3GPP TSG RAN WG1 Meeting #105-e R1-2108217

**e-Meeting, Aug. 16th – 27th, 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) | 4 | LGE, Huawei/HiSilicon, Futurewei, OPPO |
| Opt. 2 (Reference slot is the slot indicated by the legacy triggering offset) | 15 | Qualcomm, CMCC, MediaTek, Ericsson, Intel, Sharp, NTT DOCOMO, Xiaomi, Nokia/NSB, vivo, InterDigital, Samsung, CATT, NEC, Apple |

Given the super-majority view, the following FL proposal is recommended.

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

* *If DCI is transmitted in slot n, and k is the legacy triggering offset, reference slot is slot n+k.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | These two options have been discussed in multiple meetings. As we commented several times, Option 2 has no benefit from the technical perspective. Considering that the deadline of R17 completion is approaching, we can compromise, for the sake of progress, to support both Option 1 and Option 2 by separate UE capabilities, e.g.,Capability 1: Support Option 2 with the legacy triggering offset configured Capability 2: Support Option 2 without the legacy triggering offset configuredIn this case, UE has the flexibility to support one or both of them  |
| Apple | We are fine. But we need clarification that when we use legacy triggering offset as the reference slot, is it based on the legacy rule (i.e., any slot), or the new rule (i.e., only the available slot) to determine the reference slot?*FL’s response:* Reference slot is determined by the legacy rule. Specifically, if DCI is transmitted in slot n, and k is the configured legacy triggering offset, reference slot is slot n+k. |
| NEC | Support the FL proposal. |
| Huawei, HiSilicon | Not support. There are many issues for Option-2: 1) Non-flexible: due to the legacy triggering offset is still kept in Option-2, the SRS transmission can only be later than the RRC configured triggering offset. 2) More overhead: if introduce negative values of t to overcome the issue of non-flexible, then more bits to define the negative values. 3) More complexity: due to more steps for UE to determine the slot for SRS transmission, not only with t, but also need consider the legacy triggering offset. |
| Futurewei | We think Apple raised a good question. For Option 2, the UE behavior for the legacy offset and new offset may be different in terms of how to count the slots, which leads to some complexity. That is, the UE has to follow two different ways to do the counting for an A-SRS. Option 1 is a better solution. |

### 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** |
| Views | Companies | Priority rules |
| Introduce dropping rule when collision happens among aperiodic SRS resource sets | Qualcomm, ZTE (for SRS in different CCs), Ericsson, Intel, vivo (including SRS in one or more CCs triggered by one or more DCIs), Futurewei (including SRS and other UL channels/signals) | Ericsson* Based on usage: AS > BM > CB

vivo* Including usage, order of triggering DCI, CC ID and set ID

Futurewei* A/N and AP UL triggered later than R17 flexible A-SRS > R17 flexible A-SRS > other UL
 |
| Do not introduce new dropping rule | OPPO | - |

Based on views provided by companies, the following proposal is given.

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

* *FFS the priority rule considering usage, order of triggering DCI, CC ID and set ID, whether the SRS is the Rel-17 flexible SRS, etc.*
* *FFS collision handling among Rel-17 flexible SRS and other UL channels/signals*
* *FFS whether this rule is only applicable to SRS resource sets triggered by a same DCI*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We don’t think this is a problem. It is up to gNB implementation.  |
| Apple | We do not prefer collision handling. If we want to discuss it, we prefer to limit the case when colliding SRS resource sets are triggered by the same DCI *FL’s response:* Thanks for the clarification. Your position is updated in the table. An FFS point is added in the proposal on the applicable case. |
| NEC | Fine with the FL proposal. |
| LGE | Generally fine, but can we “study” whether to support dropping rule, rather than “introduce”? Because there is no details yet on the dropping rule to be supported in our perspective.And, we have similar view with Apple’s comment. |
| Huawei, HiSilicon | We are fine for it. |
| Futurewei | Support the FL proposal. We think collision handling is quite necessary, especially insufficient triggering flexibility has been introduced and the SRS capacity is limited. If companies wish to minimize collision handling spec impact, then we think more DCI indication flexibility (such as frequency domain resource indication) should be introduced to reduce potential collisions. |

### 2.1.3 Determination on the value of t

**DCI indication mechanism**

A WA was achieved in RAN1#104bis-e on DCI indication of t as given in Section 6.1. A number of companies propose to confirm this WA. Further, some companies discuss whether another mechanism is introduced for non-scheduling DCI when this new field is not configured. Companies’ views are summarized in the following table

Table 2-3

|  |
| --- |
| **On WA of DCI indication mechanism of t** |
| Number | Companies |
| Confirm the WA | ZTE, CATT, Huawei/HiSilicon, OPPO, vivo, Lenovo/MotM, Xiaomi, MediaTek, Nokia |
| **Whether another mechanism is introduced** |
| Number | Companies |
| Repurpose unused filed(s) to indicate t when the new field is not configured, for DCI format 0\_1/0\_2 without CSI request and without data | ZTE, MediaTek, Ericsson, NTT DOCOMO, Samsung, CATT |
| Do not introduce another mechanism to indicate t | Qualcomm |

At least it is common understanding to confirm the WA. Whether the other scheme is introduced can be further discussed in 2.2.

***FL Proposal:*** *Confirm the following WA.*

*For DCI indication of “t” in Rel-17 SRS triggering offset enhancement*

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support to confirm the WA |
| Apple | Support |
| NEC | Support to confirm the WA. |
| LGE | We are also fine with confirming WA. And, unified solution for “t” indication for all cases is slightly preferred. |
| Huawei, HiSilicon | Support |
| Futurewei | Support. Also fine with other mechanisms. |

**Whether to support MAC CE update**

Some companies discuss whether MAC CE is used to update the list of t for DCI indication. Companies’ views are summarized as follows.

Table 2-4

|  |
| --- |
| **Whether to support MAC CE as an inter-mediate step** |
| Alternatives | Number | Companies |
| Support using MAC CE to update the candidate values of t | 5 | Qualcomm, NTT DOCOMO, Xiaomi, Lenovo/MotM, Samsung |
| Deprioritize or do NOT support | 8 | CMCC, vivo, OPPO, LGE, Apple, NEC, Huawei/Hsilicon, Futurewei |

Since we have agreed to have up to 2 bits in DCI and 4 values configured in RRC in the list of t, the need of using MAC CE is unclear. Hence FL has the following proposal.

***FL Proposal:*** *Do not support MAC CE for t value update in Rel-17.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | We are fine with FL proposal  |
| NEC | Fine with the FL proposal. |
| LGE | Prefer to deprioritize. |
| Huawei, HiSilicon | Support FL proposal |
| Futurewei | Support FL proposal. |

## Flexible DCI format

**Re-purpose**

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

Table 2-5

|  |
| --- |
| **Repurpose unused fields in DCI format 0\_1/0\_2 without data and without CSI** |
| Categories | Detailed alternatives | Companies |
| CAT-A (Time-domain parameters) * 10 supporting companies: ZTE, MediaTek, Ericsson, NTT DOCOMO, Xiaomi, Samsung, CATT, vivo, LGE, Futurewei
 | A-1: Indication of available slot position, i.e., the t values  | ZTE, MediaTek, Ericsson, NTT DOCOMO, Xiaomi, Samsung, CATT |
| A-2: Indication of slot offset  | vivo |
| A-3: Indication of SRS symbol-level offset  | LGE, Futurewei |
| A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting  | Futurewei |
| CAT B (Frequency-domain parameters)* 7 supporting companies: Qualcomm, Futurewei, Xiaomi, Ericsson, LG, Intel, CMCC
* 1 company has concern
 | B-1: Indication of a group of CCs for SRS transmission | Qualcomm, Xiaomi |
| B-2: Indication of frequency domain resource in a BWP for SRS transmission | Ericsson, CMCC, LGE, Xiaomi, Futurewei |
| 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)* 5 supporting companies: Qualcomm (for each CC), Futurewei, Intel, Xiaomi, Huawei/HiSilicon
* 2 companies have concern
 | C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’ | Qualcomm (for each CC), Intel, Xiaomi, Futurewei |
| C-2: Indication of open loop power control parameter e.g., p0. | Huawei/HiSilicon |
| Do not support this category | CMCC, vivo |
| CAT D (Spatial-domain parameters, i.e., indication of SRS port and beamforming)* 1 supporting company: Futurewei
* 1 company has concern
 | 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)* 4 supporting companies: Futurewei, Intel, Xiaomi, NTT DOCOMO
 | Extend the number of DCI codepoints for aperiodic SRS trigger states | Intel, NTT DOCOMO, Xiaomi, Futurewei |
| New functionalities | Re-purpose to indicate set usage | Spreadtrum |
| No or deprioritize | - | Apple, OPPO |

It seems it is hard converge on this issue. Since we have discussed this issue for long time costing a lot of meeting resources, the following is recommended by FL.

***FL Proposal:*** *Further discuss the issue of repurposing DCI field(s) for SRS parameter indication until RAN1#106bis-e. If no consensus can be achieved, conclude this issue as following.*

* *No repurpose of DCI field(s) is supported for SRS parameter indication in Rel-17.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We failed to see any strong motivation to repurpose some of the existing DCI fields |
| Apple | We prefer not to repurpose unused DCI fields  |
| NEC | Fine with the proposal, while we prefer no repurposing the unused fields. |
| LGE | We are fine with no repurpose of DCI field(s), for the sake of progress. |
| Futurewei | The unused DCI fields can be used to indicate other parameters for the SRS transmission. A key objective of this WI is “*enhancements on aperiodic SRS triggering to facilitate more flexible triggering*”, and repurposing unused DCI fields for A-SRS triggering parameters is a great way to achieve this objective. Thus we think the repurposing should be further pursued.If companies wish to reduce the DCI redesign effort, we could simply change the unused DCI fields from “for the scheduled PUSCH transmission” to “for the triggered SRS transmission” whenever applicable. |

**Group-common DCI**

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

Table 2-6

|  |
| --- |
| **Whether group-common DCI enhancement is supported additionally** |
| Alternatives | Number | Companies |
| Yes | 5 | Qualcomm, Xiaomi, vivo, Samsung, Futurewei |
| No or deprioritize | 3 | Apple, LGE, Huawei/HiSilicon |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We need to see what the detailed solution is and what values offered by this enhancement are |
| Apple  | We think it is lower priority, at least. If it is referring to DCI 2\_3, based on our previous investigation, the specification itself needs some further clarification.  |
| LGE | Prefer to deprioritize. |
| Huawei, HiSilicon | We do not think the group common DCI need to be enhanced for AP-SRS triggering, since AP-SRS is triggering one slot with randomized, which is not an use case for group common DCI. |
| Futurewei | This is for DCI 2\_3. We provided some design considerations in our tdoc, but we are open for other enhancements. Also what Intel proposed in Sec. 2.6 can also be an example. We are willing to answer questions if any.  |

## Usage/overhead reduction

One remaining issue is whether to support specification enhancement on using SRS resources configured in SRS resource set with usage = “antennaSwitching” for codebook based UL transmission. Table 2-7 summarizes companies’ views.

Table 2-7

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

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Before we can agree any new action, we need to see the detailed solution and benefits, e.g., configuration, UE behavior, and so on |
| Apple | We support to discuss since some questionable configuration was observed in the field.  |
| Huawei, HiSilicon | SRS resource sharing can be used from Rel-15. There was agreement before that the use case for SRS is decided by UE in Rel-15. So, not necessary to discuss again. |
| Futurewei | We do not think spec impact is necessary, but we are open to further discuss technical issues such as virtualization to promote better understanding across companies (especially across UE vendors and NW vendors). |

## 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 2-8

|  |
| --- |
| **Update Tx/Rx antennas for SRS antenna switch in dynamic signaling** |
|  | Number | Companies | Further details |
| Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | 7 | Qualcomm (MAC CE), Ericsson (MAC CE), Intel, Xiaomi, Huawei/HiSilicon (MAC CE), ZTE, Lenovo/MotM | **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#106e.

***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 |
| OPPO | The benefits of MAC CE over RRC is still not clear. Would some proponents like to explain what the benefit is?Moreover, it has large impact on UE hardware implementation. In R15/16, the xTyR configuration for periodic, semi-persistent and aperiodic cases are the same. Thus, UE can keep the RF circuit and switching modules in the same state before each transmission. If this new proposal is used, MAC CE may indicate x’Ty’R for aperiodic, but the existing periodic SRS is for xTyR. When some transmission of them are closed to each other, UE need to change the state of RF circuit (e.g. turn on, turn off)/switching modules in a short time |
| Apple | We do not see the need to discuss this first. Firstly, the critical issue now in the specification is that NW does not know when UE changes its antenna configuration, for example, for power saving etc. Secondly, even if the antenna configuration is changed, it is normally on a longer time scale. RRC is enough, there is no meaningful benefit of using MAC-CE |
| Huawei, HiSilicon | We can support UE report the number of Rx antennas for SRS.Then, for the main bullet, remove “Tx”, since dynamic switching the number of Tx may be some problems on dynamic switching on the RF chains, which need to be discussed in RAN4. |
| Futurewei | The issues/questions we raised before and in the tdoc have not been addressed/answered. For example, “It seems that the discussions are trying to cover both the UE Tx antenna switching and UE Rx antenna switching, and often times the discussion are mixed together, though Tx antenna switching and Rx antenna switching are considerably different.” Please refer to our tdoc for the detailed analysis and questions. More discussions are needed to align the basic understanding of this topic. |

## Implicit determination of SRS parameters from data channel

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

Table 2-9

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

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | The benefit is not clear |
| Apple | No need to discuss at this stage. To deploy a feature and to implement a feature, the principle is that things need to be explicitly configured as much as possible.  |
| LGE | Support. The benefit is below.Only RRC based SRS bandwidth configuration is supported at this stage, which has less flexibility. This can also be a potential enhancement point for aperiodic SRS. Dynamic indication of SRS band may require additional DCI bits. If we’d like to avoid this issue, it is considerable to align SRS band with PUSCH and/or PDSCH band. This approach has a clear benefit to reuse former sounded/scheduled bandwidth with good channel quality and to avoid multi-UE SRS collision based on the multi-UE PUSCH/PDSCH multiplexing. |
| Futurewei | @OPPO: The performance benefit has been shown in our tdoc, which provides significant UPT gains (8% ~ 46% gain for mean UPT, and 44% to more than 2x gains for 5%ile UPT).@Apple: Here some of the SRS transmission parameters are the same as the co-scheduled PDSCH/PUSCH, so there won’t be any ambiguity/confusion in implementation. Maybe the term “implicit determination” can be improved to, e.g., “reusing”.@FL: Maybe we could change to something like “Reusing data channel transmission parameters as SRS parameters”, “Inheriting SRS parameters from data channel transmission parameters”, and remove “implicitly”?@all: One of the key ideas here is that if the A-SRS has the same transmission parameters as a PDSCH/PUSCH, such as the same PRBs, then the gNB can learn the CSI (including interference information) from the A-SRS on the PRBs and improve the PDSCH/PUSCH spectrum efficiency. And since they share the same PRBs (FDRA), the same FDRA field can be used for both transmissions without additional overhead increase. The flexibility inherited from data scheduling also leads to significant collision avoidance capability.*FL’s response:* The table has been revised per your request. |

## Others

The following issues are discussed by one company.

|  |  |
| --- | --- |
| Extend the mechanism to indicate t for available slot to SRS triggered by group common DCI 2\_3 | Intel |
| Support single scheduling DCI to trigger simultaneous A-SRS transmission across multiple component carriers | Qualcomm |

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

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | Support Intel’s proposal |
|  |  |
|  |  |

# Antenna switching up to 8Rx

## Aperiodic SRS configurations for >4Rx

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

Note that one related issue of determining N values is whether to support configuring multiple SRS resource sets for antenna switching in one slot. It decides whether to support N=N\_max is sufficient by configuring multiple resource sets in one slot.

**N values**

Table 3-1

|  |
| --- |
| **Supported N values** |
| Alternatives | Companies |
| Alt 1: All the non-zero integer values N<= N\_max are supported  | ZTE, Ericsson, Xiaomi, Nokia/NSB, OPPO |
| Alt 2: Support N=N\_max only | vivo, Spreadtrum |
| Alt 3: Support specific values for N<=Nmax | Qualcomm, Huawei/HiSilicon, CATT: all N<=Nmax except N=1 for 1T8RCMCC: * 1T6R: N=1, 2, 3
* 1T8R: N=2, 3, 4
* 2T6R: N=1, 2
* 2T8R: N=1, 2
* 4T8R: N=1

Intel, Lenovo/MotM |
| **Whether multiple SRS resource sets can be configured in one slot** |
| Views | Companies |
| Multiple SRS resource sets for antenna switching can be configured in one slot | vivo |
| UE does not expect multiple SRS resource sets for antenna switching are configured in one slot | Qualcomm |

Given companies’ input, FL believes to support N<=Nmax except N=1 for 1T8R is a good compromise among companies. Hence the following proposal is recommended.

***FL Proposal:*** *For aperiodic xTyR antenna switching SRS, where xTyR is from {1T6R, 1T8R, 2T6R, 2T8R, 4T8R}, support all the non-zero integer values N<=N\_max except N=1 for 1T8R*

* *For each xTyR configuration, UE does not expect multiple SRS resource sets are configured in one slot*
* *FFS considerations on channel variation in time domain if the number of spanned slots is large*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | We are fine |
| NEC | Fine with the FL proposal. |
| LGE | Slightly prefer Alt 3, but alt 1 is also fine. Regarding the sub-bullet, it should be carefully investigated since whole transmission of specific xTyR configuration can be located in 4 different slots which can spread more than 4 slots up to specific TDD UL-DL configuration with less UL slot. In this case, channel estimation performance can be degraded because of channel variation and phase discontinuity.*FL’s response:* In general, it can be solved by gNB implementation. If the performance is degraded because of channel variation, gNB can choose to configure a small N value. What we discuss here is anyway the values which can be supported. Despite the above, one FFS point is added to reflect your concern. |
| Huawei, HiSilicon | OK for the proposal |

**Subject to UE capability on maximum number of SRS symbols in a slot or not**

An FFS point in previous agreement is whether different configurations are specified subject to the UE capability on maximum number of symbols that can be used for SRS in a slot. Companies’ views are summarized as below.

Table 3-2

|  |
| --- |
| **Whether different configurations are specified subject to the UE capability on maximum number of symbols that can be used for SRS in a slot** |
|  | Companies |
| Yes | Intel, Xiaomi |
| No | Nokia/NSB, OPPO, Apple, LGE |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | NO |
| Apple | At least we need to address whether UE supports Rel-16 SRS in any symbol or Rel-15 SRS in only the last 6 symbols of a slot |
| LGE | Not needed. |

## Extension for aperiodic SRS with <=4Rx

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

Table 3-3

|  |
| --- |
| **Whether to support more N values for 1T4R, 2T4R, T=R and 1T2R cases** |
|  | Companies |
| Yes | Ericsson, Xiaomi, Nokia/NSB, Huawei/HiSilicon* Support N=4 for 1T4R and N=2 for 1T2R/2T4R

CATT* Support N=4 for 1T4R and N=2 for 1T2R/2T4R
* Support one resource set for 1T4R if all the symbols in a slot can be used for SRS

Intel, ZTE |
| No or deprioritize | Qualcomm, OPPO |

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

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | The current spec has supported these xTyR and additional configurations are not helpful.Moreover, it is not in the scope of R17 feMIMO WID |
| Huawei, HiSilicon | We support N=4 for 1T4R and N=2 for 1T2R/2T4R |
|  |  |

## Configurations for periodic and semi-persistent SRS

Two alternatives have been proposed on the number resource sets supported for periodic and semi-persistent antenna switching SRS. Companies’ views are summarized as follows.

Table 3-4

|  |
| --- |
| **Number of resource sets for periodic or semi-persistent SRS** |
| Alternatives | Companies |
| Support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS | Qualcomm, Ericsson, Xiaomi, vivo, CATT |
| Support up to two semi-persistent SRS resource sets in addition to a periodic SRS resource set | CMCC, Nokia/NSB, Huawei/HiSilicon, OPPO (UE optional for two SP sets) |

FL would like to suggest the following, which seems to be a good mid-ground.

***FL Proposal:*** *For antenna switching SRS, support maximum one SRS resource set for periodic SRS and maximum X SRS resource sets for semi-persistent SRS.*

* *UE can report the value of X from {1, 2} as capability*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We can support it if UE is allowed to report how many SP SRS resource sets it supports. |
| Apple | SP SRS itself is an UE optional feature. Not sure the spec impact, but as long as UE can report the corresponding capability, we are open  |
| LGE | Slightly prefer maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS. |
| Huawei, HiSilicon | At first, the issue is from real deployment. Due to only one SP-SRS resource set can be configured per UE, so there is high probability of collision of SRS. Support two semi-persistent SRS resource sets can obviously reduce the SRS collision. The detailed analysis and evaluation can be found in our Tdoc.Second, since the feature is anyway an UE capability in Rel-17, no need a redundant UE capability for 1 or 2 resource sets on it. As said in the notation, only one SP-SRS resource can be activated in a time, no UE complexity introduced. So, we slightly prefer the original wording in last meeting:*For antenna switching SRS, 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.*

But anyway, if the additional UE capability is a majority view, we are open on it. |

## Guard period

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

Table 3-5

|  |
| --- |
| **Whether to enhance guard symbols for antenna switching** |
|  | Companies |
| Alt 0: Guard symbols are always-on, which is same as Rel-15 | OPPO, Apple |
| Alt 1: Guard symbols are configurable subject to UE capability | Ericsson, vivo, Lenovo/MotM |
| Alt 2: Introduce guard symbols between two sets mapped to consecutive slots | Qualcomm, Huawei/HiSilicon, vivo, OPPO, Apple |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Alt.0 and Alt.2 are not mutually exclusive. Alt.0 is talking about the SRS within a set, whereas Alt.2 is talking about the two sets in two slots.In summary, we support Alt 0 and Alt.2  |
| Apple | We support both Alt 0 and Alt 2 |
|  |  |

## Whether 4T6R is supported

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

Table 3-6

|  |
| --- |
| **Whether to support 4T6R SRS antenna switching** |
|  | Companies |
| Yes | Qualcomm, CMCC, Xiaomi, InterDigital |
| No | Ericsson, Huawei/HiSilicon |

Given the time we have spent for this discussion and the fact that we haven’t achieved consensus, FL proposes the following.

***FL Proposal:*** *Do not support 4T6R SRS antenna switching in Rel-17.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We would like to clarify that we are open to it. If it is not supported due to the lack of consensus, we can accept it.  |
| NEC | We prefer to support 4T6R, while we can accept the FL proposal if no consensus. |
|  |  |

## 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, InterDigital |
| A 6Rx can report a capability of two, four or six layers of maximum number of DL MMO layers. And 8Rx UE can report a capability of two, four, six or eight layers of maximum number of DL MMO layer. | Qualcomm |
| Consider multi-panel UEs for antenna switching. | LGE, vivo |
| For antenna switching across multiple slots, restrict that the slots are contiguous or within a given period | LGE |
| Support antenna switching configuration for mTRP* Two periodic/semi-persistent SRS resource sets for antenna switching in multi-TRP
* The number of aperiodic SRS resource sets in single TRP is K, then number of aperiodic SRS resource sets for xTyR in multi-TRP should be 2\*K
 | Intel, vivo |

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

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

# Coverage and capacity enhancements

## Increased repetition

**Additional values for N\_symbol and R**

We have agreed to support N\_symbol = 8, R = {1, 2, 4, 8} and N\_symbol = 12, R = {1, 2, [3], 4, 6, 12}. Some companies discuss whether some additional values can be supported. The following summarizes companies’ views.

Table 4-1

|  |
| --- |
| **Additional N\_symbol and R values** |
| Views | Companies |
| Support additional values for N\_symbol and R | * Qualcomm, Spreadtrum:
	+ Ns = 10, R $\in \left\{1, 2,[5],10\right\}$
	+ Ns = 14, R $\in \left\{1, 2,\left[7\right],14 \right\}$
* vivo: N\_s = 14 with R = {1, 2, 7, 14}
* CMCC: Support additional 4 and 8 repetitions for N\_symbol = 10 and 14
* Ericsson, Huawei/HiSilicon, Futurewei: Support R=3 for N\_symbol = 12, i.e., remove the brackets
* LGE: Support more than 12 for N\_symbol
* Nokia/NSB: Support N\_symbol =10 and R={1,2,4,10} as well as N\_symbol =14 and R={1,2,7,14}
 |
| Do not support additional values | Intel, CATT, OPPO |

Given we have agreed a set of useful configurations, and companies’ views are divergent on the remaining values, FL recommends the following proposal.

***FL Proposal:*** *For SRS increased repetitions in Rel-17, support the following configurations, and no other values are supported.*

* *(N\_symbol, R) = {(8, 1), (8, 2), (8, 4), (8, 8), (12, 1), (12, 2), (12, 4), (12, 6), (12, 12)}*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | We are fine with FL proposal |
| NEC | Fine with the FL proposal. |
| LGE | We think (12, 3) can also be supported since R=3 is already supported in LTE. |
| Huawei, HiSilicon | Don’t support the proposal. Same view with LGE, R=3 for N\_symbol = 12 can achieve four times frequency hopping in one slot, so it also should be supported. |
| Futurewei | Agree with LGE |

**Reduced BW for R>1**

One FFS point in previous agreement is whether to support reduced SRS BW for repetitions with R>1. Companies’ views on this are summarized as follows.

Table 4-2

|  |
| --- |
| **Whether to support reduced SRS BW for R>1** |
| Views | Companies |
| Yes | Futurewei |
| No | vivo, CATT, Ericsson |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | RRC-based bandwidth configuration can work for R>1. |
| Futurewei | We think when SRS repetition is supported, the remaining UL resources may become very scarce. In order to multiplex more SRS, reducing the SRS BW could be helpful. In addition, this can further increase the SRS coverage. So we think this is highly motivated. |
|  |  |

## RB-level partial frequency sounding (RPFS)

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

### 4.2.1 PF values

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

Table 4-1

|  |
| --- |
| **Additional PF values** |
| Values | Companies |
| Support additional PF values | * vivo: Support {3, 8, 12}
* NTT DOCOMO: Support larger P\_F values
* Futurewei: 3, 8, 12, 16, and fractional numbers
 |
| Do not support additional PF values  | * Intel, Nokia/NSB, Huawei/HiSilicon, OPPO
* CMCC: Do not support non-integer P\_F values
 |

For P\_F values, given there is no consensus to support PF values other than {2, 4}, FL recommend the following.

***FL Proposal:*** *Do not support PF values other than {2, 4}.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | We are fine with FL proposal  |
| NEC | Fine with the FL proposal. |
| LGE | Support the proposal. |
| Huawei, HiSilicon | We are open to support {3} |
| Futurewei | Allowing more PF values leads to higher flexibility, collision avoidance capability, capacity enhancements, and coverage enhancements. We think more values should be considered. |

### 4.2.2 RB location

There is an FFS point in previous agreement about start RB location hopping for different SRS occasions, symbols or frequency hopping periods. Companies’ views are summarized as follows on this aspect.

Table 4-2

|  |
| --- |
| **Start RB location hopping** |
| Views | Companies |
| Support start RB location (Noffset) hopping in different SRS frequency hopping periods | Qualcomm, ZTE, Ericsson (Optional feature with RRC to enable), Huawei/HiSilicon, vivo, CATT, MediaTek, Nokia/NSB, OPPO, NEC |
| Do not support start RB location hopping | CMCC, NTT DOCOMO, Spreadtrum |

Given the fact that most of the vendors are interested to support this, the following proposal is recommended taking the concern from the other side into account.

***FL proposal****: Support start RB location (Noffset) hopping in different SRS frequency hopping periods for RPFS and periodic/semi-persistent SRS, where* $N\_{offset}$ *is the start RB index of the* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *RBs in the* $m\_{SRS, B\_{SRS}}$ *RBs.*

* *For a given SRS transmission occasion,* $N\_{offset}=\frac{\left(k\_{F}+k\_{hopping}\right) mod P\_{F}}{P\_{F}}m\_{SRS, B\_{SRS}}$ *, where* $k\_{hopping}$ *is same for SRS occasions within an FH period but changes across FH periods, kF and PF are at least configured by RRC signaling (kF = {0, 1, …, PF-1}).*
	+ *For each PF value, support at least one pattern for* $k\_{hopping}$ *in time domain, FFS detailed pattern*
* *This start RB location hopping is enabled or disabled by a RRC parameter.*
* *This start RB location hopping is UE optional.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | In general, we are ok with the proposal. One question for clarification. What does “one fixed pattern” mean in the sub-bullet? If a pattern is based on some parameter(s) (e.g., PF or symbol index), is it a “fixed pattern”? *FL’s response:* Thanks for the good question. For different PF values, it should be different patterns as the length for hopping is different. For different symbol indices, if they are different symbol indices in different FH periods, they are part of the pattern as pattern here means how $k\_{hopping}$ changes in time domain. For symbols within one FH period, $k\_{hopping}$ remains unchanged. To address any possible misunderstanding, “fixed” is removed. |
| Apple | We may not fully understanding the N\_offset equation, especially why we need $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ term which is the number PRBs used for SRS transmission. Maybe we missed something. *FL’s response:* We have agreed on the definition of N\_offset in last meeting, which is the start RB index of the contiguous $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ RBs in the $m\_{SRS, B\_{SRS}}$ RBs with $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ RBs as granularity. What we discuss here is how N\_offset hops/changes in different SRS locations. That’s why we need the term $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$. More details including example figures can be found in companies’ contributions [2][3][4][10][14][17][18]. The FL proposal is clarified based on this. |
| NEC | Fine with the FL proposal. |
| Huawei, HiSilicon | Ok |
| Futurewei | A couple of comments:* With a very limited set of PF values, the benefit of introducing k\_hopping becomes limited.
* How is the kF value determined? Would it go from 0 to PF-1 in the order of the hop numbering?

*FL’s response:* * At least in my understanding, the benefit does not depend on detailed values of PF as elaborated in [2][3][4][10][14][17][18]. Perhaps proponents can further reply.
* kF is determined at least in RRC as said in the first sub-bullet. The candidate values are from 0 to PF-1.
 |

### 4.2.3 Applicable cases

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

Table 4-3

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

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | For non-frequency hopping, we can have the same SRS transmission by proper configuration. Why do we need redundant feature? |
| NEC | We think this can be discussed after other details settled down, e.g. section 4.2.4. As we think the restriction on number of RBs may have impact on the final usage of partial frequency sounding. |
| LGE | If only RRC based Pf value and offset value is supported, same function can be achieved by RRC based SRS bandwidth reconfiguration for non-frequency hopping case. If we want to support non-frequency hopping case for RPFS, signaling method for Pf value and offset value should be enhanced for better flexibility. |
| Huawei, HiSilicon | No need to restrict the use case. Both should be supported. |
| Futurewei | Support both for higher flexibility. |

### 4.2.4 Further restriction on the number of RBs

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

Table 4-4

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

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support Alt.3 since it has no benefit to introduce some SRS bandwidths different from that of the current spec.  |
| Apple | $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ is limited to the number of SRS PRBs in the current specification 38.211. Alt 3 is still beyond what spec supports currently, we do not support all the integer multiple of 4 in Table 6.4.1.4.3-1 |
| NEC | We don’t support Alt 3, restriction the value to be a multiple of 4 will quite limit the usage of partial frequency sounding, as almost all possible values based on Alt 3 already supported by current spec (based on frequency hopping).Regarding Alt 1 and Alt 2, we think this has no benefit on multiplexing if the number of RBs is not a multiple of 4.So we think Alt 4 is a good solution, and meanwhile, the starting position of SRS subband should be aligned to boundary of a multiple of 4, otherwise, multiplexing can not be guaranteed.  |
| LGE | Support Alt 3. |
| Huawei, HiSilicon | No restriction is needed, since there is already sequence length is the same as legacy sequence length. Alt.3 are too restricted, only the SRS bandwidth is times 16 can be used for partial sounding.  |
| Futurewei | Both Alt 1 and Alt 2 are generally acceptable. The only difference between them is about how to handle a resulting bandwidth less than 4 PRBs. We note that the actual limitation is not directly on the number of PRBs but on the minimum sequence length. So it seems Alt 1 together with the restriction that “SRS sequence shorter than the minimum length supported in the current specification is not pursued” is the best choice.Alt 3 is very limiting, significantly restricting the potential PF values and usable SRS bandwidth configurations. Many of the SRS bandwidth values supported in the current standards cannot meet this requirement. Therefore, this is not preferred.Alt 4 assumes that UE should transmit SRS with bandwidth values as multiples of 4 only. It is unclear why this restriction has to be imposed. This is not preferred at least from a futureproof or SRS flexibility perspective. |

### 4.2.5 SRS sequence generation

Some companies discuss how to generate SRS sequence for RPFS. The following two alternatives are discussed.

Table 4-5

|  |
| --- |
| **How to generate SRS sequence for RPFS** |
| Alternatives | Companies |
| Alt 1: Generate length-$\frac{\frac{12}{P\_{F}}m\_{SRS, B\_{SRS}}}{Comb}$ ZC sequence | Qualcomm, ZTE, MediaTek, Ericsson, Apple, NTT DOCOMO, Nokia/NSB, vivo, Lenovo/MotM, Spreadtrum, CATT, NEC, OPPO |
| Alt 2: Truncate from legacy length-$\frac{12⋅m\_{SRS, B\_{SRS}}}{Comb}$ sequence according to the location of RPFS SRS | Intel (when SRS is multiplexed with legacy UE), Huawei/HiSilicon, Futurewei |

Given super majority view has formed, FL recommends the following.

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | Support FL proposal  |
| NEC  | Support the FL proposal. |
| LGE | Support the proposal. |
| Huawei, HiSilicon | Not support. Alt2 can achieve flexible multiplexing between partial SRS and legacy SRS, which is important in the case where both R15 UE and R17 UE coexist in one cell. |
| Futurewei | Even with SRS transmission not exactly carrying a complete ZC sequence, the PAPR increase is quite limited, as shown in evaluation results in our tdoc. Therefore, the PAPR increase is not really an issue for the truncated SRS sequence, especially the partial frequency sounding provides a significant power boosting. In addition, generating SRS sequences based on the partial bandwidth reduces the multiplexing benefit which is a key objective for this enhancement. Therefore, Alt 2 is preferred. |

### 4.2.6 Dynamic signaling to determine PF and kF

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

Table 4-6

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

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Not support MAC CE/DCI to update any of them |
| Apple  | Prefer not to support MAC-CE or DCI based |
| LGE | Support DCI indication for offset value, for aperiodic SRS. |
| Huawei, HiSilicon | Not support MAC-CE and DCI. RRC is sufficient for PF and kF, it’s no need to introduce other signaling. |
| Futurewei | Support DCI approach for higher flexibility.  |

## Comb-8

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

Table 4-7

|  |
| --- |
| **The maximum number of supported cyclic shifts** |
| Alternatives | Companies |
| Alt 1: The maximum number of CSs for Comb-8 is 6 | Apple, Nokia/NSB, Huawei/HiSilicon, ZTE, vivo, Samsung, Futurewei, NEC, OPPO |
| 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 | Qualcomm, Ericsson, Lenovo, CATT |

Based on that the majority view is to support max CS = 6, FL recommends the following.

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL summary |
| Apple | Support DL proposal  |
| NEC | Support the FL proposal. |
| LGE | Support the proposal. |
| Huawei, HiSilicon | Support |
| Futurewei | Support |

## Others

The following issue is discussed by one companies.

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

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

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

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

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

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

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

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

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

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

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

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

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| --- | --- | --- | --- |
| [1] | RP-193133 | New WID: Further enhancements on MIMO for NR | Samsung |
| [2] | [R1-2106468](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106468.zip) | Enhancements on SRS in Rel-17 | Huawei, HiSilicon |
| [3] | [R1-2106546](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106546.zip) | Enhancements on SRS flexibility, coverage and capacity | ZTE |
| [4] | [R1-2106576](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106576.zip) | Further discussion on SRS enhancement | vivo |
| [5] | [R1-2106645](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106645.zip) | Remaining Issues on SRS Enhancements | InterDigital, Inc. |
| [6] | [R1-2106670](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106670.zip) | Enhancements on SRS | Lenovo, Motorola Mobility |
| [7] | [R1-2106690](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106690.zip) | Considerations on SRS enhancements | Spreadtrum Communications |
| [8] | [R1-2106793](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106793.zip) | Considerations on SRS flexibility, coverage and capacity | Sony |
| [9] | [R1-2106870](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106870.zip) | Enhancements on SRS | Samsung |
| [10] | [R1-2106940](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106940.zip) | Discussion on SRS enhancements for Rel-17 | CATT |
| [11] | [R1-2107083](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107083.zip) | Enhancements on SRS flexibility, coverage and capacity | FUTUREWEI |
| [12] | [R1-2107147](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107147.zip) | Discussion on SRS enhancement | NEC |
| [13] | [R1-2107208](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107208.zip) | Enhancements on SRS flexibility, coverage and capacity | OPPO |
| [14] | [R1-2107328](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107328.zip) | Enhancements on SRS flexibility, coverage and capacity | Qualcomm Incorporated |
| [15] | [R1-2107395](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107395.zip) | Enhancements on SRS flexibility, coverage and capacity | CMCC |
| [16] | [R1-2107467](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107467.zip) | Enhancements on SRS for coverage and capacity  | Fraunhofer IIS, Fraunhofer HHI |
| [17] | [R1-2107489](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107489.zip) | Enhancements on SRS flexibility, coverage and capacity | MediaTek Inc. |
| [18] | [R1-2107558](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107558.zip) | SRS Performance and Potential Enhancements | Ericsson |
| [19] | [R1-2107575](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107575.zip) | Discussion on SRS enhancements | Intel Corporation |
| [20] | [R1-2107723](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107723.zip) | Views on Rel-17 SRS enhancement | Apple |
| [21] | [R1-2107788](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107788.zip) | Enhancements on SRS | Sharp |
| [22] | [R1-2107819](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107819.zip) | Enhancements on SRS flexibility, coverage and capacity | LG Electronics |
| [23] | [R1-2107843](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107843.zip) | Discussion on SRS enhancement | NTT DOCOMO, INC. |
| [24] | [R1-2107898](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107898.zip) | Discussion on SRS enhancements | Xiaomi |
| [25] | [R1-2108057](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2108057.zip) | Enhancements on SRS flexibility, coverage and capacity | Nokia, Nokia Shanghai Bell |