3GPP TSG RAN WG1 Meeting #106-e R1-2108373

**e-Meeting, Aug. 16th – 27th, 2021**

**Source: Moderator (ZTE)**

Title: FL summary #2 on SRS enhancements

Agenda Item: 8.1.3

Document for: Discussion and Decision

# Introduction

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

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

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

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

In this contribution, we summarize companies’ views on the issues with wide interest after the first-round discussion in RAN1#106e.

# Flexibility enhancements

## SRS triggering offset

### 2.1.1. Collision handling

***FL Proposal 2-2:*** *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 to restrict this rule is only applicable to SRS resource sets triggered by a same DCI or different DCIs*
* *Note: strive for a unified rule for single-CC and multi-CC cases*

The above proposal has been discussed in the first round. Companies’ views are summarized as given below.

Support: 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), Huawei/HiSilicon, Spreadtrum, Intel (for SRS in different CCs), CATT (for different CCs), China Telecom, Nokia/NSB, NEC

Concern: OPPO

Prefer to study first: LGE, Lenovo/MotM, MediaTek, Xiaomi, Samsung

FL’s suggestion: We have clear majority to support to introduce dropping rule. To companies who want to study first, we don’t have many meetings left, and this issue has been discussed for a while. To postpone the decision does not help. Hence FL would like to ask whether companies are okay given we already have majority view.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| vivo | Support |
| Futurewei | Support |
| Huawei, HiSilicon | Fine |
| QC | From UE perspective, we prefer to have one single rule to handle collision regardless the collision happen on same CC or across CCs. *FL’s response:* One note is added for this. |

## 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 2-1

|  |
| --- |
| **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, Lenovo/MotM, InterDigital, NEC |

It seems hard to 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 2-5:*** *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.*

An alternative proposal raised by Futurewei is given below.

***Modified Proposal 2-5:*** *Repurpose/reuse one or more existing DCI fields configured for data transmission for SRS parameter indication*

* *FFS which of the existing DCI fields: TPC command field, bandwidth part indicator field, FDRA field, etc.*

As we have discussed this issue for several meeting, it is better to make decisions as soon as possible. FL would like to ask companies to share your views on the above two alternative proposals.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Ericsson | Support Modified proposal.  |
| vivo | Support Modified proposal. But would like clarify what is difference between repurpose and reuse. Could you please give some example on how to reuse TPC field, BWP indicator field, FDRA field?  |
| Futurewei | Support Modified proposal.@vivo: Thank you for the support and the comments. ‘Repurpose’ seems to be used in RAN1 to redesign some fields for a new purpose. ‘Reuse’ does not change any field design but uses the fields to do a different operation. The wording may not be critical here and we are open to better wording choices. We can also add more restriction such as the following:***Modified Proposal 2-5:*** *Repurpose/reuse one or more existing DCI fields configured for data transmission for SRS parameter indication without changing the field bitwidths/parameters** *FFS which of the existing DCI fields: TPC command field, bandwidth part indicator field, FDRA field, etc.*

That is, only the object that the fields are applied on can be changed, from applied on PUSCH to applied on SRS. Example:

|  |  |  |  |
| --- | --- | --- | --- |
| Field in 0\_1 | Configured bitwidth | Current used for (in scheduling DCI) | Reused for (in non-scheduling DCI) |
| FDRA | e.g., 8 | PUSCH  | SRS |
| TPC command | 2 | PUSCH  | SRS |
| Bandwidth part indicator | e.g., 2 | PUSCH  | SRS |

We think the standardization effort will be very limited but the added flexibility will be highly desirable. |
| QC | Support FL proposal 2-5.We need to agree on the functionality first then decide whether to reuse/redesign bitfields.  |
| CATT | Support FL proposal 2-5. |
| CMCC | Support FL proposal 2-5. |
| Nokia/NSB | Support the FL proposal 2-5. |

## Flexible antenna switching

The following proposal has been discussed in the first round.

***FL proposal 2-6:*** *Support gNB indicating the used number of 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*
* *Support UE reporting of the preferred antenna switching configuration*
* *FFS whether DCI can be additional used*
* *FFS potential enhancements on CSI measurement to solve issues (if any) caused by this dynamic adaption*

Support: Qualcomm (MAC CE), Ericsson (MAC CE), Intel, Xiaomi, Huawei/HiSilicon (MAC CE), ZTE, Lenovo/MotM, Intel (DCI), Futurewei, InterDigital, CATT

Concern: OPPO, Apple

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Ericsson | Support the proposal |
| Futurewei | We are generally fine with the proposal. Is there only one preferred antenna switching configuration? This seems to be implied from ‘***the*** *preferred antenna switching configuration*’. Please clarify.*FL’s response:* The following is my understanding, and I think proponents can clarify more.For antenna switching configuration indicated by gNB. It should be just one configuration as this final indication should be operable to UE. Then for the reporting of UE preferred configuration, it seems simpler to report just one. But it should be up to gNB’s decision on whether to use the one preferred by UE, or another configuration which may cause smaller overhead.  |
| Huawei, HiSilicon | We support UE report the configuration and MAC-CE based. But, the modified FL’s proposal need to be updated, since Tx switching need RF chain switching, which need RAN4 discussion at first. We can restricted as “only Rx number” switching on it. Then, the feature discussed here is to reduce the power saving and resource overhead saving, so DCI based indication is not necessary, which require additional DCI design on it. So, we propose to use the previous FL proposal. |
| QC | Similar views as Huawei, support MAC-CE and only Rx adaptation based on UE reporting.  |
| CATT | Not support. The proposal is unclear. Who performs the first bullet? Does gNB “*indicating the preferred antenna switching configuration for SRS antenna switching via dynamic signaling*”? If so, why “preferred” is needed? Besides, why dynamic signaling on antenna switching configuration for periodic SRS is needed? More study is needed on whether UE reports the preferred antenna switching configuration is supported or not. *FL’s response:* The proposal is updated to clarify your questions.  |
| Nokia/NSB | Support the FL proposal. |

# Antenna switching up to 8Rx

## Extension for aperiodic SRS with <=4Rx

The following FL proposal has been discussed in the first round.

***FL Proposal 3-2:*** *For extension of antenna switching SRS configurations for <=4Rx, support N=4* *for 1T4R and N=2 for 1T2R/2T4R.*

Support: Ericsson, Xiaomi, Nokia/NSB, Huawei/HiSilicon, CATT, Intel, ZTE, NTT DOCOMO

Concern: OPPO, Lenovo/MotM

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Ericsson | Support. The reasons and motivation was explained in the first round.  |
| vivo | Benefit is not clear. |
| Huawei, HiSilicon | Support the FL’s proposal. |
| CATT | Support. Besides, we think N =1 for 1T4R also should be supported. |
| Nokia/NSB | Support the FL proposal.  |

## Configurations for periodic and semi-persistent SRS

The following proposal has been discussed extensively in the first round.

***FL Proposal 3-3:*** *For antenna switching SRS, support maximum one SRS resource set for periodic SRS and maximum 2 SRS resource sets for semi-persistent SRS.*

* *Note: the two SP-SRS resource sets are not activated at the same time*
* *This feature is UE optional: For UEs that do not support this feature, follow Rel-15 on the number of resource sets for periodic and semi-persistent SRS*

Support: CMCC, Nokia/NSB, Huawei/HiSilicon, OPPO, MediaTek, Xiaomi, ZTE, CATT, Ericsson, NTT DOCOMO, China Telecom, China Unicom

Concern: Qualcomm

FL adds the red part trying to address UE vendor’s concern. Companies are encouraged to indicate whether it is acceptable with this added.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Ericsson | Support. Although I don’t see the need for the UE optional part. Every added MIMO feature in Rel.16, 17,18,.. .will be optional. There are no mandatory MIMO features in releases beyond Rel.15. The only features that can be mandatory in Release beyond 15 is if new areas are xplored, such as broadcasting etc. Please enlighten me if my understanding is incorrect. It’s obvious if the UE does not indicate support for this Rel.17 feature, then Rel.15 behaviour will follow. Having that said, I’m ok with the sub bullet if it comforts Apple.  |
| Huawei, HiSilicon | We are fine for FL’s proposal. |
| CATT | Support the proposal except for the last bullet. There is no 6Rx and 8Rx in Rel-15, therefore “follow Rel-15 on the number of resource sets for periodic and semi-persistent SRS” is not clear. *FL’s response:* Rel-15 only supports one resource set for periodic and one resource set for SP SRS. If this feature is not supported by UE, 6Rx and 8Rx also have one resource set for periodic and one resource set for SP. |
| CMCC | Fine with the proposal. And thanks FL for trying to solve UE vendors’ concern |
| Nokia/NSB | Support the FL proposal. |

## Guard period

The following proposal has been discussed in the first round.

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

* *On the presence of guard symbols in Rel-17 for SRS antenna switching, down-select one of the following*
	+ *Alt 1-0: Guard symbols are always-on, which is same as Rel-15*
	+ *Alt 1-1: Guard symbols are configurable subject to UE capability*
* *On whether to introduce guard symbols between SRS resource sets for antenna switching, down-select one of the following*
	+ *Alt 2-0: Do not introduce guard symbols between SRS resource sets, i.e., guard symbols only appears between SRS resources in a resource set*
	+ *Alt 2-1: Introduce guard symbols between two sets mapped to consecutive slots*
* *Note: Rel-15 guard period symbols are supported if none of the above enhancements is agreed*

Alt 1-0: OPPO, Apple, Qualcomm, Intel, Nokia/NSB

Alt 1-1: Ericsson, vivo, Lenovo/MotM, InterDigital

Alt 2-0: Intel

Alt 2-1: Qualcomm, Huawei/HiSilicon, vivo, OPPO, Apple, Xiaomi, CATT

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Ericsson | Support the FL proposal. It seems more discussion and analysis is needed as companies are uniform distributed among the alternatives. Please also take into account the progress on configurable GP for LTE SRS.  |
| vivo | Support FL proposal |
| Huawei, HiSilicon | Support Alt 1-0 and Alt 2-1. |
| QC | Support FL proposal.Alt 2-1 follows the same design principles of Rel-15 to allow sufficient time for UE antenna switching between the different ports. It is important to have guard period between SRS resources of two sets on consecutive slots |
| CATT | Support the proposal in general. In our opinion, the note should be moved to be a sub-bullet of the first bullet.*FL’s response:* It should be fine as a main bullet. If we don’t adopt Alt 2-1, GP is also same as Rel-15, which means only inter-resource GP is supported. |
| CMCC | Support FL’s proposal |
| Nokia/NSB | Support the FL proposal. |

## Whether 4T6R is supported

***FL Proposal 3-5:*** *Do not support 4T6R SRS antenna switching in Rel-17.*

Support 4T6R: Qualcomm, CMCC, Xiaomi, InterDigital, Lenovo/MotM, MediaTek, NTT DOCOMO

OK not to support 4T6R: OPPO, NEC, Ericsson, vivo, Huawei/HiSilicon

We have discussed this issue since the beginning of this WI, and no progress has been made. FL encourages companies to share your view on whether the conclusion is acceptable or not, more than just your preference.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| vivo | Support FL proposal |
| QC | Do not support. Specification should be flexible and shouldn’t restrict UE implementation.  |

# Coverage and capacity enhancements

## Increased repetition

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

***FL Proposal 4-1:*** *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), (10, 1), (10, 2), (10, 5), (10,10), (14, 1), (14, 2), (14, 7), (14, 14)}*
* *Note: N\_symbol SRS symbols are adjacent in a slot.*

Support: OPPO, Apple, NEC, Lenovo/MotM, Xiaomi, ZTE, Samsung, Spreadtrum, CATT, Ericsson, Intel, NTT DOCOMO

Add (12, 3): LGE, Huawei/HiSilicon, Futurewei

Add N\_symbol = 10 and 14: Qualcomm, vivo

FL understands companies’ preference to add more values for better flexibility. However, it is not clear whether we can achieve consensus for which values should be added. If we open the door for one group of values, we may have to bring other values as well. Considering this, FL suggests to stick with what we have agreed without adding more.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Ericsson | Adding (12,3) is fine with us. Adding 10 and 14 symbols is also fine.  |
| vivo | We still think N\_symbol = 10 and 14 should be supported for flexibility.  |
| Futurewei | Similar view as Ericsson and vivo. |
| QC | Given the flexibility spirit, we suggest adding Ns = 10,14 to the FL proposal.  |
| CATT | Support the proposal |
| *FL* | Given companies’ views expressed above, let’s see whether to add Ns = 10 and 14 is also acceptable to companies. More values are added with red color in proposal 4-1. Companies are encouraged to comment along this direction.  |
| Nokia/NSB | For the sake of enhanced flexibility, we support adding values marked with red color in the proposal.  |

## RB-level partial frequency sounding (RPFS)

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

### 4.2.1 PF values

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

Support: OPPO, Apple, NEC, LGE, ZTE, Qualcomm, Samsung, Spreadtrum, CATT, Ericsson, Intel, Nokia/NSB

Add 3: Huawei/HiSilicon

Add more values (but not clear on what specific values): Futurewei, NTT DOCOMO, Fraunhofer IIS/HHI, vivo

FL’s view and suggestion are same as for 4-1.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Ericsson | Support |
| vivo | More values can be considered for flexibility. But we are opening to accept FL proposal if a majority view supports. |
| Futurewei | If RAN1 only agrees on {2,4}, the added flexibility may be too little so that RPFS may be not useful at all. For example, m=160 PRBs is supported, with PF=2 or 4, we transmit on 80 or 40 PRBs. But m=80 or m=40 is already supported and can be configured/triggered. So what is new and appealing with this feature compared with existing design? K\_hopping may add a little bit flexibility, and dynamic signaling of PF and kF may also add a little bit flexibility (though we see quite some resistance from companies), but overall the design cannot achieve the design goal with only {2,4}. |
| Huawei, HiSilicon | We are open to add value 3 considering the issue that some bandwidth of SRS is multiple of 3. |
| QC | Support. |
| CATT | Support the proposal |
| Nokia/NSB | Support the FL proposal. |

### 4.2.5 SRS sequence generation

The following proposal has been discussed in the first round.

***FL Proposal 4-4:*** *For RPFS SRS sequence generation, support Alt 1: Generate length-*$\frac{\frac{12}{P\_{F}}m\_{SRS, B\_{SRS}}}{Comb}$ *ZC sequence.*

Support: Qualcomm, ZTE, MediaTek, Ericsson, Apple, NTT DOCOMO, Nokia/NSB, vivo, Lenovo/MotM, Spreadtrum, CATT, NEC, OPPO, Xiaomi, Intel (Based on gNB configuration)

*Another alternative* – *Alt 2:* *Truncate from legacy length-*$\frac{12⋅m\_{SRS, B\_{SRS}}}{Comb}$ *sequence according to the location of RPFS SRS*

Support: Huawei/HiSilicon, Futurewei, Intel (Based on gNB configuration)

We have agreed to make the decision in this meeting. Hence FL suggests companies to be more constructive considering we have super-majority view.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Ericsson | Support from us is strong.  |
| vivo | Support FL proposal. |
| Futurewei | For capacity enhancement, Alt 2 is definitely better. For coverage enhancement, Alt 1 is better. What Intel suggested makes most sense. |
| Huawei, HiSilicon | The enhancement is motivated to increase the capacity. But, Alt.1 is with problems on multiplexing with legacy UEs obviously. So, support Alt.2. |
| CATT | Support the proposal |
| Nokia/NSB | Support the proposal. |

## Comb-8

***FL Proposal 4-5:*** *For comb-8 SRS in Rel-17, the maximum number of CSs is 6.*

Support: Apple, Nokia/NSB, Huawei/HiSilicon, ZTE, vivo, Samsung, Futurewei, NEC, OPPO, Spreadtrum, Intel

Against (Support >6 for max CS, and introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs): Qualcomm, Ericsson, Lenovo/MotM, CATT

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Ericsson | Against. There is an issue with 4 ports as several companies have pointed out.  |
| vivo | Support. 4 ports can be achieved by pre-defined CS allocation rule or FDM. Thus, no need to worry about 4 ports issue. |
| Futurewei | Support |
| Huawei, HiSilicon | Support |
| QC | We think further discussion and study is needed before making an agreement. MaxCS = 6 doesn’t improve SRS capacity and has issue for CS-index computation for 4 ports. On the other hand, there is no CS-index issues for MaxCS = 8 or 12 as it is already multiple of 4 and in addition enhances SRS capacity. It is up to gNB to proper configure the CSs (e.g., restrict some CSs configuration or use subset of CSs). For example, if we set MaxCS = 12, gNB doesn’t need to assign all CSs.  |
| CATT | Not support. We share the same view with QC. For SRS resource with 4 ports, although the sequence orthogonality can be kept by using other methods when the maximum number of CSs is 6, the SRS capacity of the MaxCS = 6 is less than that of MaxCS = 8 or 12.  |
| Nokia/NSB | Support the FL proposal. |

# 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

**RAN1#106-e****Agreement**Confirm the following WA.For DCI indication of “t” in Rel-17 SRS triggering offset enhancement* For both DCI that schedules a PDSCH/PUSCH and DCI 0\_1/0\_2 without data and without CSI request
	+ t is indicated by adding a new configurable DCI field (up to 2 bits)
		- Applies only when there are multiple candidate values of t configured
	+ No further enhancement to indicate “t” for DCI 0\_1/0\_2 without data and without CSI request at least when the new DCI field is configured

**Agreement**Support start RB location (*Noffset*) hopping in different SRS frequency hopping periods for RPFS and at least periodic/semi-persistent SRS, where *Noffset* is the start RB index of the $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ 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 all SRS occasions within a legacy FH period but changes across legacy FH periods, kF and PF are at least configured by RRC signaling (kF = {0, 1, …, PF-1}).
	+ Support at least one pattern for $k\_{hopping}$ in time domain, FFS detailed pattern
	+ Note: the legacy FH period is the period to sound the full SRS hopping bandwidth across the different subbands of $m\_{SRS, B\_{SRS}}$ RBs each.
* This start RB location hopping is enabled or disabled by RRC signaling.
	+ FFS whether MAC CE or DCI can be additionally used
	+ When this start RB location hopping is disabled, $k\_{hopping}$ is fixed to be 0 for all SRS symbols
* This start RB location hopping is UE optional.
* FFS whether start RB location hopping is also applicable on SRS occasion(s) within one FH period (e.g., when R>1) and/or on aperiodic SRS, if so, how

**Agreement**For aperiodic xTyR antenna switching SRS, where xTyR is from {1T6R, 1T8R, 2T6R, 2T8R, 4T8R}, support all the non-zero integer values N<=N\_max except N=1 for 1T8R * For each xTyR configuration, UE does not expect multiple SRS resource sets are configured or triggered in one slot
* UE does not expect that the OFDM symbols contained in one SRS resource set exceed UE capability on which OFDM symbols can be used for SRS taking guard period into account

**Agreement**Support Opt. 2: Reference slot is the slot indicated by the legacy triggering offset.* If DCI is transmitted in slot n, and k is the legacy triggering offset, reference slot is slot n+k.
* Note: the legacy triggering offset can be 0, if slotOffset is absent.
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