3GPP TSG RAN WG1 Meeting #103-e R1-2009650

**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

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

* The above proposed conclusion is agreeable to Huawei, HiSilicon, ZTE, Nokia, NSB, CMCC, Intel, Futurewei, Ericsson, MediaTek, vivo, CEWiT, InterDigital, CATT
  + Among these companies, Huawei, HiSilicon think a similar conclusion can be made for the case of nTmR where n<m, whereas ZTE, Nokia, NSB, CMCC, Intel, Futurewei, MediaTek, Ericsson, vivo, InterDigital think at least further study is needed
* The above proposed conclusion is not agreeable to OPPO, Xiaomi, Apple

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 nm, 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. |
| CMCC | Generally fine with FL’s proposal.  For #Tx = #RX, the reuse of SRS for both antenna switching and codebook based transmission could be realized based on implementation. But the realization may not be guaranteed in the expected way and the performance could only be verified through the lab or filed tests in a very late phase before the commercialization. And effort of the modification at that phase could be tremendous. A clarification or the limitation of UE behavior through the specification could regulate the UE behaviors and provide a guidance for the hardware realization. Then the work of tests could be relieved and the issues could be avoided in advance.  For #Tx< #Rx, since gNB have no idea of which CSI from the specific ports of antenna switching could be reused for the codebook based transmission, any implementation based method could not guarantee a same understanding of both gNB and UE. Then a specification related method should be introduced to solve this issue.  I am not sure the insert of “at least” to the current proposal is proper. It seems that the nTmR UE of Rel-15/16 could also support the reuse SRS for both antenna switching and codebook based transmission. Also observed from the summary provided by FL in the Table 2-3, a slightly higher number of companies support the specification solutions to reuse SRS resources for multiple usage, even in the case of nT = nR. The modifications are provided below based on FL’s proposal and observation above.  ***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.*   * *At least the reuse of nT<mR antenna switching and the usage of ‘codebook’ are supported to be specified.* * *The reuse of nT=nR antenna switching with usage of ‘codebook’ should be clarified in the specification, or at least claimed in the UE capability.* |
| Intel | After discussion, we think the case of nTmR (n=m) is not that important for discussion. In Rel-15/Rel-16, it is possible to configure only codebook SRS with nT ports, and current spec doesn’t prevent gNB to derive the DL precoder from measurement on codebook SRS.  The only problem for nTmR (n=m) is that the DL BWP and UL BWP may not be aligned, since codebook based transmission is for UL and antenna switching is for DL. For joint usage between codebook and antenna switching, we should also discuss how to support fast adaptation of SRS bandwidth.  From our perspective, it’s more important to focus on nTmR (n<m). For example, for 2T4R, two SRS resources are transmitted. But it’s not clear in current spec on which one could be used for codebook based transmission since the measurement results on these two SRS resources could be different. |
| Futurewei | At least the above proposed conclusion with n=m is agreeable.  For cases not covered in the above conclusion, we can have further study. We are open to see other usages with other configurations. |
| MediaTek | Okay for n=m (nTmR) in principle, but standard should be clear on UE’s behavior, as in R15/16, it is not guaranteed UE apply the same spatial filtering and antenna virtualization. Any specification text change or extra signaling is required or not can be further discussed.  We’re open for further discussion n<m cases. |
| vivo | Generally, support the proposed conclusion. And we share same views as Apple.  The proposed conclusion just demonstrates how resource reuse can be supported by implementation without specific limitation. The key point is whether to support SRS resource sharing mechanism for multiple usages.  For nTmR, there has some antenna virtualization ambiguities if no spec enhancement on resource sharing is supported. |
| Ericsson | Continue to support the conclusion it is important to know what is or is not supported at present. Again, simply because we can configure an SRS resource in both a ‘codebook’ set and a ‘switching’ set this doesn’t mean that it is not a gNB misconfiguration.  Suggest to further study the nTmR case. From our side, it is not clear that nTmR is supported at present. For example, in the 1T4R case, there are four single port SRS resources used for antenna switching, and how these relate to each of the at most two codebook based SRS resources is not defined. More simply put, if we use antenna switching SRS resources in the nTmR case, these can’t be used for UL MIMO antenna selection. |
| CEWiT | We are fine with the proposed conclusion. |
| InterDigital | Agree in principle but prefer CMCC revision of the proposal. |
| CATT | Fine with the conclusion. |

## 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 if needed, the mechanism to support indicating a subset of Tx/Rx antennas for SRS antenna switching.*

* *Study aspects include use cases/benefits, joint operation with other usages in STRP or MTRP scenarios, detailed signaling design, e.g., via MAC CE, DCI or RRC-level 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.  Further reply:  Not support. After reading the replied, we are still not convinced why we need to introduce subset of antennas for Switching, and also not convinced why we need to discuss MAC-CE and DCI based. It seems no critical use case need the supporting for such feature in spec.  Then, for Intel’s reply, we do not think these are the same issue. The issue mentioned by Intel is DCI triggering state is not enough for aperiodic SRS resource sets, which is discussed in aperiodic SRS resource triggering, e.g., implicit or explicit triggering by DCI. The issue should be discussed separately. |
| 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 |
| Intel | We share similar view as ZTE and Qualcomm.  In addition, in Multi-TRP session, it has been agreed that for codebook/non-codebook based transmission, the maximum number of SRS resource sets is extended to 2. However, with the current spec, the number of trigger states is 3 and there are 4 usages defined. There are issues with the SRS configuration, i.e. the current trigger scheme is not flexible enough to accommodate multiple SRS resource sets and usages.  Taking codebook based transmission with two SRS resource sets as example, all the three DCI code points may be taken for individual SRS resource set and both SRS resource sets triggering. In this case, SRS resource set triggering with other usage could not be supported. It is very important to resolve this issue in Rel-17.  Therefore, we think to trigger a subset of configured SRS could be more generic. Below is some suggestion on the FL proposal.  ***FL Proposal 4****: Study on whether and the mechanism to support indicating a subset of Tx/Rx antennas for SRS antenna switching, triggering a subset of the configured SRS resource sets in multi-TRP. ~~Via MAC CE or DCI.~~*   * *Study aspects include use cases/benefits, detailed signaling design, e.g. via MAC-CE or DCI, etc.* |
| Futurewei | We are open to discussion, but we wonder if anything has been done at the antenna port level in the standard before. If not, then this could be a significant change. In addition, for 2 different numbers of antenna ports, two sets of CSI are needed. Not sure if this has been discussed before. Further study is needed. |
| MediaTek | Open to discussion.  We all know flexibility is good, but can companies supporting this explain why RRC is not good enough? |
| vivo | Not necessary. Current approaches, such as RRC reconfiguration and BWP switching, are sufficient for power saving purpose and achieving subset of antenna switching. |
| LGE | We are not supportive company of antenna switching for subset of UE antennas, but study is study, we don’t object the study.  One comment:   * Why don’t we add RRC level signaling design for study aspects in the sub-bullet? (We are not mentioning RRC reconfiguration.) I think it is fair enough with enumerating all of signaling design, although there are differences of flexibility level. |
| Ericsson | Open to discuss; support the FL proposal. |
| Intel | Reply to Huawei: We think the issue is similar. For antenna switching, the proposal is to study how to indicate a subset of SRS for downgraded antenna switching. For multi-TRP, it’s also how to flexibly trigger a subset of the configure SRS. For example, two SRS resource sets are configured for codebook, then how to flexibly trigger individual set and both sets considering the restriction of trigger state. Regarding aperiodic SRS resource triggering mentioned by Huawei, it’s more related with the slot offset. In addition, in the FL proposal, MAC-CE/DCI/RRC are captured. We think DCI based is also included.  We suggest using our original text to make it clearer.  ***FL Proposal 4****: Study on whether and if needed, the mechanism to support indicating a subset of Tx/Rx antennas for SRS antenna switching, flexibly triggering a subset of the configured SRS resource sets in multi-TRP.*   * *Study aspects include use cases/benefits, ~~application in M-TRP scenario,~~ detailed signaling design, e.g., via MAC CE, DCI or RRC-level design etc.*   If most companies think this is separate issue, then having a separate proposal is also fine for us.  ***FL Proposal x****: Study on how to configure and flexibly trigger SRS in the scenario of multi-TRP.*   * *FFS on the* *detailed signaling design, e.g., via MAC CE, or DCI or RRC level design.*   It’s up to FL how to capture this. The important thing is the configuration and flexible triggering in multi-TRP should be addressed. |
| InterDigital | Support FL’s proposal. |
| CATT | We are fine with the proposal, but share questions on the need of such mechanism. |

# 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.*   **Further reply:**  **Not support the modified proposal. Before we clear understand the practical UE implementation and RF switching and mapping, we should keep it in study, but not rush to agree it before we clear the practical issues.**  For QC’s reply, we understand it may be optional UE feature, but what we concern is that we have agreed so many cases need to be specified in Rel-17 including 1T, 2T and 4T, we should consider whether 4T6R is critically needed in practical scenarios, but not only to discuss whether it may be useful from specification.  At least, before we clear understand the use cases/ benefits in practical scenarios, we should span our efforts on these antenna configurations that agreed by companies. For the special cases, 4T6R, we are not clear whether it is practical in real scenarios, and also not sure whether there is benefit when unbalance insertion loss considered (No companies provided the results yet). At least in RAN1, we have not discussed/evaluated such case before. By the way, we also do not think the 4T6R is from antenna subset selection from 4T8R.  From the modified proposals, it seems QC also agree that the issue should be under the discussion of practical UE implementation and antenna mapping. However, till now, we have no clear view on practical antennas structures for 4T6R and also not clear the mapping. Why we need to rush to agree the case 4T6R before we know the practical implementation and the benefits with antenna switching.  So, we still insist the above proposals that study further before we have aligned the understanding the antenna structures in practical scenarios and clear the benefits for the cases. |
| 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. |
| CMCC | Support FL’s proposal.  A unified design for multiple configuration including the 4T6R is preferred, which could reduce the workload and the complexity of the specification. |
| Intel | Firstly, we slightly prefer to include 4T6R.  Secondly, we have one question to check with companies, do we have the same understanding on the antenna architecture for xTyR except 4T6R, i.e. each Tx antenna is connected with the same number of Rx antennas? For example, for 2T8R, each Tx antenna can be switched among 4 Rx antennas.  We suggest capturing the following in FL proposal.  ***FL proposal 5:*** *For antenna switching up to 8Rx, support SRS resource configurations for {1T6R, 1T8R, 2T6R, 2T8R, 4T6R, 4T8R}.*   * *For xTyR (x={1, 2, 4}, y={6, 8}), except 4T6R, each Tx antenna can be switched among the same number of Rx antennas.* * *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.* |
| Futurewei | For 4T6R, if it can be supported using the existing standard framework/approach or a straightforward extension of it, we are fine to support it. But if the design approach becomes vastly different, we suggest to work on it later. So if the proponents can describe how this may be supported that would be helpful. |
| MediaTek | Support the FL’s proposal (include 4T6R) |
| vivo | Partially support the FL’s proposal, except 4T6R. It’s better to keep brackets in 4T6R before we reach a consensus.  For 4T6R, we have following two comments:   * From a handset vendor’s perspective, maybe there is no need to support any number of RX antennas larger than 4 in FR1. Some companies concern more than 4 RX chains can be implemented in CPE and 4T6R is a subset of 4T8R as two antennas shared across RATs or with low antenna gains. However, 4T8R can be achieved easily in those high capacity terminals, rather than 4T6R. Therefore, support 4T8R is sufficient. * For a UE with 4T6R capability seems more complicated than supporting all combinations except 4T6R. And as Rel-16 had been supported UE capability downgrade in antenna switching, we cannot guarantee 4T6R is considered as downgraded from 4T8R in any UE implementations. Thus, more UE capability options should be considered in following discussion if 4T6R agreed. |
| LGE | We don’t have strong view on configuration of 4T6R, but if there is no consensus on it, we can keep the bracket on 4T6R and further study. |
| Ericsson | Support the FL proposal. |
| InterDigital | * We believe that all antenna configurations, including 4T6R should be supported. * Regarding the sub-bullet, * *For xTyR (x={1, 2, 4}, y={6, 8}), except 4T6R, each Tx antenna can be switched among the same number of Rx antennas*   We don’t believe that such restriction is necessary, as also mentioned by Qualcomm, in certain bands, some antenna may be shared for other usages,   * As for the final proposal, we prefer Qualcomm revision. |
| CATT | * OK with the proposal. |
| QC2 | Regarding Huawei’s reply:  We proposed to add the bullet on practical UE implementation and antenna mapping to address opponents concern on 4T6R. And, to give the chance for other companies to study what they believe practical implementation/configurations till next meeting and they can challenge the support if any concerns rise up. From our side, we think there are use cases and benefits for supporting 4T6R.  Regarding vivo’s reply:  4T6R use case is not only limited to a subset or a downgrade of 4T8R. There could other devices with 4Tx chains and only 6Rx antennas. Also, it is not clear why 4T6R is more complicated to support as compared to the other configurations. Could you please further clarify why it is complicated?  Regarding intel’s suggestion:  The added bullet puts restriction on UE implementation. As the UE needs to support different SRS antenna configurations for different frequency and different technology, the current design of the RF switching network is already complicated and such proposal will add more complexity to UE implementation and make it more complicated. The main objective is to make sure that Rx antennas sounded regardless which Tx chain is used.  So, we agree with InterDigital that there is no need to introduce such constraint.  Reply to Futurewei  The support for 4T6R should be straightforward. The SRS configuration can be specified using two SRS resources, one SRS resource with 4 ports and the other resource with 2 ports. The two resources can be configured within one SRS resource set or two SRS resource sets. |

# 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*
* *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*

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

* *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*
* *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*

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?  Further reply:  The revision on previous version is not acceptable. The original Scheme 2-1 and 2-2 (i.e., TD-OCC and CS hopping) can work for repetition case, but not need to increase repetition number as a condition. So, the conditions should be removed, the original version is fine for us.  Reply-3:  For Scheme 2-1, we share the similar view as Ericsson, it should be de-prioritized.  Then, reply to Ericsson for CS hopping, sequence hopping and group hopping are the baselines in the evaluation. CS hopping and sequence hopping can be used together or separately based on configuration. In the evaluation, use CS hopping only for comparison. |
| 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. |
| Intel | At this stage, we are fine to capture the candidate schemes in the proposal. |
| Futurewei | Support the FL’s proposal.  As the FL asked above, we provide some further descriptions on **Scheme 3-3** here, in addition to the SRS coverage/capacity improvements clearly understood by most companies. The partial frequency sounding in Scheme 3-3 is not for generic CSI acquisition or other generic purposes, but can be used for specific CSI acquisition on the subband(s) that a particular UL/DL data transmission will occur. So the network first relies on existing CSI schemes to acquire CSI and decides the subbands (frequency resource allocation) for the UL/DL data transmission, and it then triggers A-SRS on these subbands to acquire more accurate channel information and DL interference (including intra-cell MU interference and inter-cell interference) information for more accurate beamforming for the UL/DL data transmission. As extensively evaluated in R1-2007547, this significantly improves spectrum efficiency and UPT throughputs (with 20% to even 100% gains) for TDD.  Note that the term “subband” in Scheme 3-3 is not defined in standards, but a subband is well understood as a set of contiguous PRBs. The granularity could be 4 PRBs or the same as the data scheduling granularity of RBGs if clarification is needed.  A comment on the relation among **Schemes 3-1 and 3-4/3-5**: If Schemes 3-4/3-5 rely on Scheme 3-1 or is a sub-scheme of Scheme 3-1 (which seems to be the case as is written now), then maybe they should be listed as sub-bullets under 3-1 rather than at the same level of 3-1, unless in some other cases they do not rely on 3-1. Please clarify. |
| MediaTek | Okay for capture all possible schemes in the proposal. Other possible schemes (if shown up later) is not precluded.  For TD-OCC collision issue that ZTE/HW talked above, variable-length TD-OCC can be designed (as discussed in R1-2008959) which can flexible control spreading factor (or repetition length) to adjust time domain span, which maximize resource use and possibly avoid collision.  Other comments:   * Many schemes are not mutually exclusive and some are the base of others. For example, Scheme 2-0 can be seen as the base for all others Scheme 2-x. We may first to agree to adopt (or not) the basic one, then proceed to others. * It is possible to have Class 2 and Class 3 co-exist * Some schemes are likely to change waveform and some are to change configuration using existing waveform. The benefits from that aspects should be further studied. |
| vivo | We are fine to capture all candidate schemes in the proposal.  reply on scheme 3-5 questions from HW:  Our initial idea was to increase flexibilities on partial frequency sounding, so a new DCI used for dynamic BW indication is not precluded from scheme 3-5. In practice, we suggest reuse some DCI fields or introduce MAC CE to achieve SRS bandwidth dynamically change.  reply on scheme 3-4/3-5 questions from ZTE:  We agree with ZTE’s suggestion. Subcarrier-level partial sounding may preclude from scheme 3-4 or 3-5. AS both functions of dynamic BW changing and SRS frequency hopping can be applied on an SRS transmission simultaneously, bandwidth changing achieves in one hopping subband level granularity. Thus, for making options more clearly, scheme 3-5 can operate independently, frequency hopping mechanism follows current spec within the SRS bandwidth |
| LGE | We are generally fine with the current formulation of possible enhancements list. We have one clarification question for Scheme 3-4 and 3-5:   * Scheme 3-4 and 3-5 are only relay on 3-1? I’m not familiar with 3-4, but for 3-5, this can be also rely on 3-2/3-3 or not? |
| Ericsson | OK to capture schemes listed. Some comments:  Scheme 2-0 seems like a logical starting point.  Scheme 2-1 (inter-slot repetition) seems to have been deprioritized based on the agreement to deprioritize class 1 SRS enhancement (time bundling). So we suggest that it be removed from the list.  Regarding scheme 2-2 (TD-OCC) this scheme should be considered along with others that provide orthogonal resources, such as 3-1 and 3-2.  Scheme 2-3: We already have sequence hopping, and this should be the baseline used for performance evaluation. Also, is the proposal that CS hopping is used without sequence hopping?  For 6B schemes, gNB receiver complexity should be considered in addition to PAPR. For example, uneven SRS allocation patterns among subcarriers may impact channel estimator complexity.  For 3-5 (dynamic SRS bandwidth change), can proponents clarify if/how this is different from the DCI 0\_1 or 0\_2 trigger for A-SRS? |
| vivo2 | Scheme 3-5 is about dynamic changing of SRS bandwidth and the subband size is scaled accordingly. A-SRS can achieve dynamic bandwidth change by associating different SRS resources with different code points however, at most 2 SRS resources in a set can be configured for codebook based scheme, it is not possible to flexibly indicate larger bandwidth and smaller bandwidths (upper half and lower half) with only 2 SRS resources configured. Dynamic change of bandwidth can also be applied for the case when only 1 SRS resource is configured. And, for SP-SRS, SRS bandwidth is RRC configured. With dynamic change of bandwidth, UE can transmit SRS in smaller bandwidth than RRC configured bandwidth with legacy hopping mechanism.  RRC configured SRS bandwidth  SRS bandwidth |
| Intel | We don’t agree to deprioritize Scheme 2-1.  In the first round of discussion, there is overlap between Class-1 and Class-2, i.e. the inter-slot repetition is captured in both Class-1 and Class-2. Then we suggested removing inter-slot repetition from Class-1 and keep it in Class-2. That’s why we agreed to deprioritize Class-1.  As FL explained in email, Scheme 2-1 means repetition symbols for one resource could be across slots. So it should be kept in Class-2.  In addition, we think at this stage we can capture the candidate schemes, and down-selection could be made in future meetings. |
| InterDigital | Support FL proposal. |
| CATT | Generally fine with the FL’s proposal to clarify each scheme. One minor suggestion is to remove “support” each scheme, as this is simply a list of candidates for studies. |
| Futurewei2 | Regarding the question whether Scheme 3-3 can jointly work with other schemes, 3-3 can jointly work with at least 3-2, i.e., with larger combs. This could potentially have the benefits of further increased SRS coverage/capacity. |
| QC | We are fine with including all different schemes at this point and then down select in the next meeting(s).  Regarding scheme 3-3, it can work with any partial-frequency scheme and is not limited to scheme 3-1 only. The partial-frequency resources can be either contiguous subset of RBs within the original SRS frequency resource, or subsets of not-contiguous RBs or subsets of RBs with larger comb (e.g. comb8, comb12). Few examples for clarification shown below.    We suggest the following edit:   * *Scheme 3-4: Support partial-frequency sounding schemes assisted with CSI-RS ~~in the case of Scheme 3-1~~* |

# Conclusion

# Appendix

## 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. |

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