3GPP TSG RAN WG1 Meeting #102-e R1-2007076

**eMeeting, 17th – 28th Aug., 2020**

**Source: Moderator (ZTE)**

Title: FL summary 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*

23 contributions have been submitted to RAN1#102e on these SRS enhancements [3]-[25]. In this document, companies’ views are summarized based on the submitted contributions.

The issues with priority levels labelled as **High (H)** and **Medium (M)** are selected for RAN1#102e discussion, as given in the following table.

|  |  |
| --- | --- |
| EVM (Section 2) | **H** |
| Flexible triggering offset (Section 3.1) | **H** |
| Flexible DCI (Section 3.2) | **H** |
| Supported configurations for antenna switching up to 8Rx (Section 4.1) | **H** |
| Scheme categorization for coverage/capacity enhancements (Section 5.1) | **H** |
| Flexible antenna switching (Section 3.3) | **M** |
| Usage/overhead reduction (Section 3.4) | **M** |
| Antenna switching using multiple UE panels (Section 4.2) | **M** |

# Remaining issues on evaluation methodology (H)

Prior to RAN1#102e, an offline discussion has been conducted in RAN1 NR reflector on the evaluation methodology for SRS enhancements [2]. The three EVM proposals given in Appendix are the outcome of this discussion.

Several contributions submitted to RAN1#102e propose to refine the three EVM proposals.

## EVM proposal 1

Qualcomm proposes to update EVM proposal 1 as

* *LLS is used to evaluate SRS enhancements in Rel-17 FeMIMO, while SLS can be used additionally for evaluating data throughput and utilized SRS resources for a given SRS capacity enhancement design*

***FL Proposal 2-1:*** *LLS is used to evaluate SRS enhancements in Rel-17 FeMIMO, while SLS can be used additionally for evaluating data throughput for a given SRS design.*

Companies’ views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Rapporteur’s assessment | In SLS, SRS resource utilization can be reflected in data throughput. For example, for a given number of UEs in a cell, a particular scheme with larger overhead reduces the number of UEs which can be multiplexed in a slot. Then to accommodate SRS transmission for all the UEs in a cell, a larger SRS periodicity is required, which reduces data throughput due to larger CSI latency. Hence to investigate the overall impact of SRS overhead/capacity, data throughput is critical and sufficient to be the metric in SLS. |
| Huawei, Hisilicon | Agree with Rapporteur. Resource utilization can determine the periodicity of SRS in the capacity limited scenario, while periodicity will impact throughput. So data throughput is sufficient for SLS. |
| Futurewei | Suggest keeping the original proposal 1, which has a broader scope. The original has “*for a given SRS design*” whereas the updated has “*for a given SRS capacity enhancement design*”. The updated seems to be limiting. |
| Samsung | FL Proposal 2-1 is considered sufficient if at least each company accurately reflects the overhead of SRS capacity enhancement in SLS. |
| OPPO | Support QC’s proposal. There are some relationship between utilized SRS resources and DL/UL data throughput. However, the relationship is varying depending on the configuration and assumptions. Thus QC’s proposal seems better. |
| QC | Regarding the SRS resource utilization, there can be a scenario where two SRS designs achieve roughly same data throughput while utilizing different SRS resources. In this case, we believe that utilized SRS resource should be considered as a metric for comparison.  In our views, SLS is beneficial to evaluate SRS capacity scheme (e.g. partial frequency sounding). The current proposal reads that the SLS are to be used for all SRS enhancements which we do not support. |
| Lenovo/MotM | Support FL’s proposal. The data throughput is sufficient to evaluate the performance of SRS and the SRS resource utilization from the system point of view. |
| ZTE | We agree with Rapporteur’s assessment. The resources used for SRS can be reflected in data throughput. Even we compare the SRS overhead of two schemes, if we don’t know how the overhead reduction is translated into performance, we are still not clear how to compare different schemes. |
| Intel | Fine with the FL proposal. |
| LGE | Support the FL’s proposal |
| CEWiT | Support the proposal. |
| InterDigital | Support the FL’s proposal |
| vivo | We agree with Qualcomm’s proposal |
| Nokia/NSB | O.K. with FL’s proposal |
| CATT | Support the FL proposal. |
| Ericsson | Support the FL proposal. We don’t see why SLS should be restricted to an SRS capacity enhancement design. Improved DL thoughput can be a key metric for coverage enhancement as well, since SRS measurements for reciprocity based precoding should be more sensitive to SINR than wideband UL CSI from SRS. Moreover, the FL proposal does not require SLS for any particular application. |
| QC | Regarding the use of SLS on the SRS coverage and capacity enhancement:   * We believe the LLS should be the primary tool for SRS coverage study (e.g. repetition and time bundling). These enhancements are link-level related where actual channel estimation is required to be able to get the actual gains from combining (e.g. coherently combine the CIR) between multiple estimates and improve the quality of the channel estimate which in turns reflects to a better DL beamformer or UL combiner. The exact mechanics does not happen at the SLS which make it less accurate. Another aspect is phase coherency model which is better modeled at link level than the system level. Also, similar discussion happened in coverage enhancement Rel-17 SI and concluded that LLS is used as the primary tool for evaluation. * On the other hand, we believe that SLS is beneficial for the SRS capacity enhancement. |

## EVM proposal 2

The following updates are proposed by companies on EVM proposal 2.

* Baseline
  + Samsung proposes to remove “FG 10-11” in baseline.
* Carrier frequency
  + Qualcomm proposes to remove “3.5GHz” and “FR2”.
* DL/UL prioritization
  + Qualcomm proposes to prioritize DL over UL.
  + Nokia proposes to prioritize UL over DL.
* UE antenna configuration
  + CATT proposes to consider directional antennas additionally for more than 2 antennas in FR1.
  + Samsung and ZTE propose not to consider directional antennas for FR1.
* SRS periodicity
  + Samsung propose to remove “Note: SRS triggering may be aperiodic.”
* Scenario and angular scaling
  + ZTE proposes to add “Companies to state whether angle scaling is performed, and if so, the desired angle spread and mean angle”.
* Difference between UL SNR and DL SNR
  + ZTE and Ericsson suggest to let companies to state one signal value. The value may depend on link budget analysis.
* Phase coherency modeling
  + Alt 1 (Qualcomm): for per SRS port
  + Alt 2 (Qualcomm): for per SRS port
  + Alt 3 (CATT): Phase noise model as in R1-165685
  + Alt 4 (Huawei, HiSilicon): Random phase rotation for each transmitted SRS in different slots follows a uniform distribution [-pi\*Δf\*x/Ts, pi\*Δf\*x/Ts], where Δf denotes the gap between central frequency and UE's SRS frequency position and Ts for sampling frequency. x can be 0.1, 0.2, 0.4.

***FL Proposal 2-2:*** *Adopt the following LLS assumptions at least for SRS enhancements on coverage/capacity in Rel-17.*

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Metric | UL/DL BLER or throughput  Note: Other metrics like MSE can be considered optionally. |
| Baseline | Rel-15 SRS. Companies to state the detailed configuration used as baseline scheme.  Note: Whether FG 10-11 can be added in the baseline configurations depends on further progress in Rel-16 UE feature discussion. If no restriction on the usage of FG 10-11 is agreed in Rel-16, it can be included as baseline.  ~~FFS: converged baseline(s).~~ |
| Carrier frequency, SCS, System BW | FR1: 3.5GHz or 4GHz, 30kHz, 20, 40 or 100 MHz  FR2: 30 GHz, 120kHz |
| Channel model | CDL-B or CDL-C in TR 38.901 with 30ns or 300ns delay spread as baseline  Note: other delay spread is not precluded.  Companies to state whether angle scaling is performed, and if so, the desired angle spread and mean angle.  ~~FFS: whether and how to define scenario~~  ~~FFS: whether and how to use CDL in MU-MIMO~~ |
| UE speed | 3km/h , 30km/h or 120km/h |
| Number of UE antennas | 1T4R, 2T4R or 4T4R |
| Number of gNB antennas | 32T32R or 64T64R |
| UE antenna configuration | FR1: omni as baseline   * + ~~FFS: whether direction can also be considered for more than 2 antennas~~   FR2: directional |
| Rank, precoder and MCS | Precoder is adaptive. Rank/MCS can be adaptive or fixed. |
| Precoding granularity | Fixed: 2, 4 or wideband for DL, wideband for UL. |
| SRS periodicity | Companies to state the used SRS periodicity. |
| SRS Comb | Comb 2 or 4 |
| SRS frequency hopping | Companies to state whether SRS frequency hopping is enabled and the hopping pattern if so. |
| DL SNR | Companies to state the used difference between DL SNR and UL SNR   * + ~~FFS detailed values~~ |
| Phase coherency | Companies to state whether the phase coherency in time domain is modelled and if so, ~~how~~ use the following model   * Random phase rotation of each SRS transmission is modeled as a uniform distribution between [ within a time window of , where companies should state the value of and . |

Companies’ views on the above are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Rapporteur’s assessment | * Baseline   + Rel-16 UE capability discussion for NR-U has concluded FG 10-11 can also be applied on licensed band. Hence it should be included in the baseline. * Carrier frequency   + FR2 or DL in 3.5GHz has global interest for operators’ deployment. It’s better not to disallow companies to conduct evaluation for them. * DL/UL prioritization   + Based on offline discussion prior to RAN1#102e and the submitted contributions, it’s impossible to prioritize one link to another. There are good points on both sides. DL may have more gain based on accurate CSI, while UL has more urgent need to enhance coverage. Hence it’s better not to prioritize any link in evaluation. * UE antenna configuration   + The current situation is to use omni antennas as baseline for FR1, as it is more useful for FR1. On the other hand, this does not preclude companies to evaluate directional antennas for FR1. Hence it is suggested to keep the current EVM proposal of having omni as baseline. * SRS periodicity   + The intention of the note is not to preclude companies to evaluate the utilization of aperiodic SRS for capacity coverage enhancement. Hence it seems fine to keep it. * Scenario and angular scaling   + Angle scaling reflects the angular spread and allows simulator to generate different angles for different UEs. Hence it is suggested to add “Companies to state whether angle scaling is performed, and if so, the desired angle spread and mean angle”. With this, we can remove the two FFS bullets in channel model. * Difference between UL SNR and DL SNR   + We can keep the current proposal to let companies report the difference and remove the FFS bullet. The reported value may depend on gNB/UE Tx power, noise figure, number of antennas, bandwidth, etc.. * Phase coherency modeling   + It’s better to align the modeling of phase coherency if it is used. Companies’ input on the three alternatives are encouraged. |
| Huawei, Hisilicon | * Baseline   + Rel-15 can be baseline since no other enhancements on SRS in Rel-16.   + For the more SRS symbols introduced in NRU, the use case for FG 10-11 is still not clear yet, e.g., UL transmission, antenna switching, or BM. The UE capability will be further discussed in RAN2. So, we also fine to remove it in the baseline. * Carrier frequency   + 3.5GHz is the most common band for operators’ deployment. So it should be used. * DL/UL prioritization   + DL is more sensitive to SRS channel estimation accuracy, it’s better to focus on DL in LLS. * UE antenna configuration   + It is not necessary to use directional antenna modes for FR1 in UE side (we agree to use directional antennas in FR2). Till now, have not any simulation based on UE side directional mode in FR1 case, the UE side antenna is not the same as gNB antennas. We also have no any definition of UE directional antennas in RAN4 for FR1 * SRS periodicity   + In our understanding, aperiodic SRS is usually used when burst traffic arrives. So the notation: “SRS triggering may be aperiodic.” can be removed, since LLS don’t have traffic model. * Scenario and angular scaling   + We are fine with the moderator’s proposal “Companies to state whether angle scaling is performed, and if so, the desired angle spread and mean angle”. * Difference between UL SNR and DL SNR   + It’s fine to keep the current values and some additional values also can be reported by companies. * Phase coherency modeling   We have the following coherency modeling in the email discussion stage:   * + For SRS time bundling, when the start of the corresponding downlink frame of timing advance (TA) is controlled by UE only (i.e., R16), random phase rotation for each transmitted SRS in different slots follows a uniform distribution [-pi\*Δf\*x/Ts, pi\*Δf\*x/Ts], where Δf denotes the gap between central frequency and UE's SRS frequency position and Ts for sampling frequency. x can be 0.1, 0.2, 0.4. |
| Samsung | * Baseline   + We keep our position to use Rel-15 as a baseline. Through evaluation, Rel-15 is enough to verify the benefit of the SRS enhancement, and when considering the spec impact, SRS change in Rel-16 NR-U can be considered. * Carrier frequency   + Considering popularity of NR spectrum, we propose to keep. * DL/UL prioritization   + We agree that SRS has an impact on both DL and UL and might have benefits on both sides. However, in a typical DL heavy TDD system, we think the impact on DL capacity is slightly more important. * UE antenna configuration   + We keep our position to use Omni as FR1 baseline and support to current FL proposal. * SRS periodicity   + Still, this note is not necessary for evaluation assumptions. * Scenario and angular scaling   + We are fine with FL’s proposal * Difference between UL SNR and DL SNR   + We are ok to remove FFS bullet. |
| OPPO | * Baseline   + Prefer to use Rel-15 SRS as baseline at this stage. This can be updated in next e-meeting when there is complete conclusion on FG 10-11. * Carrier frequency   + Keep 3.5GHz as it is. * DL/UL prioritization   + Support not to prioritize any link at least in LLS. * UE antenna configuration   + Support to keep the current EVM proposal of having omni- antennas as baseline. * SRS periodicity   + For LLS, the note is not needed. * Scenario and angular scaling   + We are fine with FL’s proposal. * Difference between UL SNR and DL SNR   + We are fine with FL’s proposal * Phase coherency   + Open to the model(s). However, different modes should be used for FR1 and FR2 |
| QC | * Carrier frequency   We want to clarify our views as there has been some misunderstanding. The motivation is to align the configurations among companies and to reduce simulations overhead. We suggested in our contribution to select only one center frequency out of the two proposed 3.5 GHz and 4 GHz. And we are fine with either 3.5 GHz or 4 GHz.   * FR2   Adding more clarification in order not to cause confusion or misunderstanding, our objectives are NOT to disallow companies to perform FR2 evaluation rather focus the efforts on one set of configurations to reduce simulation overhead.   * Phase coherency model: * To align the results between companies, we suggest to combine the proposed four alternatives into one model where the phase of each SRS transmission is modeled as random phase from a uniform distribution between [ within a time window of . |
| Lenovo/MotM | * Baseline   + Prefer Rel-15 SRS as the baseline. * Carrier frequency   + 3.5GHz should be included. * DL/UL prioritization   + Agree with OPPO that both DL and UL are important. * UE antenna configuration   + Omni should be used in FR1 and support to current FL proposal. * SRS periodicity   + This is not necessary for LLS. * Scenario and angular scaling   + We are fine with FL’s proposal * Difference between UL SNR and DL SNR * We are fine to remove FFS bullet. |
| ZTE | * Baseline   + Our understanding on the current proposal is FG 10-11 is one configuration we can use for evaluation. The detailed configuration to use still depends on companies’ choice. The following agreement is what we have now for Rel-16. With this, we don’t see any reason why it cannot be included in the configuration pool we can choose. Hence we prefer to keep it as it is.   Agreements:  ~~FFS: Type of FG10-11 is “Per UE”~~  o ~~Need of xDD/FRx differentiations are “No”~~  “TBD” is removed from prerequisite feature groups for FG10-11  This FG is also applicable to licensed bands  Agreement:  Type of FG10-11 is “Per band” |
| Intel | * Channel Model   For DL MU-MIMO, due to the sensitivity of DL precoder to the accuracy of the SRS based channel estimation, the coverage enhancement for SRS is more important. However, the existing CDL channel model is not appropriate for MU-MIMO simulation. The scaling of angular spread in CDL channel model is still not sufficient with lot of details missing on how to choose the scaling values for different UEs in MU-MIMO.  Since our concern is not addressed, we propose to have TDL channel model as an allowed option for MU-MIMO simulation.   * Phase coherency   For Alt 4, it is not clear that the phase is reset at the slot boundary since the slot is logical concepts. Is it more appropriate to reset the phase in Alt. 4 when SRS transmission is interrupted by some other UL transmission? |
| LGE | * Baseline   + Prefer to have Rel-15 as the baseline. * Carrier frequency   + 3.5GHz can be the baseline, but other options are not precluded. * Phase coherency modeling   + Fine with QC’s latest suggestion. |
| CEWiT | We support the FL proposal. |
| InterDigital | Overall agree with FL proposal, with the following considerations:   * Rel-15 to be used as the baseline * Use a single model for phase coherency, QC proposal is fine with us. |
| MediaTek | * Phase coherency modeling   We agree QC’s latest comment to merge multiple alternatives into one. In particular, we think the model should capture the phase jump for a port due to transmission on/off even if SRS in different slots are transmitted at the frequency Δf=0. This is captured by Alt.1 or Alt.2. On the other hand, the phase model should also capture different slots SRS with phase variation along frequency due to component or TA jitter, in which larger Δf results in larger phase difference. This is modeled by Alt.4. So a model that combines Alt.1+Alt.4 or Alt.2+Alt.4 can be considered in EVM. |
| vivo | * Baseline   + For LLS it doesn’t make any difference between Rel-15 baseline or Rel-16 baseline, for simplicity we prefer Rel-15 baseline. * Carrier frequency   + To align the results among companies, we suggest to select one center frequency out of the two proposed frequencies. As 3.5GHz may have common interests for current deployment, we prefer to keep 3.5 GHz. * DL/UL prioritization   + Although the impact of DL CSI maybe more sensitive than UL CSI for the following PDSCH or PUSCH transmission due to coarse codebook and wideband precoding in UL, we believe the requirement of different purpose of two usages, i.e. DL CSI and UL CSI acquisition, should be both considered in SRS capacity and/or coverage enhancement evaluation. * UE antenna configuration   + Based on current UE implementation in FR1, no need to consider directional antennas in UE side, especially in simulation assumption. * SRS periodicity   + Aperiodic SRS triggering in LLS doesn’t make sense * Scenario and angular scaling   + We are fine with FL’s proposal * Difference between UL SNR and DL SNR   + The difference between UL SNR and DL SNR is impacted on many aspects related to RF and scheduling strategy, such as Tx power, transmission bandwidth, noise figure, antenna gain in both of gNB and UE side. Thus, values of output power, noise figure, antenna gain should be aligned among companies for comparability of evaluation results. * Phase coherency modeling   We are open for discussion however the model should practical and should not complicate the evaluation |
| Nokia/NSB | * Baseline   + Prefer Rel-15 SRS as baseline * Carrier frequency   + We support both 3.5GHz and FR2. * SRS periodicity * We don’t see an importance on fixing the periodicity. Even not needed for LLS. |
| Ericsson | * Baseline   + As the rapporteur comments, **Rel-16 capability for SRS in any position in the slot (FG 10-11) can also be used in a licensed band**. Hence, it should be assumed that this capability is available in a baseline when considering enhancements that occupy symbols other than those available in Rel-15. * Carrier Frequency   + Simulating both 3.5 and 4 GHz seems unnecessary, since we should see quite similar behavior. It will help align results to some degree if we can focus on one value. **Can we make 4 GHz optional?** That way companies can provide results for either frequency, but we have some hint which to pick for better comparison to other companies. * Bandwidth   + Do we really need all 3 bandwidths? **Can we at least label 20 MHz as optional**, since midband frequencies are simulated? * Channel model   + **Support the update to state if angle scaling is used and to state the spread and mean**. The gNB angle spread of the default CDL models is a bit large for CDL-B and CDL-C (around 40 degrees). Also, if MU-MIMO is used in LLS, then how the mean angle is handled is pretty important. * Directional antennas   + We’re still puzzled why directional antennas should not be considered. UL MIMO performance can vary quite a bit according to whether the antennas are directional or not, and realistic UE antennas will always have some directionality. As the number of elements increase, they will be more correlated, and directionality will be more important to model. **Can we at least list directional antennas as optional in the 4 antenna case?** * Phase coherency   + We agree it is important to have a good model. Unfortunately, **I don’t see how to use the model proposed here unless some values of and are available**. Can proponents elaborate? |
| QC | * Phase coherency   We suggest using the values in the table below as the UE may be able to keep phase coherency per SRS port in similar spec of UL coherent MIMO.   |  |  | | --- | --- | | Max. value of absolute phase error per SRS port | Time window | | 40 degrees | 20 msec | |

## EVM proposal 3

The following update is proposed on EVM proposal 3.

* Traffic model
  + Qualcomm proposes to add full buffer in the traffic model.

***FL Proposal 2-3:*** *Adopt the following SLS assumptions at least for SRS capacity enhancements in Rel-17.*

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Metric | DL throughput |
| Baseline | Rel-15 SRS. Companies to state the detailed configuration used as baseline scheme.  Note: Whether FG 10-11 can be added in the baseline configurations depends on further progress in Rel-16 UE feature discussion. If no restriction on the usage of FG 10-11 is agreed in Rel-16, it can be included as baseline. |
| SRS error modelling | Table A.1-2 of TR 36.897  Note: The phase coherency model in LLS assumptions can be considered additionally. |
| SRS periodicity | Companies to state the simulated SRS periodicity.  Note: SRS triggering may be aperiodic |
| Carrier frequency, SCS and system bandwidth | 3.5GHz, 30KHz and 20MHz/40MHz/100MHz as baseline |
| Number of gNB antennas | (*M*, *N*, *P*, *M*g,*N*g; *M*p, *N*p) = (8,8,2,1,1,4,8). (dH,dV) = (0.5, 0.8)λ |
| Number of UE antennas | 1T4R, 2T4R or 4T4R |
| Traffic model | FTP 1 or FTP 3  Note: Full buffer can also be considered optionally. |
| Handover margin | 3dB |
| Scenario | UMi/UMa with 200m ISD.  Note: UMa with 500m ISD can also be considered. |

Companies’ views on the above are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Rapporteur’s assessment | * Traffic model   + Burst model like FTP is closer to what we have in real network, esp. considering interference, MU paring, etc. caused by on-demand scheduling. Hence it is suggested to stick with FTP models. |
| Huawei, Hisilicon | * Traffic model   + We support QC’s proposal to add full buffer as well. SLS is supposed to be used for capacity enhancement evaluation. In the capacity limited scenario, high traffic load should be assumed. So, burst buffer with high RU, e.g. 70% or 80%, should be used, and Full burst buffer also can be used. |
| Futurewei | Support to add full buffer in the traffic model. |
| Samsung | * Traffic model   + We are support to add note on the full buffer model. |
| Huawei, HiSilicon2 | One more comments for baseline FG10-11, as we commented in Section-2.3 as well, not sure the use cases for the FG, which is still under discussion. At this stage, we may not use FG10-11 for baseline. |
| QC | We support the FL proposal 2-3, but we would like to add a note at SRS modeling description that companies may utilize phase coherency model for SRS time bundling designs. |
| Lenovo/MotM | Support to add full buffer in the traffic model. |
| ZTE | We support FL’s proposal. |
| Intel | It’s fine to have full buffer traffic model. |
| InterDigital | Support FL proposal |
| Nokia/NSB | Support FL’s proposal |
| Ericsson | * Baseline   + As commented in the previous section, Rel-16 SRS can be transmitted in any symbol in both licensed and unlicensed bands, and so this should be taken into account. Rel-15 SRS is not a suitable baseline for evaluations of SRS enhancements in any symbol. * Traffic Model   + OK to have full buffer as optional, as it can be useful for calibration purposes. However, we fully agree with ZTE that full buffer misses crucial aspects of real network behavior and FTP traffic models should be the focus of evaluations. * Additional parameters:   + There are a number of missing parameters, and it would be good to align among companies intending to provide SLS results. We suggest the parameters in the table immediately below, which is based on those from the MU-CSI evaluation. Note that underlined values are taken from the preliminary agreements from the SRS evaluation methodology email discussion [2]. |
| QC | * Support FL proposal. |

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | |
| Duplex, Waveform | TDD, OFDM | |
| Multiple access | OFDMA | |
| Carrier frequency range | 3.5 GHz. | |
| Scenario | UMi and UMa 200m; UMa 500m | |
| Channel model | According to the TR 38.901 | |
| Antenna setup and port layouts at gNB | (*M*, *N*, *P*, *M*g,*N*g; *M*p, *N*p) = (8,8,2,1,1,4,8). (dH,dV) = (0.5, 0.8)λ. | |
| Antenna setup and port layouts at UE | 1T4R, 2T4R or 4T4R  4T4RX: (*M*, *N*, *P*, *M*g,*N*g; *M*p, *N*p) = (1,2,2,1,1;,1,2), (dH,dV) = (0.5, 0.5)λ | |
| BS Tx power | 46, 49, and 53 dBm for 20, 40, and 100 MHz, respectively | |
| BS antenna height | 25 m | |
| UE antenna height & gain | Follow TR 36.873 | |
| UE receiver noise figure | 9 dB | |
| gNB receiver noise figure | 5 dB | |
| Modulation | Up to 256QAM | |
| Coding on PDSCH | LDPC, max code-block size = 8448 bits | |
| Numerology | Slot | 14 OFDM symbols per slot |
| SCS | 30 kHz |
| Simulation bandwidth | 20, 40, or 100 MHz | |
| Frame structure | 3DL:1UL | |
| MIMO scheme | SU/MU-MIMO | |
| Overhead | Companies shall provide the downlink overhead assumption | |
| Traffic model | FTP model 1 or 3 with packet size 0.5 Mbytes. | |
| Traffic load (resource utilization) | 20%, 50%  Companies are encouraged to report the MU-MIMO utilization. | |
| UE distribution | 80% indoor (3km/h), 20% outdoor (30km/h) | |
| UE receiver | MMSE-IRC as the baseline receiver | |
| Evaluation Metric | DL throughput | |
| Baseline for performance evaluation | Rel-16 SRS or PMI/RI/CQI feedback, whichever performs best at the SNR of interest. | |
| Handover Margin | 3 dB | |
| SRS periodicity | Companies to state the simulated SRS periodicity.  Note: SRS triggering may be aperiodic. | |
| SRS error modelling | SRS impairment model as in Table A.1-2 of TR 36.897 with:  UEs randomly grouped to 8 groups as a baseline.  A constant dB can be used as a baseline.  Companies shall report SRS configuration details if they are different from the baseline case. | |

# Flexibility enhancements

## Flexible triggering offset (H)

In the contributions submitted to RAN1#102e, 22 companies (Apple, LG, Ericsson, NTT DOCOMO, Qualcomm, Nokia, NSB, Huawei, HiSilicon, Futurewei, ZTE, vivo, InterDigital, NEC, MediaTek, CATT, MotM, Lenovo, Intel, OPPO, Samsung, Spreatrum) see the need to enhance the determination of aperiodic SRS triggering offset. The issue comes from limited combinations of PDCCH location and SRS location for a configured SRS triggering offset, which causes PDCCH congestion or large SRS latency. See the following figure from [6] as an example.



The proposed enhancements can be categorized as follows.

* Increase the total number of available combinations of PDCCH location and SRS location for a given triggering offset:
  + 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
    - Supported by 12 companies (Ericsson, ZTE, Nokia, NSB, Huawei, HiSilicon, vivo, CATT, Intel, OPPO, Samsung, InterDigital)
* Use more dynamic signaling:
  + Alt 1: Indicate triggering offset in DCI
    - Supported by 11 companies (LG, Ericsson, Qualcomm, Futurewei, InterDigital, MediaTek, CATT, OPPO, Samsung, Spreadtrum, NEC)
  + Alt 2: Update triggering offset in MAC CE
    - Supported by 6 companies (LG, NTT DOCOMO, Qualcomm, MediaTek, MotM, Lenovo)

***FL Proposal 3-1:*** *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, multi-UE SRS multiplexing, CA aspect, etc..*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | Okay |
| NTT Docomo | We are fine with FL proposal. Regarding dynamic signaling, as an operator, we prefer not to increase DCI overhead further. Hence, MAC CE based solution is more preferable |
| Futurewei | Support the proposal.  For sufficient triggering offset flexibility, we suggest considering PUSCH/PDSCH TDRA or the like to indicate the SRS transmission in time domain.  In addition, time-domain flexibility and frequency-domain flexibility are tightly related. It would be more useful to enlarge the scope of the proposal to include time/frequency-domain triggering flexibility. The benefit of providing time/frequency-domain triggering flexibility, which includes significant spectrum efficiency gain of more than 50% for TDD, is discussed in details in our contribution to 8.1.5 R1-2005291. |
| Samsung | We are support FL proposal at the first stage of discussion and both approaches are available options. |
| NEC | We are OK with the proposal.  And we think it’s better to use dynamic signaling in DCI for the triggering offset (Alt 1 preferred). And tradeoff between signaling overhead and flexibility can be further discussed. For example, it seems there is no need to dynamically indicate all candidate values (0-32) for SRS triggering offset. |
| OPPO | Support the proposal. |
| Huawei, HiSilicon | Fine for the proposal. |
| Spreadtrum | Support the proposal |
| QC | In our views, these are two different approaches (SRS delaying/postponing and dynamic DCI/MAC-CE signaling). The first category of SRS delaying or redefining the slot offset can be described under one umbrella of ‘one or more opportunities of SRS transmission’. For the DCI based indication (Alt 2 above), there are can solutions with implicit indication of the slot offset without the need of increasing the DCI overhead. Hence, suggest the following edits:  ***FL Proposal 3-1:*** *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 and multiple opportunities of SRS transmission.*   + *Alt -2 Use more dynamic signaling with at least one of the following alternatives*     - *Alt 2-1: Indicate triggering offset in DCI explicitly or implicitly*     - *Alt 2-2: Update triggering offset in MAC CE* |
| Lenovo/MotM | Support the proposal. |
| ZTE | We support this proposal.  Compared with using DCI and redefining SRS triggering offset, we think the latter one is more efficient with fewer cost. For example, if we add one more bit in DCI to select from triggering offset 0 and 1, we can have the first three cases in FL’s figure for gNB to choose. However, if we redefine the triggering offset, we can have the following 5 combinations for gNB to choose for triggering offset 0.    Hence we think redefining SRS triggering offset provides better flexibility with fewer cost. |
| Intel | 1. The flexibility of SRS triggering offset should include same CC and cross-CC SRS triggering.  We suggest adding a note that both same-CC and cross-CC SRS triggering are considered for enhancement.  2. One thing to clarify is for Alt 1, whether the offset is purely based on DCI or it could be DCI+RRC? |
| Sharp | Support the proposal |
| LGE | We are generally fine with the FL’s proposal.  But we think multi-UE SRS multiplexing aspect should be considered here. Regarding delaying/postponing SRS(first sub-bullet), delayed/postponed SRS can be somewhat overloaded on the first UL slot. This should be investigated to avoid multi-UE SRS collision issue. |
| CMCC | We support the FL’ s proposal for the 1st phase to collect the approaches. |
| CEWiT | We support the proposal to increase flexibility in SRS triggering offsets. |
| InterDigital | Support Qualcomm revised version |
| vivo | Support the proposal. |
| Nokia/NSB | Support FL’s proposal |
| CATT | Support the proposal. |
| Ericsson | Support |

## Flexible DCI (H)

In RAN1#102e, 10 companies (Qualcomm, Ericsson, Nokia, NSB, ZTE, Huawei, HiSilicon, Samsung, vivo, Futurewei) see the need to have a DCI to trigger SRS without data and without CSI, which is not supported in the current specification for non-carrier-switching cases. This enhancement enables use cases for gNB to acquire DL or UL CSI through SRS before scheduling data. Further aspects including to indicate SRS frequency resources in the DCI can be considered.

The proposed enhancements can be categorized as follows.

* Support to have at least one DCI format to trigger SRS without data and without CSI
  + Alt 1: Use UE-specific DCI, e.g., extending DCI 0\_1
    - Supported by 6 companies (ZTE, Qualcomm, Huawei, HiSilicon, vivo, Futurewei)
  + Alt 2: Use group-common DCI, e.g., extending DCI 2\_3
    - Supported by 4 companies (Ericsson, Qualcomm, Samsung, Futurewei)

***FL Proposal 3-2:*** *Support at least one DCI format to trigger SRS without data and without CSI, by at least one of the following two alternatives, where the triggered SRS is able to be used for cases other than carrier switching*

* + *Alt 1: Use UE-specific DCI, e.g., extending DCI 0\_1*
  + *Alt 2: Use group-common DCI, e.g., extending DCI 2\_3*
  + *Further consideration aspects may include simultaneous SRS triggering among multiple CCs, dynamic indication of SRS frequency resources, etc..*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | We are okay to discuss, but we are not sure if it is truly high priority. 0\_1, 0\_2, 1\_1, 1\_2 and 2\_3 can all be used for AP-SRS triggering |
| NTT DOCOMO | We are fine with further discussing this |
| Futurewei | Support the proposal.  Please note that in our contribution we proposed to support Alt 2. So we added our position above.  We also feel Alt. 1 is useful and would like to support Alt. 1 as well. |
| Samsung | We are also support FL proposal. However, considering the main motivation of dynamic SRS triggering, we think group-common DCI can solve the problems of DCI overhead reduction, triggering without data, and dynamic triggering. |
| NEC | Support the proposal. |
| OPPO | Suggest the following changes for the main bullet  *~~Support at least one~~ Study DCI format to trigger SRS without data and without CSI, by at least one of the following two alternatives, where the triggered SRS is able to be used for cases other than carrier switching*  The motivation is not clear so far. CSI reporting can be only triggered by UL grant. Thus in some case (e.g., DL-dominated UDP data stream), there will be less chances to trigger CSI reporting. However, SRS can be triggered by DL and UL grant. If there is no much chance for both DL/UL, there will be no (or almost no) UL / DL data. In this case, why do we need to trigger SRS? |
| Huawei, HiSilicon | We are fine with Alt 1. For Alt 2, whether and how to extending DCI 2\_3 need further study. |
| Spreadtrum | Support the proposal |
| QC | Support the FL proposal 3-2 with added minor note on the enhanced GC DCI 2\_3.  ***FL Proposal 3-2:*** *Support at least one DCI format to trigger SRS without data and without CSI, by at least one of the following two alternatives, where the triggered SRS is able to be used for cases other than carrier switching, e.g., simultaneous SRS triggering across multiple component carrier.*   * + *Alt 1: Use UE-specific DCI, e.g., extending DCI 0\_1*   + *Alt 2: Use group-common DCI, e.g., extending DCI 2\_3* |
| Lenovo/MotM | We are supportive to discuss this issue with medium or low priority. |
| ZTE | We support this proposal and we think it should have high priority. Clearly some important use cases are restricted by the current specification. The use cases include the network wants to trigger SRS for CSI acquisition, interference probing, preparation for frequency-selective scheduling before scheduling DL or UL data. |
| Intel | We are fine to discuss this |
| Sharp | Support the proposal |
| LGE | Support the proposal, and we slightly prefer alt 1. |
| CMCC | Support the proposal for providing more opportunities of SRS triggering and transmission. For the specific detailed mechanisms, such as through UE specific or group-common DCI, needs more discussion and analysis. |
| CEWiT | We support the FL proposal. This will be useful especially in cases where SRS is required to be transmitted for interference emulation or cross-link interference measurement in various scenarios. |
| InterDigital | Support OPPO’s revision. We would like to have further discussion before committing to support. |
| vivo | Support the proposal. |
| Nokia/NSB | Support FL’s proposal |
| CATT | Support FL’s proposal. |
| Futurewei | Support the proposal, but we think the proposal would read better if we put the two conditions side by side with the corresponding alternatives to avoid confusion. Suggested updated proposal is:  ***FL Proposal 3-2:*** *Support at least one DCI format to trigger SRS by at least one of the following two alternatives*   * + *Alt 1: Use UE-specific DCI, e.g., extending DCI 0\_1 without uplink data and without CSI triggered*   + *Alt 2: Use group-common DCI, e.g., extending DCI 2\_3 where the triggered SRS is able to be used for cases other than carrier switching*   + *Further consideration aspects may include simultaneous SRS triggering among multiple CCs, dynamic indication of SRS frequency resources, etc.* |
| Ericsson | Support the modification by OPPO |

## Flexible antenna switching (M)

In RAN1#102e, 3 companies (Qualcomm, ZTE, Intel) see the need to enhance the flexibility of SRS antenna switching considering use cases like overhead/power saving, NW performance, etc..

The proposed enhancements can be summarized as following.

* Support triggering/updating a subset of the configured Tx/Rx antennas for antenna switching SRS.
  + Supported by 3 companies (Qualcomm, ZTE, Intel)

***FL Proposal 3-3:*** *For flexibility enhancement of SRS antenna switching, study the aspect of triggering/updating a subset of the configured Tx/Rx antennas, considering use cases like overhead/power saving, NW performance, etc..*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | Okay |
| NTT DOCOMO | Even though we do not think this is of much importance, we are open to discuss it |
| Futurewei | The WID has   * 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})*   We’d like to understand whether this fits into the scope of “flexible triggering” or “antenna switching” of the WID. Objective A does not include flexible antenna switching. Objective B will specify antenna switching but does not explicitly mention flexible switching. We might consider this as an optimization for Objective B and work on it after Objective B is done (if time allows). |
| Samsung | Depending on implementation of antenna switching, flexible antenna switching might be used but doubt the necessity of dynamic change. |
| NEC | Support the proposal. |
| OPPO | The motivation needed to be justified  Moreover, it is unclear whether this enhancement is within scope of the WID. |
| Huawei, HiSilicon | Similar concern with Samsung, and also doubt the discussion is in the scope. |
| Spreadtrum | Share the same view with Samsung. That which antenna would be switched depends on UE implementation. |
| QC | Support the FL proposal 3-3 |
| Lenovo/MotM | Support the proposal. |
| ZTE | We support FL’s proposal.  We think it is part of the WID as it is able to enhance SRS triggering flexibility clearly. |
| Intel | We think this is in the WID scope since it is related with the flexible triggering.  We are ok to discuss it and support the FL proposal. |
| Sharp | Support the proposal |
| LGE | We share the view with Samsung and Huawei. |
| CMCC | We are open to this topic |
| CEWiT | Flexibility in antenna switching will help in scenarios on multi-TRP. Hence, we support the FL proposal. |
| InterDigital | Support FL proposal |
| vivo | This may be out of scope, but we are open for discussion |
| Nokia/NSB | We do not support this proposal. We share similar view with Samsung, Huawei, and Sharp |
| CATT | Support FL proposal. |
| Ericsson | Support the proposal to study and discuss this aspect further |

## Usage/overhead reduction (M)

In RAN1#102e, 7 companies (Apple, Ericsson, vivo, MediaTek, CATT, CMCC, Spreadtrum) propose to enhance resource reuse among multiple usages explicitly, in order to reduce SRS overhead.

The proposed enhancements are summarized as following.

* Support to reuse same resource(s) for multiple usages, at least for “codebook” and “antenna switching”
  + Supported by 7 companies (Apple, Ericsson, vivo, MediaTek, CATT, CMCC, Spreadtrum), while 1 company (ZTE) propose to further study this for the case antenna switch and PUSCH have different numbers of Tx antennas.

***FL Proposal 3-4:*** *For SRS overhead reduction, study reusing same resources among multiple usages, at least for “codebook” and “antenna switching”.*

* + *The study aspects include whether implementation approach based on legacy SRS configuration is sufficient, 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, etc..*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | We think it should be high priority. |
| NTT DOCOMO | We are fine with discussing it |
| Futurewei | Support the proposal. |
| NEC | Support the proposal. |
| OPPO | We are fine to study this though we think current mechanism is sufficient. |
| Huawei, HiSilicon | The reusing SRS resources for different usage is allowed from Rel-15, through the same SRS resource are configured in different resource set. If with the following clarification, it will be more clear:  *The UE is not expected to be configured to transmit an SRS resource shared by antenna switching and codebook SRS resource sets with a different Tx power and slotoffset(for AP-SRS).* |
| Spreadtrum | Support the proposal |
| QC | Rel-15 already supports same SRS resource shared by two SRS resource sets (e.g. antenna switching and codebook). We are concerned on having more constraints on UE by having same SRS resource or SRS resource set with different usages. Also, we are wondering what the key benefit of merging SRS usages is. In our views, RRC configuration reduction doesn’t justify putting more constraints on UE implementation. |
| Lenovo/MotM | Fine with the proposal. |
| ZTE | We support the proposal. We think it should be a medium-priority issue as implementation approach based on Rel-15 specification can already achieve reusing same resource for multiple usages. Clearly more study is needed. |
| Intel | We are fine to discuss SRS with different usages and different BWP configurations.  We propose the following changes:  *The study aspects include whether UL BWP for different SRS usages is the same or different, whether implementation approach based on legacy SRS configuration is sufficient, the case that antenna switching and PUSCH have different number of Tx antennas, etc.* |
| Sharp | Support the proposal |
| LGE | We have similar view with QC. |
| CMCC | We are fine with this proposal. Reusing same resources among multiple usages could reduce the overhead and make the system more efficient. |
| CEWiT | We support the proposal of reusing same SRS resources which will be useful in scenarios like CSI/interference measurement for non-serving cell in multi-TRP scenario as proposed in our contribution. |
| InterDigital | Support FL proposal |
| vivo | Support the proposal, should be higher priority. |
| Nokia/NSB | We are O.K. to study. |
| CATT | Support the FL proposal to study. |
| Ericsson | Support the proposal and agree with Apple it should be high priority. Note that from the UE perspective, an implementation approach can be used where same virtualization is used for both codebook and antenna switching (e.g. in the 2T=2R case). However, the issue here is that the gNB does not know whether it can rely on that the UE use same virtualization, hence gNB cannot trust that the measurements on codebook SRS can be used also for reciprocity operation. From our perspective, this is the core of the problem to be resolved. |

## Others

Besides the above, the enhancements listed as following are proposed by companies.

|  |  |
| --- | --- |
| **Enhancements** | **Companies** |
| Dynamic indication of SRS frequency resource in DCI | LG, Futurewei |
| Enhance cross-carrier SRS triggering | Qualcomm, Intel |
| Dynamic indication of associated CMR or IMR in DCI | Futurewei |
| Support DCI to trigger SP SRS | Qualcomm |
| Support TRP-specific SRS triggering in multi-TRP | Intel |
| Joint triggering of SRS and CSI-RS for beam management | Intel |
| Support one usage with multiple time-domain types | CMCC |
| Enhance fast beam selection in SRS for non-codebook based UL | CEWiT, IITM, IITH, Tejas Networks, Saankhya Labs and Reliance Jio |

# Antenna switching up to 8Rx

## Supported configurations (H)

To support SRS antenna switching xTyR up to 8Rx, 6 new configurations can be identified in total: {1T6R, 1T8R, 2T6R, 2T8R, 4T6R, 4T8R}. In RAN1#102e, companies’ input on supported configurations is summarized as the following table, where “Y” means this company supports the configuration, while “N” means this company does not think this configuration is needed.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 1T6R | 1T8R | 2T6R | 2T8R | 4T6R | 4T8R |
| vivo | N | N | Y | Y | N | Y |
| ZTE | N | N |  | Y |  | Y |
| Huawei, HiSilicon |  |  | Y | Y |  | Y |
| LG |  |  | Y | Y |  | Y |
| NTT DOCOMO | Y |  | Y | Y | Y | Y |
| Sony |  | Y |  | Y |  | Y |
| OPPO | Y | Y | Y | Y |  |  |
| Qualcomm | Y | Y | Y | Y | Y | Y |
| Spreadtrum |  |  | Y | Y |  | Y |
| Nokia, NSB | Y |  | Y |  |  |  |
| MotM, Lenovo | Y | Y | Y | Y | Y | Y |
| CATT |  |  |  | Y |  | Y |
| Samsung |  |  | Y |  | N (for FR1) | N (for FR1) |
| NEC | Y | Y | Y | Y | Y | Y |
| MediaTek | Y | Y | Y | Y | Y | Y |
| CMCC |  |  | Y | Y |  |  |

In the above table, it can be observed that

* 2T6R and 2T8R are supported by most companies, where they are supported by 13 and 14 companies, respectively. No company shows concern on them.
* 4T8R is supported by 12 companies, but one company has concern on it.
* 1T6R is supported by 7 companies, but two companies have concern on it.
* 1T8R is supported by 6 companies, but two companies have concern on it.
* 4T6R is supported by 5 companies, but two companies have concern on it.

***FL Proposal 4-1:*** *For SRS antenna switching up to 8Rx, support at least the configuration of {2T6R, 2T8R}.*

* + *FFS: whether to support one or more from {1T6R, 1T8R, 4T6R, 4T8R}*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | Okay |
| NTT DOCOMO | In addition to what is captured in the table (2T6R, 4T6R, and 4T8R), we also support 1T6R, 2T8R |
| Futurewei | Support the proposal. |
| Samsung | We also support 1T6R and 1T8R |
| NEC | Support the proposal. And we think all the configurations can be supported. |
| OPPO | We suggest to modify the proposal as below  *For SRS antenna switching up to 8Rx, support at least the configuration of {2T6R, 2T8R, 1T6R, 1T8R}.*  *FFS: whether to support one or more from {~~1T6R, 1T8R~~, 4T6R, 4T8R}*  The main reason is that some CPE products in the market are equipped with 8 or 6 Rx antennas and 1 Tx antenna. We don’t have any reason to preclude enhancement for the antenna architectures already in the market.  We also think 4T8R should be supported. Considering there are no product with 8 Rx antennas and 4 Tx antennas, we are ok to keep it in the FFS part |
| Huawei, HiSilicon | OK for the proposal |
| Spreadtrum | Support |
| QC | We do not support the proposal as it is. It is not justified that some SRS antenna configuration are FFS based only on some concerns. For example, in our contribution, we show performance gain for supporting 1T6R/1T8R which are also essential from UE power savings aspects. For other wireless devices, such CPE and laptop, they can be equipped with 6 or 8 antenna and can support more transmit chains. Therefore, 4T8R and 4T6R are necessary SRS antenna switching configurations. |
| Lenovo/MotM | We think all possible configurations should be support from the specification point of view. |
| ZTE | We support the proposal. The terminal type should be clarified for this enhancement. We think an imbalanced capability between Tx and Rx antennas is not typical for a UE supporting more than 4Rx. Hence we have concern on 1T6R and 1T8R. |
| Intel | We are supportive to include {1T6R, 1T8R, 4T6R, 4T8R}. If we discuss {2T6R, 2T8R}, we think at least the UE can downgrade to {1T6R, 1T8R}. |
| Sharp | Support the proposal |
| LGE | Support the proposal. |
| CMCC | Support the proposal.  It seems that different markets have different requirements and preference for the UE type.  We stay open to this kind of UE diversity. And more efficient operations are encouraged for the study. |
| InterDigital | Support the proposal |
| MediaTek | Agree with QC. We think none of 6 configurations should be excluded in order to support difference use cases considering different purposes. |
| vivo | Support the proposal. |
| Nokia/NSB | O.K. with the proposal. But we think the supported configuration of antenna switching should be considered together whether it is targeting MPUE with panel switching. |
| CATT | Share QC’s views that the configuration listed as FFS should be given same priority as 2T6R and 2T8R. |
| Ericsson | **OK to study all listed configurations, but would like somehow to focus on the most beneficial and realistic ones.** SRS switching provides extra CSI that enhances downlink throughput. While we as network vendors appreciate UEs taking on the burden in their RF circuitry of implementing switching, we would hope that the effort RAN1 expend on specifying, and we will spend potentially going through IoT for a wide variety of switching configurations, actually pays off in enhanced downlink throughput in relevant scenarios. So we are OK to study all these different switching configurations, but would like to know what the gains are in order to spend our efforts judiciously. **Should we formalize the evalutions more to align among companies?** |

## Antenna switching using multiple UE panels (M)

In RAN1#102e, 4 companies (LG, Nokia, NSB, Sony) propose to enhance antenna switching for multi-panel UEs, especially considering CSI acquisition when fast panel switching is supported.

The proposed enhancement can be summarized as follows.

* Support SRS antenna switching over multiple UE panels, taking UE’s fast panel switching into account
  + Supported by 4 companies (LG, Nokia, NSB, Sony)

***FL Proposal 4-2:*** *Study SRS antenna switching over multiple UE panels, taking UE’s fast panel switching into account.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | Support |
| NTT DOCOMO | We are fine with discussing it |
| Futurewei | Can the proponents clarify the relation between antenna switching and panel switching? For example, if antenna switching is supported, would panel switching be also supported or not? |
| Samsung | Considering FR2 panel implementation at the UE side, we support to discuss panel switching in the antenna switching discussion. |
| NEC | Support the proposal. |
| OPPO | We need to study whether current antenna switching mechanism can support antenna switching over panels firstly.  Moreover, we prefer keep such kind of study in AI 8.1.1 since the study of fast panel switching is at there |
| Huawei, HiSilicon | The discussion is low priority, while the UL and DL panel will be discussed in beam management and MTRP cases. We can discuss them after the two parts. |
| Spreadtrum | Fine to discuss. But it should be low priority at the moment. Antenna switching up to 8Rx over one UE panel should be high priority. |
| QC | SRS antenna switching for UE with multi panels can be achieved with the proposed enhancement of SRS antenna switching configuration (xTyR, x=1,2,4; y=6,8). For example, UE with 3 panels each with 2 ports (x-pol) and one active Tx panel can be configured with 2T6R and the UE can sound the three panels over three symbols with enough guard time in between for panel switching. We would like to understand what needs to be treated differently other than guard time which is better discussed in RNA4.  Agree with Huawei, HiSilicon that this discussion should be low priority. |
| Lenovo/MotM | We prefer to discuss this issue in AI 8.1.1. |
| ZTE | We agree to perform more study on this. In our views, the AP-SRS triggering with a large triggering offset for panel activation, which is similar to AP-CSI-RS beam switching in Rel-15, e.g., 224 or 336 OFDM symbols, can be considered. In such case, the sounding procedure of antenna switching may be equivalent to that of fast panel switching.   * + For instance, one example for inter-panel antenna switching is described as follows. In such case, there may be different spatial relations applied to the respective UE panels, and the restriction about “same spatial relation for AP-SRS resources in a set for antenna switching” in the current spec may become invalid herein.   + It can be observed that the working assumption on the architecture of UE panels is very essential for studying SRS antenna switching over multiple UE panels. |
| Intel | Support the FL proposal |
| Sharp | Support the proposal |
| Sony | Support the proposal |
| LGE | Support the proposal. |
| CMCC | The relation between antenna switching and panel switching needs clarification. Then we can move into the discussion of antenna switching using multiple UE panels.  It is a little confused for us to combine the two features together. From our understanding, the UE panels are mainly used for FR2 for tx and rx beamforming. But the antenna switching is mainly used for FR1 for the downlink channel estimation. And the transmission of SRS under antenna switching is usually none beam formed. More clarifications are need for the using scenarios and how to combine those two features together. |
| InterDigital | We are ok discussing it, however needs further clarification |
| vivo | We are ok to further study with lower priority, panel switching can similar to antenna switching |
| Nokia/NSB | O.K. to discuss. But we prefer this issue to be included in SRS antenna switching configuration |
| CATT | Same view as OPPO - prefer to study this issue in 8.1.1 |

# Coverage and capacity enhancements

The Rel-17 FeMIMO WID gives three categories to be evaluated for SRS coverage and capacity enhancements, including time bundling, increase repetition and partial frequency sounding. In order to proceed with evaluating these candidates, it is needed to have clear definition and categorization on them.

## Scheme categorization (H)

### Class 1: Time bundling

Proposed definition for this category:

* This category utilizes relationship among two or more occasions of one or more SRS resources to enable joint processing within time domain.
  + 8 companies (Qualcomm, Huawei, HiSilicon, ZTE, MediaTek, Samsung, CMCC, Spreadtrum) think this category is potentially beneficial for coverage, while the majority of companies think phase discontinuity issue should be considered.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | We have concern due to the phase continuity, which should be first addressed |
| NTT DOCOMO | Agree with Apple. It is better to address phase discontinuity issue first |
| Futurewei | Agree with Apple. Can the proponents provide some reasoning that this is not a problem or suggest a potential solution? |
| Samsung | We think that the phase continuity is separate issue (we already have 4 alternatives for phase continuity models in EVM discussion) and at least for categorization, time bundling can be the one option for enhancement. |
| NEC | Agree with Apple, DoCoMo and Futurewei. |
| OPPO | Share the same view as Apple, DCM, Futurewei and NEC |
| Huawei, HiSilicon | The restriction “*without changing legacy SRS pattern in one resource*” need to be removed.  Time bundling between legacy whole band SRS transmission and SRS for partial sounding also can be considered to increase SRS capacity and/or SRS coverage. So we think the restriction “*without changing legacy SRS pattern in one resource*” need to be removed. |
| Spreadtrum | Fine to discuss. Share the same view with Samsung, EVM has considered the effect. Considering possible benefit of coverage improvement, at the moment, we should be open, and time bundling could be as one option for further evaluation. |
| QC | Agree with Apple, DCM, Futurewei, NEC and OPPO that phase coherency model is essential to evaluate the expected gains of time bundling schemes. Also, we think intra-slot and inter-slot time bundling can be applied between same or different SRS resources.  Propose the following update:   * + *Class 1 (Time bundling): Utilize relationship among two or more occasions of one or more SRS resources to enable joint processing within time domain, without changing legacy SRS pattern in one resource.* |
| Lenovo/MotM | Share the same view as Apple, DCM, Futurewei, NEC and OPPO. |
| ZTE | We agree with the proposed definition. Phase discontinuity will be taken into account in the evaluation. |
| Intel | We support the time bundling. But the design should take into account the phase continuity including interruption of SRS transmission by other UL transmission signals with different power control.  From this perspective, the contiguous time bundling should be prioritized for the study. |
| Sharp | Share the same view as companies mentioning phase discontinuity issue |
| LGE | Share the same view as Apple, DCM, Futurewei, NEC, OPPO and sharp. |
| CMCC | Support the time bundling. But the phase discontinuity issue should be clarified and addressed first. |
| CEWiT | Share the same view on phase discontinuity as Apple, NTT DOCOMO. |
| InterDigital | Support the FL proposal. Phase discontinuity may indeed be an issue, however its impact will be reflected during the evaluation. |
| vivo | We share the same view that phase discontinuity issue should be addressed first. |
| Nokia/NSB | We are O.K. for further discussion. |
| CATT | We are OK to further study time bundling. |
| Ericsson | It is not clear if bundling within a slot is included in the definition of time bundling. Can this be clarified?  Agree we need a clearly defined phase discontinuity model. The current proposals need more elaboration, as we mentioned above.  Presuming that only cross slot bundling is addressed here, increased repetition within a slot seems to be the more logical starting point, and cross slot bundling for SRS should use slot repetition as a baseline. |

### Class 2: Increase repetitions

Proposed definition for this category:

* This category changes the legacy SRS pattern in one resource from time domain by adding more symbols for repetition.
  + 20 companies (Apple, Sharp, Nokia, NSB, Huawei, HiSilicon, Futurewei, ZTE, vivo, InterDigital, Sony, CATT, NEC, MotM, Lenovo, Intel, Samsung, CMCC, Spreadtrum, CEWiT) think this category is potentially beneficial for coverage.
    - Among them, 6 companies (Apple, Sharp, Futurewei, ZTE, CATT, Intel) propose to use TD-OCC to compensate its negative impact on SRS capacity.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | Okay |
| NTT DOCOMO | We are fine with discussing it |
| Futurewei | Support |
| Samsung | We are fine with putting this class on the table. However, considering level and depth of classification, we suggest to remove the sub-bullet in class 2 of the FL proposal 5-1 |
| NEC | Support the proposal. |
| OPPO | Fine to discuss it and further clarify the benefit of TD-OCC |
| Huawei, HiSilicon | For the first proposal is confusion. Is that increasing SRS symbol for repetition? Or just increasing symbols. Increasing repetitions of SRS transmission is not efficient way to improve channel estimation accuracy, since it will reduce SRS multiplexing capability. Reducing hopping bandwidth can also be used to increase coverage, which won’t cause SRS multiplexing capability reduction, as shown in our Tdoc.  For SRS repetition transmission(as well as time bundling), inter-cell interference randomization should be supported to ensure channel estimation accuracy, such as cyclic shift hopping. |
| Spreadtrum | Support the proposal. But to use TD-OCC should be FFS, and the benefit should be further clarified. |
| QC | We have concerns with TD-OCC schemes because of the possible loss of orthogonality if SRS transmission of one UE is dropped. |
| Lenovo/MotM | Support the proposal. |
| ZTE | We agree with this definition. |
| Intel | We are ok with the proposal. |
| Sharp | Support the proposal |
| Sony | Support the proposal |
| LGE | We have similar view as OPPO, spreadtrum and QC. |
| CMCC | We are fine with the proposal.  And further discussions are needed for the TD-OCC. Since the Rel-16 NR-U has extended the available symbols for SRS transmission in a slot, the benefit and the impact to the system of TD-OCC needs more discussion. |
| CEWiT | We support increase in repetition of SRS. However, along with repetition, we also propose to support a precoder to maintain time domain circularity over the repeated symbols. |
| InterDigital | Support FL proposal |
| vivo | Support the proposal. |
| Nokia/NSB | Support to discuss |
| CATT | Support the proposal. |
| Ericsson | Can we clarify the definition, i.e. are the symbols within a slot, and if not are only consecutive slots included? |

### Class 3: Partial frequency sounding

Proposed definition for this category:

* This category supports more flexibility on SRS frequency resources to allow SRS transmission on partial frequency resources within the legacy SRS frequency resources, where the partial frequency resource can be RB level or subcarrier level.
  + 10 companies (Huawei, HiSilicon, Futurewei, ZTE, vivo, MediaTek, NEC, OPPO, Samsung, Spreadtrum) think this category is potentially beneficial for coverage and/or SRS capacity.

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| **Company** | **View** |
| Apple | This should have relatively lower importance in our view |
| NTT DOCOMO | We are fine with discussing it |
| Futurewei | We support flexible partial frequency sounding but would like to clarify some aspects.   * + To allow SRS on partial frequency resources within the legacy SRS bandwidth is already supported since SRS does not occupy all subcarriers of the bandwidth. Maybe a better wording is “to allow SRS transmission on partial frequency resources within the legacy SRS frequency resources”.   + The flexibility described here may not be limited to flexible configuration. We can down-select later but at this stage we should keep it open.   So we suggest the following update:  *Supports more flexibility on SRS frequency resources to allow SRS transmission on partial frequency resources within the legacy SRS frequency resources.* |
| NEC | Support the proposal. |
| OPPO | We think more evaluation is needed to justify the benefit of partial band sounding over larger comb. We are fine to further study it, but in proposal 5-1, we propose to add larger comb (which was proposed by multiple companies) as a candidate for capacity enhancement, as supported in positioning in rel-16. Thus we add Case 4 as below (highlighted by RED) |
| Huawei, HiSilicon | Fine to discuss it. |
| Spreadtrum | If we support partial sounding across frequency domain, actually it will be new configuration, new SRS resource.  So we suggest the following update:  *Supports more flexibility on SRS frequency resources to allow SRS transmission on partial frequency resources within the SRS frequency resources.* |
| QC | We support partial frequency sounding as in some scenarios UL BWP is smaller than DL BWP or a cell-edge UE can sound on partial of the configured SRS frequency resource to improve the SNR at gNB. Also we share similar views with OPPO as comb8 is added for positioning SRS in Rel-16, it can be adopted in Rel-17 SRS for capacity enhancement. The current description of class 3 is very narrow; hence we propose to make it broader.*Class 3 (Partial frequency sounding): Supports more flexible configuration on SRS frequency resources to allow partial frequency SRS transmission and frequency sparse SRS (e.g. comb8).*  On the evaluation and specification language of proposal 5-1, we would like to add clarification note that the decision of the specification is based on UL/DL performance considerations (e.g. DL performance improvement). |
| Lenovo/MotM | We are fine to discuss and evaluate it. |
| ZTE | We agree with the definition and the revision from Futurewei.  On Comb 8, I think it is within the scope as given in the updated definition from Futurewei. The partial frequency resource can be RB level or subcarrier level. So there is no need to list it separately.  On the revision from Qualcomm, could you please give an example that the updated definition from Futurewei cannot cover what you have in mind? In our view, Futurewei’s definition is clearer, and it is broad enough. |
| Intel | Fine with discussing it. |
| Sharp | We are fine to discuss this. |
| Sony | Fine to discuss it. |
| LGE | We are fine to discuss it. |
| InterDigital | Support the proposal. For partial sounding, depending on the design, we may need to check PAPR as part of evaluation. |
| vivo | We are fine to further study different options. |
| Nokia/NSB | Not support. We prefer to clarify the usecase and potential benefits first. We also have concerns on PAPR issue. |
| CATT | We are fine to introduce a clear definition, and further study its performance. |
| Ericsson | The revised categorization seems OK. OK to study and evaluate the options. |

***FL Proposal 5-1:*** *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 to enable joint processing within time domain.*
    - *Study aspects include the issue of phase discontinuity, etc..*
  + *Class 2 (Increase repetition): Change the legacy SRS pattern in one resource 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, etc..*
  + *Class 3 (Partial frequency sounding): Supports 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 is RB level or subcarrier level (e.g., larger comb), PAPR issue etc..*

|  |  |
| --- | --- |
| Companies | Views |
| Huawei, HiSilicon | The comments are provided in Above separate sections already. |
| Ericsson | Same question as Huawei: Is this actually a proposal, or is it covered above? |

## Others

In addition to the above, the enhancements listed as following are proposed by 1 or 2 companies. Whether these enhancements are in the WI scope is not clear.

|  |  |
| --- | --- |
| **Enhancements** | **Companies** |
| Support low PAPR waveform for SRS | MediaTek |
| Enhance SRS sounding for the case DL and UL BWPs are not aligned | Intel |
| Extend SRS root sequence | Huawei, HiSilicon |

# Conclusion

TBD

# Appendix

Outcome of the offline discussion on SRS enhancement EVM [2]

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***EVM Proposal 1:*** *LLS is used to evaluate SRS enhancements in Rel-17 FeMIMO, while SLS can be used additionally for evaluating data throughput for a given SRS design.*  ***EVM Proposal 2:*** *Adopt the following LLS assumptions at least for SRS enhancements on coverage/capacity in Rel-17.*   |  |  | | --- | --- | | **Parameter** | **Value** | | Metric | UL/DL BLER or throughput  Note: Other metrics like MSE can be considered optionally. | | Baseline | Rel-15 SRS + FG 10-11. Companies to state the detailed configuration used as baseline scheme.  FFS: converged baseline(s). | | Carrier frequency, SCS, System BW | FR1: 3.5GHz or 4GHz, 30kHz, 20, 40 or 100 MHz  FR2: 30 GHz, 120kHz | | Channel model | CDL-B or CDL-C in TR 38.901 with 30ns or 300ns delay spread as baseline  Note: other delay spread is not precluded.  FFS: whether and how to define scenario  FFS: whether and how to use CDL in MU-MIMO | | UE speed | 3km/h , 30km/h or 120km/h | | Number of UE antennas | 1T4R, 2T4R or 4T4R | | Number of gNB antennas | 32T32R or 64T64R | | UE antenna configuration | FR1: omni as baseline   * + FFS: whether direction can also be considered for more than 2 antennas   FR2: directional | | Rank, precoder and MCS | Precoder is adaptive. Rank/MCS can be adaptive or fixed. | | Precoding granularity | Fixed: 2, 4 or wideband for DL, wideband for UL. | | SRS periodicity | Companies to state the used SRS periodicity.  Note: SRS triggering may be aperiodic. | | SRS Comb | Comb 2 or 4 | | SRS frequency hopping | Companies to state whether SRS frequency hopping is enabled and the hopping pattern if so. | | DL SNR | Companies to state the used difference between DL SNR and UL SNR   * + FFS detailed values | | Phase coherency | Companies to state whether the phase coherency in time domain is modelled and if so, how. |   ***EVM Proposal 3:*** *Adopt the following SLS assumptions at least for SRS capacity enhancements in Rel-17.*   |  |  | | --- | --- | | **Parameter** | **Value** | | Metric | DL throughput | | Baseline | Rel-15 SRS + FG 10-11. Companies to state the detailed configuration used as baseline scheme. | | SRS error modelling | Table A.1-2 of TR 36.897 | | SRS periodicity | Companies to state the simulated SRS periodicity.  Note: SRS triggering may be aperiodic | | Carrier frequency, SCS and system bandwidth | 3.5GHz, 30KHz and 20MHz/40MHz/100MHz as baseline | | Number of gNB antennas | (*M*, *N*, *P*, *M*g,*N*g; *M*p, *N*p) = (8,8,2,1,1,4,8). (dH,dV) = (0.5, 0.8)λ | | Number of UE antennas | 1T4R, 2T4R or 4T4R | | Traffic model | FTP 1 or FTP 3 | | Handover margin | 3dB | | Scenario | UMi/UMa with 200m ISD.  Note: UMa with 500m ISD can also be considered. | |

# References

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

[2] Offline email discussion on FeMIMO evaluation methodology: Item 3

[3] R1-2005247, Enhancements on SRS for Rel-17, Huawei, HiSilicon

[4] R1-2005288, Enhancements on SRS flexibility, coverage and capacity, FUTUREWEI

[5] R1-2005368, Discussion on SRS enhancement, vivo

[6] R1-2006963, Enhancements on SRS flexibility, coverage and capacity, ZTE

[7] R1-2005487, Discussion on SRS Enhancements, InterDigital, Inc.

[8] R1-2005565, Considerations on SRS flexibility, coverage and capacity, Sony

[9] R1-2005622, Enhancements on SRS flexibility, coverage and capacity, MediaTek Inc.

[10] R1-2005688, Discussion on enhancements on SRS flexibility, coverage and capacity, CATT

[11] R1-2005754, Discussion on SRS enhancement, NEC

[12] R1-2005824, Enhancements on SRS, Lenovo, Motorola Mobility

[13] R1-2005863, Discussion on SRS enhancements, Intel Corporation

[14] R1-2005988, Enhancements on SRS flexibility, coverage and capacity, OPPO

[15] R1-2006133, Enhancements on SRS, Samsung

[16] R1-2006205, Enhancements on SRS flexibility, coverage and capacity, CMCC

[17] R1-2006255, Considerations on SRS enhancement, Spreadtrum Communications

[18] R1-2006364, Discussion on enhancement of SRS in Rel. 17 further enhanced MIMO, CEWiT

[19] R1-2006504, Views on Rel-17 SRS enhancement, Apple

[20] R1-2006568, Enhancement on SRS, Sharp

[21] R1-2006601, Enhancements on SRS flexibility, coverage and capacity, LG Electronics

[22] R1-2006610, SRS Performance and Potential Enhancements, Ericsson

[23] R1-2006723, Discussion on SRS enhancement, NTT DOCOMO, INC.

[24] R1-2006795, Enhancements on SRS flexibility, coverage and capacity, Qualcomm Incorporated

[25] R1-2006848, Enhancements on SRS in Rel-17, Nokia, Nokia Shanghai Bell