3GPP TSG RAN WG1 Meeting #103-e R1-200xxxx

**e-Meeting, Oct. 26th – Nov. 13th, 2020**

**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*

The relevant agreements made in previous RAN1 meetings are given in Appendix.

In this contribution, we summarize companies’ views on the above SRS enhancements submitted to RAN1#103e [2]-[27].

# Flexibility enhancements

## SRS triggering offset

Void.

## Flexible DCI

Void.

## Usage/overhead reduction

A number of companies discuss the issue of supporting specification solution to reuse same SRS resource(s) for multiple usages explicitly. Table 2-3 summarize their views.

Table 2-3 Summary of companies’ views on SRS resource reuse enhancement

|  |  |  |
| --- | --- | --- |
|  | Number | Companies |
| Support specification solution to reuse same SRS resource(s) for multiple usages | 12 | MediaTek (for only T=R), Intel (for only T=R, and Full power mode 2 is not enabled), Spreadtrum (Using MAC CE or DCI to indicate multiple usages), NTT DOCOMO, Ericsson, vivo, CATT (for the case that ‘codebook’ and ‘antenna switching’ has same number of Tx ports), CMCC, Apple, Nokia, NSB, CEWiT |
| Do not support or need further study | 10 | Futurewei, Huawei, HiSilicon, Qualcomm, OPPO, ZTE, Xiaomi, LG, Lenovo, MotM |

It seems more input and discussion are needed to draw conclusion for this issue.

The following proposed conclusion from Ericsson in the first-round discussion can be a good start point to move forward.

***Proposed conclusion:***

*A Rel-15/16 UE that supports at least nT=nR antenna switching with n={1,2,4} can be configured with an n port SRS resource that is in both an SRS resource set with usage=’codebook’ and another SRS resource set with usage=’antennaSwitching’, provided that the SRS resource sets have the same time domain behavior.*

Companies are encouraged to provide feedback on this proposed conclusion, esp. on the following questions

* Whether you can agree with the proposed conclusion
	+ If no, what the missing part is in the current specification to support such configuration
	+ If yes, whether it is sufficient to support reusing same SRS resource(s) for multiple usages based on this conclusion

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Resource sharing for different usage is supported in Rel-15 not only for the case that nTnR, but also for nTmR antenna switching and codebook based PUSCH transmission. In our understanding, the current spec is sufficient for resource sharing in general cases.*A Rel-15/16 UE that supports nTnR and nTmR antenna switching with n={1,2,4} can be configured with an n port SRS resource that is in both an SRS resource set with usage=’codebook’ and another SRS resource set with usage=’antennaSwitching’, provided that the SRS resource sets have the same time domain behavior.* |
| OPPO | We don’t think it is a good way to discuss such kind of conclusion here. In the current spec, it allows gNB to signal the above-mentioned configuration. There are thousands of valid NR configurations and it is impossible for us to make conclusion for all possible configurations. A better way is to encourage the proponents to explain what the exact problem is for nT=nR. If some problem(s) is justified, we can further discuss how to address it, e.g., make a conclusion.One question for the above configuration: What’s the benefit for gNB to signal this configuration? A simple configuration is that gNB signals an SRS resource set with usage=’codebook’. Then, gNB can schedule the codebook-based UL MIMO transmission and also acquire DL CSI based on the same SRS resource. Even if gNB signals two resource sets respectively, gNB will also use the same SRS resource to do the two functionalities but at the cost of more signaling overhead and SRS resource overhead.  |
| ZTE | We agree with the proposed conclusion. * We think it is sufficient to support reusing same nT=nR SRS resource for multiple usages based on this conclusion. Except saving a bit RRC overhead, we fail to see the clear benefit of spec effort for this case.

On the case of nT<nR, there may be some specification impact if we consider antenna subset selection discussed in section 2.4. For example, if we reuse SRS resources for antenna switching and codebook based PUSCH, the antenna subset selection mentioned in section 2.4 can also be used to perform antenna selection transmission for PUSCH. This is beneficial for ensuring the performance for PUSCH transmission and saving UE power at the same time. Hence we think this direction can be further studied. |
| CEWiT | This proposal only captures a very specific scenario for "reusing same SRS resource(s) for multiple usages". However, there are other scenarios (eg. reciprocity/multi-TRP etc) where reduction of SRS resources is possible by reusing and it can be under any usage category (like beam management/non-codebook). Thus, we do not support the down-selection of usage. There should be a provision to accommodate other applicable usages as well where overhead can be reduced.  |
| Xiaomi | Not support the proposal. As the premise of this resource sharing scheme is that to ensure UE applies the same antenna virtualization when SRS resource for “antenna switching” is also used for UL CSI acquisition, we have doubts with how this can be ensured currently. So the benefits of this resource sharing motivation other than RRC overhead reduction is quite limited to us, as ZTE also mentioned. But we can feel comfortable with agreeing with the majority view on this issue. |
| Nokia/NSB | O.K. in principle with FL’s proposal. For further clarification, we agree to Huawei’s view that resource sharing for different usage of SRS is not restricted to the case of nTnR in Rel-15/16. But we also think the UE behavior is not clarified how to apply spatial filtering in case SRS resource sharing is apply between configurations for nTmR antenna switching and n ports codebook. Here is our understanding for Rel-15/16: *A Rel-15/16 UE ~~that supports nT=nR antenna switching with n={1,2,4}~~ can be configured with an n port(s) SRS transmission ~~resource~~ that is configured in both an n port(s) SRS resource set with usage=’codebook’ and another SRS resource set with usage=’antennaSwitching’ for nTmR, provided that the SRS resource sets have the same time domain behavior.** *But UE behavior is not clarified for the case n*$\ne $*m, whether/how to UE applies spatial filtering for remained m/n-1 SRS resource(s) configured by SRS resource set for antenna switching, but not overlapped with SRS resource set for codebook.*
 |
| Apple  | There is no point for such a conclusion.The whole argument is whether to support multiple usage of the same SRS resource set, which can be useful for the case when #Tx < #Rx.Imagine, if we made an agreement that we support such a simpler and clean design in NR, there is no reason not to apply the same design to the case #Tx = #Rx, at least, in order to reduce the signalling overhead. We understand there are companies objecting the design, but objection is objection, the proposed conclusion would not solve the fundamental conflict at all.  |

## Flexible antenna switching

Companies discuss the issue of indicating a subset of antennas to support more flexible antenna switching. Their views are summarized in the following table.

Table 2-4 Summary of companies’ views on antenna switching flexibility enhancement

|  |  |  |
| --- | --- | --- |
|  | Number | Companies |
| Support indicating a subset of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | 6 | Qualcomm, ZTE, Intel, Samsung, Lenovo, Motorola Mobility |
| Not supportive | 5 | Nokia, NSB, Huawei, HiSilicon, LG, CATT |

The following proposal for further study is proposed by FL based on companies’ comments in the first round.

***FL Proposal 4****: Study on whether and the mechanism to support indicating a subset of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI.*

* *Study aspects include use cases/benefits, detailed signaling design, etc..*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Not support. There is no special use case should introduce MAC-CE and DCI. Even in power saving case mentioned by some company, the RRC configuration is sufficient since antennas activation and de-activation need a relative long time |
| ZTE | We support FL’s proposal. We think it is beneficial to achieve good trade-off between NW performance and UE power saving. If UE supports combined capability of multiple combinations of Tx/Rx antennas, e.g., 1T2R and 2T4R, and gNB is willing to use the smaller number of antennas to assist UE power saving, this is used for NW to control the performance loss. When 4T8R is supported, the performance loss can be even larger if gNB uses 1T2R or 2T4R to assist UE to save power. |
| Xiaomi | Support FL’s proposal, and we are open to this discussion. |
| Qualcomm | Support the FL proposal.We see many benefits for having flexible adaption of SRS antenna switching.* Network can achieve better utilization of SRS resources (reduce SRS overhead).
* Also, as highlighted by ZTE, it helps with UE power savings where UE can back off from 4 simultaneous Tx chains to 2Tx or 1Tx and turn off some of the Tx chains.
* Also, dynamic indication will make the adaption much faster and enable lower overhead as compared to RRC re-configuration.
 |
| Nokia/NSB | Not Support. We don’t see a critical usecase of L1 signal based adaptation of SRS resource for antenna switching. We think the DL rank change via L1 signal based BWP switching which is supported In Rel-15/16 may cover the scenario of UE power saving.  |
| Apple | Fine to study |

# Antenna switching up to 8Rx

## Supported configurations

During the first-round email and online discussions, the only controversial part on the following FL proposal is whether 4T6R should be supported.

***FL proposal 5:*** *For antenna switching up to 8Rx, support SRS resource configurations for {1T6R, 1T8R, 2T6R, 2T8R, 4T6R, 4T8R}.*

* *Note: companies are encouraged to evaluate directional UE antennas*
* *For 4T6R, consider only practical UE implementation for RF switching and mapping between the Tx chains and Rx antennas.*

Companies are encouraged to share your views focusing on 4T6R, esp. on potential use cases, benefit or on the other hand, issues, to support 4T6R.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | The potential physical antennas (include switches) mapping and workable switching need to be clarified before we agree the pattern. We will be not objection when the case is clear workable in practical scenarios.**A possible revision is that:** ***FL proposal 5:*** *For antenna switching up to 8Rx, support SRS resource configurations for {1T6R, 1T8R, 2T6R, 2T8R, [4T6R], 4T8R}.** *Note: companies are encouraged to evaluate directional UE antennas*
* *Study the practical physical antenna mappings and workable switching for 4T6R, and decide whether support 4T6R in RAN1#104-e.*
 |
| OPPO | We don’t support 4T6R, but can keep open and follow majority view on 4T6R. |
| ZTE | Support the FL proposal. If some gNB or UE vendors would not deploy 4T6R, it is fine since all above configurations will be optional UE features anyway. So we think it is at least no harm for specification to support 4T6R. It is future-proof and may give gNB vendors more flexibility to do antenna switching. |
| Xiaomi | Support the FL’s proposal, we can capture this 4T6R configuration as an option for implementation. |
| Qualcomm | 3GPP specifications should be flexible enough and future looking to encourage the commercial deployment of wireless devices with large number of antennas. As it stands right now, the lack of support of 4T6R will pose a constraint and exclude UE support for such SRS antenna configuration. In our views, it is very important to support such SRS antenna switching configuration. One practical use-case is for UE with 4Tx chains and 8 Rx antennas which can operate in some of the NR bands with 4T8R while it has to operate in some other NR bands with only a subset of antennas (i.e. 6 Rx antennas) and therefore it needs to support 4T6R. This is a real-case scenario and it can happen in some band where 1) two antennas are shared with other RAT (e.g. WiFi or Bluetooth) at that frequency band or 2) two antenna have low gain or efficiency at these frequency bands. Regarding the concern of non-uniform insertion loss for the example implementation of 4T6R that we share earlier: it is not something new or abnormal that some Tx chains have different insertion loss than other Tx chains. That is the case for current RFFE implementation of UE with 4Rx. For example, a UE with 1T4R, the RF switching network may be implemented as a set of cascaded of 2x1 RF switches. So, the first antenna will have the least insertion loss (least number of switches) while the last antenna will have the highest insertion loss. Regarding the SRS sounding configuration, we are open to limit the support to only the practical implementation approaches. For example, one configuration could be a single SRS resource set with two resources, first resource with 4 ports and 2 resource with 2 ports.At the end, this SRS antenna configuration will be an optional feature and most probably the UE may support a combo of SRS antenna switching (e.g. {4T6R, 2T6R}) and it will be up to the NW to configure the UE with the proper SRS configuration. We ask the opponent companies for their flexibility to support the proposal so that we can more progress and focus our efforts on other discussion.***FL proposal 5:*** *For antenna switching up to 8Rx, support SRS resource configurations for {1T6R, 1T8R, 2T6R, 2T8R, 4T6R, 4T8R}.** *For 4T6R, consider only practical UE implementation for RF switching and mapping between the Tx chains and Rx antennas.*
* *Note: companies are encouraged to evaluate directional UE antennas*
 |
| Nokia/NSB | Support the FL proposal. We also O.K. with Qualcomm’s modification. |
| Apple | No opinion, all of those will be optional for UE anyway.  |

# Coverage and capacity enhancements

We have agreed to support at least one scheme from Class 2 and Class 3. The following two proposals are to collect companies’ input on candidate schemes.

***FL Proposal 6A:*** *Candidate schemes for Class 2 (Increase repetition):*

* *Scheme 2-0: Increase the number of repetition symbols in one slot*
* *1*
* *Scheme 2-2: Support repetition with TD-OCC in the case of Scheme 2-0 or 2-1*
* *Scheme 2-3: Support repetition with CS hopping in the case of Scheme 2-0 or 2-1*

***FL Proposal 6B:*** *Candidate schemes for Class 3 (Partial frequency sounding):*

* *Scheme 3-1: Support RB-level partial frequency sounding*
* *Scheme 3-2: Support subcarrier-level partial frequency sounding*
* *Scheme 3-3: Support subband-level partial frequency sounding*
* *Scheme 3-4: Support partial-frequency sounding schemes assisted with CSI-RS in the case of Scheme 3-1*
* *Scheme 3-5: Support dynamic change of SRS bandwidth in the case of Scheme 3-1*
* *Note: consider the PAPR issues with above schemes*

Companies are encouraged to share your further input on the above candidate schemes, esp. on the following aspects.

* Your question for better understanding of one or more particular schemes
	+ Further, suggestions to better describe one or more particular schemes to avoid misunderstanding
* Use cases/benefits of one or more particular schemes
* Concerns about one or more particular schemes

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | Questions for Scheme 2-1: TD-OCC, is it for intra-slot? What’s the mapping of TD-OCC, is that fixed in frequency domain? How to handle the collision with other channels, such as PUCCH?Questions for Scheme 3-2: how can subcarrier-level partial frequency sounding increase SRS capacity, since larger comb will reduce the orthogonality for cyclic shift?Questions for Scheme 3-4: Is that further details after partial sounding is supported?Questions for Scheme 3-5: how can dynamic change the SRS band, introduce new DCI to indicate? |
| OPPO | Ok to list candidates for further discussion |
| ZTE | Some reply on TD-OCC questions from HW:We think TD-OCC is performed for repetition symbols within one slot, then it is intra-slot.We think OCC sequence can be configured per UE, or per SRS resource. A same OCC sequence can be used in the whole frequency domain, like TD-OCC for DM-RS.If there is collision between the SRS with TD-OCC and other UL channel/signal, we can just drop the whole SRS resource if it is lower priority. The partially transmitted SRS resource is anyway not very helpful in gNB side. Alternatively, we can keep the non-overlapping symbols for one of multiplexing UEs to avoid resource waste. Anyway, this is just next step detail, we are open to further discuss it. Our questions and further suggestions:For scheme 2-0 in Class 2, is this for one SRS resource ? if yes, we prefer to make the proposal clearer:* *Scheme 2-0: Increase the number of repetition symbols for one SRS resource in one slot*

For Schemes in Class 3, the last two schemes seems not be in the same dimension as the first three. Hence we would like to ask the proponents on whether only some of the combinations between {3-1, 3-2, 3-3} and {3-4, 3-5} make sense.For example, it seems not relevant between subcarrier-level partial sounding and 3-4 or 3-5. So we suggest to refine the last two schemes as follows.* *Scheme 3-4: Support partial-frequency sounding schemes assisted with CSI-RS in the case of Scheme 3-1*

*Scheme 3-5: Support dynamic change of SRS bandwidth in the case of Scheme 3-1* |
| Xiaomi | Fine with the candidate schemes list for further input in the next meeting |
| Nokia/NSB | We are generally O.K. with FL proposal. But schemes in class 2 are not exclusive to each other. For class 2, we prefer to decide whether intra- or inter- slot repetition would be supported first. |

# Conclusion

# Appendix

## Previous agreements

|  |
| --- |
| **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.
 |

# References

[1] RP-193133, New WID: Further enhancements on MIMO for NR, Samsung

[2] R1-2007544, Enhancements on SRS flexibility, coverage and capacity, FUTUREWEI

[4] R1-2007591, Discussion on SRS enhancements for Rel-17, Huawei, HiSilicon

[5] R1-2007631, Discussion on SRS Enhancements, InterDigital, Inc.

[6] R1-2007649, Further discussion on SRS enhancement, vivo

[7] R1-2007768, Enhancements on SRS flexibility, coverage and capacity, ZTE

[8] R1-2007829, On enhancements on SRS flexibility, coverage and capacity, CATT

[9] R1-2008005, Enhancements on SRS flexibility, coverage and capacity, CMCC

[10] R1-2008153, Enhancements on SRS, Samsung

[11] R1-2008222, Enhancements on SRS flexibility, coverage and capacity, OPPO

[12] R1-2008351, Considerations on SRS flexibility, coverage and capacity, Sony

[13] R1-2008443, Views on Rel-17 SRS enhancement, Apple

[14] R1-2008578, Enhancements on SRS flexibility, coverage and capacity, LG Electronics

[15] R1-2008900, Enhancements on SRS for coverage and capacity, Fraunhofer IIS, Fraunhofer HHI

[16] R1-2008908, Enhancements on SRS flexibility, coverage and capacity, Nokia, Nokia Shanghai Bell

[17] R1-2008914, Enhancements on SRS, Lenovo, Motorola Mobility

[18] R1-2008948, Discussion on SRS enhancement, NEC

[19] R1-2008959, Enhancements on SRS flexibility, coverage and capacity, MediaTek Inc.

[20] R1-2008982, Discussion on SRS enhancements, Intel Corporation

[21] R1-2009031, Discussion on SRS enhancements, Xiaomi

[22] R1-2009131, Enhancements on SRS, Sharp

[23] R1-2009146, Considerations on SRS enhancement, Spreadtrum Communications

[24] R1-2009179, Discussion on SRS enhancement, NTT DOCOMO, INC.

[25] R1-2009211, SRS Performance and Potential Enhancements, Ericsson LM

[26] R1-2009255, Enhancements on SRS flexibility, coverage and capacity, Qualcomm Incorporated

[27] R1-2009286, Discussion on enhancement of SRS in Rel. 17 further enhanced MIMO, CEWiT