3GPP TSG RAN WG1 Meeting #104b-e R1-2103878

**e-Meeting, Apr. 12th – 20th, 2021**

**Source: Moderator (ZTE)**

Title: FL summary #2 on SRS enhancements

Agenda Item: 8.1.3

Document for: Discussion and Decision

# Introduction

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

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

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

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

In this contribution, we summarize companies’ views on the above SRS enhancements submitted to RAN1#104b-e [2]-[25].

# Flexibility enhancements

## SRS triggering offset

### 2.1.1. Reference slot definition

Two options are given in RAN1#103e’s agreement on the definition of reference slot. The following table summarizes companies’ views on these two options.

Table 2-1

|  |
| --- |
| **Reference slot definition** |
|  | Number | Companies |
| Opt. 1 (Reference slot is the slot with the triggering DCI) | 8 | Samsung (when ‘slotoffset’ is absent but a list of ‘t’ is configured), LG, ZTE, NTT DOCOMO, Huawei, HiSilicon, OPPO, Futurewei |
| Opt. 2 (Reference slot is the slot indicated by the legacy triggering offset) | 12 | Qualcomm, Samsung (when ‘slotoffset’ and a list of ‘t’ are configured), Ericsson, Sharp, NEC, InterDigital, vivo, CATT, MediaTek, Intel, CMCC, Xiaomi, Lenovo, MotM |

These issue has been discussed extensively in RAN1#104e without any conclusion. This is a necessary component to complete the Rel-17 feature of aperiodic SRS triggering offset enhancement. A compromised solution is needed given both two sides have strong views.

The following observation can be seen based on companies’ input to RAN1#104e and RAN1#104b-e.

* Opt. 1 is a subset of Opt. 2 (Opt. 1 and Opt. 2 is equivalent when the legacy triggering offset is configured as 0 in Opt. 2).
* Some companies claimed that Opt. 2 requires extra processing on top of Opt. 1 as UE needs to perform offset operation twice.

Based on the above, FL propose the following compromised direction to solve the dilemma ahead of us.

* Supports Opt. 2 for reference slot definition.
* The configuration of Opt. 1 is a basic feature if UE supports the Rel-17 enhancement on SRS triggering offset, and the other configurations in Opt. 2 is optional.

Based on the above spirit, the following FL proposal is given.

***FL Proposal:*** *Support Opt. 2: Reference slot is the slot indicated by the legacy triggering offset.*

* *For a UE supporting the Rel-17 SRS triggering offset enhancement, only 0 can be configured for legacy triggering offset, or both 0 and non-zero values can be configured as legacy triggering offset, when using this enhancement, is an optional UE feature.*
	+ *Note: This does not impact the case when Rel-15/16 mechanism to determine the aperiodic SRS slot is used for an SRS resource set.*
* *No negative t values are introduced.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL’s clarification | The term “basic feature” should be well understood as it has been widely used in UE feature session. Here basic feature means supporting zero value for legacy triggering offset is mandatory if this UE supports the Rel-17 SRS triggering offset enhancement. UE can also optionally indicate it can support non-zero values for legacy triggering offset through capability reporting.Then for an aperiodic SRS resource set, either Rel-17 mechanism or Rel-15/16 mechanism can be used. If the Rel-17 mechanism is configured,* If UE does not report it supports non-zero values for legacy triggering offset when using Rel-17 triggering offset enhancement, gNB can only configure legacy triggering offset as 0 when it configures the Rel-17 mechanism to determine aperiodic SRS slot. In this case, Opt. 1 and Opt. 2 are equivalent.
* If UE reports the support of non-zero values for legacy triggering offset, it means gNB can configure legacy triggering offset as zero or non-zero when it configures the Rel-17 mechanism. In this case, it is a full set of Opt. 2.

For companies who may not want to implement a full set of Opt. 2 (e.g., Opt. 1 proponents) on their UEs, they can choose to implement only a subset, i.e., Opt. 1. But the specification can support Opt. 2, so other companies can choose to implement a full set of Opt.2 by indicating support of non-zero legacy offset in capability reporting. From FL perspective, this is a mid-ground between the two camps. |
| Huawei, HiSilicon | Not support Opt.2. There are following issues for Opt.2: The flexibility is restricted due to keeping the RRC configured Slot-offset in reference slot;More overhead for dynamic indication is required for the negative value of ‘t’, while the negative value of ‘t’ is due to the configuration of Slot-offset.More complexity for UE, since there are two counting solutions for Slot-offset and available slot ‘t’. By the way, it is also difficult to define the negative value of ‘t’.The detailed analysis can be find in R1-2102338.So, we support Opt.1, which is clear and simple solution with lower overhead and complexity, and also with more flexibility. |
| Nokia/NSB | Support Option 1. And before we agree on Option 2, we need to clarify whether ‘negative’ t value will be supported if option 2 is supproted  |
| Apple | We are fine. |
| MTK | Support Opt 2. without negative t values.  |
| Samsung | Support FL’s proposal, we also think negative “t” values are not needed. If limited flexibility is a problem with slotoffset, gNB can configure zero slotoffset and rely on “t” values as in option 1. We think this is intention of FL’s proposal. |
| NEC | Support the proposal. |
| Futurewei | As expressed before, we prefer Option 1, but we appreciate the FL’s effort. The “basic” and “optional” UE features seem to be a good compromise and acceptable to us.One minor comment: in the basic feature, configuring triggering offset as 0 is not needed. That is, if the UE reports to support R17 SRS triggering offset enhancement, no “slotoffset” or “slotoffset=0” field is needed; the default is just 0 offset. The field “slotoffset” is configured to take any non-zero value conditioned on additional UE feature. Not sure how RAN2 will handle this, but assuming they can, and we can support this proposal.(FL’s reply: I think RAN2 can handle this in as configuring slot offset as 0 from RAN1 perspective should be same as not configuring slot offset in RAN2 signaling.) |
| InterDigital | Support Option 2 with negative t values. Reasons:* Option 1 is a special case of Option 2 when *slotoffset* is zero.
* There is no difference in complexity between the two options as *slotoffset* needs to be configured anyway for the legacy operation.
* Supporting negative t values has no impact on DCI overhead.

Despite our preference for Option 2, as a compromise, we can agree to the following,***Proposal:*** *Support Opt. 2: Reference slot is the slot indicated by the legacy triggering offset, i.e., slotoffset.* *Based on the reported capability, a Rel-17 UE can be configured in one of the following modes** *Mode 1: Aperiodic SRS resource set is transmitted in the (t + 1) counted from the reference slot*
* *Mode 2: Aperiodic SRS resource set is transmitted in the (t – slotoffset + 1) counted from the reference slot*

(FL’s reply: Thanks IDC for the proposal. But I don’t think this proposal can address the issue we have now.* Several companies cannot accept negative values for t.
* We have an agreement on where to identify the aperiodic SRS slot, i.e., (t+1)-th slot counting from the reference slot. Mode 2 violates this agreement.
* Mode 2 itself is not correct. It is not identical with Opt.1. If reference slot is the slot indicated by *slotoffset*, *slotoffset* indicates the number of slots between DCI and reference slot, not the number of available slots. We can only count available slots in Rel-17 mechanism. So this mode 2 may end up with very strange situations.)
 |
| CATT | We appreciate the FL’s effort in harmonizing the alternatives, however “basic UE feature” is still quite confusing. To avoid further delaying this issue, a possible wording change is suggested below. ---***FL Proposal:*** *Support Opt. 2: Reference slot is the slot indicated by the legacy triggering offset.** *For a UE supporting the Rel-17 SRS triggering offset enhancement, configuring legacy triggering offset as 0 or non-zero values when using this enhancement is an optional UE feature.*
* *No negative t values are introduced.*

(FL’s reply: the wording is updated based on your suggestion with some refinement to make it clear. The term “basic feature” is removed.) |
| OPPO | Thanks FL to try a compromised way to move forward. However, the proposal seems to introduce duplicated functionalities. From the technical perspective, we don’t think Option 1 is a subset of Option 2. Let’s assume a specific example* For Option 2: the legacy trigger offset is A and the list of t includes x1, x2, …
* For Option 1: the list of t includes x1+A, x2+A, …

The transmission of SRS Option 1 and Option 2 are the same, except Option 2 uses more RRC parameters to achieve the same purpose.  |
| Intel | Support Option 2. |
| LGE | We also appreciate the FL’s effort, but we don’t think combined solution is needed. |
| QC | We understand the two camps preferences and appreciate FL efforts to reach a compromise solution. In our understanding, the FL proposal accommodates option-1 as the baseline/default mode where it restricts configuration of slot offset to only zero. Additionally, based on optional UE capability (or preference) a non-zero offset can be configured to accommodate some flavor of option 2. From UE perspectives, this is similar to supporting option 2 while letting the network to either set SlotOffset value to zero or non-zero values. The UE should handle any slotOffset value. However, from gNB perspective, it is bit complicated as it needs to handle two sets of UEs.For sake of progress, we are fine with the updated FL proposal with the clarifying note on Rel-15/16 legacy triggering and no negative t-values.  |

### 2.1.2. 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 2-2

|  |
| --- |
| **Collision handling** |
| Schemes | Companies |
| Introduce dropping rule when collision happens among aperiodic SRS resource sets | Qualcomm, ZTE (for SRS in different CCs), Ericsson, vivo (for SRS in different CCs or same CC) |
| Update collision handling rule for SRS colliding with other UL channel/signal | Futurewei (A/N and AP UL triggered later than R17 flexible A-SRS > R17 flexible A-SRS > other UL) |

***FL Proposal:*** *Further discuss in future meetings.*

### 2.1.3 Determination on the value of t

**DCI indication mechanism**

Alternatives to indicate t values in DCI are listed in RAN1#104e’s agreements. Companies’ views in RAN1#104b-e are summarized in the following table.

Table 2-3

|  |
| --- |
| **DCI** |
| Cases | Alternatives | Number | Companies |
| Scheduling DCI (DCIs scheduling a PDSCH or PUSCH) | Alt 2-1: t is indicated by adding a new configurable DCI field | 12 | Apple, ZTE, NEC, NTT DOCOMO, Huawei, HiSilicon, Spreadtrum, vivo, MediaTek, IDC, CATT, Futurewei |
| Alt 2-2: t is indicated without adding DCI payload | 8 | Qualcomm (using aperiodic SRS trigger state), Samsung, Nokia, NSB (using aperiodic SRS trigger state), Ericsson, OPPO, Intel, Xiaomi |
| Non-scheduling DCI (DCI 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 | 11 | Apple, ZTE, NEC, NTT DOCOMO, Huawei, HiSilicon, OPPO, Spreadtrum, CATT, Intel, IDC |
| Alt 1-2: Re-purpose unused DCI field to indicate t | 9 | Qualcomm, ZTE, Samsung, Ericsson, NTT DOCOMO, vivo, MediaTek, CMCC, Xiaomi |
| 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 | 3 | Nokia, NSB, vivo |

We have agreed to strive for a unified solution for scheduling DCI and non-scheduling DCI. Hence FL proposes the following for offline/online discussion in RAN1#104b-e. Companies are encouraged to share your views on these two alternatives.

***FL Proposal:*** *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, discuss and decide one of the following alternatives in RAN1#104b-e*
	+ *Alt 1: t is indicated by adding a new configurable DCI field*
		- *Supported by Apple, ZTE, NEC, NTT DOCOMO, Huawei, HiSilicon, Spreadtrum, vivo, MediaTek, IDC, CATT, Futurewei*
	+ *Alt 2: t values are associated with SRS triggering states*
		- *Supported by Samsung, Intel, Xiaomi, OPPO, Nokia, NSB, Qualcomm, NTT DOCOMO*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Prefer Alt.1. Only three states for AP-SRS triggering for different SRS resource sets, if reuse the bits for available slot t indication, how can gNB triggering different resource sets for different usages, such as antenna switching, CB based transmission, NCB based UL transmission and beam management? Alt.2 will be impact on the use of SRS resource sets for different usages.  |
| Nokia/NSB | Prefer Alt 2 with increase # of codepoints triggering SRS transmission  |
| Apple | Prefer Alt 1You anyhow need to increase DCI size otherwise you suffer scheduling flexibility. I do not understand why it matters in the end. Separate field is much cleaner without tough the legacy operation |
| MTK | Support Alt 1 for *scheduling DCI*. For case of *non-scheduling DCI*, we prefer to re-purpose unused DCI field which is also discussed in section 2.2 |
| NEC | Prefer Alt 1.  |
| Futurewei | Support Alt 1. An explicit indication of t is needed for sufficient flexibility / scalability / future-proof for SRS triggering. Alt 2 is much more limited and not flexible enough. |
| CATT | Support. In our opinion, Alt 1 and Alt 2 are not conflict. By configuring multiple t for each trigger state for each SRS resource set, t values are associated with SRS triggering state, and the new configurable DCI field can be used to indicate t values for each SRS resource set from the list corresponding to the trigger state respectively. |
| OPPO | Prefer Alt.2 |
| Intel | Support Alt 2. |
| QC | Support Alt 2 |

**Size of t list**

We have agreed that a list of t values is configured per SRS resource set. The size of each list is to be determined. Companies’ views are summarized as follows.

Table 2-4

|  |
| --- |
| **Size of t list in each SRS resource set** |
| Alternatives | Number | Companies |
| Up to 2 | 3 | Qualcomm, vivo, NEC |
| At least up to 4 | 10 | Ericsson, ZTE, IDC, CATT, Huawei, HiSilicon, NTT DOCOMO, Lenovo, MotM, Sharp |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Support FL proposal.4 states (2bits) is sufficient considering the general slot configurations. |
| Nokia/NSB | Support FL proposal |
| NTT DOCOMO | Support FL’s proposal |
| Samsung | Ok to support |
| CATT | Support FL proposal.  |
| Intel | We don’t see strong need to have more values of ‘t’, since the restriction on PDCCH slot to trigger SRS has been removed by introducing the concept of ‘available slot’. From our view, two values of ‘t’ is sufficient. If we go Alt-1 of indication of ‘t’, more values of ‘t’ means more DCI overhead.Suggest discussing this after agreement on how to indicate ‘t’. |
| LGE | OK but prefer to postpone the discussion. It is related with t indication mechanism. |
| QC | To further discuss after down selection between the two alternatives for t indication, our preference is only up to two values. |

**Whether to support MAC CE update**

Another FFS point in previous agreement is whether to support MAC CE as an inter-mediate step to update candidate values of t. Companies’ views are summarized as follows.

Table 2-5

|  |
| --- |
| **Whether to support MAC CE as an inter-mediate step** |
| Alternatives | Number | Companies |
| Support using MAC CE to update the candidate values of t | 11 | Qualcomm, Samsung, Nokia, NSB, NTT DOCOMO, MediaTek, Lenovo, MotM, Xiaomi, IDC, NEC |
| Deprioritize or do NOT support | 9 | CMCC, CATT, Huawei, HiSilicon, vivo, Futurewei, LGE, Intel, OPPO |

***FL Proposal:*** *Further discuss in future meetings.*

## Flexible DCI format

**Re-purpose**

In last meeting, we have agreed to support DCI format 0\_1/0\_2 to trigger SRS without data and without CSI request. One remaining issue is whether to re-purpose the unused fields. Companies’ views are summarized as follows.

Table 2-6

|  |
| --- |
| **Repurpose unused fields in DCI format 0\_1/0\_2 without data and without CSI** |
| Categories | Detailed aternatives | Companies |
| CAT-A (Time-domain parameters) * 13 supporting companies: Qualcomm, ZTE, Samsung, Ericsson, NTT DOCOMO, vivo, MediaTek, CMCC, Xiaomi, Nokia, NSB, Futurewei, LG
 | A-1: Indication of available slot position, i.e., the t values  | Qualcomm, ZTE, Samsung, Ericsson, NTT DOCOMO, MediaTek, CMCC, Xiaomi |
| A-2: Indication of slot offset  | Nokia, NSB, Ericsson, vivo, Futurewei |
| A-3: Indication of SRS symbol-level offset  | LG, Futurewei |
| A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting  | vivo, Futurewei |
| CAT B (Frequency-domain parameters)* 6 supporting companies: Qualcomm, Futurewei, Xiaomi, Ericsson, LG, Intel
 | B-1: Indication of a group of CCs for SRS transmission | Qualcomm, Futurewei, Xiaomi |
| B-2: Indication of frequency domain resource in a BWP for SRS transmission | Ericsson, LG, Futurewei, Xiaomi |
| 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)* 6 supporting companies: Qualcomm (for each CC), Futurewei, Intel, Xiaomi, Huawei, HiSilicon
 | C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’ | Qualcomm (for each CC), Futurewei, Intel, Xiaomi |
| C-2: Indication of open loop power control parameter e.g., p0. | Huawei, HiSilicon |
| Do not support this category | Vivo, Lenovo, MotM |
| CAT D (Spatial-domain parameters, i.e., indication of SRS port and beamforming)* 1 supporting company: Futurewei
 | Re-purpose CSI-RS/TPMI indication to indicate SRS spatial-domain parameters | Futurewei |
| Do not support this category | CMCC |
| CAT E (Extend the number of DCI codepoints for aperiodic SRS trigger states)* 6 supporting companies: Nokia, NSB, Futurewei, Intel, Xiaomi, NTT DOCOMO
 | Extend the number of DCI codepoints for aperiodic SRS trigger states | Nokia, NSB, Futurewei, Intel, Xiaomi, NTT DOCOMO |
| New functionalities | Re-purpose to indicate set usage | Spreadtrum |
| No or deprioritize | - | Apple, OPPO, CATT, Lenovo, MotM |

The majority of companies have interest in CAT A, while the other categories do not attract major interest. Hence the following is proposed by FL.

***FL Proposal:*** *Support enhancement on aperiodic SRS time-domain resource management based on repurposing unused fields in DCI format 0\_1/0\_2 without data and without CSI, by at least one of the following alternatives:*

* *Alt A-1: Indication of available slot position, i.e., the t values*
* *Alt A-2: Indication of legacy slot offset*
* *Alt A-3: Indication of SRS symbol-level offset and/or number of SRS symbols*
* *Alt A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting*
* *Note: discussion on the other categories (CAT B-E) is still allowed*
* *FFS the applicable RNTIs or using new RNTI when doing repurposing*
* *FFS the interpretation for BWP indicator*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Not support. For Alt.A-1/2, the available slot t indication is already discussion in 2.1.3. If more bits for without data case for t indication, how can indication of t for with data scheduling case? For A-3/4, we do not see the clear benefits, more study is needed. |
| Nokia/NSB | Support ‘offset’ indication whether the offset should count available slot only. I wonder Alt A-1 should mean this operation.As response to Huawei, we think repurposing of unused filed can increase the flexibility on SRS triggering |
| Apple | Do not support. No re-purposing. Currently, it is the same DCI that schedules or not schedules PUSCH, i.e., DCI 0\_1/0\_2. There is no need to introduce fragmented design. We enhance slot offset and that is it.  |
| MTK | Okay for one of Alt A-1 or A-2 (but not both).As in section 2.1.3 Alt 1 is *configurable* new field, repurposing unused fields can still be useful when the new field is not configured.  |
| NTT DOCOMO | Support FL’s proposal. In particular, regarding the FFS point on applicable RNTI, we propose to introduce a new RNTI to differentiate between DCI with and without data/CSI scheduling. With that, if the UE specific DCI is CRC scrambled using the new RNTI, this DCI is treated as the extended DCI without data /CSI scheduling. Otherwise, the DCI is the existing DCI with data/CSI scheduling. |
| Futurewei | Support |
| CATT | We prefer to deprioritize the discussion until an agreement on how to configure and indicate “*t*” is achieved. |
| OPPO | Not support |
| Intel | We don’t see the strong need of CAT-A, the available slot indication is discussed in Section 2.1.3. |
| QC | We believe that CAT-B (freq.) and CAT-C (power) are beneficial functionality that are overlooked. xCC A-SRS triggering using single DCI reduces DCI/PDCCH overhead while power control enables refinement of SRS total power. * *Alt A-1 and Alt A-2* should be discussed after the agreement on t-indication method as they have some dependency on which alternative is selected.

We do not see the benefits or need of *Alt A-3* and *Alt A-4.* |

**Group-common DCI**

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

Table 2-7

|  |
| --- |
| **Whether group-common DCI enhancement is supported additionally** |
| Alternatives | Number | Companies |
| Yes | 5 | Qualcomm, Samsung, vivo, Futurewei, Xiaomi |
| No or deprioritize | 8 | OPPO, Huawei, HiSilicon, Nokia, NSB, Lenovo, MotM, LGE |

***FL Proposal:*** *Further discuss in future meetings.*

## Usage/overhead reduction

One remaining issue is whether to specification enhancement on reusing SRS resource(s) for multiple usages. Table 2-8 summarize companies’ views.

Table 2-8

|  |
| --- |
| **Whether to support configuring one SRS resource set with multiple usages explicitly** |
|  | 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 | 5 | Apple, ZTE, Ericsson, NTT DOCOMO, CATT |
| Action 2: Add a RRC parameter to turn on/off the UE behavior in Action 1 | 4 | Apple, Ericsson, NTT DOCOMO, CATT |
| Action 3: Have a conclusion to clarify same virtualization is used if SRS resource(s) for antenna switching also belong to a set for codebook | 3 | Ericsson, ZTE, CATT |
| None of the above actions is needed | 9 | Samsung, Huawei, HiSilicon, Futurewei, Intel, IDC, Lenovo, MotM, Qualcomm |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Not necessary for spec enhancement, since SRS resource sharing is already supported from Rel-15 with implementation. |
| Apple | Action 1 is the minimum since there is no consensus we support usage sharing. That is the issue in real deployment because some infra-vendor making hacked configured without clear UE behavior specified.  |
| CATT | As a gNB vendor we support tying up the loose end of SRS reuse. We are fine to start with either Action-1 or Action-3.  |
| Intel | Same view as previous round. |

## 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 2-9

|  |
| --- |
| **Update Tx/Rx antennas for SRS antenna switch in dynamic signaling** |
|  | Number | Companies | Other comments |
| Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | 9 | Apple, Qualcomm (MAC CE), Ericsson (MAC CE), Huawei, HiSilicon (MAC CE), Lenovo, MotM, Xiaomi, ZTE | **UE reporting**Apple, Xiaomi, Qualcomm: Support UE reporting of the preferred antenna switching configuration/Rx/Tx antenna numbers**Applicable cases**Case 1: aperiodic SRS* Ericsson

Case 2: periodic or semi-persistent SRS* Huawei, HiSilicon
 |

The following proposal is given based on companies’ input to RAN1#104b-e.

***FL proposal:*** *Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE.*

* *Applicable to at least one of the following two cases*
	+ *Case 1: aperiodic SRS*
	+ *Case 2: periodic or semi-persistent SRS*
* *FFS UE reporting of the preferred antenna switching configuration*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | We only support periodic and semi-persistent SRS case, i.e., Case 2. As claimed by supporting companies, the benefits on this proposal is for power saving or resource saving, so the benefits only be in periodic or semi-persistent SRS cases.  |
| Nokia/NSB | Not support. For power saving purpose, we first need to confirm how the adaption can be triggered. It is premature to decide whether MAC CE based adaptation of SRS antenna switching is needed for UE power saving. |
| Apple | Support UE reporting, then, discuss NW configuration  |
| Futurewei | Do not support.We have pointed out several issues that need to be clarified / discussed. For example, Tx antenna switching and Rx antenna switching have different considerations / impacts. For another, for Tx switching, is this R15-type of switching or R16-type of downgrading? How about the virtualization? There are many issues. |
| CATT | Prefer further discussion. |
| OPPO | Not support since the use case and benefits are not justified. |
| Intel | We don’t see the need for MAC-CE. The SRS resource sets for downgraded antenna switching could be configured with another trigger state. In this way, the different number of antennas for antenna switching can be selected by DCI. |
| LGE | We still think the benefit is not clear. |
| QC | Support FL proposal.Benefits both UE (by reporting preferred SRS switching configuration) and also NW for efficient utilization of resources. |

## Others

The following issues are discussed by one company.

|  |  |
| --- | --- |
| Support single scheduling DCI to trigger simultaneous AP SRS transmission across multiple component carriers | Qualcomm |
| Support triggering multiple SRS resource sets and/or triggering multi-shot SRS by a single DCI | LG |
| Reuse parameters from a co-scheduled/associated PDSCH/PUSCH for AP SRS | Futurewei |
| Allow non-contiguous/almost contiguous sounding | Futurewei |
| Support update the association between aperiodic SRS resource set(s) and aperiodic SRS triggering states by MAC CE | Lenovo, MotM |

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

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | As described above, scheduling DCI flexibility enhancements should also be discussed. We suggest to add a discussion point for it.A related issue is to further clarify the SRS transmission parameters and the expected UE behavior. For the parameters explicitly indicated in the DCI, they should overwrite any RRC/MAC parameters of exactly the same type. For parameters not explicitly indicated in the DCI, they can generally follow RRC/MAC parameters but some of them may still be able to be reused from elsewhere, such as from the co-scheduled PUSCH/PDSCH.  |
| Futurewei2 | Again on the scheduling DCI --- we had an agreement before:**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

All FFS are being discussed except that we have no place to discuss the scheduling DCI. We’d like to ask this to be discussed. |
| LGE | We also prefer to discuss “FFS UL/DL DCI with data for aperiodic SRS”. |

# Antenna switching up to 8Rx

## Aperiodic SRS configurations for >4Rx

RAN1 agreed the general framework to support configuring >4Rx SRS configurations, while the supported values for N\_max and N is FFS. The following tables summarize companies’ views. Note that 4T6R is not included as the decision is pending.

**N\_max values**

Table 3-1

|  |
| --- |
| **N\_max** |
| xTyR | Value | Companies |
| 4T8R | Confirm the WA with | N\_max = 1 | 3 companies: Qualcomm, Spreadtrum, CMCC, Intel |
| N\_max = 2 | 11 companies: Samsung, ZTE, Ericsson, NTT DOCOMO, OPPO, Spreadtrum, CATT, Lenovo, MotM, Xiaomi |
| Update the WA with * For *ullyAndPartialAndNonCoherent* Ues, K=2, N\_max = [4], and each resource has 4 ports
* For *partialAndNonCoherent* and *oncoherent* Ues, K=4, N\_max = [2], and each resource has 2 ports
 | 1 company: InterDigital |

Following majority view, FL proposes the following.

***FL Proposal:*** *On aperiodic SRS configuration for antenna switching with 4T8R, support N\_max = 2*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | We cannot support the proposal.In our contribution (R1-2102437), we have shared our evaluation of 4T8R vs. 2T8R SRS configuration for a 4T8R partial coherent UE. According to our observations:* For partial coherent 4T8R Ues, 2T8R-based AS performs better than 4T8R AS configuration.
* For partial coherent Ues with a 4T8R-based AS configuration, increasing calibration accuracy does not result in any major improvements.
* For partial coherent Ues with a 2T8R-based AS configuration, increasing calibration accuracy significantly improves the performance.

So our proposal is to update the WA with * **For *ullyAndPartialAndNonCoherent* Ues, K=2, N\_max = [4], and each resource has 4 ports**
* **For *partialAndNonCoherent* Ues, K=4, N\_max = [2], and each resource has 2 ports**

A couple of notes and clarifications:* Therefore, for the purpose of channel sounding, a fully coherent UE will send SRS transmission simultaneously over 4 ports (K=2). However, a partially coherent UE, will perform channel sounding by performing SRS transmission over 2-ports at the time (K=4).
* The proposal poses no restriction on the number of MIMO layers, capability, etc. It only enhances accuracy of the DL CSI estimation obtained by the antenna switching procedure.
 |
| Huawei, HiSilicon | Support the FL proposal. |
| Nokia/NSB | Support FL proposal.As response to InterDigital, your consideration should be separately discussed. In issue 3.1, we consider SRS configuration for a UE reported capability of 4T8R, while InterDigital’s issue is whether UE with partial coherence can report 4T8R capability.  |
| Apple | We are fine |
| NTT DOCOMO | Support FL’s proposal |
| Samsung  | Support |
| NEC | Support the proposal. |
| CATT | Support FL proposal |
| OPPO | Support |
| Intel | Prefer to change *N\_max = ~~2~~1* |
| LGE | Support. |
| QC | Our preference is to have N\_max = 1 Configuring two sets (one SRS resource per set) may degrade the quality of SRS and subsequent UL signal/channel transmission due to the time-mask transient period requirement to allow change of power and UE ports.  |

**N values**

Table 3-2

|  |
| --- |
| **N** |
| Alternatives | Sub-alternatives | Companies |
| Alt 1: All the non-zero integer values <= N\_max are supported for N | - | 9 supporting companies: Samsung, ZTE, Ericsson, CATT, Lenovo, MotM, Huawei, HiSilicon, OPPO |
| Alt 2: Support N=N\_max only | - | 2 supporting companies: vivo, Spreadtrum |
| Alt 3: Support specific N values | 1T6R | N={2, 3} | Nokia, NSB, CMCC (if only the last 6 symbols can transmit SRS) |
| N=2 | CMCC (if all the symbols can transmit SRS) |
| 1T8R | N={2, 4} | Nokia, NSB |
| N={3, 4} | CMCC (if only the last 6 symbols can transmit SRS) |
| N=2 | CMCC (if all the symbols can transmit SRS) |
| 2T6R | N={1, 3} | Nokia, NSB |
| N={1, 2} | CMCC (if only the last 6 symbols can transmit SRS) |
| N=1 | CMCC (if all the symbols can transmit SRS) |
| 2T8R | N={1, 2, 4} | Nokia, NSB |
| N=2 | CMCC (if only the last 6 symbols can transmit SRS) |
| 4T8R | N=1 | CMCC |

***FL Proposal:*** *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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | *Support Alt.1.* |
| NTT DOCOMO | Support Alt 1 |
| Samsung | Support Alt.1 |
| CATT | Support Alt.1, with FFS for 1T8R, In our opinion, with the restriction that there is a GP with at least one symbol between any two SRS resources in the same set in a slot, at least N =2 is needed for 1T8R. |
| OPPO | Prefer Alt.1.  |
| Intel | We think different UE capability on OFDM symbol position for SRS (either the last 6 OFDM symbols or any OFDM symbols in the slot) should be considered separately. Suggest the following change to the main bullet:*On supported values of N for Rel-17 aperiodic SRS antenna switching with >4Rx for a given UE capability on OFDM symbol position for SRS, down-select at least one of the following alternatives in RAN1#105e*For example, for 1T6R with N\_max=3, if the UE only supports SRS over the last 6 OFDM symbols, then obviously N=1 is not applicable. |
| LGE | Support FL’s proposal. |
| QC | Support Alt 3 to have specific configurations of sets/resources.  |

## Extension for aperiodic SRS with <=4Rx

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

Table 3-3

|  |
| --- |
| **Whether to support increasing N\_max for 1T4R, 2T4R, T=R and 1T2R cases** |
|  | Number | Companies |
| Yes | 5 | Ericsson (Support N=4 for 1T4R and N=2 for 1T2R/2T4R), Xiaomi (Support N=4 for 1T4R and N=2 for 1T2R/2T4R), CATT (Support N = 1 for 1T4R), Intel, ZTE |
| No or deprioritize | 5 | Qualcomm, CMCC, vivo, Lenovo, MotM |

***FL Proposal:*** *Further discuss in future meetings*

## Configurations for periodic and semi-persistent SRS

Table 3-4

|  |
| --- |
| **Number of resource sets for periodic or semi-persistent SRS** |
|  | Number | Companies |
| Alt 1: Support only one SRS resource set for either periodic or semi-persistent SRS | 8 | Qualcomm, ZTE, vivo, CATT, CMCC, Xiaomi, Lenovo, MotM |
| Alt 2: Support at least one resource set for periodic SRS and at least two SRS resource sets for semi-persistent SRS | 3 | Huawei, HiSilicon, Intel |

***FL Proposal:*** *For antenna switching with >4Rx, support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL’s clarification | This updated proposal is to address the request from Huawei (at least partially). This allows gNB to configure both semi-persistent SRS and periodic SRS for antenna switching with >4Rx. |
| Huawei, HiSilicon | Some clarifications: 1. In Rel-15, we have already support one periodic and one semi-persistent SRS resources for 1T2R and 2T4R, etc. Why we design the only one SRS resource for P-SRS or SP-SRS in Alt.1? It does not make sense.2. The discussion is for both >=4Rx or <4Rx, the SRS collision already happens in current networks, and the issue is from real network. So, it is not for >4Rx case only.3. Configured two SP-SRS resource sets are beneficial to avoid the SRS collision by MAC-CE to activation and deactivation one of SP-SRS.4. If companies concern on the complexity, we can have a restriction on the UE does not activate two SP-SRS resource sets at the same time.4. By the way, in the reply from Intel, they also propose multiple SP-SRS resource sets.So, the proposal is: ***For antenna switching, 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.*** |
| Nokia/NSB | Not support. We need to confirm amount of required SRS resource of SRS symbols first. For example, we need to confirm whether SRS repetition can be applied on SRS antenna switching for coverage extension |
| Apple | Sorry. I am little configured, “*maximum one SRS resource set for aperiodic SRS”?*So what about the N\_max agreement(FL’s reply: It was a typo. Thanks for spotting this.) |
| NTT DOCOMO | Support FL’s proposal |
| Samsung | We think the FL’s proposal might be *For antenna switching with >4Rx, support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-periodic ~~aperiodic~~ SRS.* Is it correct?(FL’s reply: Yes.) |
| CATT | Support FL proposal.  |
| Intel | We do have concern if only one periodic SRS resource set or only one semi-persistent SRS resource set is configured for antenna switching in multi-TRP scenario. If so, there would be a lot of signaling to reconfigure the SRS among different TRPs.We could be ok with the following change.*For antenna switching with >4Rx in the scenario of single TRP, support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS.* |
| QC | Support FL proposal. In addition, we are open for discussion on SRS repetition for SRS antenna switching as suggested by Nokia. |

## Configured time-domain types for 1T4R

Multiple companies discuss enhancing the number of configured time-domain types to more than one for antenna switching SRS with 1T4R.

Table 3-5

|  |
| --- |
| **Number of configured time-domain types** |
|  | Number | Companies |
| Alt 1: Only one time-domain type (periodic, semi-persistent ~~or aperiodic~~) can be configured for 1T4R (same as Rel-15) |  |  |
| Alt 2: Support configuring more than one time-domain types (periodic, semi-persistent ~~or aperiodic~~) for antenna switching SRS with 1T4R | 3 | ZTE, Huawei, HiSilicon |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL’s clarification | @Ericsson, for the xTyR configurations supported in the current specification, only 1T4R has the issue that only one time-domain type can be configured. For >4Rx, it is discussed in Section 3.3. |
| Huawei, HiSilicon | For 1T4R, there is only up to one SRS resource set can be configured for periodic or semi-persistent.*“For 1T4R, zero or one SRS resource set configured with higher layer parameter resourceType in SRS-ResourceSet set to 'periodic' or 'semi-persistent'..”*The similar proposal as Section 3.3:***For antenna switching for 1T4R, 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.*** |
| Intel | Open for discussion |

## Guard period

Multiple companies discuss whether to remove some always-on guard symbols between two adjacent SRS resources for antenna switching.

Table 3-6

|  |
| --- |
| **Whether to remove some always-on guard symbols between two adjacent SRS resources for antenna switching** |
|  | Number | Companies |
| Alt 0: Guard symbols are always-on, which is same as Rel-15 | 1 | LG |
| Alt 1: Make the present of guard symbols configurable subject to UE capability | 3 | Ericsson, Lenovo, MotM |
| Alt 2: Remove some of the guard symbols based on certain conditions | 3 | Sony, IDC, NTT DOCOMO |
| Alt 3: Introduce guard symbols between different SRS resource sets | 2 | vivo, LG |

***FL Proposal:*** *For guard symbols of antenna switching SRS in Rel-17, adopt at least one of the following, with Alt 0 as the baseline*

* *Alt 0: Guard symbols are always-on, which is same as Rel-15*
* *Alt 1: Make the present of guard symbols configurable, subject to UE capability*
* *Alt 2: Remove some of the guard symbols based on certain conditions*
* *Alt 3: Introduce guard symbols between different SRS resource sets*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Some further discussion is needed: which case is for the change of number of guard symbols?  |
| Nokia/NSB | We are open for further discussion, but Alt 0 should be the baseline, if no consensus achieved. |
| Apple | We are fine for further discussion. But gNB cannot randomly remove the guard interval. |
| NTT DOCOMO | Support FL’s proposal. In particular, we prefer Alt 1 |
| Samsung | Similar view as Nokia. |
| NEC | Support the proposal. |
| CATT | Support. |
| OPPO | Not support |
| Intel | Fine with FL proposal.One question regarding Alt 2 for clarification. Under what condition the guard symbols could be removed? |
| LGE | Support. |
| QC | Fine to further discuss |

## Whether 4T6R is supported

One remaining issue is whether 4T6R is supported. Companies’ views are summarized as follows.

Table 3-7

|  |
| --- |
| **Whether to support 4T6R SRS antenna switching** |
|  | Number | Companies |
| Yes | 10 | Qualcomm, NEC, InterDigital, Spreadtrum, Lenovo, MotM, CMCC, Xiaomi, NTT DOCOMO, MediaTek |
| No or deprioritize | 5 | Ericsson, Futurewei, Huawei, HiSilicon, vivo |

***FL Proposal:*** *Further discuss in future meetings.*

## Others

The following issues are discussed by one or two companies.

|  |  |
| --- | --- |
| Support UE capability reporting of power offset across antenna ports for SRS DL CSI acquisitions | Qualcomm |
| 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 |
| Consideration on antenna switching for multi-panel UEs | Sony, vivo, LGE |
| Further study SRS resource/resource set configurations for multi-TRP | Intel |

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

|  |  |
| --- | --- |
| Companies | Views |
| vivo | In FR2 with multi-panel UE, SRS configuration (combination of set and number of resource) should consider UE multi-panel capability |
| LGE | Antenna switching across multi-panel should be considered in antenna switching up to 8Rx. Let’s consider 2 Rx panel UE with 8 Rx antennas, e.g., 4 Rx antennas for each panel, and the UE has 4 Tx chain. 4T8R can be configured for this UE, so 2 SRS resource set (each set has 4T) may be configured. If the UE cannot activate both Rx panel simultaneously (MP-UE assumption 1 or 3 in Rel-16 MB discussion), the gap between the 2 SRS resource set should be more than 1 symbol, e.g., multiple symbols or multiple slots. This can be a huge impact for gNB configuration.Also, in M-TRP PUCCH enhancement (8.1.2.1), the gap symbol between PUCCH beam switching is considered within a panel. This gap symbol can be more needed for PUCCH panel switching case, being discussed in RAN4 reply LS. |
| QC | * Current 3GPP spec allows only for UE capability reporting (maxNumberMIMO-LayersPDSCH’) of 2,4 or 8 maxMIMO DL layers.
	+ 6Rx/8Rx UE should be able to report capability of 6 layers.
* For 6Rx/8Rx Ues, there is an increase of insertion loss due to the added RF switching circuity needed for the UE to sound all Rx antenna ports.
	+ A UE capability reporting of power offset between antenna ports can help the gNB to compensate of the power offset (reciprocity mismatch) between the UL and DL channels and improve the DL throughput.
 |

# Coverage and capacity enhancements

## Increased repetition

Void.

## RB-level partial frequency sounding (RPFS)

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

### 4.2.1 Issues related to PF and start RB

Table 4-1

|  |
| --- |
| **Supported PF values** |
| Values | Companies |
| PF = {2, 4} | 16 supporting companies* Qualcomm, ZTE, Sony, Nokia, NSB, Ericsson, Sharp, Fraunhofer IIS, Fraunhofer HHI, Huawei, HiSilicon, OPPO, vivo, Lenovo, MotM, MediaTek
 |
| PF = 8 | 12 supporting companies* Qualcomm, ZTE, Sony, Nokia, NSB, Sharp, Fraunhofer IIS, Fraunhofer HHI, vivo, Lenovo, MotM, MediaTek
 |
| PF = 3 | 2 supporting companies* Sony, vivo

3 companies have concern* Nokia, NSB, Spreadtrum
 |
| Other values | PF = {12, 16} | 2 supporting companies* Fraunhofer IIS, Fraunhofer HHI
 |
| Fractional values | 1 supporting company* Futurewei

1 company has concern* CMCC
 |
| **How to avoid fractional values for** $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$**, e.g., in the case of PF = 8** |
| Alternatives | Number | Companies |
| Alt 1: Restrict that $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is an integer value | 10 | Qualcomm, ZTE, Samsung, Sony, Huawei, HiSilicon, OPPO, Lenovo, MotM, MediaTek |
| Alt 2: Introduce a rule to round $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ | 1 | vivo |
| **How to restrict SRS sequence length for RPFS** |
| Alternatives | Number | Companies |
| Alt 1: Restrict that the final SRS sequence (i.e., the number of SRS subcarriers) is a multiple of 6, which has been supported by the current specification | 6 | ZTE, Sony, Ericsson, Sharp, OPPO, MediaTek |
| Alt 2: Restrict that the minimum number of RBs given by $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is 4 | 4 | Qualcomm, Huawei, HiSilicon, Futurewei |
| Alt 3: Restrict that the number of RBs given by $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is a multiple of 4 | 1 | vivo |
| **Supported N\_offset value, which is the start RB index of the** $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ **RBs in the** $m\_{SRS, B\_{SRS}}$ **RBs** |
| Values | Companies |
| $\frac{k\_{F}}{P\_{F}}m\_{SRS, B\_{SRS}}$, where kF = {0, …, PF-1} | 11 supporting companies* Apple, ZTE, Qualcomm, Huawei, HiSilicon, OPPO, CATT, MediaTek, Futurewei, Lenovo, MotM
 |
| **Whether to support hopping of start RB location** |
| Views | Companies |
| Support start RB location hopping in different SRS occasions or symbols | 8 supporting companies* Qualcomm, ZTE, Ericsson, Huawei, HiSilicon, vivo, MediaTek, Spreadtrum
 |
| **Signaling to determine PF and Noffset** |
| Alternatives | Number | Companies |
| Alt 1: Determine PF value and Noffset value by RRC configuration per SRS resource | 7 | ZTE, Huawei, HiSilicon, CATT, MediaTek, Apple, Ericsson |
| Alt 2: Configure multiple P\_F and N\_offset values in RRC, and update the used one in MAC CE | 3 | CMCC, Lenovo, MotM |

Based on the online GTW discussion on Tuesday, FL has the following proposals.

***FL Proposal:***

*For RB-level partial frequency sounding (RPFS) in Rel-17*

* *The start RB index of the* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *RBs in the* $m\_{SRS, B\_{SRS}}$ *RBs is* $N\_{offset}=\frac{k\_{F}}{P\_{F}}m\_{SRS, B\_{SRS}}$*, where kF = {0, …, PF-1}*
	+ *FFS support start RB location (*$N\_{offset}$*) 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*

***FL Proposal:***

*For RPFS in Rel-17, determine the supported values for PF from the set {2, 4, 8} in RAN1#105e, with potential consideration on the following alternatives*

* *Alt 1:* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *is an integer value*
* *Alt 2:* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *is an integer value with minimum value 4*
* *Alt 3:* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *is a multiple of 4*
* *FFS other values for PF, including 12, 16 and fractional numbers*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL’s clarification | The two proposals are updated based on online GTW discussion. The first one contains the last two bullet in previous FL proposal. Also, it does not impact the decision on P\_F and alternatives in the second proposal.The second proposal contains both the decision on P\_F and the issue of restriction on $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$.FL believes with this formulation, these two proposals should be acceptable to everyone. Let’s target for email endorsement for these two proposals. |
| Huawei, HiSilicon | Support the first FL proposal.For the second FL proposal, we prefer the original proposal in Chairman note to agree PF values in this meeting, which is common part. Then, for further discussion the next details in this meeting or next meeting. There is no reason to bund the values of partial bandwidth on the PF values selection, since the discussion on partial bandwidth is anyway needed for any value of PF. If some company concern to remove PF=3, it can be also open to further study.**Possible Agreement***For RB-level partial frequency sounding (RPFS) in Rel-17,* * *Support PF = {2, 4}*
	+ *FFS 3, 8, 12, 16 or fractional values*
	+ $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *~~is a multiple of 4~~*
	+ *FFS further restrictions on* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$*, which support at least one of*
		- *Alt 1:* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *is an integer value*
		- *Alt 2:* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *is an integer value with minimum value 4*
		- *Alt 3:* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *is a multiple of 4*

(FL’s reply: I’m okay to agree on {2, 4} first. I don’t think there would be any company with real concern on these two values. Further, at least we have to select one from the three alternatives. So it should not be an FFS point. Let’s check other companies’ input first.) |
| Apple | Fine for further discussion  |
| MTK | Support FL’s Proposals |
| NTT DOCOMO | Support FL’s proposal. Regarding the 2nd bullet point of the first proposal, as per our understanding, RRC should configure $k\_{F}$ value (not $N\_{offset}$) along with $P\_{F}$(FL’s reply: Either k\_F or N\_offset is a purely signaling detail which only impacts 331. This proposal just says we should at least use RRC signaling to determine N\_offset, which should be accurate from RAN1 perspective.) |
| Samsung | We are ok with the first proposal and support alt 3 in the second one. |
| NEC | Support the proposal. |
| Futurewei | Support the first proposal.Support the second proposal in principle. We wonder if we really have to restrict the PF values to be certain values. As long as the PF values for a SRS resource meet the to-be-defined requirement for $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$, we can just allow the gNB to configure any PF values it wants to. For example, is there any issue with PF values being chosen from {1,2,3,4,…,64}?(FL’s reply: At least we should have a step forward for the supported values of P\_F. A lot of companies have shown their views on the values. 2, 4 and 8 are the ones with most support, and the interest on the other values is quite low. Hope it can be understandable to Futurewei.) |
| CATT | Support FL’s proposal. |
| OPPO | Support. We prefer Alt.3 for the second proposal |
| Intel | Fine with FL proposal |
| LGE | Support FL’s proposal. We also support Alt 3 in the second proposal. |
| Nokia/NSB | Support FL’s proposal. |
| QC | Support FL’s proposal.  |

### 4.2.3 Applicable cases

On the FFS point of applicable cases for RPFS, the following table summarize companies’ views.

Table 4-2

|  |
| --- |
| **Whether to restrict the applicable cases for RPFS** |
| Views | Number | Companies |
| RPFS is applicable only for frequency hopping case | 6 | Qualcomm, OPPO, Spreadtrum, vivo, Intel, CMCC |
| RPFS is applicable for both frequency hopping and non-frequency hopping cases | 8 | Nokia, NSB, NEC, Huawei, HiSilicon, Xiaomi, Lenovo, MotM |

***FL Proposal:*** *Further discuss in future meetings*

### 4.2.4 SRS sequence

Some companies discuss how to generate SRS sequence for RPFS. The following two alternatives can be identified.

Table 4-6

|  |
| --- |
| **How to generate SRS sequence for RPFS** |
| Alternatives | Number | Companies |
| Alt 1: Generate length-$\frac{\frac{12}{P\_{F}}m\_{SRS, B\_{SRS}}}{Comb}$ ZC sequence | 6 | ZTE, NTT DOCOMO, Ericsson, Qualcomm, MediaTek, NEC |
| Alt 2: Truncate from legacy length-$\frac{12⋅m\_{SRS, B\_{SRS}}}{Comb}$ sequence according to the location of RPFS SRS | 4 | Huawei, HiSilicon, Futurewei, Intel |

Companies are encouraged to share your views on the two alternatives. We’ll see whether we can make the down-selection in this meeting.

***FL Proposal:*** *For RPFS SRS in Rel-17, adopt one of the following alternatives for sequence generation*

* *Alt 1: Generate length-*$\frac{\frac{12}{P\_{F}}m\_{SRS, B\_{SRS}}}{Comb}$ *ZC sequence, where no new sequence length other than the ones supported in the current spec is pursued*
* *Alt 2: Truncate from legacy length-*$\frac{12⋅m\_{SRS, B\_{SRS}}}{Comb}$ *sequence according to the location of RPFS SRS*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Support Alt 2. The enhancement with partial sounding is mainly for high SRS capacity. So, the SRS multiplexing between UEs is the key issue for partial sounding. Alt.1 is with the problem on multiplexing between partial SRS sequence and legacy SRS sequence, and also problem on the multiplexing between partial SRS with different PF.  |
| Apple | We prefer to consider only the length supported in the current specification without new SRS sequence generation.  |
| NTT DOCOMO | Support Alt.1. The purpose of partial sounding is for both capacity enhancement and for power boosting (for better coverage). However, truncation of legacy sequence will have adverse impact on the PAPR. We understand the benefit of Alt.2 is that it can multiplex Ues between partial sounding and regular sounding (legacy Ues). However, we believe that multiplexing can be done using FDM. Hence we do not see much benefit from Alt.2 |
| Samsung | Same as Apple.  |
| NEC | Support Alt 1. |
| Futurewei | Support Alt 2. Truncation is a simple solution. |
| OPPO | We share the same view as Apple |
| Intel | Need further discussion. Suggest making decision in future meetings. |
| LGE | Share the similar view with Apple, Samsung and OPPO. |
| Nokia/NSB | We share the same view with Apple, Samsung, OPPO, and LGE |
| QC | Support Alt1Have concerns on Alt-2 as it impacts PAPR and hence coverage gain. Also, from our perspectives, Alt 2 can be considered a new sequence which contradicts with the previous agreement that No new sequence including length is introduced. |

## Comb-8

The major remaining issue on Comb-8 is the maximum number of supported cyclic shifts. The following table summarizes companies’ views.

Table 4-8

|  |
| --- |
| **The maximum number of supported cyclic shifts** |
| Alternatives | Number | Companies |
| Alt 1: The maximum number of CSs for Comb-8 is 6 | 3 | Huawei, HiSilicon, 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 | 1 | Ericsson |

***FL Proposal:*** *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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Support Alt.1. Already discussed in Positioning in Rel-16. It is difficult to support more than 6 CSs in the case of Comb-8 in a real channel. |
| Samsung | Support Alt.1 |
| Intel | Open for discussion |
| LGE | OK with Alt 1. |
| Nokia/NSB | Support Alt. 1 |
| QC | Fine with further discussion and down selection in the coming meeting. |

## Others

The following issue is discussed by two companies.

|  |  |
| --- | --- |
| Support different repetition factors/SRS bandwidths for different symbols within one SRS resource | Nokia, NSB |
| Different RE level comb offset (non-zero $k\_{offset}^{l^{'}}$) in each OFDM symbol | MediaTek |

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 $\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ contiguous RBs in one OFDM symbol, where$m\_{SRS,B\_{SRS}}$  indicates the number of RBs configured by BSRS and CSRS
	+ Support at least one PF value from {2, [3], 4, 8}
		- FFS other candidate values, e.g., non-integer values for PF
	+ Note: SRS sequence shorter than the minimum length supported in the current specification is not pursued.
	+ No new sequence including length is introduced
	+ FFS it is applicable to frequency hopping and non-frequency hopping
	+ FFS detailed signaling mechanism to determine PF and the location of the $\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ RBs
* Support Comb 8
	+ Note: SRS sequence shorter than the minimum length supported in the current specification is not pursued.
* FFS whether and if needed, how to use harmonized approach to define the three supported schemes
* Note: other schemes for SRS capacity and coverage enhancements are not supported in Rel-17.

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

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

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

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

1. RP-193133, New WID: Further enhancements on MIMO for NR, Samsung
2. R1-2102338, SRS Enhancements in Rel-17, Huawei, HiSilicon
3. R1-2102383, Enhancements on SRS flexibility, coverage and capacity, OPPO
4. R1-2102437, Enhanced SRS Transmission and Antenna Switching, InterDigital, Inc.
5. R1-2102446, Consideration on SRS enhancement, Spreadtrum Communications
6. R1-2102511, Further discussion on SRS enhancement, vivo
7. R1-2102603, Enhancements on Rel-17 SRS, CATT
8. R1-2102665, Enhancements on SRS flexibility, coverage and capacity, ZTE
9. R1-2102678, Enhancements on SRS flexibility, coverage and capacity, MediaTek Inc.
10. R1-2102765, Enhancements on SRS flexibility, coverage and capacity, FUTUREWEI
11. R1-2102842, Enhancements on SRS, Lenovo, Motorola Mobility
12. R1-2102882, Enhancements on SRS flexibility, coverage and capacity, CMCC
13. R1-2102964, Discussion on SRS enhancements, Xiaomi
14. R1-2103019, Discussion on SRS enhancements, Intel Corporation
15. R1-2103093, Views on Rel-17 SRS enhancement, Apple
16. R1-2103155, Enhancements on SRS flexibility, coverage and capacity, Qualcomm Incorporated
17. R1-2103226, Enhancements on SRS, Samsung
18. R1-2103292, Considerations on SRS flexibility, coverage and capacity, Sony
19. R1-2103370, Enhancements on SRS flexibility, coverage and capacity, Nokia, Nokia Shanghai Bell
20. R1-2103444, SRS Performance and Potential Enhancements, Ericsson
21. R1-2103471, Enhancements on SRS, Sharp
22. R1-2103509, Enhancements on SRS flexibility, coverage and capacity, LG Electronics
23. R1-2103525, Discussion on SRS enhancement, NEC
24. R1-2103564, Discussion on SRS enhancement, NTT DOCOMO, INC.
25. R1-2103679, Enhancements on SRS for coverage and capacity, Fraunhofer IIS, Fraunhofer HHI