3GPP TSG RAN WG1 Meeting #104b-e R1-210xxxx

**e-Meeting, Apr. 12th – 20th, 2021**

**Source: Moderator (ZTE)**

Title: FL summary #2 on SRS enhancements

Agenda Item: 8.1.3

Document for: Discussion and Decision

# Introduction

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

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

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

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

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

# Flexibility enhancements

## SRS triggering offset

### 2.1.1. Reference slot definition

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

Table 2-1

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

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

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

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

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

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

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

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

* *For a UE supporting the Rel-17 SRS triggering offset enhancement, configuring legacy triggering offset as 0 when using this enhancement is a basic UE feature, and configuring legacy triggering offset as non-zero values when using this enhancement is an optional UE feature.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL’s clarification | The term “basic feature” should be well understood as it has been widely used in UE feature session. Here basic feature means supporting zero value for legacy triggering offset is mandatory if this UE supports the Rel-17 SRS triggering offset enhancement. UE can also optionally indicate it can support non-zero values for legacy triggering offset through capability reporting.  Then for an aperiodic SRS resource set, either Rel-17 mechanism or Rel-15/16 mechanism can be used. If the Rel-17 mechanism is configured,   * If UE does not report it supports non-zero values for legacy triggering offset when using Rel-17 triggering offset enhancement, gNB can only configure legacy triggering offset as 0 when it configures the Rel-17 mechanism to determine aperiodic SRS slot. In this case, Opt. 1 and Opt. 2 are equivalent. * If UE reports the support of non-zero values for legacy triggering offset, it means gNB can configure legacy triggering offset as zero or non-zero when it configures the Rel-17 mechanism. In this case, it is a full set of Opt. 2.   For companies who may not want to implement a full set of Opt. 2 (e.g., Opt. 1 proponents) on their UEs, they can choose to implement only a subset, i.e., Opt. 1. But the specification can support Opt. 2, so other companies can choose to implement a full set of Opt.2 by indicating support of non-zero legacy offset in capability reporting. From FL perspective, this is a mid-ground between the two camps. |
|  |  |
|  |  |

### 2.1.2. Collision handling

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

Table 2-2

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

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

### 2.1.3 Determination on the value of t

**DCI indication mechanism**

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

Table 2-3

|  |  |  |  |
| --- | --- | --- | --- |
| **DCI** | | | |
| Cases | Alternatives | Number | Companies |
| Scheduling DCI (DCIs scheduling a PDSCH or PUSCH) | Alt 2-1: t is indicated by adding a new configurable DCI field | 12 | Apple, ZTE, NEC, NTT DOCOMO, Huawei, HiSilicon, Spreadtrum, vivo, MediaTek, IDC, CATT, Futurewei |
| Alt 2-2: t is indicated without adding DCI payload | 8 | Qualcomm (using aperiodic SRS trigger state), Samsung, Nokia, NSB (using aperiodic SRS trigger state), Ericsson, OPPO, Intel, Xiaomi |
| Non-scheduling DCI (DCI 0\_1/0\_2 without data and without CSI request) | Alt 1-1: Reuse the same scheme used for DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH | 11 | Apple, ZTE, NEC, NTT DOCOMO, Huawei, HiSilicon, OPPO, Spreadtrum, CATT, Intel, IDC |
| Alt 1-2: Re-purpose unused DCI field to indicate t | 9 | Qualcomm, ZTE, Samsung, Ericsson, NTT DOCOMO, vivo, MediaTek, CMCC, Xiaomi |
| Alt 1-3: t is indicated by a configurable DCI field, where the DCI field may contain bits from unused fields and additional bits configured by gNB | 3 | Nokia, NSB, vivo |

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

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

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

Companies’ further views are collected as follows.

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

**Size of t list**

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

Table 2-4

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

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

Companies’ further views are collected as follows.

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

**Whether to support MAC CE update**

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

Table 2-5

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

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

## Flexible DCI format

**Re-purpose**

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

Table 2-6

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

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

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

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

Companies’ further views are collected as follows.

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

**Group-common DCI**

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

Table 2-7

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

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

## Usage/overhead reduction

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

Table 2-8

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

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

Companies’ further views are collected as follows.

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

## Flexible antenna switching

Multiple companies discuss the issue of indicating the number of antennas to support more flexible antenna switching in dynamic signaling. Their views are summarized in the following table.

Table 2-9

|  |  |  |  |
| --- | --- | --- | --- |
| **Update Tx/Rx antennas for SRS antenna switch in dynamic signaling** | | | |
|  | Number | Companies | Other comments |
| Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | 9 | Apple, Qualcomm (MAC CE), Ericsson (MAC CE), Huawei, HiSilicon (MAC CE), Lenovo, MotM, Xiaomi, ZTE | **UE reporting**  Apple, Xiaomi, Qualcomm: Support UE reporting of the preferred antenna switching configuration/Rx/Tx antenna numbers  **Applicable cases**  Case 1: aperiodic SRS   * Ericsson   Case 2: periodic or semi-persistent SRS   * Huawei, HiSilicon |

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

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

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

Companies’ further views are collected as follows.

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

## Others

The following issues are discussed by one company.

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

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

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | As described above, scheduling DCI flexibility enhancements should also be discussed. We suggest to add a discussion point for it.  A related issue is to further clarify the SRS transmission parameters and the expected UE behavior. For the parameters explicitly indicated in the DCI, they should overwrite any RRC/MAC parameters of exactly the same type. For parameters not explicitly indicated in the DCI, they can generally follow RRC/MAC parameters but some of them may still be able to be reused from elsewhere, such as from the co-scheduled PUSCH/PDSCH. |
| Futurewei2 | Again on the scheduling DCI --- we had an agreement before:  **Agreement**  Support at least DCI 0\_1 and 0\_2 to trigger aperiodic SRS without data and without CSI.   * FFS whether/how to re-purpose the unused fields, e.g., the triggering offset(s) and the frequency resources for triggering A-SRS on one or more component carriers, SFI-index, etc. * FFS UL/DL DCI with data for aperiodic SRS * FFS group common DCI   All FFS are being discussed except that we have no place to discuss the scheduling DCI. We’d like to ask this to be discussed. |
|  |  |

# Antenna switching up to 8Rx

## Aperiodic SRS configurations for >4Rx

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

**N\_max values**

Table 3-1

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

Following majority view, FL proposes the following.

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | We cannot support the proposal.  In our contribution (R1-2102437), we have shared our evaluation of 4T8R vs. 2T8R SRS configuration for a 4T8R partial coherent UE. According to our observations:   * For partial coherent 4T8R UEs, 2T8R-based AS performs better than 4T8R AS configuration. * For partial coherent UEs with a 4T8R-based AS configuration, increasing calibration accuracy does not result in any major improvements. * For partial coherent UEs with a 2T8R-based AS configuration, increasing calibration accuracy significantly improves the performance.   So our proposal is to update the WA with   * **For *fullAndPartialAndNonCoherent* UEs, K=2, N\_max = [4], and each resource has 4 ports** * **For *partialAndNonCoherent* UEs, K=4, N\_max = [2], and each resource has 2 ports**   A couple of notes and clarifications:   * Therefore, for the purpose of channel sounding, a fully coherent UE will send SRS transmission simultaneously over 4 ports (K=2). However, a partially coherent UE, will perform channel sounding by performing SRS transmission over 2-ports at the time (K=4). * The proposal poses no restriction on the number of MIMO layers, capability, etc. It only enhances accuracy of the DL CSI estimation obtained by the antenna switching procedure. |
|  |  |
|  |  |

**N values**

Table 3-2

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

***FL Proposal:*** *On supported values of N for Rel-17 aperiodic SRS antenna switching with >4Rx, down-select at least one of the following alternatives in RAN1#105e*

* *Alt 1: All the non-zero integer values <= N\_max are supported for N*
* *Alt 2: Support N=N\_max only*
* *Alt 3: Support specific N values <= N\_max*

Companies’ further views are collected as follows.

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

## Extension for aperiodic SRS with <=4Rx

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

Table 3-3

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

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

## Configurations for periodic and semi-persistent SRS

Table 3-4

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

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL’s clarification | This updated proposal is to address the request from Huawei (at least partially). This allows gNB to configure both semi-persistent SRS and periodic SRS for antenna switching with >4Rx. |
|  |  |
|  |  |

## Configured time-domain types for 1T4R

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

Table 3-5

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

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL’s clarification | @Ericsson, for the xTyR configurations supported in the current specification, only 1T4R has the issue that only one time-domain type can be configured. For >4Rx, it is discussed in Section 3.3. |
|  |  |
|  |  |

## Guard period

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

Table 3-6

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

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

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

Companies’ further views are collected as follows.

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

## Whether 4T6R is supported

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

Table 3-7

|  |  |  |
| --- | --- | --- |
| **Whether to support 4T6R SRS antenna switching** | | |
|  | Number | Companies |
| Yes | 9 | Qualcomm, NEC, InterDigital, Spreadtrum, Lenovo, MotM, CMCC, Xiaomi, NTT DOCOMO |
| No or deprioritize | 5 | Ericsson, Futurewei, Huawei, HiSilicon, vivo |

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

## Others

The following issues are discussed by one or two companies.

|  |  |
| --- | --- |
| Support UE capability reporting of power offset across antenna ports for SRS DL CSI acquisitions | Qualcomm |
| A 6Rx can report a capability of two, four or six layers of maximum number of DL MMO layers. And 8Rx UE can report a capability of two, four, six or eight layers of maximum number of DL MMO layer. | Qualcomm |
| Consideration on antenna switching for multi-panel UEs | Sony, vivo, LGE |
| Further study SRS resource/resource set configurations for multi-TRP | Intel |

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

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

# Coverage and capacity enhancements

## Increased repetition

Void.

## RB-level partial frequency sounding (RPFS)

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

### 4.2.1 Issues related to PF and start RB

Table 4-1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Supported PF values** | | | | | |
| Values | | Companies | | | |
| PF = {2, 4} | | 15 supporting companies   * Qualcomm, ZTE, Sony, Nokia, NSB, Ericsson, Sharp, Fraunhofer IIS, Fraunhofer HHI, Huawei, HiSilicon, OPPO, vivo, Lenovo, MotM | | | |
| PF = 8 | | 11 supporting companies   * Qualcomm, ZTE, Sony, Nokia, NSB, Sharp, Fraunhofer IIS, Fraunhofer HHI, vivo, Lenovo, MotM | | | |
| PF = 3 | | 2 supporting companies   * Sony, vivo   3 companies have concern   * Nokia, NSB, Spreadtrum | | | |
| Other values | PF = {12, 16} | 2 supporting companies   * Fraunhofer IIS, Fraunhofer HHI | | | |
| Fractional values | 1 supporting company   * Futurewei   1 company has concern   * CMCC | | | |
| **How to avoid fractional values for , e.g., in the case of PF = 8** | | | | | |
| Alternatives | | Number | | Companies | |
| Alt 1: Restrict that is an integer value | | 9 | | Qualcomm, ZTE, Samsung, Sony, Huawei, HiSilicon, OPPO, Lenovo, MotM | |
| Alt 2: Introduce a rule to round | | 1 | | vivo | |
| **How to restrict SRS sequence length for RPFS** | | | | | |
| Alternatives | | | | Number | Companies |
| Alt 1: Restrict that the final SRS sequence (i.e., the number of SRS subcarriers) is a multiple of 6, which has been supported by the current specification | | | | 5 | ZTE, Sony, Ericsson, Sharp, OPPO |
| Alt 2: Restrict that the minimum number of RBs given by is 4 | | | | 4 | Qualcomm, Huawei, HiSilicon, Futurewei |
| Alt 3: Restrict that the number of RBs given by is a multiple of 4 | | | | 1 | vivo |
| **Supported N\_offset value, which is the start RB index of the RBs in the RBs** | | | | | |
| Values | | | Companies | | |
| , where kF = {0, …, PF-1} | | | 11 supporting companies   * Apple, ZTE, Qualcomm, Huawei, HiSilicon, OPPO, CATT, MediaTek, Futurewei, Lenovo, MotM | | |
| **Whether to support hopping of start RB location** | | | | | |
| Views | | | Companies | | |
| Support start RB location hopping in different SRS occasions or symbols | | | 8 supporting companies   * Qualcomm, ZTE, Ericsson, Huawei, HiSilicon, vivo, MediaTek, Spreadtrum | | |
| **Signaling to determine PF and Noffset** | | | | | |
| Alternatives | | | | Number | Companies |
| Alt 1: Determine PF value and Noffset value by RRC configuration per SRS resource | | | | 7 | ZTE, Huawei, HiSilicon, CATT, MediaTek, Apple, Ericsson |
| Alt 2: Configure multiple P\_F and N\_offset values in RRC, and update the used one in MAC CE | | | | 3 | CMCC, Lenovo, MotM |

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

***FL Proposal:***

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

* *The start RB index of the RBs in the RBs is , where kF = {0, …, PF-1}*
  + *FFS support start RB location () hopping in different SRS occasions, symbols or frequency hopping periods, and if supported, detailed hopping pattern*
* *Support to determine PF and Noffset at least via RRC configuration per SRS resource.*
  + *FFS whether to introduce DCI and/or MAC CE in addition*

***FL Proposal:***

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

* *Alt 1: is an integer value*
* *Alt 2: is an integer value with minimum value 4*
* *Alt 3: is a multiple of 4*
* *FFS other values for PF, including 12, 16 and fractional numbers*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL’s clarification | The two proposals are updated based on online GTW discussion. The first one contains the last two bullet in previous FL proposal. Also, it does not impact the decision on P\_F and alternatives in the second proposal.  The second proposal contains both the decision on P\_F and the issue of restriction on .  FL believes with this formulation, these two proposals should be acceptable to everyone. Let’s target for email endorsement for these two proposals. |
|  |  |
|  |  |

### 4.2.3 Applicable cases

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

Table 4-2

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

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

### 4.2.4 SRS sequence

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

Table 4-6

|  |  |  |
| --- | --- | --- |
| **How to generate SRS sequence for RPFS** | | |
| Alternatives | Number | Companies |
| Alt 1: Generate length- ZC sequence | 4 | ZTE, NTT DOCOMO, Ericsson, Qualcomm |
| Alt 2: Truncate from legacy length- sequence according to the location of RPFS SRS | 4 | Huawei, HiSilicon, Futurewei, Intel |

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

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

* *Alt 1: Generate length- ZC sequence, where no new sequence length other than the ones supported in the current spec is pursued*
* *Alt 2: Truncate from legacy length- sequence according to the location of RPFS SRS*

Companies’ further views are collected as follows.

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

## Comb-8

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

Table 4-8

|  |  |  |
| --- | --- | --- |
| **The maximum number of supported cyclic shifts** | | |
| Alternatives | Number | Companies |
| Alt 1: The maximum number of CSs for Comb-8 is 6 | 3 | Huawei, HiSilicon, vivo |
| Alt 2: The maximum number of CSs for Comb-8 is 12, and introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs | 1 | Ericsson |

***FL Proposal:*** *Study the maximum number of cyclic shifts for Comb-8 in Rel-17, with the following alternatives as starting points*

* *Alt 1: The maximum number of CSs for Comb-8 is 6*
* *Alt 2: The maximum number of CSs for Comb-8 is 12, and introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs*

Companies’ further views are collected as follows.

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

## Others

The following issue is discussed by two companies.

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

Companies’ further views are collected as follows.

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

# Conclusion

# Appendix

## Previous agreements

Table 6-1

|  |
| --- |
| **RAN1#102e**  **Agreement**  Enhance the determination of aperiodic SRS triggering offset, with at least one of the following alternatives   * + Alt 1: Delay the SRS transmission to an available slot later than the triggering offset defined in current specification, including possible re-definition of the triggering offset   + Alt 2: Indicate triggering offset in DCI explicitly or implicitly   + Alt 3: Update triggering offset in MAC CE   + Further consideration aspects may include the cost v.s. the total combinations PDCCH and SRS locations for gNB to choose, DCI overhead, multi-UE SRS multiplexing, CA aspect, whether to have multiple opportunities to transmit SRS, etc.   **Agreement**  Study the following two alternatives in the scope to enhance at least one DCI format for aperiodic SRS triggering   * + Alt 1: Use UE-specific DCI, e.g., extending DCI 0\_1 without uplink data and without CSI   + Alt 2: Use group-common DCI, e.g., extending DCI 2\_3 for cases other than carrier switching   + Further consideration aspects may include simultaneous or CC-specific SRS triggering for multiple CCs, dynamic indication of SRS frequency resources, etc..   **Agreement**  For SRS overhead reduction, study reusing same resources among multiple usages, at least for “codebook” and “antenna switching”. Study aspects include   * + Whether implementation approach based on legacy SRS configuration is sufficient     - If not, and if there are benefits other than RRC overhead reduction, study further on the case that antenna switching and PUSCH have different number of Tx antennas, whether UL BWP for different SRS usages is the same or different, whether and how to ensure UE to use same virtualization, the set of applicable usages, UE implementation complexity and overhead, etc..   **Agreement**  For SRS antenna switching up to 8Rx, study the configuration of {1T6R, 1T8R, 2T6R, 2T8R, 4T6R, 4T8R}.   * + Study points may include CSI latency, performance considering aspects like insertion loss, use cases, antenna structure, UE power saving, SRS resource configuration, etc..   **Agreement**  For SRS coverage/capacity enhancements, evaluate and, if needed, specify one or more from three categories based on the following definition.   * + Class 1 (Time bundling): Utilize relationship among two or more occasions of one or more SRS resources in one or more slots to enable joint processing within time domain.     - Study aspects include the issue of phase discontinuity, interruption of SRS transmission by other UL signals, etc..   + Class 2 (Increase repetition): Change the legacy SRS pattern in one resource and one occasion from time domain by increasing SRS symbols for repetition.     - Study aspects include to use TD-OCC to compensate the negative impact on SRS capacity, inter-cell interference randomization, whether these SRS symbols are in one slot or consecutive slots, etc..   + Class 3 (Partial frequency sounding): Support more flexibility on SRS frequency resources to allow SRS transmission on partial frequency resources within the legacy SRS frequency resources.     - Study aspects include the partial frequency resources are with RB level or subcarrier level (e.g., larger comb, partial bandwidth), PAPR issue, etc..   **RAN1#103e**  **Agreement**  A given aperiodic SRS resource set is transmitted in the (t+1)-th available slot counting from a reference slot, where t is indicated from DCI, or RRC (if only one value of t is configured in RRC), and the candidate values of t at least include 0. Adopt at least one of the following options for the reference slot.   * Opt. 1: Reference slot is the slot with the triggering DCI. * Opt. 2: Reference slot is the slot indicated by the legacy triggering offset. * FFS the detailed definition of “available slot” considering UE processing complexity and timeline to determine available slot, potential co-existence with collision handling, etc., e.g.,   + Based on only RRC configuration, “available slot” is the slot satisfying: there are UL or flexible symbol(s) for the time-domain location(s) for all the SRS resources in the resource set and it satisfies the minimum timing requirement between triggering PDCCH and all the SRS resources in the resource set * FFS explicit or implicit indication of t * FFS whether updating candidate triggering offsets in MAC CE may be beneficial   **Agreement**  Support at least DCI 0\_1 and 0\_2 to trigger aperiodic SRS without data and without CSI.   * FFS whether/how to re-purpose the unused fields, e.g., the triggering offset(s) and the frequency resources for triggering A-SRS on one or more component carriers, SFI-index, etc. * FFS UL/DL DCI with data for aperiodic SRS * FFS group common DCI   **Agreement**  In Rel-17 SRS coverage and capacity enhancement, support at least one scheme from Class 2 and Class 3, and deprioritize Class 1.   * Note: Extensions of Rel-15/16 frequency hopping are included in Classes 2 and 3, e.g. where UE hops once per symbol within a Rel-17 SRS resource.   **Agreement**  Candidate schemes for Class 2:   * Scheme 2-0: Increase the number of repetition symbols in one slot * Scheme 2-1: Inter-slot repetition on consecutive symbols or non-consecutive symbols across slots * Scheme 2-2: Repetition with TD-OCC * Scheme 2-3: Repetition with CS hopping   Candidate schemes for Class 3:   * Scheme 3-1: RB-level partial frequency sounding * Scheme 3-2: Subcarrier-level partial frequency sounding * Scheme 3-3: Subband-level partial frequency sounding * Scheme 3-4: Partial-frequency sounding schemes assisted with CSI-RS, where SRS is transmitted in a subset of RBs of the original SRS frequency resource * Scheme 3-5: Dynamic change of SRS bandwidth with RB-level subband size scaling * Note: Consider issues like gNB receiver complexity, PAPR, etc., with above schemes * Note: Joint operation between Class 2 and Class 3 schemes can be considered   **Agreement**  For antenna switching up to 8Rx, support SRS resource configurations for {1T6R, 1T8R, 2T6R, 2T8R, [4T6R], 4T8R}.  **RAN1#104e**  **Agreement**  For Rel-17 SRS capacity and coverage enhancement, support the following   * Increase the maximum number of repetition symbols in one slot and one SRS resource to S   + Support at least one S value from {8, 10, 12, 14}     - FFS other candidate values * Support to transmit SRS only in  contiguous RBs in one OFDM symbol, where  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  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 modifications  An “available slot” is a slot satisfying there are UL or flexible symbol(s) for the time-domain location(s) for all the SRS resources in the resource set and it satisfies UE capability on the minimum timing requirement between triggering PDCCH and all the SRS resources in the resource set.   * From the first symbol carrying the SRS request DCI and the last symbol of the triggered SRS resource set, UE does not expect to receive SFI indication, UL cancellation indication or dynamic scheduling of DL channel/signal(s) on flexible symbol(s) that may change the determination of “available slot”. * Note: Collision handling between the triggered SRS and any other UL channel/signal is performed after the determination of available slot. * FFS: Rules to handle the case of multiple SRS resource sets with overlapping symbols and/or triggered by a same DCI |

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