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

**e-Meeting, Apr. 12th – 20th, 2021**

**Source: Moderator (ZTE)**

Title: FL summary #3 on SRS enhancements

Agenda Item: 8.1.3

Document for: Discussion and Decision

# Proposals for email endorsement

This section summarizes stable proposals after two rounds of discussion. These proposals are targeted for email endorsement in the first check point.

## 1.1 Support N values for aperiodic SRS with >4Rx

***Proposal 6 for email endorsement***

*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*

## 1.2 Maximum number of cyclic shifts for Comb-8

***Proposal 7 for email endorsement***

*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*

## 1.3 Size of “t” values per set

***Proposal 8 for email endorsement***

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

# Proposals for further discussion

This section summarize proposals to be further discussion until the next GTW session or check point.

## 2.1 Sequence generation for RPFS SRS

***Proposal 4 for further discussion***

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

* *Alt 1: Generate length-*$\frac{\frac{12}{P\_{F}}m\_{SRS, B\_{SRS}}}{Comb}$ *ZC sequence, where no new sequence length other than the ones supported in the current spec is pursued*
	+ *Supported by ZTE, NTT DOCOMO, Ericsson, Qualcomm, MediaTek, NEC, Apple, Samsung, OPPO, LGE, Nokia, NSB, Lenovo, MotM (14)*
* *Alt 2: Truncate from legacy length-*$\frac{12⋅m\_{SRS, B\_{SRS}}}{Comb}$ *sequence according to the location of RPFS SRS*
	+ *Supported by Huawei, HiSilicon, Futurewei, Intel (4)*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL | We have clear majority view on this issue. Let’s continue the discussion and try to conclude in this meeting. |
| Huawei, HiSilicon | Support Alt.2. The motivation on the partial sounding is mainly for capacity enhancement. Alt.1 is with the problem on multiplexing between UEs, i.e., it is difficult to guarantee the orthogonality on the SRS sequence of Rel-17 UE and legacy UE, and also the orthogonality is not kept between the sequences of UE with different PF values. So, Alt.1 is not acceptable. |
| Nokia/NSB | Support Alt. 1. And we suggest to set a deadline of the discussion as decision within RAN1 104bis.As a response to Huawei, it would not be a new issue but a thing has been discussed multiple times for the SRS sequence design. |
| QC | Support Alt 1.PAPR concerns on Alt 2.  |
| Samsung | Same view as Nokia/NSB and QC |
| vivo | Support alt1 |
| Huawei, HiSilicon2 | To reply concerns:For PAPR issue, we have already evaluated the PAPR for truncated ZC sequence in R1-2102338, there is 0.5~1.5dB loss, but please note that there is 3~6dB power boosting for partial sounding using PF=2 or PF=4. So, it is not a big issue for PAPR.However, with Alt.1, the multiplexing capacity will be much impacted since the sequence in partial sounding cannot be orthogonal with legacy UEs, and there is also problem that SRS sequences for different values of PF are also not orthogonal. In our understanding, the main benefits for partial sounding is for multiplexing capacity enhancements. But, with Alt.1, the benefits on partial sounding will be impacted.So, the above issue should be considered. Then, for the restriction on “*no new sequence length other than the ones supported in the current spec*”, we do not have strong view on it, it can be for both options, i.e., the restriction can be also added for Alt.2. |

## 2.2 PF values for RPFS

***Proposal 5 for further discussion***

*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*
	+ *Alt 1:* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *is an integer value*
	+ *Alt 2:* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *is an integer value with minimum value 4*
		- *Supported by Qualcomm, Huawei, HiSilicon, Futurewei*
	+ *Alt 3:* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *is a multiple of 4*
		- *Supported by Samsung, vivo, OPPO, LGE, Nokia, NSB*
	+ *Alt 4: Round* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *to a multiple of 4 in case of Alt 1 or Alt 2*
		- *Supported by vivo*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL | All the proposed alternatives have been summarized as above. Further, it seems no companies have real concern on {2, 4}. FL recommends to agree on this package. |
| Huawei, HiSilicon | Fine for the proposal |
| Nokia/NSB | Support Alt 3. As clarification, partial sounding is supported as a way of coverage enhancement. No further modification not for coverage enhancement should be out of work item scope.  |
| Apple  | Slightly prefer Alt 3 |
| QC | Support the proposal.We are fine with Alt 3 as well.  |
| Samsung | Support FL’s proposal and prefer Alt.3 |
| vivo | Support Alt 3 and Alt 4. |
| Huawei, HiSilicon2 | OK for the proposal. For the alternatives, we support Alt.2. But can accept Alt.1.For Alt.3, it means the SRS bandwidth should be multiple of 4\*PF, i.e., multiple of 8 or 16, there is very limited number of SRS bandwidth per hop can be multiple of 8 or 16. So, it is too restriction for using partial sounding. Then, the scope of WI is for SRS capacity and/or coverage, not sure the comment from Nokia. Partial sounding reduce the SRS bandwidth for each hop per UE, which means more UEs can be multiplexed for SRS transmission, i.e., SRS capacity is enhanced. It’s the main benefits for partial sounding. |

## 2.3 N\_max for aperiodic SRS with 4T8R

Companies’ views are summarized as following table.

|  |
| --- |
| **N\_max** |
| xTyR | Value | Companies |
| 4T8R | Confirm the WA with | N\_max = 1 | 4 companies: Qualcomm, Spreadtrum, CMCC, Intel |
| N\_max = 2 | 17 companies: Samsung, ZTE, Ericsson, NTT DOCOMO, OPPO, Spreadtrum, CATT, Lenovo, MotM, Xiaomi, Huawei, HiSilicon, Nokia, NSB, Apple, NEC, LGE |
| Update the WA with * For *ullyAndPartialAndNonCoherent* Ues, K=2, N\_max = [4], and each resource has 4 ports
* For *partialAndNonCoherent* and *oncoherent* Ues, K=4, N\_max = [2], and each resource has 2 ports
 | 1 company: InterDigital |

***Proposal 9 for further discussion***

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL | Super majority view has shown for N\_max = 2 after we giving sufficient time for offline discussion. Hence FL suggests to agree on this proposal. |
| Huawei, HiSilicon | Fine for the proposal. |
| Nokia/NSB | Support FL proposal.  |
| Samsung | Support |
| vivo | Support the proposal. |

## 2.4 Guard period

***Proposal 10 for further discussion***

*For guard symbols of antenna switching SRS in Rel-17, adopt at least one of the following, with Alt 0 as the baseline*

* *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 |
| FL | More technical discussion is needed. For example, companies (esp. the proponents) are encouraged to share your view on the following aspects* Whether this proposal is needed? What the motivation is to have anything other than Alt 0?
* What are the “certain conditions” in Alt 2? It’s better to clarify these conditions.
 |
| Huawei, HiSilicon | Need to further study |
| Nokia/NSB | Open for further discussion. |
| Apple | Prefer Alt 0. But we are open to discussion and understand, under which conditions, the guard symbols can be removed  |
| QC | Further clarification needed on Alt -2.  |
| Samsung | Prefer alt.0 but ok to further study |
| vivo | Support Alt 3. Current guard symbol is defined between symbols in a set, now with multiple sets configured for antenna switching in one slot or in two consecutive slots, guard symbols between sets should also be considered.Alt 2 should be further clarified |
| Huawei, HiSilicon2 | Fine for FL proposal to further discuss. |

## 2.5 Configurations for periodic and semi-persistent SRS with >4Rx

***Proposal 11 for further discussion***

*For antenna switching with >4Rx, 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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| FL | FL believes all the comments in the previous rounds have been addressed. Let’s see whether this is agreeable now. |
| Huawei, HiSilicon | Both >4Rx and <=4Rx should be included in the discussion, so remove 4Rx. |
| Apple | We can be flexible. But this only means the specification supports. If Alt 2, we need to ensure that for SP-SRS, for UE supporting AS SRS, UE can report whether and how many SP-SRS it supports  |
| QC | RAN1 discussion is only for 6Rx and 8Rx SRS antenna switching. We should not remove >4Rx from the main bullet. Support Alt-1 and do not see the need for two SP SRS resource sets.  |
| vivo | Support Alt 1. |
| Huawei, HiSilicon2 | Not fine for the proposal. The issue is come from the real deployment, there are hundreds activated UE need to SRS transmission. There is only one set of semi-persistent SRS can be configured per UE. So, the pattern and periodicity for semi-persistent SRS will be configured with overlapping. When the overlapping Semi-persistent SRS are activated, then the SRS from different UE will be collide.2 or more semi-persistent SRS can be very beneficial to address the issue on SRS collision, since gNB can flexible to decide which set of SP-SRS to be activated to avoid SRS collision. There is no any complexity for UE side since only one of SP-SRS can be activated at one time. The issue already agreed to be discussed for both >4Rx and <=4Rx. We do hope we can address the collision issue.  |

# Conclusion

# Previous agreements

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| --- |
| **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 ($N\_{offset}$) 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
 |