command field for SRS.  We also support to reuse the FDRA field for SRS. |
| Samsung | Do not support. We failed to see what the difference between this proposal and Re-purpose above. |
| Huawei, HiSilicon | Agree with Samsung. The discussion is the same as Proposal 2-4. |

## 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 |
| Action 2: Add a RRC parameter to turn on/off the UE behavior in Action 1 | Apple, NTT DOCOMO |
| Action 3: Clarify same virtualization is used if SRS resource(s) for antenna switching also belong to a set for codebook |  |
| None of the above actions is needed |  |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | Not needed and Rel-15 works fine. |
| Huawei, HiSilicon | Not necessary. SRS resource sharing is already supported in Rel-15. |
| Ericsson | Support Action 1+2 to introduce SRS resource sharing in NR. |

## 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), Apple  No: 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*
* *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 |
| InterDigital | Support the FL proposal without the note. It almost contradicts the first bullet. The main point of such flexibility is to also allow UE to indicate preferred TX dimension, obviously gNB would not be obliged to respect it. |
| Futurewei | We think “without changing the numbers of Tx/Rx antennas” needs to be added to the proposal.  We are not convinced that the UE should report a preferred antenna switching configuration. Some companies argued that this is similar to UE CQI reporting, in which UE reports its preference but the gNB does not have to follow the report for its MCS determination. However, CQI/MCS have a large number of potential values and hence higher uncertainty, so the UE reporting of CQI would lead to significant uncertain reduction and performance gains. For antenna switching configurations, however, there is only a very small set of antenna switching configurations for each UE. Therefore, we doubt the reporting will lead to any meaningful uncertain reduction and performance gains. |
| vivo | Support the FL proposal |
| Samsung | Support FL proposal. Regarding 3rd bullet with the application timing, we think the same MAC-CE activation time is enough. |
| Huawei, HiSilicon | Generally is fine for us. But we cannot accept the change of Tx number which impacts chain switching that needs RAN4 discussion. So, we are not fine to remove the note. And also prefer to restrict on only periodic and semi-persistent SRS cases, while AP-SRS is not the use case for resource and power saving. |
| Ericsson | Support although “*Support UE reporting of one preferred antenna switching configuration in MAC CE”* is obsolete*,* This information will not be used by gNB. |

## 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 2-8

|  |  |
| --- | --- |
| **Implicit determination of SRS parameters from data channel** | |
|  | Companies |
| The FDRA field in a DCI can apply to the triggered aperiodic SRS resource set*.* | LGE, Futurewei |

***FL proposal 2-9:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| 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.  We can make this more focused, e.g.:  *The FDRA field in a DCI can apply to the triggered aperiodic SRS resource set.* |
| LGE | We share the view as Futurewei. We also fine with Futurewei’s suggestion. |
| Huawei, HiSilicon | Seems the same discussion in proposal 2-4. |
| Ericsson | Support |

## 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 |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Not necessary to introduce additional MAC-CE. |
| Ericsson | Support |
|  |  |

## 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 |
| Support to trigger aperiodic SRS by non-scheduled DCI format 1-1 and 1-2. | vivo |
| 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 |

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

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | Support Intel’s proposal.  Ok with vivo’s proposal, but we’d like to see more discussions.  Support CATT’s proposal. |
| LGE | We support vivo’s proposal. |
| Ericsson | Support vivo |

# 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 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 |
| Alt 1-1: Guard symbols are configurable subject to UE capability | Nokia/NSB, ZTE, CMCC, Samsung, NTT DCM, vivo, CATT, LG |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support Alt 1-1, it makes more sense. If a UE has such capability, why it should be prevented from using it. It enhances overall system spectrum efficiency, |
| LGE | We share the view with InterDigital. If there is an enhanced UE which is capable of fast antenna switching, the configurability of guard symbol based on the UE capability has clear benefit to save unnecessary guard symbol. |
| vivo | Support Alt 1-1 |
| Samsung | Support Alt 1-1. |
| Ericsson | 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 |
| 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 | CMCC, NTT DOCOMO |

***FL Proposal 3-2:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| NEC | Support to discuss. And we also think uplink signals are allowed to be transmitted at least in remaining symbols excluding Y symbols. |
| Huawei, HiSilicon | Support Alt.1.  Question to DCM for no need to handle this case: if two AP-SRS resource sets are configured in two consecutive slots, there are 10 symbols between the two SRS sets, then whether the PUSCH is allowed for the 10 symbols?  We prefer no any restriction for PUSCH transmission if the gap between two SRS resource sets are large than Y as Alt.1 mentioned. But we can also live with Alt.2 or 3. |
|  |  |

## 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 | Intel, Xiaomi, CMCC (2nd), NEC, Samsung, NTT DCM, Qualcomm, ZTE, CATT, OPPO, LG | Supported number of aperiodic resource sets:   * 1 or 2: Intel, ZTE, CATT   Enhance the transmit power determination of 4T6R SRS to ensure a constant ratio of the transmit power for the 2-port SRS resource and the transmit power for the 4-port SRS resource   * CATT |
| 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 |  |  |
| 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 majority view is to Alt 1, and this is a necessary component to complete 4T6R, the following is suggested by FL.

***FL Proposal 3-3:*** *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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | We don’t support FL proposal. As it has been discussed in the previous meeting, there are performance issues resulted from Alt 1. |
| LGE | Support the FL proposal, which is the simplest way. |
| NEC | Support the proposal. |
| vivo | Support Alt 2-1 |
| Samsung | Support the FL proposal. |
| Huawei, HiSilicon | Do not support.  We have following concerns on 4+2:  One is channel estimation quality imbalance. Since the channel estimation SINR of 4-port SRS resource is always 3dB less than that of 2-port SRS resource, the channel estimation quality is imbalanced and the whole channel estimation quality is limited by the 4-port SRS resource. Please note that the 3dB loss is due to the transmission power restriction, which can not be compensated by receiver side (i.e., gNB).  Another is power imbalance. For power class-3, we only define 3dB for power imbalance tolerance. If there already exist 3dB power difference between 4-port resource and 2-port resource because of the antenna switching structure, then how can guarantee there is no insertion loss between antennas?  Please note that due to the introduction of 4+2 antenna switching structure, the channel estimation quality imbalance and power imbalance always exist under any antenna architectures. Here it is meaningless to discuss some corner cases under special antenna architectures in which the UE is lack of full power transmission capability. |
| Ericsson | Do not support, Alt. 2-2 is simpler. |

## 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 |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | We share the same view as Qualcomm. This problem is not about just passing UE tests, it is performance-related and it cannot be addressed with report ∆TRxSRS = 0 dB as a UE capability (in RAN4). |
| Huawei, HiSilicon | Not necessary. We do not see the cases for further enhancement. |
| Ericsson | Support. This is an important issue since reciprocity based MU-MIMO performance can be bad for some UEs in the field, due to this SRS antenna power imbalance. TDD based reciprocity fails. |

## 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 |

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} * 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, 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.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | More PF values should be supported, to allow this design to be useful for both capacity enhancement and coverage enhancement with higher flexibility. |
| LGE | Support the FL proposal. |
| NEC | Fine with the proposal. |
| Samsung | Support the FL proposal. |
| Huawei, HiSilicon | Support to introduce 3, since many SRS bandwidth is multiple times of 3. |
| Ericsson | Support |

### 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**

Companies’ views on this aspect are summarized as follows.

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 |
| For aperiodic SRS, support start RB location hopping across repetition symbols for R>1 | CATT |
| Start RB location hopping is not applicable on aperiodic SRS | Intel, OPPO |

***FL Proposal 4-2:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | Support this as it provides higher flexibility. |
| LGE | We are open to support start RB location hopping for aperiodic SRS, but not to support repetition symbols for R>1 case. R>1 case has own purpose to achieve coverage gain. |
| NEC | Support start RB location hopping for aperiodic SRS. |
| vivo | No need to introduce start RB location hopping into aperiodic SRS. |
| Huawei, HiSilicon | Support to extend start RB location hopping to aperiodic SRS, since it can be useful when there is more than one FH period for aperiodic SRS. |
| Ericsson | We continue to support the 1st option. |

**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 |
| LGE | Prefer to deprioritize. |
| Huawei, HiSilicon | Not necessary. |
|  |  |

### 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 |
| Applicable for both frequency hopping and non-frequency hopping cases | NEC, ZTE, Futurewei, CATT, LGE |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | Support both cases, which will be especially useful when dynamic indication of PF and kF values is supported. |
| LGE | We share the view with Futurewei. |
| NEC | Support both cases. |
| vivo | Support applicable for frequency hopping case only |
| Huawei, HiSilicon | It’s not necessary to add the restriction. Partial sounding is beneficial for both case in terms of power boosting and capacity increase. |
| Ericsson | Support both cases |

### 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: is an integer value | NEC, ZTE, Futurewei, Ericsson |
| Alt 2: is an integer value with minimum value 4 | NEC, NTT DCM, Nokia/NSB |
| Alt 3: is a multiple of 4 | Intel, Samsung, Apple, Nokia/NSB, Qualcomm, vivo, OPPO, LG |
| Alt 4: Round to a multiple of 4 in case of Alt 1 or Alt 2 | NEC, Qualcomm, vivo, CATT |

***FL Proposal 4-5:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | Support Alt 1.  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. |
| LGE | Support Alt 3 considering multiplexing between Rel-17 SRSs and between Rel-17 SRS and legacy SRS without complexity. |
| NEC | Support alternatives except Alt 3, as Alt 3 is too restrict and almost all cases are already supported by legacy configuration, the benefit of the feature is limited and the effort for discussion is wasted.  This has been discussed for several meetings, maybe we can firstly decide whether to restrict to be a multiple of 4 or not.  Proposal:   * Alt A: Support to be an integer value not restricted as a multiple of 4   + FFS: the details on the values. * Alt B: Restrict to be a multiple of 4 |
| vivo | Support Alt 3 or Alt 4. |
| Samsung | Support Alt3. Since this issue has been discussed so many meetings, it seems there is no consensus. Then, the default option can be Alt3 which is a current specification. |
| Huawei, HiSilicon | The further restriction is not necessary, since we already agreed that there is no new sequence length, i.e., length is 6 or multiple of 6, which is equivalent with Alt.1. For Alt 3, it’s too restricted which will limit the use case of partial sounding, which requires the bandwidth of SRS configuration is multiple of 8 or 16. And for Alt 4, the rounding will cause RB wasting. |
| Ericsson | As shown in our contribution, Alt.3 makes the whole feature useless since all but a handful of RPFS schemes (highlighted in green) can already be configured with existing equivalent SRS configurations. Neither of Alt.2,3,4 increase the SRS capacity. Hence, to make this feature useful and save our reputation, Alt.1 must be chosen. |

### 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 |

***FL Proposal 4-6:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | Added our support in above table.  Support dynamic indication via DCI for aperiodic SRS. If DCI indication is not supported, using MAC CE is also acceptable to us. |
| LGE | We support dynamic indication of P\_F and/or k\_F for aperiodic SRS for flexibility. |
| Samsung | Do not support to use MAC CE or DCI to update |
| Huawei, HiSilicon | Not necessary. RRC is enough for the signaling. |
| Ericsson | RRC is enough. |

## 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

Companies’ views on this aspect are summarized as follows.

Table 4-7

|  |  |  |
| --- | --- | --- |
| **How to support 4 ports when Max CS = 6** | | |
| Alternatives | Companies | Further details |
| Alt 1: Use two comb offsets to support 4 ports | Samsung, ZTE, vivo, Huawei/HiSilicon | ZTE: Configure two comb offset values and two CS values  vivo: Revise the CS and comb offset allocation formulas as following |
| Alt 2: Allow 4 CSs for each comb offset to support 4 ports | Ericsson | Ericsson: Revise the CS allocation formula as following |

FL believes a simple solution is sufficient to address this issue. Hence FL recommends the following.

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

* *Port 0 and Port 1 locate in n\_CS and (n\_CS+3) mod 6 in comb offset k\_TC, respectively.*
* *Port 2 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.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| vivo | Support the FL proposal |
| Samsung | We are fine with the FL proposal. |
| Huawei, HiSilicon | Support the proposal. |
| Ericsson | We believe Alt 1 can work IF partial sounding in < 4 RBs is NOT agreed and it will work for both maxCS = 6 and maxCS = 12.  If, however, partial sounding in < 4 RBs is agreed then one would have to update formula also there as sequence length will not always be multiple of maxCS. With Alt.2, there is no such dependencies on other agreement since it is more general.  So either we settle other agreements first or we select Alt.2  We also think port 0 and 2 should be together and 1 and 3 should be together as in 2 and 4 port cases.. |

### 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 |
| No | Samsung, Huawei/HiSilicon, Spreadtrum, Futurewei, vivo |

***FL Proposal 4-8:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | No. For the maximum number of cyclic shifts for comb 8, if 12 is supported, then on the same resources, up to 8 x 12 = 96 SRS resources are multiplexed. It is questionable whether these many multiplexed resources are practical. |
| vivo | No |
| Samsung | Not support 12. |
| Huawei, HiSilicon | Not support 12 CSs.  Agree with Futurewei, in the practical case as we analyzed in our Tdoc (R1-2110786), we do not see the use cases to support 12 CSs for Comb-8.  In practical network, the number of available CSs is restricted by the channel delay, TA error and PDP leakage. In the case of 30K SCS, Comb-8 and 12 CSs, the tolerable delay corresponding to each cyclic shifts is about 343.73ns. However, even for the indoor case (CDL-A with 39ns RMS delay spread, the maximum is 376.68ns), the maximum delay is more than it.  Moreover, to ensure the orthogonality when the TA error exists, the delay gap between two CSs should be larger than double of TA error. However, the adjustment indicated by TA command is a multiple of 260.6ns for 30K SCS in current spec which means the TA error could be ≥260ns. So, how to ensure the orthogonality in the case of 12 CSs? |
| Ericsson | Support 12 CS. Whether MUX is possible depends on delay spread and implmentation. For indoor office where DS can be as low as 30 ns, it is certainly possible to enjoy this high SRS capacity. In Qualcomm contribution there are also evaluation showing the feasibility. |

## 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 |
| Futurewei | Dynamic indication of comb and offset provides higher flexibility for SRS transmissions, which can enhance coverage/capacity and reduce collision. |
|  |  |
|  |  |

# Conclusion

The following proposals are recommended for further online and offline discussion.

# 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   **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 when start RB location hopping across legacy FH periods 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, …}   **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: means totally K resources are needed, where the k-th resource contains ports, 1<=k<=K |

# References

|  |  |  |  |
| --- | --- | --- | --- |
| [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. |