3GPP TSG RAN WG1 Meeting #106bis-e R1-2110475

**e-Meeting, Oct. 11th – 19th, 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. Companies’ contributions submitted to RAN1#106bis are listed in [2]-[23].

In this contribution, we summarize companies’ views in the second round offline discussion for the above SRS enhancements in RAN1#106bis-e.

# Flexibility enhancements

## SRS triggering offset

### 2.1.1. Collision handling

One FFS point from RAN1#104e’s agreement on available slot definition is “rules to handle the case of multiple SRS resource sets with overlapping symbols and/or triggered by a same DCI”. Companies’ detailed views are given in the table below.

Table 2-1

|  |
| --- |
| **Collision handling** |
| Views | Companies | Priority rules |
| Introduce dropping rule when collision happens among aperiodic SRS resource sets | Huawei/HiSilicon, Futurewei (including collision between Rel-17 AP SRS with other UL channels/signals), ZTE, vivo, Lenovo/MotM, CATT, Xiaomi, Samsung, Intel, Nokia/NSB, Qualcomm, Ericsson, Apple (UE optional feature), NEC | * Rule 1 – Based on usage: Qualcomm, Nokia/NSB, Ericsson, vivo, Xiaomi,
* Rule 2 – Based on set ID and CC ID: vivo, Xiaomi, Huawei/HiSilicon, ZTE, NEC, Spreadtrum
* Rule 3 – Based on order of the triggering DCI: Lenovo/MotM, Samsung, CATT
* Rule 4 – Based on type of the aperiodic SRS and the UL channel/signaling: Futurewei
 |
| Do not introduce new dropping rule | OPPO, CMCC, LGE, InterDigital |  |

Based on majority view, the following proposal is recommended by FL.

***FL Proposal 2-1:*** *Introduce dropping rule when collision happens among multiple aperiodic SRS resource sets in a same CC or different CCs.*

* *Select one or more of the following priority rules*
	+ *Rule 1 – Based on usage*
	+ *Rule 2 – Based on set ID and CC ID*
	+ *Rule 3 – Based on order of the triggering DCI*
	+ *Rule 4 – Based on type of the aperiodic SRS (e.g., with Rel-17 offset or not)*
* *The new dropping rule is a UE optional feature*
* *FFS collision handling among Rel-17 flexible SRS and other UL channels/signals*

Companies are encouraged to indicate whether you can accept this proposal and/or your further suggestions in Round 2.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | SRS collision handling is something not fully specified in the specification. We are not sure if we can resolve the issue completely in the last two meetings But we think, it is better if we can restrict the discussion to the AP-SRS resource sets *triggered by the same DCI*, to avoid or minimize the time line discussion.  |
| MediaTek | Support FL proposal |
| OPPO | Not support. The reasons have been inputted several times. |
| Intel | What does it mean by ‘type of aperiodic SRS’ in Rule 4? |
| QC | Support Ruel #1 for sets triggered by same DCI. If there is no conesus, then this should be treated as an error case by the UE similar to rel-15/16. |
| Samsung | We support rule 3 but we have similar concern with Apple and QC. |
| Spreadtrum | We support rule 2. |
| CATT | Support at least Rule-3 for AP-SRS resource sets triggered by multiple DCIs.For the proposal, “*type of the aperiodic SRS*” in Rule-4 is not clear, more clarification on it is needed. |
| Xiaomi | Prefer rule-1 at least.  |
| Lenovo/MotM | Multiple AP SRS resource sets can be configured with the same usage and be triggered by a same or different DCIs, so rule 1 cannot handle this collision.We prefer rule 2 or rule 3. |
| vivo | Support FL proposal |
| NEC | Support the proposal, and prefer rule 2. |
| Docomo | We are skeptical if we can complete the prioritization order within two e-meetings. Besides, we are open for any rules.  |
| LGE | Not support as commented in Round 1. |
| Nokia/NSB | Support Rule 1. |
| Ericsson | Rule 2 and/or Rule 4 |
| InterDigital | Support FL proposal. Rules 1, 3 and 4 are straightforward. |
| Futurewei | Support@Intel @CATT: “*type of the aperiodic SRS*” in Rule-4 means whether it is R17 AP SRS or not. The thinking is to limit the collision handling rule to be related to the new R17 AP SRS only, without affecting legacy behaviors.@FL: would it be ok to modify “*type of the aperiodic SRS*” in Rule-4 to “*type of the aperiodic SRS (e.g., with R17 offset or not)*”? |

## 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 2-2

|  |
| --- |
| **Repurpose unused fields in DCI format 0\_1/0\_2 without data and without CSI** |
| Categories | Detailed alternatives | Companies |
| CAT A (Time-domain parameters) * 6 supporting companies: ZTE, Xiaomi, NTT DOCOMO, vivo, LGE, Futurewei
* 1 company has concern
 | A-1: Indication of available slot position, i.e., the t values  | ZTE, Xiaomi, NTT DOCOMO |
| A-2: Indication of slot offset  | vivo |
| A-3: Indication of SRS symbol-level offset  | Futurewei, LGE |
| A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting  | Futurewei |
| Do not support this category | Intel |
| CAT B (Frequency-domain parameters)* 5 supporting companies: Futurewei, Xiaomi, Qualcomm, CMCC, Intel
* 1 company has concern
 | B-1: Indication of a group of CCs for SRS transmission | Futurewei, Xiaomi, Qualcomm |
| B-2: Indication of frequency domain resource in a BWP for SRS transmission | CMCC, LGE |
| 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)* 4 supporting companies: Futurewei, NTT DOCOMO, Qualcomm Huawei/HiSilicon
* 2 companies have concern
 | C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’ | Futurewei, NTT DOCOMO, Qualcomm |
| C-2: Indication of open loop power control parameter e.g., p0. | Huawei/HiSilicon |
| Do not support this category | vivo, CMCC |
| CAT D (Spatial-domain parameters, i.e., indication of SRS port and beamforming)* 1 company has concern
 | Re-purpose CSI-RS/TPMI indication to indicate SRS spatial-domain parameters |  |
| Do not support this category | CMCC |
| CAT E (Extend the number of DCI codepoints for aperiodic SRS trigger states)* 5 supporting companies: Futurewei, Xiaomi, Intel, NTT DOCOMO, Nokia/NSB
 | Extend the number of DCI codepoints for aperiodic SRS trigger states | Futurewei, Xiaomi, Intel, NTT DOCOMO, Nokia/NSB |
| No or deprioritize | - | OPPO, Samsung, Apple, Lenovo/MotM |

It seems it is hard converge on this issue. Since we have discussed this issue for long time costing a lot of meeting resources, and companies’ interest on this has cooled down, the following conclusion is recommended by FL.

***FL Proposal 2-3A:*** *No consensus to support repurpose of DCI field(s) for SRS parameter indication in Rel-17.*

Supported by Apple, OPPO, Qualcomm, Samsung, Spreadtrum, CATT, Xiaomi, Lenovo/MotM, vivo (2nd), NEC, Nokia/NSB, InterDigital

Futurewei proposed another alternative proposal in Round 1 as given below.

***FL Proposal 2-3B:*** *Further discuss and decide if the existing TPC command field, bandwidth part indicator field, and FDRA field in the DCI configured for data transmission apply to the AP SRS or not.*

Supported by Intel, vivo (1st), NTT DOCOMO, Futurewei

FL encourages companies to further provide your views on the above two alternative proposals.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We prefer proposal 2-3A, i.e., no consensus |
| OPPO | Share the same view as Apple. |
| Intel | Support proposal 2-3B. |
| QC | Support FL proposal 2-3A.  |
| Samsung | Support 2-3A |
| Spreadtrum | Support 2-3A |
| CATT | Support proposal 2-3A. We have discussed this issue for many meetings. We don’t think adopt proposal 2-3B would be helpful for the progress. |
| Xiaomi | Support FL proposal 2-3A |
| Lenovo/MotM | Support 2-3A |
| vivo | We prefer 2-3B, however no consensus can be reached then fine with 2-3A. |
| NEC | Support 2-3A. |
| Docomo | We support Proposal 2-3B. If we go with 2-3A, we will lose the benefit of introducing DCI without data/CSI. |
| Nokia/NSB | Support 2-3A. |
| InterDigital | Support 2-3A |
| Futurewei | Support 2-3B. The spec impact is very small, and it introduces high flexibility without new overhead. |

## 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 2-3

|  |
| --- |
| **Update Tx/Rx antennas for SRS antenna switch in dynamic signaling** |
| Views | Companies | Further details |
| Clarify the interpretation of dynamic Tx/Rx antenna change first* Int. 1: Change the number of antennas dynamically
* Int. 2: Change the number of SRS ports dynamically but do no change the number of antennas
 | Futurewei | Futurewei requests to clarify this question first before discussing further details. |
| Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | Huawei/HiSilicon (MAC-CE for periodic/semi-persistent SRS, only for Rx), ZTE, Spreadtrum (MAC CE), vivo (MAC CE with enhancements on activation time), OPPO (MAC CE, applicable on all CCs in a frequency band, and need to clarify the number of Rx antennas for PDSCH), CATT (DCI based on SRS triggering states), Xiaomi, Samsung (MAC CE), Intel (DCI, no MAC CE), Ericsson (DCI) (MAC CE), Qualcomm (MAC CE), Lenovo/MotM(MAC CE) | Applicable casesCase 1: all of aperiodic, periodic and semi-persistent SRS* Xiaomi

Case 2: only periodic or semi-persistent SRS* Huawei/HiSilicon
 |
| Support UE reporting of the preferred antenna switching configuration | Yes: Xiaomi (MAC CE), AppleNo: Intel |  |

The following proposal is given based on majority view.

***FL proposal 2-4:*** *Support gNB indicating the used SRS resources from the configured SRS resources in SRS resource set(s) for antenna switching via MAC CE.*

* *Applicable to at least one of the following two cases*
	+ *Case 1: all of aperiodic, periodic and semi-persistent SRS*
	+ *Case 2: only periodic or semi-persistent SRS*
	+ *Case 3: only for aperiodic SRS*
* *Support UE reporting of one preferred antenna switching configuration in MAC CE*
* *The gNB indicated or UE reported antenna switching configuration belongs to the supported antenna switching reported by UE capability signaling*
* *FFS whether DCI can be additional used to indicate the used antenna switching configuration*
* *FFS the application timing of the MAC CE activation*
* *Note: Any change on the configured number of Tx antennas in each SRS resource is precluded in either the gNB indication or UE reporting*

The following are the major discussion points in the first round.

* Some companies (e.g., Intel and Ericsson) suggested to change MAC CE to DCI in the first round.
* Some companies (e.g., Intel and Ericsson) questioned how the UE reporting work.
* Some companies (e.g., Futurewei and OPPO) seek clarification on the above Int. 1 and Int. 2.

Companies are encouraged to share your further views on these aspects.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | For this featuer to be useful, gNB should also be able to change the number of ports per SRS resource. Since the most usefuly case in the field would be swtiching between 2T4R and 1T2R.  |
| OPPO | Clarification is necessary. Otherwise, different companies will have different understanding on the implementation and spec impact.Regarding the down-selection between MAC CE and DCI, we prefer MAC CE. The additional benefit of DCI based indication is not clearRegarding the 2nd question, one example is that UE may recommend to change from 1T4R to 1T1R with the intention to reduce the power consumption.From the perspective of power consumption, we suggest to add a bullet: the MAC-CE indication can be applied to all the intra-band CCs.  |
| Intel | Same view as first round. |
| Samsung | We support MAC-CE based solution only. |
| Spreadtrum | We support MAC-CE only. |
| CATT | Firstly, the proposal is not clear enough, there are two interpretations on “*gNB indicating the used SRS resources from the configured SRS resources in SRS resource set(s) for antenna switching*”:Alt 1: SRS resource sets corresponding to multiple xTyR schemes are configured, respectively, gNB indicating SRS resources by selecting one xTyR scheme from multiple schemes.Alt 2: SRS resources for one xTyR scheme are configured, gNB indicating SRS resources from the configured SRS resources.Which interpretation is the right one?Secondly, we prefer to clarify gNB’s behavior after receive the preferred antenna switching configuration in MAC CE reported by UE. For example, use the clarification is as follows: *It is up to gNB that whether the used SRS resources from the configured SRS resources in SRS resource set(s) for antenna switching is changed.*Besides, flexible SRS triggering via DCI is more preferred than via MAC-CE, since it has less spec efforts.  |
| Xiaomi | Firstly, our current understanding is Int.2. Tx switching is not preferred due to current UE implementation issues.From UE power saving point of view, we’d like the configurations of all types of SRS for AS to be the same. But from the SRS overhead reduction perspective, this may not be optimized for the DL CSI acquisition. So we suggest to add the previous option for down selection, * *Applicable to at least one of the following two cases*
	+ *Case 1: all of aperiodic, periodic and semi-persistent SRS*
	+ *Case 2: only periodic or semi-persistent SRS*
	+ *Case 3: only aperiodic SRS*

For the gNB indication, MAC-CE may be enough in our view. @CATT, our understanding is alt.2.From system point of view, more antennas UE equipped with (maybe up to 8Rx), it is more likely that partial sounding for AS would be frequently used among multiple users. So selection of ports used for DL CSI acquisition may be higher demanding. That’s why we think this feature is beneficial.For UE reporting, UE has more accurate information (due to UL SRS reception has different interference than the DL reception) on which set of antenna ports having better channel conditions and thus UE can report the preferred AS config. to the NW, eg. for a 1T8R UE, UE can measure and report whether 1T4R or 1T2R is more suitable for data reception without consideration of the available resources. And this mechanism would be beneficial for gNB scheduling for the tradeoff between the selection of different partial sounding configurations and the available SRS resources, also the MIMO layer supported. UE reporting information would be beneficial especially when SRS reception is not prompt enough. From UE perspective, UE may also want to save power abruptly at some point, or have other usage change with subset of antennas (such information is unknown from NW side), which may need change on the UE functioning for data reception. And we think it is reasonable to let the network acknowledge such need or demand from UE side. @CATT, UE only recommend the xTyR configuration, and it is up to gNB for scheduling decisions.Current spec does not support the report of Tx and/or Rx antenna switching that UE prefers, but with the increase of Tx or Rx antennas UE equipped, the need for Tx or Rx switching (antenna number change) should also be quite demanding, especially Tx antenna switching for power saving purpose, so we think reporting of the UE suggested xTyR configuration would provide the possibilities and flexibilities which would be beneficial both for the UE and NW. So it is no harm to support the UE reporting for the current feature or reserve some flexibility for the power saving needs we foresee.Currently, UE reporting via MAC-CE can be considered as first priority in our view, and we are open to further discussions and solutions to complete the feature. |
| Lenovo/MotM | Support MAC CE based solution only. |
| vivo | If MAC CE based flexible antenna switching feature is supported, application timing of the MAC CE should be also supported. For example, a MAC CE is activated in slot n + 3ms (X) and a UE activates disabled RF front ends completely in slot n + Y if the RF front ends are activated beginning from slot n, where the UE would transmit a HARQ-ACK information in slot n corresponding to a MAC CE used for activating/indicating the used resources from configured SRS resources. If Y < 3ms, it seems ok when only applying original MAC CE timeline, i.e. slot n + 3ms. However, if Y > 3ms shown in above figure, applying the same mechanism for a MAC CE effective timeline may not be suitable as activation processing is not completed.Thus, application timing of the MAC CE is a mandatory feature which should be specified. And we propose modified version as below:*Support gNB indicating the used SRS resources from the configured SRS resources in SRS resource set(s) for antenna switching via MAC CE.** *Applicable to at least one of the following two cases*
	+ *Case 1: all of aperiodic, periodic and semi-persistent SRS*
	+ *Case 2: only periodic or semi-persistent SRS*
* *Support UE reporting of one preferred antenna switching configuration in MAC CE*
* *Introduce additional time for application timing*
	+ *It can be a UE capability.*
* *The gNB indicated or UE reported antenna switching configuration belongs to the supported antenna switching reported by UE capability signaling*
* *FFS whether DCI can be additional used to indicate the used antenna switching configuration*
* *~~FFS the application timing of the MAC CE activation~~*

*Note: Any change on the configured number of Tx antennas in each SRS resource is precluded in either the gNB indication or UE reporting* |
| Docomo | Support MAC CE indication (from gNB to UE) for the used SRS resources. |
| LGE | We have similar question as CATT’s first question. If Alt.2 is the intention, gNB may activate/deactivate (via MAC CE) subset of SRS resources for specific xTyR configuration based on UE reporting (via MAC CE?), is it correct understanding?If this is correct understanding, and if periodic SRS is to be supported as target case, the MAC CE can update the periodic SRS? We think MAC CE activation/deactivation for periodic resource is new behavior. |
| Nokia/NSB | As said in previous round, the main benefit of the feature is to enable fast switching between different xTyR configurations according to traffic and/or channel conditions. Additionally, this can be also seen as useful feature in the multi-TRP operation.  |
| Intel2 | 1. For periodic SRS, we don’t see the need to have MAC-CE based solution at all. The RRC reconfiguration is sufficient.2. For aperiodic SRS, introducing MAC-CE to activate/deactivate some resources just introduce additional signaling overhead. For aperiodic SRS, flexible antenna switching can be achieved via DCI, which has less spec impact as indicated by CATT.3. Why the changing of number of Tx antennas is precluded? We think this is important case. As pointed by Apple, the most useful case is to switch between 2T4R and 1T2R.4. Regarding semi-persistent SRS, in previous meeting, it was agreed that two semi-persistent SRS resource sets could be supported. Therefore, the existing MAC-CE to activate/deactivate semi-persistent SRS can be used to enable flexible switching between xTyR.For example, the UE could be configured with one semi-persistent resource set for 2T4R and another semi-persistent SRS resource set for 1T2R. In this way, the gNB can use the existing MAC-CE to activate corresponding semi-persistent SRS resource set for 1T2R or 2T4R operation.Comparing with introducing new MAC-CE, re-using the existing MAC-CE is the simplest way and has minimum spec impact. In addition, re-using the existing MAC-CE can also support changing the number of ports of SRS.5. One question to Nokia, could you please explain more on how to use this feature in multi-TRP scenario? |
| Ericsson | As said in previous round, the main benefit of the feature is to enable fast switching between different xTyR configurations according to traffic and/or channel conditions. Same view as first round. DCI based and aperiodic should be supported |
| InterDigital | We have a similar view as Xiaomi, Nokia, Intel … that reporting of the UE suggested xTyR configuration should be the key essence of this proposal which may also call for a change in the preferred no. of Tx antennas. |
| Nokia2/NSB2 | Reply to Intel:We think that reporting can be seen as beneficial in multi-TRP framework with MPUE at FR2, where different aperiodic xTyR antenna-switching UL SRS resource sets need to be associated with certain spatial relations according to UE antenna-switching capabilities. Moreover, new MAC CE can enable fast switching of antenna configuration x1Ty1R to x2Ty2R e.g. between TRP1 and TRP2 (channel conditions assumed to be different between UE and different TRPs or MPUE with different xTyR capabilities) without need to preconfigure a large number of resource sets with different xTyR configurations or need for RRC based reconfigurations.  |
| Futurewei | The explicit replies on Int. 1 vs Int. 2 are all Int. 2. But some previous discussions talked about turning on/off PA / RF front end, etc. To be sure that companies are on the same page, we suggest to add Int. 2 “*Change the number of SRS ports dynamically but do no change the number of antennas*” to the proposal. @CATT: our understanding is Alt 1. The gNB can only indicate an AS configuration that the UE can already support. We are also open to other understandings. |

# Antenna switching up to 8Rx

## 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.

The following FL proposal is discussed in the first round.

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

* *The above extension is UE optional*

Supported by Huawei/HiSilicon, CATT, Xiaomi, Nokia/NSB, Ericsson, Intel, ZTE, Qualcomm, Apple, vivo, NTT DOCOMO

Concerned by OPPO, Lenovo/MotM

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We are fine if it is UE optional. We would prefer the AS resource to be configured as compact as possible in time domain to avoid performance loss due to phase continutity issue |
| OPPO | We are still not convinced with the use cases and benefits. We prefer to take more time for discussion and make final conclusion/agreement in this meeting. If more evidences or clarifications convince us during the following discussion, we would be ok with the proposal.I copy our previous comments here and hope the proponent(s) can better clarify the motivation/benefit. Based on discussions in meetings and the tdocs, we get an impression that there are two motivations mentioned by the proponent(s).* M1: some operator(s) only allows SRS transmission in the two symbols of UL slot. Thus, it cannot support 1T2R and 2T4R antenna switching in this network
* One clarification from my side: We don’t have any question on the UL-DL configuration (including special slot) and we understand the coexistence requirement of some operators. Our question is why AS-SRS is restricted in the two UL symbols of the special slot.
* We also double checked this issue with the operator suggested in your email. We got the information that the operator does not restrict that only two UL symbols of special slot can be used for SRS transmission. It is also allowed to transmit SRS in some symbols of the UL slots.
* Regarding the comment on higher 5G penetration, if more UL slots are used for SRS transmission, the original motivation of this proposal no longer exists. When there are more 5G UEs, more SRS will be needed for codebook PUSCH. Then, gNB can trigger CB-SRS in the two symbols of the special slot and trigger AS-SRS in the normal UL slots.
* Thus, we failed to see that M1 is valid
* M2: Resources can be saved since guard period is avoided
* If the main motivation is to reduce the guard period, it is not a critical issue from practical deployment, but a better-to-have optimization (its benefit needs further justification as explained in the next sub-bullet).
* For 1T4R, Rel-15 supports two resource sets since we have no other choice, but doesn’t not mean it is an optimized solution. If multiple sets are used for antennas switching, it seems that the guard period is avoided since spec doesn’t specify any explicit guard period for this case. However, UE still need some transient period to transmit SRS if the consecutive transmissions (PUSCH/PUCCH+SRS) are using different Tx antennas, which will impact the performance of SRS reception.
 |
| Intel | Fine with FL proposal. |
| CATT | Support FL’s proposal. |
| Xiaomi | Support FL proposal |
| Lenovo/MotM | As the supporter pointed that this feature is useful for the special case that only two UL symbols in a slot, which means that at least 4 continuous slots are required for SRS transmission for DL channel estimation, we are not sure the estimated channel matrix is still effective.  |
| vivo | Fine with the FL proposal |
| Docomo | Fine with FL proposal.  |
| Nokia/NSB | Support the FL proposal.  |
| Ericsson | Support the proposal. Thanks to Apple for reconsidering. With being optional, I assume you mean there will be a UE capability associate with it, which I think is natural. (since Rel.17 MIMO is optional to begin with)Reply to OPPO:* M1: some operator(s) only allows SRS transmission in the two symbols of UL slot. Thus, it cannot support 1T2R and 2T4R antenna switching in this network
* One clarification from my side: We don’t have any question on the UL-DL configuration (including special slot) and we understand the coexistence requirement of some operators. Our question is why AS-SRS is restricted in the two UL symbols of the special slot.
* **Ericsson:** It is not restricted, but it is desirable to use these two symbols, it is a perfect location for aperiodic SRS, since otherwise these symbols will be unused and instead, the UL slot needs to contain many SRS symbols and this takes capacity away from PUSCH. Using these for periodic SRS exaggerates the sensitive to Doppler since the time between periodic SRS transmissions is larger than for aperiodic SRS
* We also double checked this issue with the operator suggested in your email. We got the information that the operator does not restrict that only two UL symbols of special slot can be used for SRS transmission. It is also allowed to transmit SRS in some symbols of the UL slots.
* **Ericsson:** After our offline email discussion, more operators have an issue with this since FH+AS is desirable and these operators have 3 and 4 UL symbols in the s-slot. The problem for these operators can also be resolved be the proposal on the table.
* Regarding the comment on higher 5G penetration, if more UL slots are used for SRS transmission, the original motivation of this proposal no longer exists. When there are more 5G UEs, more SRS will be needed for codebook PUSCH. Then, gNB can trigger CB-SRS in the two symbols of the special slot and trigger AS-SRS in the normal UL slots.
* **Ericsson:** Thanks for sharing your view. I don’t quite follow how this solves the problem.
* Thus, we failed to see that M1 is valid
* M2: Resources can be saved since guard period is avoided
* **Ericsson:** This is another proposal discussed under a different sub-agenda point. I don’t see how it is relevant for this proposal.
* If the main motivation is to reduce the guard period, it is not a critical issue from practical deployment, but a better-to-have optimization (its benefit needs further justification as explained in the next sub-bullet).
* For 1T4R, Rel-15 supports two resource sets since we have no other choice, but doesn’t not mean it is an optimized solution. If multiple sets are used for antennas switching, it seems that the guard period is avoided since spec doesn’t specify any explicit guard period for this case. However, UE still need some transient period to transmit SRS if the consecutive transmissions (PUSCH/PUCCH+SRS) are using different Tx antennas, which will impact the performance of SRS reception.

Reply to LenovoAs the supporter pointed that this feature is useful for the special case that only two UL symbols in a slot, which means that at least 4 continuous slots are required for SRS transmission for DL channel estimation, we are not sure the estimated channel matrix is still effective.* **Ericsson:** This feature is intended to be used for 2,3 and 4 UL symbols in the slot. For 6 and 8 RX, we support N\_max=4, what is your view on this agreement?
 |

## Guard period

Companies discuss possible enhancements on guard symbols for antenna switching SRS. The first-round discussion focused more on the inter-set GP issue. We still need to solve whether GP can be configurable.

The proposed alternatives on the presence of guard symbols are summarized as follows.

Table 3-1

|  |
| --- |
| **Presence of guard symbols** |
| Alternatives | Companies |
| Alt 1-0: Guard symbols are always-on, which is same as Rel-15 | Huawei/HiSilicon, OPPO, Xiaomi, MediaTek, Intel, Qualcomm, Apple |
| Alt 1-1: Guard symbols are configurable subject to UE capability | Spreadtrum, ZTE, vivo, CATT, CMCC, Samsung, NTT DOCOMO, Nokia/NSB, LGE, Ericsson, Lenovo/MotM |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We prefer Alt 1-0 |
| MediaTek | Support Alt 1-0 |
| OPPO | Support Alt.1-0.  |
| Intel | Support Alt 1-0. |
| QC | Support Alt 1-0.Just as a reminder, based on the RAN1 agreement in the last meeting, if there is no Conesus to support Alt 1-1, then rel-15 guard periods (i.e. Alt 1-0) is supported by default. **Agreement*** On the presence of guard symbols in Rel-17 for SRS antenna switching, down-select one of the following
	+ Alt 1-0: Guard symbols are always-on, which is same as Rel-15
	+ Alt 1-1: Guard symbols are configurable subject to UE capability
* On whether to introduce guard symbols between SRS resource sets for antenna switching, down-select one of the following
	+ Alt 2-0: Do not introduce guard symbols between SRS resource sets, i.e., guard symbols only appears between SRS resources in a resource set
	+ Alt 2-1: Introduce guard symbols between two sets mapped to consecutive slots
* Note: Rel-15 guard period symbols are supported if none of the above enhancements is agreed
 |
| Spreadtrum | Support Alt 1-1. |
| CATT | It is our view that guard symbols are configured by configuring two SRS resources in a set in symbols with a period equals or larger than the number of guard symbols in-between. Does Alt 1-1 means if UE reports values for guard symbol other than that for Rel-15, then the number of guard symbol(s) equals to the value that UE reported, or it means if UE reports values for guard symbol other than that for Rel-15, gNB indicates whether the number of guard symbol(s) equals to what UE reported or is the same as Rel-15? |
| Xiaomi | Support Alt1-0 |
| Lenovo/MotM | Support Alt 1-1.It has agreed that the guard period between different SRS resource sets is configured subject to UE capability. We think it should also apply to SRS resources within a set since they are configured for the same purpose. |
| vivo | Support Alt 1-1. |
| Docomo | Support Alt 1-1. Similar view with Lenovo. Also, since the guard period can be reported as UE capability, if UE cannot support smaller guard period than Rel.15, the UE is allowed to report it. Alt.1-0 precludes possibility for high capable UE to support smaller guard period than Rel.15. |
| LGE | Support Alt 1-1. If there is an enhanced UE which is capable of fast antenna switching, the configurability of guard symbol based on the UE capability has clear benefit to save unnecessary guard symbol. |
| Nokia/NSB | Support Alt 1-1 |
| Ericsson | Support Alt 1-1 |

## 4T6R configurations

It has been agreed to support 4T6R antenna switching in Rel-17. Companies’ views on the detailed 4T6R configuration are summarized as follows.

Table 3-3

|  |
| --- |
| **4T6R SRS antenna switching configurations** |
| Alternatives | Companies | Further details |
| Alt 1: 4 + 2 | ZTE, CATT, CMCC, Samsung, Intel, Qualcomm, OPPO, Lenovo/MotM, NTT DOCOMO, Xiaomi |  |
| Alt 2: 2 + 2 + 2 | Huawei/HiSilicon, InterDigital, CMCC, vivo, Ericsson, NTT DOCOMO | Huawei/HiSilicon: * No guard symbols between the first two resources,
* No guard symbols between the last two resources if the required number of guard symbols is 1,
* Have 1 guard symbol if the required number of guard symbols is 2

InterDigital: * No guard symbols between the first two resources,
* No guard symbols between the last two resources
 |
| Alt 3: 4 + 4 | NEC, CMCC, LGE, Nokia/NSB |  |
| Alt 4: 4 + 4 + 4 | Ericsson, Qualcomm, Xiaomi |  |
| Clarification on the notation:$x\_{1}+\cdots +x\_{K}$ means totally K resources are needed, where the k-th resource contains $x\_{k}$ ports, 1<=k<=K.Whether to distribute the K resources in one or more sets is to be discussed afterwards. |

Based on the first-round discussion, it seems the first two alternatives attract higher interest than the other two. Hence FL recommends to focus on these two in further discussions.

***FL Proposal 3-3:*** *Support at least one of the following SRS configurations for 4T6R*

* *Alt 1: 4 + 2*
* *Alt 2: 2+2+2*
* *Clarification on the notation:* $x\_{1}+\cdots +x\_{K}$ *means totally K resources are needed, where the k-th resource contains* $x\_{k}$ *ports, 1<=k<=K*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We are fine with the proposal.  |
| MediaTek | Support the FL proposal |
| OPPO | Support the proposal |
| Intel | Fine with FL proposal.In addition, we think the maximum number of aperiodic SRS resource sets for 4T6R should be discussed.*FL’s response:*Of course. Let’s discuss this after we know how many resources we will need. |
| QC | Although our first preference is 4+4+4, we are fine with FL proposal and support Alt 1. |
| Samsung | Support the proposal |
| CATT | Support FL’s proposal. |
| Xiaomi | Support the FL proposal |
| Lenovo/MotM | Support the FL proposal. |
| vivo | Support the proposal |
| NEC | We are fine with the proposal, and support Alt 1. |
| Docomo | Support the FL proposal.  |
| LGE | Prefer to add 4+4 as Alt 3. In 4+4, there should be two common sounding ports between two SRS transmission instances, those common ports can be used for gNB to estimate phase rotation and/or channel variation between two different SRS transmission instances, especially when the two instances are spread out in time domain. We are also OK to optionally/additionally support 4+4, based on Alt 1(4+2) case.Regarding the alt 2(2+2+2), what’s the difference with 2T6R configuration? If alt 2 is only supported, there is no difference with 2T6R configuration, and 4T6R shouldn’t be supported. |
| Nokia/NSB | We have concerns about Alt-3 regarding to increased resource overhead and latency. However, we have fine with FL proposal. |
| Ericsson | Support |
| InterDigital | Support FL proposal, with preference of Alt2  |
| Nokia2/NSB2 | We have concerns about Alt-2 (2+2+2) regarding to increased resource overhead and latency. However, we have fine with FL proposal. |

# Coverage and capacity enhancements

## RB-level partial frequency sounding (RPFS)

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

### 4.1.1 PF values

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

Table 4-1

|  |
| --- |
| **Additional PF values** |
| Values | Companies |
| Support additional PF values | * vivo: Support {3, 8, 12}
* Fraunhofer IIS/Fraunhofer HHI: Support an additional PF value which is a multiple of 4
* Futurewei: 3, 8, 12, 16, and fractional numbers
* Huawei/HiSilicon: Support 3 if $m\_{SRS, B\_{SRS}}$ is a multiple of 3
 |
| Do not support additional PF values  | * Intel, Ericsson, Qualcomm
 |

For PF values, given there is no consensus on whether and how to support PF values other than {2, 4}, FL recommends the following.

***FL Proposal 4-1:*** *No consensus to support PF values other than {2, 4} for RPFS in Rel-17.*

Supported by LGE, OPPO, Samsung, Qualcomm, CATT, Ericsson, Spreadtrum, Intel, Xiaomi, Nokia/NSB, MediaTek, Lenovo/MotM, NEC, InterDigital, Apple, ZTE

Concerned by NTT DOCOMO

Considering the majority of companies can accept this proposal, FL encourages companies to consider the limited time we have now.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We are fine with the proposal  |
| MediaTek | Support the FL proposal |
| OPPO | Support |
| Intel | Support FL proposal |
| QC | Support.  |
| Samsung | Support |
| Spreadtrum | Support FL proposal |
| CATT | Support |
| Xiaomi | Support the FL proposal |
| Lenovo/MotM | Fine with the proposal. |
| NEC | Support the proposal. |
| Docomo | We believe larger value should be introduced. Introducing larger value of P F have more benefit to improve coverage/capacity. Moreover, we don’t understand the problem to introduce the larger values than P F =4. For example, when we have 8, and limit the number of exact RBs with Alt 2 (or Alt 3) in 4.1.4, we see few (or no) issue remains. What is the problem to introduce the larger value e.g. PF = 8?  |
| LGE | Support. |
| Nokia/NSB | Support the FL proposal |
| Ericsson | Support |
| InterDigital | Support FL proposal |
| Futurewei | Not support. We agree with Docomo.If only 2 and 4 are supported, the resulting SRS BWs can be alternatively configured based on existing R15 specs. We are not sure how useful this feature is. |

### 4.1.2 Start RB location hopping

The remaining issues of start RB location hopping includes two aspects

* Whether to support start RB location hopping within a legacy FH period
* Whether to extend start RB location hopping to aperiodic SRS

Companies’ views on these three aspects are summarized as follows.

Table 4-2

|  |
| --- |
| **Whether to support start RB location hopping within a legacy FH period** |
| Views | Companies |
| Yes | Start RB location hopping is performed across repetition symbols in one SRS resource when R>1 | Spreadtrum, CATT, MediaTek |
| Start RB location hopping is performed across SRS occasions in one legacy FH period | Ericsson |
| No or deprioritize | vivo, OPPO, NTT DOCOMO, Lenovo/MotM, LGE |
| **Whether to extend start RB location hopping to aperiodic SRS** |
| Views | Companies |
| For aperiodic SRS, support same start RB location hopping approach as for P/SP SRS | ZTE, Qualcomm |
| For aperiodic SRS, support start RB location hopping across repetition symbols for R>1 | MediaTek, CATT, NEC |
| Start RB location hopping is not applicable on aperiodic SRS | Intel |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| MediaTek | Support start location hopping for A-SRS and within FH period when R>1  |
| Intel | We don’t see strong need to apply it within FH period and for aperiodic SRS. |
| Qualcomm | We are okay to support start RB hopping for A-SRS when more than one legacy FH exist.  |
| Spreadtrum | For A-SRS, support start RB hopping within one FH period (R>1) and across multiple FH periods.  |
| CATT | The start location hopping has been supported for P-SRS and SP-SRS. Considering specification uniformity, the start location hopping should be supported for A-SRS as well. If the start location hopping is supported within a FH period, the entire bandwidth may be sounded in one FH period, which can reduce the latency of sounding the whole bandwidth and improve the channel estimation accuracy without requiring additional interpolation calculation.  |
| vivo | Not support start RB location hopping applied within FH period and for aperiodic SRS. We shared same view with intel as there is no obvious benefit for supporting start RB location hopping to aperiodic SRS. And it has serious impacts on the definition of SRS repetition scheme in current specification and may decrease repetition performance due to unaligned SRS frequency resource.  |
| NEC | Support start RB location hopping within FH period.And support RB location hopping across repetition symbols for R>1. |
| Docomo | For the application of start location hopping within FH period, we do not see strong need. For the application of start location hopping to A-SRS, we are fine with supporting it.  |
| LGE |  Our view is added above table. |
| Futurewei | We tend to support both, but would like to know more about the A-SRS part. Does it require DCI indication? |

### 4.1.3 Applicable cases

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

Table 4-3

|  |
| --- |
| **Whether to restrict the applicable cases for RPFS** |
| Views | Companies |
| Applicable for frequency hopping case only | vivo, OPPO, CMCC, Intel, Qualcomm, Nokia/NSB |
| Applicable for both frequency hopping and non-frequency hopping cases | Huawei/HiSilicon, Futurewei, NEC, CATT, Lenovo/MotM, Spreadtrum, Ericsson, MediaTek |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| MediaTek | Support applicable for both cases |
| OPPO | Rel-15 spec can support the same functionality for non-frequency hopping cases |
| Intel | Support to apply for frequency hopping only. |
| QC | Support only for FH. We would like to ask supporting companies for non-frequency hopping, what is the motivation and added feature compared to rel-15?  |
| Spreadtrum | Support both cases. |
| CATT | Support to apply RPFS for both frequency hopping and non-frequency hopping. Since the start RB location hopping across legacy FH periods is supported, SRS can sound the whole bandwidth through multiple FH periods even if non-frequency hopping is configured. If RPFS is not applicable for non-frequency hopping, the sounding bandwidth of SRS is always fixed and the function of RPFS cannot be obtained for non-frequency hopping. |
| vivo | Applicable for frequency hopping case only, the motivation of this feature is to allow power boosting and sweep the whole SRS bandwidth quickly. |
| NEC | Support applicable to both cases. |
| Docomo | Support to apply RPFS to both cases.  |
| LGE | We support both cases and support dynamic indication of PF and KF. |
| Nokia/NSB | Agree with Qualcomm that benefits are not clear with non-hopping. Support applicable for frequency hopping case only. |
| Futurewei | Support both.As explained before, we support to introduce dynamic indication to partial sounding, which helps both capacity and coverage. Otherwise, R15 schemes can configure narrow SRS BWs anyway, for both hopping or non-hopping. |

### 4.1.4 Further restriction on the number of RBs

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

Table 4-4

|  |
| --- |
| **Further restriction on the number of RBs for RPFS** |
| Alternatives | Companies |
| Alt 1: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ is an integer value | ZTE, Huawei/HiSilicon, Futurewei, NEC, Ericsson, MediaTek |
| Alt 2: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ is an integer value with minimum value 4 | NEC, NTT DOCOMO, Futurewei, MediaTek, Lenovo/MotM |
| Alt 3: $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is a multiple of 4 | vivo, OPPO, CATT, Intel, Apple, LGE, Qualcomm, Xiaomi, Nokia/NSB |
| 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 | vivo, NEC (Starting RB index of the $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ RBs in the $m\_{SRS, B\_{SRS}}$ RBs aligns with a multiple of 4), CATT, Qualcomm, Xiaomi |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We prefer Alt 3.  |
| MediaTek | Prefer Alt. 1 or Alt. 2Alt.3 and Alt.4 look very restricted comparing to existing R15 configuration |
| OPPO | We prefer Alt.3  |
| Intel | Support Alt 3. |
| QC | Support Alt 3 and Alt 4. This issue has been discussed over last few meetings, we need to make a resolution one way or the other.  |
| Samsung | Support Alt.3 |
| CATT | Support Alt 3 and Alt 4. |
| Xiaomi | Support Alt 3 and Alt 4. |
| Lenovo/MotM | Prefer Alt 2. |
| vivo | Support alt3 and 4 |
| NEC | Prefer Alt 4, and also fine with either Alt 1 and Alt 2.Maybe we can decide whether to restrict $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ to be a multiple of 4 firstly, we think legacy configuration can support almost all cases for Alt 3, if we restrict to be a multiple of 4, then RB level partial sounding seems useless and a waste of effort.Proposal:* Alt A: Support $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ to be an integer value not restricted to be a multiple of 4
	+ FFS: the details on the values.
* Alt B: Restrict $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$$\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ to be a multiple of 4
 |
| Docomo | Prefer Alt 2.  |
| LGE | Support Alt 3. |
| Nokia/NSB | Support Alt 3. |
| Futurewei | Support Alt 1 or 2. |

## Comb-8

The only remaining issue for Comb 8 is the maximum supported number of CSs. The following proposal is discussed in the first round.

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

***Alt 1:*** *For comb-8 SRS in Rel-17, the maximum number of CSs is 6.*

* *Two comb offsets are used to carry 4 ports in this case, FFS details*

Supported by Huawei/HiSilicon, ZTE, Futurewei, Spreadtrum, vivo, OPPO, NEC, Samsung, Intel, Apple (10)

***Alt 2:*** *For comb-8 SRS in Rel-17, the maximum number of CSs is 12.*

* *Introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs, FFS detailed rule*

Supported by Ericsson, MotM/Lenovo, MediaTek, Qualcomm, NTT DOCOMO, Intel, Xiaomi, Nokia/NSB, CATT (9)

Considering the majority support of max CS = 6, FL encourage companies to be more flexible in the second round as it is a necessary component to complete this feature.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We are supportive of 6 maximum CS. On how to support 4 port, we do cknowledge the issue and open to discuss the solutions.  |
| MediaTek | Not support. Max CS=12 is preferred. Main consideration is max CS=6 has no capacity increase comparing (comb-4, max CS=12) case.  |
| OPPO | Support the proposal  |
| Intel | Fine with both options. Max CS=12 is also acceptable to us since it provides more capacity. |
| QC | Prefer Max CS = 12.  |
| Samsung | Support proposal 4-3 |
| Spreadtrum | Support FL proposal |
| CATT | Max CS = 12 is preferred. |
| Xiaomi | Prefer Max CS=12 considering the capacity  |
| Lenovo/MotM | Prefer Max CS = 12.The case that *SRS sequence is shorter than the maximum number of CSs* may also appear for the Rel-15 CS and Comb combination. For example, when the sounding band is 4 PRB with $K\_{TC}$=2 and $P\_{F}$=4, the result SRS sequence length is 6 which is less than the supported $n\_{SRS}^{CS,max}$=8. When the sounding band is 4 PRB with $K\_{TC}$=4 and $P\_{F}$=2, the result SRS sequence length is 6 which is less than the supported $n\_{SRS}^{CS,max}$=12. So, we prefer to have a unified solution to handle this problem.  |
| vivo | Support FL proposal |
| NEC | Support the proposal. |
| Docomo | After consideration, we support max CS=12. Since the purpose of comb8 is capacity enhancement, we should increase capacity compared to existing comb4 with 12CS. If max CS =6, there is no benefit to introduce comb8 feature. |
| Nokia/NSB | To enhance antenna port multiplexing capacity, max. CS=12 is preferred. |
| Ericsson | The current proposal doesn’t provide opportunity for capacity increase. CS=12 is preferred.  |
| Futurewei | Support Alt 1 |
| CATT2 | It seems our preference is missed. We prefer Alt 2 for increasing capacity. |

# Conclusion

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

**Max CS for Comb-8**

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

***Alt 1:*** *For comb-8 SRS in Rel-17, the maximum number of CSs is 6.*

* *Two comb offsets are used to carry 4 ports in this case, FFS details*

Supported by Huawei/HiSilicon, ZTE, Futurewei, Spreadtrum, vivo, OPPO, NEC, Samsung, Intel, Apple (10)

***Alt 2:*** *For comb-8 SRS in Rel-17, the maximum number of CSs is 12.*

* *Introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs, FFS detailed rule*

Supported by Ericsson, MotM/Lenovo, MediaTek, Qualcomm, NTT DOCOMO, Intel, Xiaomi, Nokia/NSB, CATT (9)

**Extension of aperiodic SRS for <=4Rx**

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

* *The above extension is UE optional*

Supported by Huawei/HiSilicon, CATT, Xiaomi, Nokia/NSB, Ericsson, Intel, ZTE, Qualcomm, Apple, vivo, NTT DOCOMO

Concerned by OPPO, Lenovo/MotM

**4T6R configurations**

***FL Proposal 3-3:*** *Support at least one of the following SRS configurations for 4T6R*

* *Alt 1: 4 + 2*
* *Alt 2: 2+2+2*
* *Clarification on the notation:* $x\_{1}+\cdots +x\_{K}$ *means totally K resources are needed, where the k-th resource contains* $x\_{k}$ *ports, 1<=k<=K*

**Repurpose**

***FL Proposal 2-3A:*** *No consensus to support repurpose of DCI field(s) for SRS parameter indication in Rel-17.*

Supported by Apple, OPPO, Qualcomm, Samsung, Spreadtrum, CATT, Xiaomi, Lenovo/MotM, vivo (2nd), NEC, Nokia/NSB, InterDigital, ZTE

***FL Proposal 2-3B:*** *Further discuss and decide if the existing TPC command field, bandwidth part indicator field, and FDRA field in the DCI configured for data transmission apply to the AP SRS or not.*

Supported by Intel, vivo (1st), NTT DOCOMO, Futurewei

**P\_F values**

***FL Proposal 4-1:*** *No consensus to support PF values other than {2, 4} for RPFS in Rel-17.*

Supported by LGE, OPPO, Samsung, Qualcomm, CATT, Ericsson, Spreadtrum, Intel, Xiaomi, Nokia/NSB, MediaTek, Lenovo/MotM, NEC, InterDigital, Apple, ZTE

Concerned by NTT DOCOMO

**Collision handling**

***FL Proposal 2-1:*** *Introduce dropping rule when collision happens among multiple aperiodic SRS resource sets in a same CC or different CCs.*

* *Select one or more of the following priority rules*
	+ *Rule 1 – Based on usage*
	+ *Rule 2 – Based on set ID and CC ID*
	+ *Rule 3 – Based on order of the triggering DCI*
	+ *Rule 4 – Based on type of the aperiodic SRS (e.g., with Rel-17 offset or not)*
* *The new dropping rule is a UE optional feature*
* *FFS collision handling among Rel-17 flexible SRS and other UL channels/signals*

**Flexible antenna switching**

***FL proposal 2-4:*** *Support gNB indicating the used SRS resources from the configured SRS resources in SRS resource set(s) for antenna switching via MAC CE.*

* *Applicable to at least one of the following two cases*
	+ *Case 1: all of aperiodic, periodic and semi-persistent SRS*
	+ *Case 2: only periodic or semi-persistent SRS*
	+ *Case 3: only for aperiodic SRS*
* *Support UE reporting of one preferred antenna switching configuration in MAC CE*
* *The gNB indicated or UE reported antenna switching configuration belongs to the supported antenna switching reported by UE capability signaling*
* *FFS whether DCI can be additional used to indicate the used antenna switching configuration*
* *FFS the application timing of the MAC CE activation*
* *Note: Any change on the configured number of Tx antennas in each SRS resource is precluded in either the gNB indication or UE reporting*

# 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 khopping is same for all SRS occasions within a legacy FH period but changes across legacy FH periods, kF and PF are at least configured by RRC signaling (kF = {0, 1, …, PF-1}).
* Support at least one pattern for khopping in time domain, FFS detailed pattern
* Note: the legacy FH period is the period to sound the full SRS hopping bandwidth across the different subbands of $m\_{SRS, B\_{SRS}}$ 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,$k\_{hopping}$ khopping is fixed to be 0 for all SRS symbols
* This start RB location hopping is UE optional.
* FFS whether start RB location hopping is also applicable on SRS occasion(s) within one FH period (e.g., when R>1) and/or on aperiodic SRS, if so, how

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

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

**Conclusion**MAC CE for t value update in Rel-17 is not supported.**Agreement**For antenna switching SRS, support maximum one SRS resource set for periodic SRS and maximum 2 SRS resource sets for semi-persistent SRS.* Note: the two SP-SRS resource sets are not activated at the same time
* For xTyR where y>4, if UE does NOT support this feature, support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS
* Applies for all supported xTyR where y<=8
* For each xTyR antenna switching (except for 4T6R if supported), each periodic or semi-persistent resource set contains y/x resources.

This feature is UE optional: For UEs that do not support this feature, follow Rel-15 on the number of resource sets for periodic and semi-persistent SRS**Agreement*** Support 4T6R SRS antenna switching in Rel-17.

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

**Agreement**For SRS increased repetitions in Rel-17, support the following configurations, and no other values are supported.* (N\_symbol, R) = {(8, 1), (8, 2), (8, 4), (8, 8), (12, 1), (12, 2), (12, 3), (12, 4), (12, 6), (12, 12), (10, 1), (10, 2), (10, 5), (10,10), (14, 1), (14, 2), (14, 7), (14, 14)}
* Note: N\_symbol SRS symbols are adjacent in a slot.

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

**Agreement**For Comb-8 SRS in Rel-17, down-select one of the following in RAN1#106bis-e* Alt 1: The maximum number of CSs for Comb-8 is 6
* Alt 2: The maximum number of CSs for Comb-8 is 12, and introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs

**RAN1#106bis-e****Agreement**For two SRS resource sets of an xTyR antenna switching located in two consecutive slots, if UE is capable of transmitting SRS in all symbols in one slot, a minimum gap period of Y symbols exists between the last OFDM symbol occupied by the SRS resource set in the first slot and the first OFDM symbol occupied by the SRS resource set in the second slot* The value of Y is same as the inter-resource GP defined in Rel-15
* FFS: Whether or not the minimum GP exists can be RRC configurable subject to UE capability
* Whether this inter-set GP is needed for 4T6R can be discussed later per the decision on 4T6R configuration.
* FFS: How/Whether to handle the case where the interval between SRS resource sets is larger than Y

**Agreement**For the detailed pattern of $k\_{hopping}$ when start RB location hopping across legacy FH periods is enabled, support the following* For PF = 2, $k\_{hopping}$ = {0, 1}
* For PF = 4, $k\_{hopping}$ = {0, 2, 1, 3}
* Note: $k\_{hopping}=\{x\_{0},\cdots x\_{P\_{F}-1}\}$ means $k\_{hopping}=x\_{n mod P\_{F}}$ for the (n+1)-th legacy FH period, where n = {0, 1, 2, 3, …}
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# References

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