3GPP TSG RAN WG1 Meeting #104b-e R1-2102674

**e-Meeting, Apr. 12th – 20th, 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#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 |

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, configuring legacy triggering offset as 0 when using this enhancement is a basic UE feature, and configuring legacy triggering offset as non-zero values when using this enhancement is an optional UE feature.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support only the main proposal, and not the sub-bullet. We are not sure what is meant by basic feature, and why the sub-bullet is needed, as gNB can freely select a zero value for the legacy triggering offset |
| CATT | Similar views as InterDigital. The main bullet is agreeable. Some clarification is needed for the sub-bullet.  |
| Huawei, HiSilicon | Not support Option-2. We have shown the issues on Option-2 in R1-2102338, including not flexible due to the RRC configuration on *slot-offset*, more DCI overhead due to negative values introduced, and more complexity on UE side due to two counting solution mixed for Opt.2.  |
| Apple | We are fine with the main proposal in principleThe sub-bullet needs more discussion. In our view, the main issue is how to differentiate the multiple AP-SRS resource sets that are associated with the same trigger state |
| Samsung | We are also fine with main bullet but similar concern of feature related one similar as IDC. |
| vivo | support main proposal only, we have shown in our tdoc that it is not flexible if reference slot is the slot where triggering DCI is sent when multiple A-SRS resource sets are triggered by one triggering state. |
| Futurewei | We have pointed out more limitations of Opt. 2 in our tdoc. We appreciate the FL’s effort to suggest a compromised direction. Something along this line may be eventually agreeable. To this aim, “basic feature” and “optional” may be clarified. Does “optional” mean an optional UE feature? Or does “optional” mean an optional RRC field? If it is an optional RRC field, then this proposal is essentially just Option 2. |
| Nokia/NSB | Sharing similar view with Futurewei that we need further clarification on the subbullet.  |
| FL | The proposal is updated based on companies’ questions.The following is to clarify FL’s intention on this proposal.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, as either Rel-17 mechanism or Rel-15/16 mechanism can be used* 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. |
| OPPO | Not support since the solution will need more RRC signaling overhead and less flexibility |
| Intel | Fine with the main bullet.Option 1 is a special case of Option 2. |
| Xiaomi | Support only the main bullet. The sub-bullet equals to set a default value to legacy triggering offset which would complicate the implementation and alleviate the benefits of option.2. |

### 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:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| CATT | We are not sure if dropping rule needs to be introduced. However the rule is defined, in the end what/how SRS are transmitted is definitively known to the gNB which can be similarly achieved by gNB scheduling. Leaving it to implementation seems feasible.  |
| Huawei, HiSilicon | Not sure why need to introduce dropping rule for SRS collide with SRS for the same UE. Both gNB and UE side know well on the AP-SRS triggering and timing, it seems a scheduling issue.  |
| Apple | We can open to discuss. But we prefer that the collision is an error case that UE does not need to handle. We already introduce flexible SRS triggering.  |
| vivo | Collision handling (dropping or delaying) is needed for SRS-SRS, SRR-other UL channel, collision will happen more often due to introduction of available slot concept. |
| Futurewei | We support to define collision handling / dropping rules. For a collision among aperiodic SRS resource sets, as AP SRS triggering is fully controlled by the gNB, such a collision may be avoidable by the gNB, unless the gNB would like to overwrite its past decision / past AP SRS triggering, and gNB should have that flexibility since the AP SRS may be quite some slots after the triggering, by which something else may occur and a change may be needed. Therefore, we think it is more reasonable to use AP SRS triggering times to determine which AP SRS should be dropped. This principle can be extended for collisions between AP SRS and other transmissions, with the only possible exception of A/N.As we expressed in our tdoc, collision avoidance via more flexible indication of AP SRS parameters is crucial. Without such flexibility, more collisions will occur, which increases standardization effort and UE/gNB complexity. Even with SRS capacity enhancement, if SRS parameters cannot be dynamically/flexibly indicated but mainly rely on RRC pre-configuration, many SRS still cannot be transmitted. Therefore, we suggest to discuss to increase SRS flexibility, not just in time domain, but also in frequency domain, cyclic shift, etc. |
| Nokia/NSB | We do not sure whether we need collision handling or dropping rules. In general sense, collision may happen when gNB has limited flexibility at scheduling, while Rel-17 is now importing further flexibility on SRS triggering. |
| OPPO | We don’t see the need of new collision handling or dropping rules. We have introduced new feature to support more flexible SRS triggering. It is up to gNB implementation |
| Intel | Open for discussion. |
| Xiaomi | Open to discuss. |

### 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 | 11 | Apple, ZTE, NEC, NTT DOCOMO, Huawei, HiSilicon, Spreadtrum, vivo, MediaTek, IDC, CATT |
| 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*

* *Discuss and decide one of the following alternatives in RAN1#104b-e for both scheduling DCI and non-scheduling DCI*
	+ *Alt 1: t is indicated by adding a new configurable DCI field*
	+ *Alt 2: t values are associated with SRS triggering states*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support Alt1.As for Alt2, since t is agreed to be configured per SRS resource set, then we don’t see any benefit by relating it not to trigger states. We believe this reduces the flexibility of the configurations. |
| CATT | Support alt.1. According to current specs, only three trigger states can be used to trigger aperiodic SRS resource sets. From the perspective of overhead reduction, SRS resource sets for different usages are more likely to be configured with different trigger states. Hence to adequately address SRS triggering flexibility, it is desirable to have a dedicated DCI field.  |
| Huawei, HiSilicon | 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 impact on the use of SRS resource sets for different usages. So, Alt.1 is a proper solution. |
| Apple | Prefer Alt 1 |
| Samsung | Support FL’s proposal to keep alt 1 and 2 as sub-bullets. |
| vivo | Support Alt 1 with minimal DCI overhead  |
| 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. |
| Spreadtrum | Support Alt1. |
| OPPO | Support the proposal with a preference on Alt.2 from the perspective of DCI overhead |
| Intel | Prefer Alt 2. With Alt 2, there is no need to introduce additional DCI overhead. |
| Xiaomi | Support alt.2 considering DCI overhead. |

**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 | 2 | Qualcomm, vivo |
| At least up to 4 | 8 | Ericsson, NEC, ZTE, IDC, CATT, Huawei, HiSilicon, NTT DOCOMO |

***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 | 2 bits for up to 4 values of t seem a good tradeoff on DCI overhead and flexibility. |
| vivo | RRC configured slot offset provides some flexibility in A-SRS triggering, on top of that minimal DCI overhead, e.g. 1 bit can provide further flexibility. We can be fine with “at most 4” |
| Futurewei | At least up to 4 should be considered. Up to 2 is too limited. |
| OPPO | Postpone it until the discussion on DCI indication of “*t*” is finished. |
| Intel | This should be discussed after agreement on how to indicate ‘t’. |
| Xiaomi | Up to 4 is more reasonable. |

**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 | 10 | Qualcomm, Samsung, Nokia, NSB, NTT DOCOMO, MediaTek, Lenovo, MotM, Xiaomi, IDC |
| Deprioritize or do NOT support | 6 | CMCC, CATT, Huawei, HiSilicon, vivo, Futurewei |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| CATT | Between using DCI to choose from a list of t values and using MAC-CE to update the t values, the first is preferable and sufficient. It does not seem necessary to have yet another MAC-CE for t value update, when dynamically choosing t value already can address this issue.  |
| Huawei, HiSilicon | Not necessary to add MAC-CE in the inter-mediate step. Up to 4 states for DCI flexible indication based on the normal slot configuration, no need with MAC-CE activate and deactivate. |
| vivo | We don’t see benefit of additional MAC-CE update given RRC slot offset plus ‘t’ value indicated in DCI is flexible enough to address all TDD frame structures. |
| Futurewei | Deprioritize or do NOT support. MAC CE based approach is not as flexible as DCI based approach.  |
| Nokia/NSB | We support MAC CE based update, since it can support more options than DCI.  |
| OPPO | Not support since DCI has provide sufficient flexibility |
| Intel | We don’t see the necessity to have MAC-CE to update the value of ‘t’. The ‘t’ is an available slot for SRS which removes the restriction on PDCCH slot carrying the trigger DCI. It’s already sufficient. |
| Xiaomi | Support the update via MAC-CE, which is more efficient. |

## 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 |
| 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)* 5 supporting companies: Nokia, NSB, Futurewei, Intel, Xiaomi
 | Extend the number of DCI codepoints for aperiodic SRS trigger states | Nokia, NSB, Futurewei, Intel, Xiaomi |
| New functionalities | Re-purpose to indicate set usage | Spreadtrum |
| No or deprioritize | - | Apple, OPPO, CATT |

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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support Alt A-1 |
| CATT | We prefer to deprioritize the discussion until an agreement on how to configure and indicate “*t*” is achieved. |
| Huawei, HiSilicon | Not support for the proposal. For 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, not see the clear benefits. |
| Apple | We do not support any re-purposing. This issue needs to be discussed after 2.1.3, i.e., regular UL DCI with PUSCH scheduling  |
| vivo | Support indicating “slot offset”, which provides most flexibility which comes for free, non-scheduling DCI triggering A-SRS also amount to overhead in DL which should be utilized for maximum flexibility  |
| Futurewei | The alternatives seem not mutually exclusive and may be combined. The number of SRS symbols may also be indicated.We suggest to also discuss other categories. It seems a bit incomplete if we only enhance time-domain flexibility. For example, SRS frequency-domain parameter indication can be very useful to avoid SRS collision and make full use of increased time-frequency resources made available for SRS.In addition, we’d like to bring back scheduling DCI discussion. It was agreed to also “FFS UL/DL DCI with data for aperiodic SRS”. Therefore, we suggest the FL to provide a discussion point for scheduling DCI enhancements so that interested companies can provide their views.  |
| Nokia/NSB | We may need clarification on what this note in the agreements mean: *Note: RAN1 should strive for unified solution for different DCI formats.*Should it mean unified solution within DCIs with grants only or unified solution within DCIs with grants and another unified solution within DCIs without grants? If we go with 1st case, we cannot repurpose unused filed. We also have some uncertainty what ‘position’ may mean by Alt A-1. (FL’s reply: This proposal does not violate the unified solution principle in my view. Please see the FL proposal in 2.1.3, where it has already ensured the unified principle for both scheduling and non-scheduling DCI. What is discussed here is whether some more mechanisms/features can be added on top of that. Of course companies may have different views on the need.Re A-1, I think it is quite simple to be understood from “i.e., the t values”.) |
| OPPO | Not support since no benefit is justified.  |
| Intel | We don’t support the FL proposal.How to indicate ‘t’ is discussed in Section 2.1.3.We think CAT E should be discussed, since the current number of trigger states for aperiodic SRS is very limited.We also think the SRS power control for SRS triggered by DCI 0\_1/0\_2 without scheduling PUSCH/CSI Request should be clarified, i.e. how to determine the SRS power control adjustment state, $h\_{b,f,c}(i,l)$. Following the current 38.213 spec, if RRC configures SRS power control state to be the same as PUSCH, then we have $h\_{b,f,c}\left(i,l\right)=f\_{b,f,c}\left(i,l\right)$, where $f\_{b,f,c}\left(i,l\right)$ is the PUSCH power control state. However, for aperiodic SRS triggered by DCI 0\_1/0\_2 without scheduling PUSCH/CSI Request, PUSCH is not transmitted. So how to determine SRS power control adjustment state should be clarified.In addition, we think the following issue should be clarified and discussed for SRS triggered by DCI 0\_1/0\_2 without PUSCH/CSI Request.*1. Which RNTI is considered for DCI 0\_1/0\_2 without PUSCH/CSI Request and with SRS triggered? Currently DCI 0\_1/0\_2 can be scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI, and SP-CSI-RNTI.**2. What’s the impact on BWP switching operation? Currently the BWP indicator field in DCI 0\_1/0\_2 is used for BWP switching. For SRS triggered by DCI 0\_1/0\_2 without PUSCH/CSI Request, is the field of BWP indicator still used as BWP switching command?* |
| Xiaomi | Support Alt A-1 |

**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 | 5 | OPPO, Huawei, HiSilicon, Nokia, NSB |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Not support. We do not think the discussed the UE specific flexible SRS triggering should be on Group common DCI, which is for a group of UEs. |
| Samsung | Support, group DCI can be used for triggering UE specific information without using UE-specific DCI. |
| vivo | Support enhancing group-common DCI for flexible triggering of A-SRS |
| Futurewei | GC DCI enhancement should be supported. Most likely a group of SRS transmissions will be triggered in the same slot, i.e., they share some common time-domain parameters. Rather than signaling the common time-domain parameters separately using multiple UE-specific DCIs, it is a lot more efficient to use GC DCI. |
| Nokia/NSB | We prefer low priority on this issue since we don’t see a necessity yet |
| OPPO | We don’t see the benefit/necessity so far.  |
| Intel | Open for discussion |
| Xiaomi | Support the triggering more efficiently with GC DCI for multi-users |

## 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 | 6 | Samsung, Huawei, HiSilicon, Futurewei, Intel, IDC |

***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 | We believe active 1 is the minimum Or we conclude that specification does not support SRS with multiple usage at all. It is up for UE/gNB implementation and IoDT  |
| Samsung | We slightly prefer to rely on implementation as in Rel-15. |
| vivo | For the case of xTxR SRS for antenna and xT SRS for codebook it looks straight forward, however some discussion is needed for sharing between xTyR SRS for antenna and xT SRS for codebook |
| Futurewei | Is this discussion limited to aperiodic SRS only, or also for P/SP SRS? Please clarify. Note that the WID is for “aperiodic SRS triggering”. We think this can already be done based on the existing standards / implementation, so no enhancement is necessary. |
| Nokia/NSB | We are supportive for specification based SRS resource reuse, since Rel-15 implementation based solution would not let gNB know whether reuse is possible or not. We are open for further discussion on how to support. |
| OPPO | Open to further discuss it |
| Intel | We could be open for discussion if there is clear benefit to introduce explicit multiple usage over the Rel-15 operation, i.e. to derive DL precoder based on codebook SRS. However, from the discussion, we don’t see the necessity. |
| Xiaomi | Open to discuss. |

## 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: 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 |
| InterDigital | We need further discussion on this. |
| CATT | Need further discussion. |
| Huawei, HiSilicon | 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. So, we only support periodic and semi-persistent SRS case.  |
| Apple | This can only be discussed under the condition that UE first request the change of Tx/Rx for example in UE assistance information. Even that, we do not know why RRC is not enough since UE will not change its antenna configuration in ms level. This adds complexity to the UE without much benefit |
| vivo | We don’t see motivation, as proponents claim benefit is for power saving, which can be addressed by dynamic BWP switching. |
| 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. |
| Nokia/NSB | Not support. In some sense, we share similar view with Huawei that this scheme will be needed only for periodic/semi-persistent SRS for power saving. But we don’t see a strong reason to hesitate at updating the configuration of periodic/semi-persistent SRS for the purpose of power saving.  |
| OPPO | Not support since the benefit is not clear |
| Intel | The MAC-CE based solution is not fast enough to control the overhead. It could be done by DCI based, i.e. the subset of the SRS resource sets is configured with another trigger state. |
| Xiaomi | Agree with Apple that UE assisted feature would be more efficient and beneficial for both the UE and the network. |

## 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 |

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.  |
|  |  |
|  |  |

# 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 |
| 1T6R | N\_max = 2 | 1 company: OPPO |
| N\_max = 3 | 9 companies: Qualcomm, Nokia, NSB, NTT DOCOMO, Spreadtrum, Lenovo, MotM, CMCC, ZTE, Intel |
| N\_max = 4 | 4 companies: Samsung, Ericsson, CATT, Xiaomi,  |
| N\_max = 6 | 2 companies: Spreadtrum, vivo |
| 1T8R | N\_max = 2 | 2 companies: OPPO, Spreadtrum |
| N\_max = 4 | 14 companies: Qualcomm, Samsung, ZTE, Nokia, NSB, Ericsson, NTT DOCOMO, Spreadtrum, CATT, Lenovo, MotM, CMCC, Xiaomi, vivo, Intel |
| 2T6R | N\_max = 1 | 1 company: Spreadtrum |
| N\_max = 2 | 5 companies: Qualcomm, OPPO, Lenovo, MotM, CMCC, Intel |
| N\_max = 3 | 10 companies: Samsung, ZTE, Nokia, NSB, Ericsson, NTT DOCOMO, Spreadtrum, CATT, Xiaomi, vivo |
| 2T8R | N\_max = 2 | 6 companies: Qualcomm, OPPO, Spreadtrum, Lenovo, MotM, CMCC, Intel |
| N\_max = 4 | 10 companies: Samsung, ZTE, Nokia, NSB, Ericsson, NTT DOCOMO, Spreadtrum, CATT, Xiaomi, vivo |
| 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 *fullAndPartialAndNonCoherent* UEs, K=2, N\_max = [4], and each resource has 4 ports
* For *partialAndNonCoherent* and *nonCoherent* UEs, K=4, N\_max = [2], and each resource has 2 ports
 | 1 company: InterDigital |

Clear majority view has formed for each xTyR. Hence FL propose the following on N\_max.

***FL Proposal:*** *On aperiodic SRS configuration for > 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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | * Do not support the case for *4T8R: N\_max = 2*

For 4T8R, based on our evaluation that is shared in our contribution, there will be a significant performance loss if SRS transmission occur over all TX chains in a partially coherent UE. Therefore, our proposal is that to apply FL proposal only for fully coherent 4T8R UEs, and then use SRS configuration of 2T8R case for partially coherent 4T8R UEs.* For *fullAndPartialAndNonCoherent* 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
 |
| CATT | OK with the table.  |
| Huawei,HiSilicon | Fine for the proposal. |
| Apple | Large N\_max has deployment issue since it is hard for UE to maintain phase continuity, if there is any change for example duplexing direction, power control, etc. So on paper, larger N\_max might look good, but in practice, it is rather useless. It makes reciprocity based DL CSI hardly useful. Not sure how can NW even benefit from this flexibility when UE cannot maintain phase continuity. |
| Samsung | Support FL’s proposal for progress. |
| vivo | We support only 1 value of N, it can be a large value, gNB can configured different sets on same slot or different slots, in Rel-15 2 sets for 1T4R is introduced due to limitation on configurable SRS symbols in a slot.  |
| Spreadtrum | Fine with FL’s proposal. |
| NTT DOCOMO | Support FL’s proposal |
| OPPO | As shown in our tdoc, larger N\_max may lead to significant performance loss in some cases/configurations. Moreover, we also share the similar view as Apple.Having said that, for the sake of progress, we can accept the proposal as a compromise.  |
| Intel | We think it should be clarified that the SRS configuration is for single TRP case. For multi-TRP case, it should be further studied. If the same SRS resource sets are used among different TRP for antenna switching, then a lot of reconfiguration signaling is required.We suggest the flowing change in the main bullet:*On aperiodic SRS configuration for > 4Rx, support the following N\_max values in single TRP case*The table is also updated to include our preference on the number of N\_Max. |
| Xiaomi | Support the FL’s proposal. |

**N values**

Table 3-2

|  |
| --- |
| **N** |
| Alternatives | Sub-alternatives | Companies |
| Alt 1: All the non-zero integer values <= N\_max are supported for N | - | 8 supporting companies: Samsung, ZTE, Ericsson, CATT, Lenovo, MotM, Huawei, HiSilicon |
| 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:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| CATT | According to current specs, at least 1 symbol is required for the guard period. Therefore up to 7 SRS resources for antenna switching can be transmitted in a slot, and at least 2 aperiodic SRS resource sets are needed for 1T8R. We prefer that:- for 1T8R, 2 <= N <=N\_max; - for other cases, 1 <= N <=N\_max. |
| Huawei, HiSilicon | Support Alt.1 for the flexibility on SRS resource configurations. |
| vivo | Only support 1 N value, the reason behind is if we “up to N\_max” is agreed then complicated configurations of sets and resources are needed. For example as proposed 1T8R with N\_max=4, then there are many configurations 1 set, 8 resources; 2 sets and variety of combinations (1+7, 2+6, 3+5, 4+4); 3 sets and variety of combinations; 4 sets and variety of combinations… these are unnecessary combinations which will lead to endless discussion. |
| Spreadtrum | Support Alt.2. |
| OPPO | We prefer Alt.1 |
| Intel | This can be further discussed if agreement is reached on the value of N\_Max.Basically, we think it should consider the OFDM symbol positions for SRS, subject to UE capability. |

## 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 | 3 | Qualcomm, CMCC, vivo |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| CATT | When SRS starting at any OFDM symbol within a slot is supported, N =1 can be supported for 1T4R. N =1 for 1T4R is expected to be supported to have less latency. |
| Apple | Similar comment as 3.2 |
| vivo | Deprioritize the discussion |
| OPPO | Not support |
| Intel | Support to extend for 1T4R, 2T4R and 1T2R. Not necessary for T=R. |
| Xiaomi | support |

## 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 | 6 | Qualcomm, ZTE, vivo, CATT, CMCC, Xiaomi |
| Alt 2: Support at least one resource set for periodic SRS and at least two SRS resource sets for semi-persistent SRS | 2 | Huawei, HiSilicon |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Support Alt 2. The issue happens on the real networks. There is SRS collision due to the restriction on the number of semi-persistent SRS resource sets. There are hundreds UEs in a cell for SRS transmission, but each UE is only with one SP-SRS can be configured (for 1T2R and 2T4R can be with a periodic SRS set). Normally, P-SRS is for long periodicity small data package transmission and SP-SRS is used for big data package transmission (also for high mobility/heavy traffic) in a short periodicity. In the current network, different UEs will be RRC configured with same resources and periodicity for the SP-SRS since hundreds RRC connected UEs in a cell, then if the SP-SRS are active for transmission at the same time, SRS collision will happen. Please note that increasing SRS capacity is not sufficient to avoid the collision in a short periodicity as shown in R1-2102338, while the partial SRS for capacity enhancements are already included in the analysis.In Figure-1 shows an example for the current SRS configurations.  Figure 1. SRS configuration with one P-SRS and one SP-SRSTo avoid SRS collision in the practical scenarios, more than one SP-SRS resource sets for one UE can be configured, as shown in Figure 2. If the SP-SRS resource set-2 is with potential collide with other UE’s SRS transmission, gNB is flexible to active SP-SRS resource set-1 instead of SP-SRS set-2.Figure 2. SRS configuration with one P-SRS and two SP-SRS |
| vivo | Support configuring one SRS resource set each for periodic and semi-persistent SRS, i.e. removing the restriction of only one time domain behavior in Rel-15 |
| Intel | We think more periodic/semi-persistent SRS resource sets, e.g. 2, are required in multi-TRP scenario. If only one periodic/semi-persistent SRS resource set is configured in multi-TRP, then frequent reconfiguration signaling is needed to reconfigure the SRS spatial relation, power control parameters, etc. |

## 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 |
| Huawei, HiSilicon | For 1T2R and 2T4R, P+SP are already supported in current spec. But for 1T4R, only one Periodic or Semi-persistent can be configured. The description is not accurate, we are supportive on increasing multi-type for 1T4R.  |
| Apple | Need more discussion.  |
| vivo | Can be further discussed |
| Intel | Open for discussion. |
| Xiaomi | Fine to discuss. |

## 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 |  |  |
| Alt 1: Make the present of guard symbols configurable | 1 | Ericsson |
| 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 | 1 | vivo |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We are not sure under what condition guard can be removed since it is the time UE needs for antenna switching. We feel this also involves RAN4. Need more discussion  |
| vivo | Our proposal is not to remove guard symbol, rather redefining it, current guard symbol is defined between symbols in a set, now with multiple sets configured for antenna switching guard symbols between sets should also be considered |
| OPPO | No discussion needed |
| Intel | Open for discussion. |

## 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 | 8 | Qualcomm, NEC, InterDigital, Spreadtrum, Lenovo, MotM, CMCC, Xiaomi, NTT DOCOMO |
| No or deprioritize | 5 | Ericsson, Futurewei, Huawei, HiSilicon, vivo |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Not support 4T6R. We do not think antenna switching on 4T6R is necessary to be supported. Since there are many issues for such antenna switching solutions, such as insertion loss, power imbalance. Actually, we already support 2T6R antenna switching solution, which seems better than 4T6R in our evaluation. The detailed analysis can be found in R1-2102338,  |
| OPPO | We are open to it |
| Intel | Open for discussion. |

## 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 |
| 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 |
|  |  |
|  |  |

# Coverage and capacity enhancements

## Increased repetition

The major remaining issue on increased repetition is the supported number of repetition symbols, which impacts the configuration on N\_symbol (number of OFDM symbols in one SRS resource) and R (repetition factor). Companies views on this are summarized as follows.

Table 4-1

|  |
| --- |
| **Supported N\_symbol and R values** |
| N\_symbol | R |
| N\_symbol = 8* Qualcomm, ZTE, Huawei, HiSilicon, OPPO, vivo, Futurewei, Intel, CMCC, Xiaomi, Apple, Ericsson, Sharp, Fraunhofer IIS, Fraunhofer HHI
 | R = {1, 2, 4, 8}* Qualcomm, ZTE, vivo
 |
| N\_symbol = 10* Qualcomm, ZTE, vivo, Futurewei, Xiaomi, Apple, Ericsson, Sharp
 | R = {1, 2, 10}* Qualcomm, ZTE

R = {1, 2, 5, 10}* vivo
 |
| N\_symbol = 12* Qualcomm, ZTE, Huawei, HiSilicon, OPPO, vivo, Futurewei, Xiaomi, Apple, Ericsson, Sharp, LG
 | R={1, 2, 4, 6, 12}* Qualcomm, ZTE, vivo
 |
| N\_symbol = 14* Qualcomm, ZTE, vivo, Futurewei, Xiaomi, Apple, Sharp, LG
 | R = {1, 2, 14}* Qualcomm, ZTE

R = {1, 2, 7, 14} * vivo
 |

It can be observed that all these 4 values of N\_symbol have good support from companies, and there is no particular reason to preclude any of them. Hence FL proposal the following.

***FL Proposal:*** *For increased repetition supported 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 = 10, R = {1, 2, 5, 10}*
* *N\_symbol = 12, R = {1, 2, 4, 6, 12}*
* *N\_symbol = 14, R = {1, 2, 7, 14}*
* *Note: The definition of N\_symbol and R as well as their relation is same as what is defined in the current specification.*
* *FFS options to reduce SRS BW for R>1*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
| Huawei, HiSilicon | Support N\_sym=8 and 12 |
| Apple | We are fine with FL proposal  |
| Samsung | Support FL’s proposal |
| vivo | Fine with FL proposal |
| Futurewei | It is a bit unclear about the relation of N and R here. What is the number of symbols without repetition? For example, if N=8, R=1, does it mean the SRS resource will span 8 symbols? Please clarify.Also as we mentioned, the increased repetition will cause that fewer signals/UEs can be multiplexed at the same time. This negative effect may be partially compensated via reduced SRS BW. We suggest to have an option to reduce the SRS BW for R>1.(FL’s reply: The definition of N\_symbol, R and their relation is same as what is defined as in the current specification. R denotes the number of contiguous repetition symbols. So N\_sybmol=8 and R=1 means only one repetition with 8 times of frequency hopping. Likewise, N\_sybmol=8 and R=2 means two repetitions with 4 times of frequency hopping.On options to reduce SRS BW for R>1, an FFS is added. But if we configure both RPFS and R>1, it can be achieved through this gNB implementation? ) |
| Spreadtrum | Support FL’s proposal |
| OPPO | Support *N\_symbol = 8 and 12* |
| Intel | Only support the sub-bullet of N\_sym=8. |

## RB-level partial frequency sounding (RPFS)

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

### 4.2.1 Issues related to PF

**Supported PF values**

Table 4-2

|  |
| --- |
| **Supported PF values** |
| Values | Companies |
| PF = {2, 4} | 13 supporting companies* Qualcomm, ZTE, Sony, Nokia, NSB, Ericsson, Sharp, Fraunhofer IIS, Fraunhofer HHI, Huawei, HiSilicon, OPPO, vivo
 |
| PF = 8 | 9 supporting companies* Qualcomm, ZTE, Sony, Nokia, NSB, Sharp, Fraunhofer IIS, Fraunhofer HHI, vivo
 |
| 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 | 7 | Qualcomm, ZTE, Samsung, Sony, Huawei, HiSilicon, OPPO |
| Alt 2: Introduce a rule to round $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ | 1 | vivo |

Following majority views shown in the above table, FL has the following proposal.

***FL Proposal:*** *For RB-level partial frequency sounding (RPFS) in Rel-17, support PF = {2, 4, 8}*

* *In the case of PF = 8,* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *shall be an integer value.*
* *FFS other values*
* *FFS further restrictions on* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
| Huawei, HiSilicon | Support PF={2, 4}. For PF=8, since the bandwidth will be small, more study is needed.  |
| Apple | We are fine with FL proposal  |
| Samsung | Support FL’s proposal |
| vivo | We are fine not support PF=3, however partial frequency band should also follow basic principle of Rel-15, i.e. frequency band is multiple of 4 PRBs, this is motivation of additional restriction agreed in last meeting. This allows multiplexing of legacy UEs and Rel-17 UE. And, multiplexing of different comb size within partial bandwidth(FL’s reply: On the number of RBs, it can be discussed together with other options in 4.2.4. One more option is added based on this input. One FFS point is added to cover this here.) |
| Futurewei | We suggest to make the candidate PF value set larger, so that the gNB can configure a subset of the PF values for each particular SRS resource based on the SRS resource’s m value and gNB’s need. The current way seems a bit too restrictive.(FL’s reply: Add an FFS on other values.) |
| Spreadtrum | Support FL’s proposal |
| NTT DOCOMO | Support FL’s proposal |
| OPPO | We support PF = {2, 4}. For the sake of progress, we can accept 8 |
| Intel | Support PF={2,4}. |

### 4.2.2 RB location

Another remaining issue is the start RB location of the $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ RBs in the $m\_{SRS, B\_{SRS}}$ RBs. Companies’ views are summarize as follows.

Table 4-3

|  |
| --- |
| **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} | 9 supporting companies* Apple, ZTE, Qualcomm, Huawei, HiSilicon, OPPO, CATT, MediaTek, Futurewei
 |
| **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
 |

Based on companies’ input, the following FL proposal is given

***FL Proposal:*** *For Rel-17 RPFS, 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}*

* *Support start RB location (*$N\_{offset}$*) hopping in different SRS occasions, symbols or frequency hopping periods*
	+ *FFS detailed hopping pattern*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
| CATT | Support FL’s proposal |
| Huawei, HiSilicon | For the sub bullet, does it mean in different hopping period can be with different starting RB? For example, each hop period is with 1-3-2-4 hop order, the starting RB is KF=0; then for the second hop period (1-3-2-4), the starting RB is KF=1. |
| Apple | We are fine with the main body. But the sub-bullet needs more discussion. This may triggers the discussion of hopping pattern for offset which is not clear to us |
| vivo | Generally fine with FL proposal |
| Futurewei | Support in principle |
| NTT DOCOMO | We are fine with FL’s proposal in general. However, sub-bullet requires more discussion |
| OPPO | Support the main bullet. The sub-bullet needs more discussion. |
| Intel | Only support the main bullet. The starting RB location hopping should be further studied. |

### 4.2.3 Applicable cases

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

Table 4-4

|  |
| --- |
| **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 | 6 | Nokia, NSB, NEC, Huawei, HiSilicon, Xiaomi |

The common ground between the above two alternatives is RPFS is applicable at least for frequency hopping. Hence the following is proposed.

***FL Proposal:*** *Rel-17 RPFS is applicable at least for frequency hopping case*

* *FFS non-frequency hopping case*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
| Huawei, HiSilicon | Support both hopping and non-hopping cases, not necessary to have such restriction. |
| Apple | We are fine with FL proposal  |
| Samsung | Support FL’s proposal |
| vivo | Fine with FL proposal |
| Futurewei | Both should be supported. In general, the per-hop sounding bandwidth is already quite narrow with hopping, but can be very wide without hopping. Thus, reducing the bandwidth for non-hopping SRS is needed. |
| Spreadtrum | Support FL’s proposal |
| OPPO | For non-hopping cases, Rel-15/16 can provides the same configuration. No need to support duplicated features. |
| Intel | Only support the frequency hopping case. |

### 4.2.4 Issues related to SRS sequence

**How to restrict sequence length**

RAN1#104e agreement restricts that no new sequence or length is introduced. How to achieve this restriction is discussed by companies. The follow table shows companies’ views.

Table 4-5

|  |
| --- |
| **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 | 5 | ZTE, Sony, Ericsson, Sharp, OPPO |
| 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 |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| vivo | Further restriction on partial bandwidth in terms of number of PRBs is needed as explained above. |
| Futurewei | Support Alt 2. We should restrict the minimum sequence length, but no need to restrict other parameters of the sequence. As long as the minimum length is 6 or more, no other restriction is needed. Truncation of the sequence should be fine.(FL’s reply: Let me know whether I understand your position correctly, but I’m a bit confused about whether your position is well aligned with the argument. Alt 2 introduces further restriction on the other parameters (number of RBs) besides minimum sequence length. Even for two-RB SRS, the minimum sequence length can be 12 (for comb-2) or 6 (for comb-4). Alt 1 does not bring any extra restriction besides what has been agreed. The current specification only supports SRS sequences whose length are multiples of 6.) |
| OPPO | SRS with short length will suffer performance degradation and needs more UE/gNB complexity |
| Intel | Need further discussion. |

**Sequence generation**

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 | 2 | ZTE, NTT DOCOMO |
| Alt 2: Truncate from legacy length-$\frac{12⋅m\_{SRS, B\_{SRS}}}{Comb}$ sequence according to the location of RPFS SRS | 3 | Huawei, HiSilicon, Futurewei |

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

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 the multiplexing between partial SRS with different PF.  |
| vivo | No need to introduce new method on top of what is supported in current spec |
| Futurewei | Support Alt 2. Truncation is a simple solution. |
| Intel | Alt 2 is straight forward. If Alt 2 is supported, it may be good to also inform RAN4 about the possible impact on SRS P-MPR requirement. |

### 4.2.5 Signaling to determine PF and Noffset

The signaling to indicate PF and Noffset also needs to be addressed. The following alternatives are identified.

Table 4-7

|  |
| --- |
| **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 |

Alt 1 is the majority view, and both alternatives require determining PF and Noffset by RRC. Hence FL proposes the following.

***FL Proposal:*** *For Rel-17 RPFS, 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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
| Huawei, HiSilicon | OK for the proposal. |
| Apple | We are fine. But RRC can already configure flexible SRS subband size based on the different columns. This seems to be different from the condition when PF is agreed and makes the benefit of this feature, if there is any, more questionable. Anyway, we do not see any reason for UE to support PF at all.  |
| Samsung | Support FL’s proposal |
| vivo | Fine with FL proposal |
| Futurewei | We think more flexibility is useful here. For coverage enhancement, more flexibility is not quite necessary, but for capacity enhancement, more flexibility is critical. We suggest to also consider DCI based approach.(FL’s reply: One FFS point is added for this.) |
| NTT DOCOMO | Support FL’s proposal |
| Intel | RRC configuration is sufficient |

## 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:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Support Alt.1. It is difficult to support more than 6 CSs in the case of Comb-8 in a real channel. |
| Futurewei | Open for further evaluation/discussion. |
| Intel | Open for discussion. What is the benefit of 6 CSs for Comb-8 over existing 12 CSs for Comb-4? |

## Others

The following issue is discussed by two companies.

|  |  |
| --- | --- |
| Support different repetition factors/SRS bandwidths for different symbols within one SRS resource | Nokia, NSB |

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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