**3GPP TSG RAN WG1 #112bis-e R1-23XXXXX**

**e-Meeting, April 17th – April 26th, 2023**

**Source: Moderator (Huawei)**

**Title: FL summary on UE SRS IL imbalance issue#1**

**Agenda item: 5**

**Document for: Discussion and Decision**

# Introduction

In RAN4#106-e meeting, LS R4-2303519 [1] was sent to RAN1 with following action:

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| **ACTION:** RAN4 respectfully ask RAN1 to consider above issue with, but not limited to the three resolutions listed in the Annex for their future study. **ANNEX:** 1. Enable UE report on the actual IL imbalance for each diversity branch used for SRS so network can use this information for AS-SRS based channel estimation accuracy improvement where the granularity of such report can be per SRS resource and either static or dynamic.2. Utilize PCMAX, f, c via PHR type 3, where power imbalances across antenna ports are derived by comparing the maximum configured power of main branch to those of diversity branches, where such report is per transmission occasion per SRS (only a report of a single SRS resource is transmitted per transmission occasion).3. Define UE measurements of downlink channels which are reported in order to assist the network in determining the difference between the UE insertion losses for two given antenna ports, where the network also does its own measurements of SRS channels.4. RAN4 does not preclude other options.The above alternatives are considered from Release 18 onwards and for 8Rx capable UE’s, and possible applicability UE’s supporting 2RX or 4RX is FFS. |

This document contains summary of the company’s contributions and FL proposals. Any additional inputs from any company can also be provided in this document.

# Discussion

SRS antenna switching is the key feature to acquire DL CSI for reciprocity-based TDD. However, due to the Tx switching at UE side, the insertion loss (IL) of diversity branch(es) can differ from that of main branch as identified by RAN4. Aforementioned IL imbalance is called SRS IL imbalance, which can be led by RF switch and trace loss difference as shown in Figure 1 [1].



**Figure 1. Exemplary RF architecture of ‘t1r4’ (left) and ‘t1r8’ (right) UE**

Facing SRS IL imbalance, RAN4 has defined a relaxation ∆TRxSRS for 4Rx as a non-ideal factor in PCMAX\_L, f, c, the definition of which is attached below. The ongoing RAN4 discussion is considering an even larger ∆TRxSRS for 8Rx.

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| PCMAX\_L,f,c = MIN {PEMAX,c– ∆TC,c, (PPowerClass – ΔPPowerClass) – MAX(MAX(MPRc+∆MPRc, A-MPRc)+ ΔTIB,c + ∆TC,c +∆TRxSRS, P-MPRc) }∆TRxSRS is applied during SRS transmission occasions with *usage* in *SRS-ResourceSet* set as ‘antennaSwitching’ when a) UE transmits SRS on the second SRS resource in every configured SRS resource set when the *SRS-TxSwitch* capability is indicated as 't1r2' or 't1r1-t1r2' b) UE transmits SRS on the second, third and fourth SRS resources of the total 4 SRS resources from all configured SRS resource set(s) consisting of one SRS port when the *SRS-TxSwitch* capability is indicated as 't1r4' or, 't1r4-t2r4' or 't1r1-t1r2-t1r4' or, 't1r1-t1r2-t2r2-t1r4-t2r4' c) UE transmits SRS from the second SRS port pair on the second SRS resource in every configured SRS resource set consisting of two SRS ports when the *SRS-TxSwitch* capabilityis indicated as' t2r4' or ' t1r4-t2r4', or 't1r1-t1r2-t2r2-t2r4' or 't1r1-t1r2-t2r2-t1r4-t2r4', ord) UE transmits SRS to a DL-only carrierThe value of ∆TRxSRS is 4.5dB for bands whose FUL\_high is higher than the FUL\_low of n79 and 3 dB for bands whose FUL\_high is lower than the FUL\_low of n79 when the device is capable of power class 3 or power class 5 or power class 1.5 in the band, or when the device is capable of power class 2 in the band and ΔPPowerClass = 3 dB, or when UE indicating *txDiversity-r16*~~.~~. The value of ∆TRxSRS is 7.5dB for bands whose FUL\_high is higher than the FUL\_low of n79 and 6 dB for bands whose FUL\_high is lower than the FUL\_low of n79 during SRS transmission occasions with configured SRS resources consisting of one SRS port when the device is capable of power class 2 in the band and ΔPPowerClass = 0 dB and not indicating *txDiversity-r16*.For other SRS transmissions ∆TRxSRS is zero; |

Compared with defining relaxation only, reporting the SRS IL imbalance directly/indirectly can help the gNB to compensate the IL imbalance and improve the channel estimation accuracy, which facilitates DL precoder/rank/MCS calculation and harvests obvious performance benefit [2-3]. Furthermore, most of the companies providing contribution also share the same view that directly/indirectly reporting the SRS IL imbalance should be supported [4-8].

Based on RAN4’s request and above assessment, FL proposal 1 is suggested as below:

## **FL Proposal 1**

**Support directly/indirectly reporting the SRS IL imbalance to gNB for 8Rx UE.**

* **FFS: Static, semi-persistent or dynamic reporting**
* **FFS: Reporting method**
* **FFS: For 2Rx, 4Rx UE**

### **Round1**

Please companies provide your views towards above proposal.

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| **Company** | **Comment** |
| vivo | We do not support the proposal. As we analyzed in our contribution, there could be many reasons IL imbalance stays even if the UE reports. And, considering impact on performance, there could be some degradation for 1T8R UE, but for 4Rx and 2Rx UEs performance degradation is not observed. |
| NTT DOCOMO | We support the FL proposal. This will be quite useful to measure DL CSI based on SRS. Besides we’d like to understand vivo’s intention above. For the comment “As we analyzed in our contribution, there could be many reasons IL imbalance stays even if the UE reports”, could you clarify how the comment motivates no enhancement on reporting? Yes, we agree that even if specifications enhances reporting feature, the power degradation still exists. But such a reporting enables NW to observe what power degradation UE encounters, which is the actual target of reporting in our view. Could vivo clarify the intention? |
| ZTE | We support the FL proposal in general, although “directly/indirectly” is confusing. Maybe we need to focus the following resolution. FL: Sorry for bringing confusion. “Directly/indirectly” actually corresponds to the resolutions given in the LS. |
| MediaTek (+ ***update***) | We think it is premature to agree on the FL proposal on 8Rx. We believe that it is more important that companies in RAN1 have time to investigate this issue properly, in order to understand better whether they are practical benefits of any IL reporting and the relevant operating scenario where it may provide gain. As this is linked to Rel-18 it seems that we have some time to do that.**Comments on some contributions:*** **Regarding the simulation results from Qualcomm, the case where there is an imbalance between Tx antennas with no reporting of the offset is not shown (also pointed out by Samsung).**
* **From the Huawei contribution, there is an indirect correlation between the actual precoder performance with mismatch and the ideal precoder performance.**

We believe that the SRS imbalance issue should only occur when the UE is operating at, or close to, maximum Tx power. In that specific scenario, we suspect that the SRS-based CSI will degrade anyway due to the lower received SRS power at the gNB (and even more so on the non-primary Tx branches). Therefore, when considering realistic channel estimation at the gNB, we question whether gNB having knowledge of the insertion loss delta from the UE would really help, considering that the imbalance is still there. But we are open to investigate further as said above. |
| Nokia/NSB | We support FL proposal in general. Because the power imbalance due to insertion loss is fixed, we don’t need to use dynamic reporting. It can easily be reported as UE capability. To vivo, could you share your results in RAN4? In our understanding, UE SRS coverage is limited by IL, so coverage of antenna switching is limited to cell-center UE. We don’t understand why UE performance degradation is not observed. Of course, for 8RX, larger IL loss is discussed in RAN4, then it should be serious limiting factor applying antenna switching. To MTK, if SRS power is not limited in NR deployment, your observation is correct. But, in the current deployment, SRS antenna switching is highly coverage limited. So, losing coverage by IL is critical. We cannot use wide-band SRS reporting in such case, instead using frequency hopping with narrow BW resulting in longer transmission periodicity.Also, we have identified the ambiguity of the current UE behavior. Without reporting, UE will limit the max SRS tx power by max IL value. But, with reporting, it is beneficial to allow primary or other SRS ports to be transmitted with more power for better channel estimation performance. Thus, how to utilize the reported value for SRS power control should be determined. Thus, we propose to update the proposal as follows. **FL Proposal 1A****Support directly/indirectly reporting the SRS IL imbalance to gNB for 8Rx UE.*** **FFS: Static, semi-persistent or dynamic reporting**
* **FFS: Reporting method**
* **FFS: For 2Rx, 4Rx UE**
* **FFS: UE behavior (Tx power for each SRS transmission)**

FL: Thanks for the constructive discussion. Since seems not all companies are OK with the fourth FFS, we can discuss that later after we agree the main bullet. |
| Apple | We do not support any form of report Firstly, the issue, i.e., impact of channel reciprocity is a combined effect of both DL and UL insertion loss, etc. For example, if due to DL and UL insertion loss, the same antenna observes similar IL imbalance with respect to the primary antenna for both DL and UL, then, there is no issue for AS SRS. In practice, a physical antenna can be placed at some location that needs additional cabling, etc., but it is typically the similar issue for both DL and UL, hence we are not convinced that this problem needs any specification change. Secondly, even if there is problem, it would be more complicated especially considering that UE needs to perform proprietary Rx antenna selection. In practice, for example, consumer cannot be forced to hold device in particular position to avoid the antenna blockage, etc., therefore, a reasonable device implementation needs to perform Rx antenna selection, etc. If any report needs to be considered, we need to consider the UE Rx antenna selection that is right now proprietary to the UE.Lastly, the UL power control and Pc,max have its own error tolerance in RAN4. There can already be implementation based solution to handle the issue if there is any. There is no need to device a solution in 3GPP for UE to explicitly report it which, as we explained, can be considered as UE proprietary thing. Regarding coverage limited scenario, we doubt any solution would really help. We do acknowledge that if the composite imbalance jointly considering DL and UL is very large, there might be some benefit of allowing UE to sound all the port with Pc,max. But large composite imbalance is highly unlikely to be a practical implementation.In summary, we hold quite strong position that no report is needed.  |
| Qualcomm | We support the FL proposal and prefer semi-static direct reporting as UE capability. Trying to address some of the comments by other companies:1. The main motivation for SRS IL reporting is to make the gNB aware of the power imbalance between SRS ports. RAN4 spec defined a power relaxation ∆TRxSRS for diversity antenna of 4Rx a UE which can be up to 7.5 dB and expected to be higher for 8Rx UE. gNB doesn’t know whether/which diversity antennas have SRS IL and what values.
2. How is this information used? It is to gNB implementation. One important information is that gNB can know that a weak channel for an SRS port doesn’t always mean that channel is bad, but it could be due to large power offset at UE diversity antenna. We presented in our contributions (R4-2300696, R1-2303620) one solution where gNB compensate the UL channel based on the reported IL.
3. The motivation is not for cell edge UE when UE operating at maximum Tx Power, but for all power levels. This power offset due to imbalance is fixed regardless of UE Tx Power.
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| Intel | As pointed out by other companies, the SRS IL is fixed and doesn’t change over time. So, UE capability reporting is sufficient to address the issue and no RAN1 spec impact is expected.Regarding the FL proposal, we think the sub-bullet of “FFS: For 2Rx, 4Rx UE” could be removed. The UE with 2Rx and 4Rx is already there and it can work. There is no need to optimize this for 2Rx/4Rx case.In addition, we don’t think the new bullet from Nokia is necessary. |
| Samsung | Before discussing possible solutions, we want to check whether this SRS IL is really problem which degrades the system performance or not. In Qualcomm’s contribution for TEI (R1-2303620), we can check the throughput performance evaluation with LLS. In the result, we cannot check the performance without reporting/compensation when the power offset exists (i.e., non-ideal). Therefore, we are not sure how much SRS IL affects on the throughput performance degradation without power offset reporting/compensation.  |
| MediaTek1 | To Qualcomm: We have a different view to you on the impact of the insertion loss. From the discussion it seems that there is already some freedom for the UE to overcome the issue by itself, and we see companies commenting that there was no problem observed with 4Rx and 2Rx UEs in the field. The 8Rx requirements are only for CPE/FWA devices, so there may be other ways of overcoming any insertion loss issues in the majority of scenarios |
| CMCC | We support the FL proposal and believe there will be benefits in UE reporting IL to gNB.To Apple: We have a different view to you on your first point. As per our understanding, the main motivation for SRS IL reporting is to make the gNB aware of the power imbalance between main SRS port(s) and diversity SRS ports to obtain the power offset between DL and UL. Considering gNB uses UL SRS to acquire DL CSI, the awareness of the power offset between DL and UL will be helpful for gNB to acquire more accurate channel estimation, which could lead to better PMI selection and better overall system performance.The same antenna will observe different IL between DL and UL since for the same antenna will have different RF circuit paths between DL and UL. (Please check the snapshot below for reference.) So, there will be different IL between DL and UL even for the same antenna.We tend to agree there might be some points in Apple’s second view that it may deserve for us to take antenna performance into consideration also for the time being. |
| Ericsson | We support the FL proposal.Power imbalances for SRS antenna switching lead to inaccurate CSI for reciprocity-based DL precoding as gNB cannot distinguish between power difference due to channel conditions and power difference due to insertion loss. UE reporting of relative SRS power offset can mitigate this issue. We are open to study and further discuss whether such reporting should be static, semi-persistent, or dynamic.Furthermore, we don’t think the problem is limited to 8 Rx UEs and, hence, 2 Rx and 4 Rx should be considered as well. UE that complies with existing RAN4 requirements on relative SRS power offset can still benefit from reporting said relative SRS power offset such that the NW can take it into account when estimating the DL channel. |

### **Round2**

Thanks the group for the good discussion. Companies’ attitude towards FL Proposal 1 is summarized as below:

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| **Support/fine** | **Open** | **Concern** |
| NTT DOCOMO, ZTE, Nokia, Nokia Shanghai Bell, Qualcomm, Intel, CMCC, Ericsson, Huawei, HiSilicon (10) | MTK, Samsung (2) | Vivo, Apple (2) |

From FL’s perspective, this IL imbalance issue has been recognized and identified by RAN4 (“RAN4 think it is necessary to address such IL imbalance issue”), we should respect the work of RAN4 Group and evaluate the possible resolutions already given / newly introduced. The intention of FL Proposal 1 is actually given a superior summary of the given resolutions and list the potential decision points.

Now that companies have raised some concern about the IL issue, I’ll try to address some based on my understanding, and other supporters please feel free to supplement. Hope by clarification RAN1 Group can also reach a consensus to deal with the IL issue.

@vivo, thanks for you good discussion. In your contribution section 1.3 you assume that the overall effect of IL imbalance would be limited attribute to the almost counterbalanced UL and DL IL imbalance, but that cannot be always ensured under different RF architecture (e.g., the RF architecture in Figure 1 or CMCC’s response).

@MTK, thanks for your good discussion. FL believes this IL imbalance issue has already been recognized and identified by RAN4 although further investigation is for sure not precluded.

Regarding the comments on contributions, please @QC and @ Huawei try to response.

Regarding “SRS imbalance issue should only occur when the UE is operating at, or close to, maximum Tx power”, based on FL’s understanding, the existence of IL imbalance issue comes from the RF architecture rather than the specific power setting, which is also mentioned by QC. If you’re assuming UE always has the ability to conduct self-supplement during SRS transmission, even if that’s the case although FL doesn’t think the discussion should base on any spec-transparent hypothesis unless a consensus have been reached, Nokia also provide a good point.

@Apple, thanks for your good discussion.

Regarding the first bullet, please see my reply to vivo.

Regarding the second bullet, if this kind of advanced implementation means antenna degradation (i.e., using 8Rx -> 4Rx for PDSCH reception), than seems it’s to some extent irrelevant to the IL reporting towards full channel, cause anyway the DL precoder calculated based on the full channel is not perfectly matched with the degraded partial channel. If I misunderstand something please correct me.

Regarding the last bullet, indeed the error tolerance has been defined in RAN4, but compared with “handling” the IL imbalance issue, it’s more or less “tolerating” the issue, which for sure will not ameliorate the situation. If there exists some method that can help the gNB to compensate the IL imbalance and improve the channel estimation accuracy, why not to specify it.

@Samsung, thanks for your detailed checking. Please see whether Huawei’s simulation can help.

Given the reply above and the majority support, FL suggests companies to further consider whether the FL Proposal 1 is acceptable. Companies’ further views towards the proposal and the reply above are appreciated.

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| **Company** | **Comment** |
| Apple | Even with majority support, we do not see the issue and see the necessity of any form of report. Our understanding is that this is mainly motivated by 8Rx for FWA/CPE. Now, companies are saying that it is even for 2Rx and 4Rx consumer devices, and honestly speaking, mostly from operators and infra-vendors. There are two things we need further clarification * Can we first discuss what device is expected to have performance so significantly impacted by this IL imbalance that requires UE to explicitly report the imbalance
	+ Do we expect the issue significant enough for consumer 2Rx/4Rx handheld devices?
	+ Is the issue only limited to 8Rx CPE/FWA?
* The situation is very clear. There is unanimous support from operators and infra-vendors for UE to report the so called IL imbalance. However, there are multiple UE-vendors either don’t see the issue or need further clarification. Maybe we also need to turn the table around
	+ Specification also supports reciprocal based UL operation, i.e., non-codebook based PUSCH whose performance will be impacted by the CSI-RS IL imbalance at gNB side. We do not believe gNB can perform perfect calibration and the IL imbalance will also impact the reciprocal based UL operation. If gNB can calibrate, why CPF/FWA cannot considering that they are not form factor limited, etc.
	+ We also want to understand why NW does not need to configure the CSI-RS IL imbalance for UL reciprocal based PUSCH. We know nonCodebook based PUSCH is not deployed. But the specification should treat both solution equally and we also want to know why such impact is not considered in a reciprocal manner.
	+ The figure from RAN4 LS does not match to the UE implementation. Please do not make false assumption that UL IL imbalance has to be there while DL IL imbalance is not. In fact, we can also draw the case in which UL is balance and DL is not which is also 100% valid, then, what is the solution? If needed., we can send LS back to RAN4 to ask about it and ask about the realistic range of the IL imbalance. In addition, the expected impact to 2Rx., 4Rx consumer handheld device, vs., 8Rx CPE/FWA

Overall, we feel the RAN4 LS is not clear with some illustration that can be misleading. At least, the following aspects are not clearly addressed in RAN4 LS which is very important to make a technical decision * Is there any Rx IL imbalance for at least some implementation or UE is always expected to perfectly balance the Rx ports. If there is, the expected relationship to the Tx IL imbalance.
* What is the expected range of IL imbalance for typical implementation of (1) 2Rx handheld device (2) 4Rx handheld device (3) 8Rx CPE/FWA
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FL: Following part can be postponed. Further inputs are still welcome.

In terms of the resolutions given by RAN4, companies’ position is summarized below. The corresponding reporting granularity supported by each resolution is also listed based on FL’s understanding.

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|  | **Support/fine** | **Concern** |
| **Resolution 1****(static, semi-persistent or dynamic)** | Nokia (Study and specify the UE behavior in terms of Tx power setting), Intel (No RAN1 specification impact), Qualcomm | Vivo (No Enhancement), ZTE, Huawei/HiSilicon |
| **Resolution 2****(dynamic)** | ZTE | Vivo (No Enhancement), Nokia, Huawei/HiSilicon |
| **Resolution 3****(semi-persistent or dynamic)** | Huawei/HiSilicon | Vivo (No Enhancement), Nokia, ZTE |

Please companies provide your views towards above resolutions. Also feel free to suggest other effective resolutions. Decision on whether/which resolution to choose can be delayed after we’ve reached a consensus on FL proposal 1.

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| **Company** | **Comment** |
| NTT DOCOMO | Our preference is Resolution 1. For Resolution 2, if we understand correctly, it tries to derive ∆TRxSRS by comparing PCMAX reported by multiple PHRs. To achieve the purpose of SRS IL identification, we believe some restrictions across the PHRs need to be considered, which will require quite some specification impacts in our view (potentially in RAN1/RAN2/RAN4). If such a detail is left untouched, the functionality itself will not be very useful. For Resolution 3, how would the UE understand that the difference of measurement solely comes from IL? Isn’t there a possibility that it actually comes from the difference of e.g., propagation channel? We wonder how it is practical.  |
| ZTE | Our preference is Resolution2. Then, we have the following analysis:* Regarding resolution 1, if the report is a static one, it can be realized as a UE capability report, and this may have no big spec impact. However, RAN4 recognized that UE may change the physical Tx antenna mapping of each antenna port in some conditions for example due to hand blocking issue, so it is hard to only support static one. If the report is a dynamic one, it may need a new procedure/framework to support the new report, and then the details on report format, report content (e.g., UCI or MAC-CE), and UE/gNB-initiated procedure should be studied in RAN1.
* Regarding resolution 2, since SRS IL imbalance introduced by RAN 4 works very similar to the enhancement for MPR in FR2, in which additional indication of reduction of Pcmax due to MPE is introduced in PHR report. Therefore, the similar procedure as MPE related PHR procedure may be introduced for handling this IL issue of SRS. We believe the workload should be acceptable.
* Regarding resolution3, it is more complicated than resolution#1, if our understanding is correct. The new report procedure/framework in Alt1 is also needed in addition to the measurement procedure in Alt3. But instead of reporting of IL related parameter, the real difference between DL Rx port and UL Tx port in UE may be probed in real time. To be more specific, in order to obtain the measurement/report value for all branches, it may need lots of dedicated DL RS transmission, especially when such measurement is periodic. Due to the additional overhead of DL RS and spec effort for supporting a new report procedure/framework, this Alt 3 should be deprioritized in our initial thought.
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| MediaTek | We would not like to take steps to agreeing any signalling mechanism until there is some clear outcome on the characterization and quantification of the practical issue.  |
| Nokia/NSB | We share view with DOCOMO. We prefer Resolution 1 reporting as UE capability. As mentioned in above, because the power imbalance due to insertion loss is fixed, we don’t need to use dynamic reporting. It can easily be reported as UE capability. Resolution 2 has no gain over Resolution 1, because PHR derivation in UE shall be just considering fixed IL value (because UE has no way to measure IL value dynamically). Then, this is just increasing overhead. Also, introducing SRS resource specific PHR has large specification impact. Resolution 3, reporting power ratio is also identical to direct reporting IL. We don’t think this value is dynamically changing, and UE can measure it.  |
| Qualcomm  | Solution #1 based static reporting of the actual IL imbalance for each diversity branch is a simple and most beneficial solution. In addition, this solution has the least specification impact as it only requires UE capability reporting. The other solutions have either extra signalling overhead, don’t provide extra benefits and require nontrivial RAN1 time and efforts for specification |
| Intel | We could be fine with UE capability reporting. Since the IL doesn’t change over time, the static capability reporting is sufficient.Dynamic or semi-persistent signaling would require a lot of discussion and efforts, no matter whether it is layer-1 or layer-2 signaling. Therefore, it is not preferred.We are also fine to discuss the signaling after decision can be made regarding FL Proposal 1. |
| Samsung | In this stage, we want to clarify whether this SRS IL is really problem which degrades the system performance or not first. |
| CMCC | In this stage, we tend to prefer Resolution 1 with static reporting. And we are also open to dynamic reporting if the antenna performance (e.g. hand blocking issue as mentioned by ZTE above) is also regarded as valuable inputs to gNB pending on FFS. |

# Conclusion

TBD

# References

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| [1] | R1-2302267 | LS on the UE SRS IL imbalance issue | Huawei, HiSilicon |
| [2] | R4-2300696 | 8RX UE RF requirements | Qualcomm |
| [3] | R4-2301763 | On FR1 8Rx UE RF requirements | Huawei, HiSilicon |
| [4] | R1-2303270 | Discussion on RAN4 LS on the UE SRS IL imbalance issue | Nokia |
| [5] | R1-2303457 | SRS IL Reply LS | Intel |
| [6] | R1-2303563 | Draft reply to RAN 4 LS on the UE SRS IL imbalance issue | Qualcomm |
| [7] | R1-2303657 | Discussion on RAN4 LS on the UE SRS IL imbalance issue | ZTE |
| [8] | R1-2303860 | Discussion on the UE SRS IL imbalance issue | Huawei, HiSilicon |