3GPP TSG-RAN WG1 Meeting #118bis Tdoc R1-24nnnnn

Hefei, China, October 14th – 18th, 2024

Agenda Item: 7

Source: Moderator (Ericsson)

Title: Summary of NR Pre-Rel18 maintenance discussion for SRS power scaling and transmission occasion

Document for: Discussion, Decision

# 1 Introduction

In RAN1#116, how SRS antenna port power scaling is defined for an SRS transmission occasion was further discussed [2], following on from RAN1#115 [1]. In RAN1#116bis, conclusions were reached on the relative power of the SRS resources for non-codebook and beam management SRS usages:

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| **Conclusion**The transmit power of each of the simultaneously transmitted SRS resources for usage ‘nonCodebook’ is equal in the fully overlapping time/frequency case, regardless of whether calculated transmission power across all SRS resources is higher or lower than Pcmax.* No specification change

**Conclusion:**If total transmission power exceeds the maximum transmission power, for simultaneous transmission of SRS resources in different SRS resource sets for **beam management**, the transmission power of the SRS resources is left to UE implementation. |

In RAN1#118, it was agreed that the power control of multiple simultaneously transmitted SRS resource is done ‘per SRS resource’, and it was also clarified that the power is split equally among SRS ports of each SRS resource of an SRS resource set as can be seen in the agreement below [3]. While there was a view from multiple companies that 38.213 subclause 7.5 should also be revised in order to reflect behavior near Pcmax, there was no consensus for this in RAN1#118, and further discussion on this aspect is to conclude in this meeting.

**Agreement**

The following TP is agreed for Rel-18 TS38.213. Final CR in R1-2407562.

* Further discuss specification change to 38.213 subclause 7.5 in RAN1#118bis. If no consensus, no future discussions beyond RAN1#118bis.

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| 7.3 Sounding reference signalsFor SRS, - if a UE is provided *nrofSRS-Ports-n8* = ‚ports8tdm‘for an SRS resource with 8 ports in an SRS resource set with usage ‘codebook’ or ‘antennaSwitching’, the UE splits a linear value $\hat{P}\_{SRS,b,f,c}(i,q\_{s},l)$ of the transmit power $P\_{SRS,b,f,c}(i,q\_{s},l)$ on active UL BWP $b$ of carrier $f$ of serving cell $c$ equally across the ~~configured antenna~~SRS ports of an SRS resource of an SRS resource set on each symbol for SRS transmission.- else, a UE splits a linear value $\hat{P}\_{SRS,b,f,c}(i,q\_{s},l)$ of the transmit power $P\_{SRS,b,f,c}(i,q\_{s},l)$ on active UL BWP $b$ of carrier $f$ of serving cell $c$ equally across the ~~configured antenna ports for SRS~~ SRS ports of each SRS resource of an SRS resource set in a symbol for SRS transmission. 7.3.1 UE behaviourIf a UE transmits SRS based on a configuration by *SRS-ResourceSet* on active UL BWP $b$ of carrier $f$ of serving cell $c$ using SRS power control adjustment state with index $l$, the UE determines the SRS transmission power $P\_{SRS,b,f,c}(i,q\_{s},l)$ of each SRS resource in SRS transmission occasion $i$ as  [dBm]where,- $P\_{CMAX,f,c}(i)$ is the UE configured maximum output power defined in [8, TS 38.101-1], [8-2, TS 38.101-2], [TS 38.101-3] and [8-5, TS 38.101-5] for carrier $f$ of serving cell $c$ in SRS transmission occasion $i$ |

In this contribution, we summarize the continuation of the discussion in RAN1#118 on SRS power scaling and the SRS transmission occasion.

Comments for the initial discussion are invited in section 2. Responses will be summarized after first round discussion in section 3.

Note that delegates participating in this topic are invited to provide their contact information in section 6 to facilitate offline discussions. I’ve taken the liberty of adding contact information from prior discussions of this topic.

# 2 Discussion

In this meeting, 6 discussion papers [4]-[9] and two draft CRs [10] and [11] were submitted on this topic. A high level summary of these discussion papers paraphrasing the arguments for the two approaches with the supporting companies is given below. They can be classified into two categories:

Alt. 1) supporting a spec change for SRS power scaling near Pcmax (supported by Google, CATT, Ericsson, and vivo (2nd choice)), and

Alt. 2) leaving the SRS power scaling near Pcmax to UE implementation (supported by ZTE, vivo (1st choice), and Huawei).

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|  | **Supporting arguments** |
| **Alternative 1**Update SRS power scaling near Pcmax | * If the network does not know if UE power scales, it doesn’t know if total target power exceeds Pcmax, and may select poorly performing SRIs. It should be specified that UE keeps equal Tx power for SRS resources when power reduction is required due to max Tx power constraints. [6]
* Option 2) transmit power of each SRS resource is equally backed off so that the total UE transmit power is smaller than or equal to $P\_{CMAX,f,c}(i)$ [5] (See detailed view in Alternative 2 below).
* Cases 1) where total power across simultaneous non-codebook SRS resource sets exceed Pcmax and 2) where total power including higher priority UL transmissions and non-CB SRS exceed Pcmax should be clarified in specification. If total UL power would exceed $\hat{P}\_{CMAX}\left(i\right)$, transmit power of the SRS resources should be equal, regardless of if target total SRS power exceeds Pcmax.[7] (CR in [11])
* Despite the RAN1#116b conclusion that SRS resource powers are equal, there is still debate on what is allowed in the spec, and so a need to clarify. The UE is unaware of radio conditions and interference at a receiving TRP, or even which TRP receives its uplink. Therefore, the UE has insufficient information to autonomously adjust relative Tx chain power in order to increase UL throughput. Especially since the network will not be aware it is used, UE implementation based unequal power split among its Tx chains is likely to degrade, rather than enhance, UL capacity (see example analysis/results in [9]). Clarify that the UE scales combined SRS resource power to be less than $P\_{CMAX,f,c}(i)$ and that their powers are equal. [9] (CR in [10])
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| **Alternative 2**Leave SRS scaling near Pcmax to UE implementation | * Equally splitting total power or not is up to UE implementation, unless there is a critical issue for UL transmission. Equal split should be a normal solution, but the bar for Rel-15 changes should be high and no critical issues have been found in 5G deployments. [4]
* Splitting transmit power $P\_{SRS,b,f,c}(i,q\_{s},l)$ equally across SRS resources when total power does not exceed $P\_{CMAX,f,c}\left(i\right)$, but across ports of SRS resources in a set will lead to two different UE behaviors of SRS power control. SRS power scaling should either Option 1) be left to implementation or Option 2) transmit power of each SRS resource is equally backed off so that the total UE transmit power is smaller than or equal to $P\_{CMAX,f,c}(i)$ [5]
* It would be better to let UE implementation allocate power to SRS resources (i.e. without specification changes), since the UE could allocate the transmission power based on channel reciprocity according to the downlink measurement. [8]
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First, to give Moderators’ view on the status of the discussion. The RAN1#116bis agreement below states clearly that the SRS resources’ powers should be the same regardless of whether the powers are near Pcmax, so without further agreements the spec should be read according to the conclusion. The agreement in the introduction from RAN1#118 sets the power of each SRS resource according to a single set of parameters, and so the powers are equally split at least according to 38.213 section 7.3. However, as is reflected above, some companies feel UE implementation can set the powers to be different according to the power reduction rules in 38.213 section 7.5. Therefore, further discussion is needed on the question of UE implementation.

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| **Conclusion**The transmit power of each of the simultaneously transmitted SRS resources for usage ‘nonCodebook’ is equal in the fully overlapping time/frequency case, regardless of whether calculated transmission power across all SRS resources is higher or lower than Pcmax.* No specification change
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**Observation 2.1**

According to the RAN1#116b conclusion, power is equally split among simultaneously transmitted SRS resources with usage ‘nonCodebook’ regardless of if the calculated Tx power is above or below Pcmax, which is reinforced by the use of one set of parameters for the ‘per SRS resource’ power control agreed in RAN1#118. However, some companies interpret the current spec as allowing unequal resource power near Pcmax according to power reduction rules.

A second comment is in order on the release for which a further change on SRS power scaling might target, given the concern above made on Rel-15 changes, and that contributions were made to both the pre-Rel-18 and Rel-18 agenda points to this meeting. Moderator’s understanding is that since the changes from RAN#118 were agreed only for Rel-18, subsequent changes to complete the clarification of ‘per-SRS resource’ power control should be made for Rel-18.

**Observation 2.2**

The changes in RAN1#118 to clarify ‘per SRS resource’ power control were agreed for Rel-18, so Moderator’s expectation is that any further clarifications should be made for Rel-18.

The differences in views summarized above seem to be based on two main factors:

1. Pros and cons of leaving power allocation to UE implementation from a performance perspective
2. How a potential change to set equal power should be expressed in terms of $P\_{CMAX,f,c}\left(i\right)$ and/or $\hat{P}\_{CMAX}\left(i\right)$,

**Regarding the question on UE implementation**, again from Moderator’s perspective, two mechanisms come to mind: downlink measurements and UE transmitter related measurements, such as proximity detection.

If downlink measurements are used, the UE must infer the uplink channel conditions in order to autonomously decide the relative power of the SRS resources. As summarized above for [9], the UE is unaware of radio conditions and interference at a receiving TRP, or even which TRP receives its uplink. Therefore, the UE only has coarse information from downlink measurements to set the relative power of the SRS resources. It seems reasonable that the UE could at least determine if one receiving antenna is severely blocked.

UE transmitter related measurements may determine if an antenna is blocked, or if the UE should back off power e.g. to meet maximum permissible exposure requirements, to share power with another RAT, etc. RAN4 supports such power backoff with the P-MPR mechanism in 38.101 section 6.2.4. The RAN1 specs operate assuming these power reductions are not applied, and when they are applied they can modify the nominal RAN1 assumed behavior, and so no RAN1 spec changes would be needed if the unequal SRS resource power behaviors are covered by the RAN4 mechanisms.

The UE is also naturally aware of its transmit power on its various transmit chains, and when transmit power is near its limit, there may be concerns that an equal power split could waste SRS power by transmitting it on a path that would anyway not be used for PUSCH. However, the UE being at maximum transmit power does not require that the signal received from the UE is at low SINR at a given point in time. The received SNR target is set by power control and can be relatively high (e.g. targeting multi-layer transmission), so reaching a power limit does not necessarily imply low SNR, e.g. where only single layer transmission is feasible. It is also possible the network may not use power control at all, and so the UE would transmit at max power under all conditions.

**Observation 2.3**

* UE based measurements (either received signals or transmitter related measurements) can provide only coarse estimates of SINR at a receiving TRP.
	+ The most obvious form of UE implementation based setting of relative power would therefore seem to be to turn completely turn off one or more SRS resources.
* The UE is allowed to reduce power on blocked antenna ports according to specific conditions using the P-MPR mechanism in RAN4, and so adjusting relative SRS resource power for conditions using P-MPR would be outside the scope of RAN1 specifications.

The following questions attempt to check if the above is the common understanding,

**Question 2.1**

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| Can the UE accurately (e.g. consistently within a few dB or so) determine the uplink SINR at its receiving TRP from one or more of a) if transmit power UE is at Pcmax, b) if UE determined PA backoff (e.g. from proximity detection, applied P-MPR, etc) c) from downlink measurements. If so, how? |
| **Company** | **Y/N** | **Comments** |
| Apple |  | It is irrelevant to this discussion in our view. Estimate UL SINR within a few dB is neither necessary or sufficient condition to require UE to perform equal power scaling. |
| ZTE |  | Share the same views as Apple. |
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**Question 2.2**

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| Can the UE determine that the SINR at the gNB would be sufficiently low such that only single layer transmission is possible at the gNB? |
| **Company** | **Y/N** | **Comments** |
| Apple |  | It is irrelevant to this discussion in our view. We are talking about UL operation, do not understanding “only single layer transmission is possible at the gNB“ |
| ZTE |  | Share the same views as Apple. |
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**Question 2.3**

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| Do RAN4 requirements such as P-MPR already sufficiently enable a UE that would adapt its SRS transmission by turning off one or more of its SRS resources to do so such that a potential change to RAN1 specs could assume that the power would always be equal? |
| **Company** | **Y/N** | **Comments** |
| Apple |  | No, MPR is Maximum Power Reduction. Or this is still irrelevant to this CR.  |
| ZTE |  | Have not got the point. In our initial thought, it seems not relevant to this discussion. |
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The analysis in [9] illustrates that, assuming an i.i.d channel, boosting the total Tx power by increasing the power on one Tx chain in a multiantenna transmission can improve single link PUSCH throughput in a power limited scenario. However, it was also found that introducing an imbalance in power among Tx chains can generally degrade single link throughput in a non-power limited scenario. This would imply that if the UE were to introduce power imbalances in SRS resources that would be mirrored in PUSCH transmission, it should do so only in special cases.

The performance gains from turning off some of simultaneously transmitted SRS resources would come from being able to combine Tx chain power by virtualization, enabling higher SRS resource transmit power. This would not improve PUSCH power, since the network can select any number of layers via SRI, reflecting any of the virtualizations the UE used for the SRS resources. That is, the benefit of higher SINR SRS is the better CSI that enables better selection of how many non-codebook based PUSCH layers and PRBs should be transmitted, rather than improving PUSCH directly. This seems to further reduce the scenarios in which there may be performance benefits from different SRS resource transmit powers.

**Observation 2.4**

* There seem to be limited conditions where boosting power of subsets of Tx chain would improve, rather than degrade PUSCH throughput.
* Reducing the number of SRS resources by virtualizing Tx chains will improve the SNR of an SRS resource, but this only improves CSI accuracy of one layer, not PUSCH throughput. Reducing the number of SRS resources also naturally reduces the CSI.

Then given the preceding discussion, since UE implementation should not commonly set different SRS resource transmit power, there seem to be two alternatives: always setting equal power or setting unequal power in exceptional cases. These are addressed in the following question.

**Question 2.4**

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| For simultaneously transmitted SRS resources with usage ‘nonCodebook’, would the UE a) always set equal power for the SRS resources or b) set unequal power for the SRS resources only in exceptional cases? |
| **Company** | **Alt a) or b)** | **Comments** |
| Apple |  | Power scaling to meet the maximum transmit power limitation is up to UE implementation.We have the following agreement made in RAN1#92, Feb. 2018**Agreement:**Following working assumption is confirmed with the understanding that the CCs are in the same cell group:* In Case 2, (CCs/uplinks configured for UE have same or different numerologies and partially overlapping transmissions between different CCs/uplinks and same/different transmission duration and one or two PUCCH group(s)), when the UE is power limited due to simultaneous transmission on multiple serving CCs/uplinks,
	+ PRACH of PCell > PUCCH/PUSCH with ACK/NACK and/or SR > PUCCH/PUSCH with other UCIs > PUSCH w/o UCI > SRS/PRACH of Scell
		- Within a same priority level, PCell is prioritized over Scell
		- In case that transmission power exceeds Pcmax, Scaling/dropping is applied to the lowest priority first until the aggregated power is within Pcmax.
		- Note: different priority of SRS used for carrier switching can be discussed further
	+ Scaling or dropping of the whole or part(s) of a transmission is left to UE implementation.
* Note: If the aggregated transmission power does not exceed Pc\_max within any part of a transmission that overlaps with other transmission(s), the transmission is considered as non-power limited case.
* Note: power control with look-ahead is not required at UE.

FFS: Priority on the UL and SUL  |
| ZTE |  | Share the same views as Apple |
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**Regarding the potential changes to 38.213 section 7.5:**

The following is proposed in [6] and [9], which limits the combined power the SRS resources to no more than $P\_{CMAX,f,c}\left(i\right)$ and sets the SRS resources powers to be equal. The constraint for transmissions on all carriers/cells to meet the total UE transmit power limit $\hat{P}\_{CMAX}\left(i\right)$ uses existing mechanisms.

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| 7.5 Prioritizations for transmission power reductionsFor single cell operation with two uplink carriers or for operation with carrier aggregation or for operation with a candidate cell configured by *LTM-Config*, if a total UE transmit power for PUSCH or PUCCH or PRACH or SRS transmissions on serving cells or on a candidate cell, if any, in a frequency range in a respective transmission occasion $i$ would exceed $\hat{P}\_{CMAX}(i)$, where $\hat{P}\_{CMAX}(i)$ is the linear value of $P\_{CMAX}(i)$ in transmission occasion $i$ as defined in [8-1, TS 38.101-1] for FR1 and [8-2, TS 38.101-2] for FR2, the UE allocates power to PUSCH/PUCCH/PRACH/SRS transmissions according to the following priority order (in descending order) so that the total UE transmit power for transmissions on serving cells or on a candidate cell, if any, in the frequency range is smaller than or equal to $\hat{P}\_{CMAX}(i)$ for that frequency range in every symbol of transmission occasion $i$. If the UE transmits SRS on multiple SRS resources according the *XYZ* [6, TS 38.214], the UE allocates power so that all REs of the SRS transmission have same power.…In case of same priority order and for operation with carrier aggregation, the UE prioritizes power allocation for transmissions on the primary cell of the MCG or the SCG over transmissions on a secondary cell. In case of same priority order and for operation with two UL carriers, the UE prioritizes power allocation for transmissions on the carrier where the UE is configured to transmit PUCCH. If PUCCH is not configured for any of the two UL carriers, the UE prioritizes power allocation for transmissions on the non-supplementary UL carrier.For the simultaneous transmissions of SRS resources in an SRS resource set with the higher layer parameter *usage* configured as ‘*non-Codebook*’, if the total UE transmit power for the transmissions on a carrier $f$ of serving cell $c$ in SRS transmission occasion $i$ would exceed $P\_{CMAX,f,c}(i)$, where $P\_{CMAX,f,c}(i)$ is the UE configured maximum output power defined in [8, TS 38.101-1], [8-2, TS 38.101-2], [TS 38.101-3] and [8-5, TS 38.101-5], the UE allocates equal power to the SRS resource transmissions so that the total UE transmit power is smaller than or equal to $P\_{CMAX,f,c}(i)$. |

On the other hand, the proposal from [7] ensures an equal power split, but does not first limit the total power of the SRS resources to $P\_{CMAX,f,c}\left(i\right).$

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| 7.5 Prioritizations for transmission power reductionsFor single cell operation with two uplink carriers or for operation with carrier aggregation or for operation with a candidate cell configured by *LTM-Config*, if a total UE transmit power for PUSCH or PUCCH or PRACH or SRS transmissions on serving cells or on a candidate cell, if any, in a frequency range in a respective transmission occasion $i$ would exceed $\hat{P}\_{CMAX}(i)$, where $\hat{P}\_{CMAX}(i)$ is the linear value of $P\_{CMAX}(i)$ in transmission occasion $i$ as defined in [8-1, TS 38.101-1] for FR1 and [8-2, TS 38.101-2] for FR2, the UE allocates power to PUSCH/PUCCH/PRACH/SRS transmissions according to the following priority order (in descending order) so that the total UE transmit power for transmissions on serving cells or on a candidate cell, if any, in the frequency range is smaller than or equal to $\hat{P}\_{CMAX}(i)$ for that frequency range in every symbol of transmission occasion $i$. If SRS resource(s) in an SRS resource set with usage set to ‘nonCodebook’ is to be transmitted, and there are multiple SRS resources in the SRS resource set with usage set to ‘nonCodebook’ in the same transmission occasion $i$, the UE transmits all the SRS resources in the SRS resource set with usage set to ‘nonCodebook’ and allocates equal power to the SRS resources. If the UE transmits SRS on multiple SRS resources according the *XYZ* [6, TS 38.214], the UE allocates power so that all REs of the SRS transmission have same power. |

In option 2) from [5], the transmit power of each SRS resource is equally backed off so that the total UE transmit power is smaller than or equal to $P\_{CMAX,f,c}(i)$. This aligns with the proposal from [6] and [9]. However, the discussion in [5] seems to consider where per SRS resource power control would target different power levels, which seems to address the beam management usage as well. If that is indeed the intent, specifying a change would conflict with the conclusion from RAN1#116b below. If the proposed change only targets non-codebook usages, then would be no conflict with the conclusion.

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| **Conclusion:**If total transmission power exceeds the maximum transmission power, for simultaneous transmission of SRS resources in different SRS resource sets for **beam management**, the transmission power of the SRS resources is left to UE implementation. |

**Question 2.5**

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| If an equal power split among simultaneously transmitted SRS resources with usage nonCodebook is to be specified in section 7.5 of 38.213, a) should the combined power of the SRS resources be limited to no more than $P\_{CMAX,f,c}\left(i\right)$, or b) should the power of the SRS resources be set equal and limited by $\hat{P}\_{CMAX}(i)$ without an explicit limit to $P\_{CMAX,f,c}\left(i\right)$?  |
| **Company** | **Alt a) or b)** | **Comments** |
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If the conclusion from Question 2.4 is that UE implementation can set unequal power only in exceptional cases, then one solution can be to specify that the UE is generally, but not strictly required to set equal power. The 3gpp drafting rules in 21.801 Annex E with respect to Table E.2 say that the word ‘should’ can be used: “to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others”.

**Question 2.6**

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| If an equal power split among simultaneously transmitted SRS resources with usage nonCodebook is to be specified in section 7.5 of 38.213, if UE implementations set unequal power only in exceptional cases, do you support using phrasing like “the UE **should** allocate equal power to the SRS resources”.  |
| **Company** | **Y/N** | **Comments** |
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# 3 Summary of discussion so far and way forward

## 3.1 First round summary

TBD

## 3.2 First round outcome

TBD

# 4 Conclusion

TBD

# 5 References

1. vivo, “R1-2311072, Discussion on SRS transmission occasion”, 3GPP TSG RAN1#115, Chicago, USA, November 13-17, 2023.
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3. Moderator(Ericsson), “R1-2407547, Final summary of NR Pre-Rel18 maintenance discussion for SRS power scaling and transmission occasion”, 3GPP TSG RAN1#118, Maastricht, NL, August 19th – 23rd, 2024.
4. ZTE Corporation, Sanechips, “R1-2407779, Discussion on SRS power scaling once extending Pcmax”, 3GPP TSG RAN1#118bis, Hefei, China, October 14th – 18th, 2024.
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7. CATT, “R1-2408008, Discussion on SRS power scaling and transmission”, 3GPP TSG RAN1#118bis, Hefei, China, October 14th – 18th, 2024.
8. Huawei, HiSilicon, “R1-2408173, Discussion on transmission power for simultaneously transmitted SRS resources”, 3GPP TSG RAN1#118bis, Hefei, China, October 14th – 18th, 2024.
9. Ericsson, “R1-2408766, SRS Resource Power Scaling Near Pcmax”, 3GPP TSG RAN1#118bis, Hefei, China, October 14th – 18th, 2024.
10. Ericsson, “R1-2408960, Draft CR on Multi-Resource SRS Power Scaling Near Pcmax”, 3GPP TSG RAN1#118bis, Hefei, China, October 14th – 18th, 2024.
11. CATT, “R1-2408009, Clarification on SRS power scaling for non-codebook based UL transmission”, 3GPP TSG RAN1#118bis, Hefei, China, October 14th – 18th, 2024.

# 6 Contact info

Please provide your contact information below in order to facilitate offline discussion.

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