**3GPP TSG-RAN WG4 Meeting # 111 R4-2408937**

**Fukuoka, Japan, May 20 – May 24, 2024**

**Agenda item:** 10.1.2

**Source:** Moderator (AT&T)

**Title:** Topic summary for [111][126] NR\_ENDC\_RF\_Ph4\_part3

**Document for:** Information

# Introduction

This document summarizes the contributions submitted under agenda item 10.1.1.4. The topics that are covered include REFSENS (delta RIB,6R), SRS antenna switching and ΔTRxSRS, MIMO layer evaluation for 6Rx UE, and SRS IL imbalance issue.

# Topic #1: REFSENS (delta RIB,6R)

## Companies’ contributions summary

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| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2407071 | Apple | Observation 1: Due to limited area to accommodate more antennas, achieving good REFSENS for 6Rx will be challenging due to sub-optimal component placement, and severe RF coupling due to poor isolation between the different the Rx paths.  Proposal 1: We recommend using the following values for ΔRIB,6R:   |  |  | | --- | --- | | ***Operating band*** | ***ΔRIB,6R (dB)*** | | n41 | -3.3 | | n77, n78, n79, n104 | -3.0 | |
| R4-2407313 | MediaTek Inc. | Proposal 1: Define the same ΔRIB,6R value for handheld UE and FWA.  Proposal 2: Define ΔRIB,6R for band n41 as -3.4dB, and for bands n77/n78/n79/n104 as -3.1dB. |
| R4-2407552 | CATT | Proposal 1: RAN4 not to draw a conclusion on whether to classify band n104 within the high band category and leave it as an implementation issue.  Proposal 2: RAN4 to specify the same ΔRIB,6R for both handheld UEs and FWA devices. |
| R4-2407803 | Xiaomi | Proposal 1: RAN4 to define ΔRIB,6R in following table for both handheld UE and FWA.   |  |  | | --- | --- | | **Operating band** | **ΔRIB,6R (dB)** | | n41 | -3.2 | | n77, n78, n79, n104 | -3.0 | |
| R4-2407988 | LG Electronics | Observation 1: The frequency range of 4Rx high band (n48, n77, n78, n79 and n104) is quite broad, around 3800 MHz. In the case of 4 Rx, the n104 band could be considered a high band because the high frequency performance degradation of 4Rx UEs is less than 6Rx or 8Rx UEs. The complexity of UEs for 6Rx or 8Rx can be higher than 4Rx UEs, which may result in a higher potential for high frequency performance degradation.  Observation 2: Depending on the operating frequency bands, the optimum antenna placement may vary and may affect the REFSENS. For example, handheld UEs typically have less space for antenna placement than FWA UEs, which means that applying the optimal antenna placement for the handheld UEs can be more difficult than FWA UEs.  Observation 3: The 6Rx UEs are more complex than 4Rx but less complex than 8Rx, therefore the Relaxation6Rx can be considered to be larger than Relaxation4Rx (0.3~0.8 dB) and smaller than Relaxation8Rx (1.5~2 dB).  Proposal 1: It is necessary to consider different frequency category between UHB (n104) and HB (n77, n78 and n79).  Proposal 2: It is necessary to consider the more REFSENS relaxation for handheld UEs than for the FWA UEs.  Proposal 3: ΔRIB,6R can be defined considering following range.  ΔRIB,6R = -4.77 (ideal ΔRIB,6R) + Relaxation6Rx  [0.3 ~0.8] dB< Relaxation6Rx<[1.5~2] dB |
| R4-2407992 | Spreadtrum Communications | Proposal 1: n104 should be included in the high band (n77, n78, n79) category for 6RX case.  Proposal 2: Different values are used for hand held UE and FWA.  Proposal 3: Adopt the value of ΔRIB,6R in Table1 for n41/n77/n78/n79/n104 for handheld UE and FWA.  **Table1: Six antenna port reference sensitivity allowance ΔRIB,6R**   |  |  | | --- | --- | | **Operating band** | **ΔRIB,6R (dB)** | | n41 | -3.61,-3.32 | | n77, n78, n79, n104 | -3.21,-3.02 | | NOTE 1: When 6 Rx operation is supported by FWA form factor.  NOTE 2: When 6 Rx operation is supported by handheld UE. | | |
| R4-2408031 | Meta Ireland | Proposal 1: Based on the 2Rx REFSENS requirements, the 6Rx REFSENS levels for HHUE and FWA UE would be specified with ΔRIB,6R as follow:  - ΔRIB,6R is [- 3.0] dB for n77, n78, n79 and n104  - ΔRIB,6R is [- 3.3] dB for n41  Proposal 2: If RAN4 agrees to specify the REFSENS based on REFSEN equation, then we are also fine to make consensus with the diversity gain of 6Rx and other parameters such as IM level.  Proposal 3: For n104 of 6Rx supporting, RAN4 can apply the same ΔRIB,6R as above proposal 1 since RAN4 already defined 2Rx and 4Rx REFSENS requirements in TS38.101-1 even though the Note 10 has been included in REFSENS Table 7.3.2-1b for TDD bands. |
| R4-2408124 | vivo | Proposal 1: Confirm that this ambiguity of n104 applicability for 2Rx is not relevant to 6Rx REFSENS requirements since 6Rx is always optional.  Proposal 2: It is suggested to define ΔRIB,6R as:   * -3dB for ΔRIB,6R value for all bands n41, n77, n78, n79, n104, for FWA and Handheld UE   Or   * different values for FWA and Handheld  |  |  |  | | --- | --- | --- | | Operating bands | ΔRIB,6R for FWA | ΔRIB,6R for Handheld | | n77, n78, n79, n104 | -3.2 dB | -3.0 dB | | n41 | -3.4 dB | -3.2 dB | |
| R4-2408354 | ZTE Corporation, Sanechips | Proposal 1: The same ΔRIB,6R value is used for handheld UE and FWA.  Proposal 2: ΔRIB,6R = -3.5dB for band n41, and ΔRIB,6R = -3dB for n77/n78/n79/n104. |
| R4-2408725 | Nokia | Observation 1: RAN4 should only select a single value for ΔRIB,6R  Proposal 1: ΔRIB,6R = -4 dB for bands n1, n2, n3, n5, n7, n8, n13, n25, n26, n28, n30, n40, n34, n38, n39, n41, n66, n70, n71, n85, n105.  Proposal 2: No other ΔRIB,6R is defined for these bands. |
| R4-2408726 | Nokia | Proposal 3: 6Rx REFSENS without 6-layer MIMO is release independent from Rel-15. |
| R4-2408759 | OPPO | Proposal 1: Define 6Rx ΔRIB,6R for n41 as 3.6dB, and for n78/n77/n79/n104 as 3.2dB for both handheld UE and FWA. |
| R4-2408840 | Qualcomm France | Proposal 1: Use the following ΔRIB,6R for both handheld and FWA   |  |  | | --- | --- | | **Operating band** | **ΔRIB,6R (dB)** | | n41 | -3.5 | | n77, n78, n79, n104 | -3.0 | |
| R4-2409049 | Google Inc. | Proposal 1: For n77/n78/n79, considering that the different implementation complexity for the handheld UE and the FWA UE, it is proposed to determine ΔRIB,6R = -3.0 for the handheld UE and ΔRIB,6R = -3.3 for the FWA UE.  Proposal 2: For n41, considering that the different implementation complexity for the handheld UE and the FWA UE, it is proposed to determine ΔRIB,6R = -3.4 for the handheld UE and ΔRIB,6R = -3.7 for the FWA UE.  Proposal 3: Considering the frequency range of n104 is much higher than n77/n78/n79, PCB tracing loss and RFFE insertion loss may become higher for n104 6Rx UE implementation. Hence, it is proposed to differentiate ΔRIB,6R requirements for n104 from the high-band categories n77/n78/n79, and the ΔRIB,6R value for n104 can be further discussed. |
| R4-2409172 | Huawei, HiSilicon | Observation 1: Due to form factor limitation, physical antenna layout in order to accommodate increased Rx number could lead to compromised performance on:   * RF isolation * Antenna efficiency   Such degradation could be more severe for higher frequency range.  Proposal 1: Check whether ΔRIB,6R for the example bands n41, n77/n78, n79 can be -3dB for FWA UE:   * Further check the ΔRIB,6R for n104. * Further check whether to apply the same ΔRIB,6R for handheld UE. |
| R4-2409666 | Ericsson | Observation 1 : There is no difference between the handheld and FWA devices for ΔRIB,4R requirement with the example bands of this WI.  Observation 2: Following a similar approach, existing ΔRIB requirements for 4Rx and 8Rx can be used to predict the value of ΔRIB for 6Rx.  Proposal 1: It is proposed to use -3.6 dB for ΔRIB for 6Rx for n41, and -3.2 dB for n77, n78, n79 and n104. |

## Open issues summary

### Sub-topic 1-1: General considerations for specifying ΔRIB,6R value

**Issue 1-1-1: Whether band n104 should be included in the high band (n77, n78 and n79) category for 6Rx case**

* Proposals
  + Option 1: Include n104 in the high band (n77, n78, n79) category (Apple, MediaTek, Xiaomi, Spreadstrum, Meta, vivo, ZTE, Sanechips, OPPO, Qualcomm, Ericsson)
  + Option 2: Treat n104 separately as ultra-high band for 6Rx requirement (LGE, Google)
  + Option 3: RAN4 defers decision on band n104 being included in the high band (n77, n78 and n79) category (CATT, Huawei, HiSilicon)
* Recommended WF
  + Option 1.

LGE: We do not agree with option 1 without option 2. We should consider n104 separately.

Huawei: Agree with LGE. More consideration is needed. We have CR to check whether the delta\_T SRS should be re-considered.

Google: Same view as LGE. In our view, we prefer to remove n104 from high band group.

OPPO: we are OK to remove it from high band.

Qualcomm: in our view, if n104 is treated separately, the requirements can be applied to n104 in the same way as for others.

Moderator: the delta\_T\_SRS will be treated in the other topic. We cannot delay the WI although we treat n104 separately.

Mediatek: prefer option 1. We can use n77~n79 as reference for n104.

OPPO: for n104, we can provide more input.

Vivo: for 4Rx or 6Rx, we do not differentiate n104 from others. We are OK to option 3.

Ericsson: We prefer to use option 1 to categorize n77~79 and n104.

ZTE: Prefer to use option 1.

LGE: To middle band and high band, why do we specify the middle band and high band separately for delta-R\_IB.

Apple: Prefer to option 1 for REFSENS. But delta\_T\_SRS can be treated separately for n104.

CATT: the band categorization considers the implementation impact. We propose option 3.

Agreement:

* For ΔRIB,6R, include n77, n78, n79 and [n104] into the same group.

**Issue 1-1-2: Whether to use same ΔRIB,6R value for handheld UE and FWA**

* Proposals
  + Option 1: RAN4 needs to determine whether to define different ΔRIB,6R value for handheld UE and FWA separately (LGE, vivo, Huawei, HiSilicon)
  + Option 2: Same value for handheld UE and FWA (MediaTek, CATT, Xiaomi, Meta, ZTE, Sanechips, Nokia, OPPO, Qualcomm, Ericsson)
  + Option 3: Different value for handheld UE and FWA (Spreadtrum, Google)
* Recommended WF
  + Option 2.

Spectrum: support option 3. There are difference between FWA and UE.

Google: for 6Rx handheld UE, it uses the legacy antenna. Some antenna switcher may be needed. Prefer to option 3.

LGE: Prefer option 1 and option 3. We can tighten the requirements for FWA.

Nokia: Support option 2. Only single value applies to handheld UE and FWA. The value should be based on FWA. It is optional feature. We can request the better performance for handheld UE.

Vivo: Suggest to go through the value and average them to get the results. If the gap between handheld and FWA is small, we can use the same requirement. Otherwise we need separate requirements.

LGE: It is pre-mature to decide the same set of requirements for handheld and FWA. We can do the same study as for 3Tx first.

Qualcomm: Option 2 is straightforward. The very similar data is provided for handheld and FWA from companies.

OPPO: Vivo suggestion is good.

Mediatek: share the similar view as Qualcomm an OPPO. We can first check the averaged value.

Apple: Support option 2.

CATT: our proposal is option 2. We are also OK to leave it open. We are not OK to make decision now.

LGE: the Delta\_R\_IB values in 4Rx are different between handheld and FWA.

Moderator: even with the contributions, the difference is small between UE handheld and FWA, e.g., 0.2dB.

Nokia: Similar view as CATT.

Qualcomm: to LGE, the delta\_R-IB are different only for low bands.

**Issue 1-1-3: Release independence of ΔRIB,6R value**

* Proposals
  + Proposal 1: 6Rx REFSENS without 6-layer MIMO is release independent from Rel-15 (Nokia)
* Recommended WF
  + TBA

Chair: Defer the release independence discussions until the requirements are stable.

### Sub-topic 1-2: ΔRIB,6R values for handheld UE and FWA

**Issue 1-2-1: Proposed ΔRIB,6R values for handheld UE and FWA**

* Proposals
  + Option 1: Use the following values for ΔRIB,6R (Apple)

|  |  |
| --- | --- |
| ***Operating band*** | ***ΔRIB,6R (dB)*** |
| n41 | -3.3 |
| n77, n78, n79, n104 | -3.0 |

* + Option 2: Define ΔRIB,6R for band n41 as -3.4dB, and for bands n77/n78/n79/n104 as -3.1dB (MediaTek)
  + Option 3: Define ΔRIB,6R in following table for both handheld UE and FWA (Xiaomi)

|  |  |
| --- | --- |
| **Operating band** | **ΔRIB,6R (dB)** |
| n41 | -3.2 |
| n77, n78, n79, n104 | -3.0 |

* + Option 3: ΔRIB,6R can be defined considering following range. (LGE)
    - ΔRIB,6R = -4.77 (ideal ΔRIB,6R) + Relaxation6Rx
    - [0.3 ~0.8] dB< Relaxation6Rx<[1.5~2] dB
  + Option 4: Adopt the value of ΔRIB,6R in table below for n41/n77/n78/n79/n104 for handheld UE and FWA (Spreadtrum)

|  |  |
| --- | --- |
| **Operating band** | **ΔRIB,6R (dB)** |
| n41 | -3.61,-3.32 |
| n77, n78, n79, n104 | -3.21,-3.02 |
| NOTE 1: When 6 Rx operation is supported by FWA form factor.  NOTE 2: When 6 Rx operation is supported by handheld UE. | |

* + Option 5: Specify handheld UE and FWA UE with ΔRIB,6R as follows: (Meta)
    - ΔRIB,6R is [- 3.0] dB for n77, n78, n79 and n104
    - ΔRIB,6R is [- 3.3] dB for n41
  + Option 6: Define -3dB for ΔRIB,6R value for all bands n41, n77, n78, n79, n104, for FWA and Handheld UE (vivo)
  + Option 7: Define different values for FWA and Handheld as follows (vivo)

|  |  |  |
| --- | --- | --- |
| Operating bands | ΔRIB,6R for FWA | ΔRIB,6R for Handheld |
| n77, n78, n79, n104 | -3.2 dB | -3.0 dB |
| n41 | -3.4 dB | -3.2 dB |

* + Option 8: ΔRIB,6R = -3.5dB for band n41, and ΔRIB,6R = -3dB for n77/n78/n79/n104 for FWA and handheld UE. (ZTE, Sanechips, Qualcomm)
  + Option 9: ΔRIB,6R = -4 dB for bands n1, n2, n3, n5, n7, n8, n13, n25, n26, n28, n30, n40, n34, n38, n39, n41, n66, n70, n71, n85, n105 (Nokia)
  + Option 10: Define ΔRIB,6R for n41 as -3.6dB, and for n78/n77/n79/n104 as -3.2dB for both handheld UE and FWA (OPPO, Ericsson)
  + Option 11: Define different values for FWA and Handheld as follows (Google)

|  |  |  |
| --- | --- | --- |
| Operating bands | ΔRIB,6R for FWA | ΔRIB,6R for Handheld |
| n77, n78, n79 | -3.3 dB | -3.0 dB |
| n41 | -3.7 dB | -3.4 dB |

* + Option 12: Specify ΔRIB,6R for the example bands n41, n77/n78, n79 as -3dB for FWA UE (Huawei)
  + Option 13: Consider range of ΔRIB,6R in brackets for each case based on existing proposals above for further discussion.
* Recommended WF
  + TBA

Apple: we can merge 1, 2, 3 and 5.

Nokia: almost all the values are really old. Provide the analysis.

Huawei: We can consider the moderator suggestions.

Meta: we prefer to average all the proposed values for the requirement.

CATT: set the deadline to collect the input.

# Topic #2: SRS antenna switching and ΔTRxSRS

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2407552 | CATT | Proposal 3: RAN4 to focus on discussing ∆TRxSRS until RAN1 concludes works on 3T6R and 4T6R. |
| R4-2407804 | Xiaomi | Observation 1: RAN4 postpones the discussion on ∆TRxSRS requirements for t3r6 and t4r6 configuration unless RAN1 agrees to support t36r and t46r SRS antenna switching.  Proposal 1: The ∆TRxSRS for t1r6 is defined in table 1.  **Table 1: SRS IL link budget for t1r6**   |  |  |  | | --- | --- | --- | |  | **Bands whose FUL\_high is lower than the FUL\_low of n79 (dB）** | **Bands whose FUL\_high is higher than the FUL\_low of n79 (dB）** | | **Ant 3/4/5/6** | **2\*SP2T+PCB trace loss = 2\*0.5+1.8 = 2.8dB** | **2\*SP2T+PCB trace loss = 2\*0.6+2.4 = 3.6dB** |   Proposal 2: The ∆TRxSRS for t1r6 is defined in table 2.  **Table 2: SRS IL link budget for t2r6**   |  |  |  | | --- | --- | --- | |  | **Bands whose FUL\_high is lower than the FUL\_low of n79 (dB）** | **Bands whose FUL\_high is higher than the FUL\_low of n79 (dB）** | | **Ant 2/3/4/6** | **SP2T+PCB trace loss = 0.5+1.8 = 2.3dB** | **SP2T+PCB trace loss = 0.6+2.4 = 3dB** |   Proposal 3: The ∆TRxSRS for t1r6 and t2r6 is defined in table 3.  **Table 3: SRS IL link budget for t1r6 and t2r6**   |  |  |  | | --- | --- | --- | |  | **Bands whose FUL\_high is lower than the FUL\_low of n79 (dB）** | **Bands whose FUL\_high is higher than the FUL\_low of n79 (dB）** | | **Ant 6** | **3\*SP2T+PCB trace loss = 3\*0.5+1.8 = 3.3dB** | **3\*SP2T+PCB trace loss = 3\*0.6+2.4 = 4.2dB** | |
| R4-2407989 | LG Electronics | Proposal 1: Concentrate on t1r6 and t2r6 first before deciding on 3T6R and 4T6R from RAN1.   * 6Rx SRS antenna switching IL scenarios regarding t1r6 and t2r6.   + t1r6   + t2r6   + t1r6-t2r6   Proposal 2: Consider RF impairments as shown in below for analysing the ΔTRxSRS values.   * RF impairments for analysing the ΔTRxSRS values.   + Switches (SPDT, SP3T, DP3T etc.) insertion loss   + SRS feed line insertion loss   Proposal 3: It is necessary to consider the different ΔTRxSRS values depending on the operating frequency. |
| R4-2407993 | Spreadtrum Communications | Proposal 1: support option3. RAN4 discussion on 6 Rx ΔTRxSRS requirements should focus on 1T6R and 2T6R.  Proposal 2: Adopt the value of ΔTRxSRS in Table 1 for 1T6R, 2T6R for PC3 in Table 1.  **Table 1: ΔTRxSRS for 1T6R, 2T6R for PC3**   |  |  |  | | --- | --- | --- | | UE capability | Bands whose FUL\_high is lower than the FUL\_low of n79 (dB） | Bands whose FUL\_high is higher than the FUL\_low of n79 (dB） | | 1T6R/1T6R-2T6R | 3.5 | 5 | | 2T6R | 3 | 4.5 | |
| R4-2408031 | Meta Ireland | Proposal 4: RAN4 need to define the detailed ΔTRxSRS values based on actual RF architecture with multiple switches to support 6Rx.  Proposal 5: RAN4 can update the work scope in WID with the final SRS antenna configurations based on RAN1 feedback regarding support for T3R6 and T4R6 SRS antenna configurations or not. |
| R4-2408126 | vivo | Proposal 1: Define ΔTRxSRS requirements for 6Rx as follows.   |  |  |  |  | | --- | --- | --- | --- | | Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 | | Band n41, n77, n78 | 4 dB | 3.5 dB | 5.5 dB | | Band n79 | 5 dB | 4.0 dB | 6.5 dB | |
| R4-2408355 | ZTE Corporation, Sanechips | Proposal 1. Postpone 4T6R and 3T6R SRS antenna switching discussion in May meeting.  Proposal 2. Apply 4.5dB for n41/n77/n78 and 5.5dB for n79 for t1r6 ΔTRxSRS requirements.  Proposal 3. Apply 4dB for n41/n77/n78 and 5dB for n79 for t2r6 ΔTRxSRS requirements.  Proposal 4. Apply 5dB for n41/n77/n78 and 6dB for n79 for t1r6-t2r6 ΔTRxSRS requirements. |
| R4-2408761 | OPPO | Proposal 1: The additional SRS IL for antenna switching capability of t1r6 can be defined as 6dB @<3.5GHz, and 7.5dB @4.9GHz.  Proposal 2: The additional SRS IL for antenna switching capability of t2r6 is 3dB@<3.5GHz, and 3.8dB@4.9GHz.  Proposal 3: The additional SRS IL for antenna switching capability of t2r6+t1r6 is 4.5dB@<3.5GHz, and 6dB@4.9GHz.  Summarized values:   |  |  |  | | --- | --- | --- | |  | **<3.5GHz** | **4.9GHz** | | **t1r6** | 6 | 7.5 | | **t2r6** | 3 | 3.8 | | **t1r6 + t2r6** | 4.5 | 6 | |
| R4-2408841 | Qualcomm France | Proposal 1: Use the same ΔTRxSRS for 1T6R, 2T6R, and 1T6R-2T6R as specified for 1T8R, 2T8R, and 1T8R-2T8R, respectively. |
| R4-2409052 | Google Inc. | Proposal 1: It is proposed to preclude 3T6R and 4T6R SRS antenna switching configurations for 6 Rx ΔTRxSRS requirements in Rel-19. |
| R4-2409174 | Huawei, HiSilicon | Observation 1: Ultra high frequency bands e.g. n104 may need further check for the ΔTRxSRS requirements.  Proposal 1: Adopt the following framework regarding ΔTRxSRS requirements.   * When antenna switching SRS capability is indicated as 't1r6' or ‘t2r6’:   + 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*.     - For the bands whose FUL\_high is lower than the FUL\_low of n79, the value of ΔTRxSRS is [4] dB.     - For the bands whose FUL\_high is lower than the FUL\_low of n104, the value of ΔTRxSRS is [5.5] dB.     - For the bands whose FUL\_high is higher than the FUL\_low of n104, the value of ΔTRxSRS is [TBD] dB. * When antenna switching SRS capability is indicated as 't1r6-t2r6':   + 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*.     - For the bands whose FUL\_high is lower than the FUL\_low of n79, the value of ΔTRxSRS is [4.5] dB.     - For the bands whose FUL\_high is lower than the FUL\_low of n104, the value of ΔTRxSRS is [6] dB.     - For the bands whose FUL\_high is higher than the FUL\_low of n104, the value of ΔTRxSRS is [TBD] dB. |
| R4-2409760 | Ericsson | Proposal 1: For ‘t1r6’ AS capability, for bands n41 and n77/78 ∆TRxSRS should be specified as 3.5 dB, while for band n79 ∆TRxSRS should be specified as 5.0 dB.  Proposal 2: For ‘t2r6’ AS capability, for bands n41 and n77/78 ∆TRxSRS should be specified as 3.5 dB, while for band n79 ∆TRxSRS should be specified as 5.0 dB.  Proposal 3: For ‘t1r6-t2r6’ AS capability, for bands n41 and n77/78 ∆TRxSRS should be specified as 4.0 dB, while for band n79 ∆TRxSRS should be specified as 5.5 dB. |

## Open issues summary

### Sub-topic 2-1: General considerations for SRS antenna switching and ΔTRxSRS

**Issue 2-1-1: SRS antenna switching configurations**

* Proposals
  + Proposal 1: RAN4 to focus on discussing ∆TRxSRS for 1tr6 and t2r6 until RAN1 concludes works on 3t6r and 4t6r (CATT, Xiaomi, LGE, Spreadtrum, ZTE Corporation, Sanechips)
  + Proposal 2: Preclude t3r6 and t4r6 SRS antenna switching configuration for 6Rx in Rel-19 and update the WID objective in the next plenary. (Google)
  + Proposal 3: RAN4 can update the work scope in WID with the final SRS antenna configurations based on RAN1 feedback regarding support for t3r6 and t4r6 SRS antenna configurations or not (Meta)
* Recommended WF
  + Proposal 1 can be endorsed (endorsed in WF at RAN4#110bis). Proposal 3 can be further discussed after RAN1 feedback.

**Issue 2-1-2: Whether to use different ∆TRxSRS based on operating frequency**

* Proposals
  + Proposal 1: RAN4 defines different ∆TRxSRS values based on operating frequency (Xiaomi, LGE, Spreadtrum, vivo, ZTE Corporation, Sanechips, OPPO, Qualcomm, Huawei, HiSilicon, Ericsson)
  + Proposal 2: Consider additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of n104 (Huawei, HiSilicon)
* Recommended WF
  + Proposals 1 can be endorsed. Proposal 2 needs further discussion based on company contributions given that n104 was excluded from some of the proposed ∆TRxSRS values.

### Sub-topic 2-2: ΔTRxSRS values

**Issue 1-2-1: Proposed ∆TRxSRS values**

* Proposals
  + Option 1: Use the following values for ΔTRxSRS (Xiaomi)

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 2.8 dB | 2.3 dB | 3.3 dB |
| Band n79, n104 | 3.6 dB | 3.0 dB | 4.2 dB |

* + Option 2: Use the following values for ΔTRxSRS (Spreadtrum)

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 3.5 dB | 3.0 dB | 3.5 dB |
| Band n79, n104 | 5.0 dB | 4.5 dB | 5.0 dB |

* + Option 3: Use the following values for ΔTRxSRS (vivo)

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 4.0 dB | 3.5 dB | 5.5 dB |
| Band n79 | 5.0 dB | 4.0 dB | 6.5 dB |

* + Option 4: Use the following values for ΔTRxSRS (ZTE Corporation, Sanechips)

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 4.5 dB | 4.0 dB | 5.0 dB |
| Band n79 | 5.5 dB | 5.0 dB | 6.0 dB |

* + Option 5: Use the following values for ΔTRxSRS (OPPO)

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 6.0 dB | 3.0 dB | 4.5 dB |
| Band n79 | 7.5 dB | 3.8 dB | 6.0 dB |

* + Option 6: Use the following values for ΔTRxSRS (Qualcomm)

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 4.0 dB | 4.0 dB | 4.5 dB |
| Band n79, n104 | 5.5 dB | 5.5 dB | 6.0 dB |

* + Option 7: Use the following values for ΔTRxSRS (Huawei)

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | [4.0] dB | [4.0] dB | [4.5] dB |
| Band n79 | [5.5] dB | [5.5] dB | [6.0] dB |

* + Option 8: Use the following values for ΔTRxSRS (Ericsson)

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 3.5 dB | 3.5 dB | 4.0 dB |
| Band n79 | 5.0 dB | 5.0 dB | 5.5 dB |

* + Option 9: Use the average values from companies as summarized below for ΔTRxSRS as a starting point

**Table: Averaged values based on proposals**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Operating Bands | ΔTRxSRS t1r6 (dB) | ΔTRxSRS t2r6 (dB) | ΔTRxSRS t1r6-t2r6 (dB) |
| Xiaomi | Band n41, n77, n78 | 2.8 | 2.3 | 3.3 |
| Band n79, n104 | 3.6 | 3 | 4.2 |
| Spreadtrum | Band n41, n77, n78 | 3.5 | 3 | 3.5 |
| Band n79, n104 | 5 | 4.5 | 5 |
| vivo | Band n41, n77, n78 | 4 | 3.5 | 5.5 |
| Band n79 | 5 | 4 | 6.5 |
| ZTE | Band n41, n77, n78 | 4.5 | 4 | 5 |
| Band n79 | 5.5 | 5 | 6 |
| OPPO | Band n41, n77, n78 | 6 | 3 | 4.5 |
| Band n79 | 7.5 | 3.8 | 6 |
| Qualcomm | Band n41, n77, n78 | 4 | 4 | 4.5 |
| Band n79, n104 | 5.5 | 5.5 | 6 |
| Huawei | Band n41, n77, n78 | 4 | 4 | 4.5 |
| Band n79 | 5.5 | 5.5 | 6 |
| Ericsson | Band n41, n77, n78 | 3.5 | 3.5 | 4 |
| Band n79 | 5 | 5 | 5.5 |
| **Average** | Band n41, n77, n78 | **4.0** | **3.4** | **4.4** |
| Band n79, [n104] | **5.3** | **4.5** | **5.7** |

# Topic #3: MIMO layer evaluation for 6Rx UE

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2407272 | Apple | Observation 1: Achieving full rank requires good antenna isolation and low correlation, which is challenging to obtain when increasing the number of receive antennas to 6Rx.  Observation 2: The gains between 6Rx vs 4Rx in terms of diversity are clear, but demodulation performance analysis at high throughput conditions needs to be carried between 6Rx / 6L vs 6Rx / 4L.  Proposal 1: For high throughput conditions consider TDLA30-10 and 256QAM modulation as baseline.  Observation 3: RAN4 could reuse the existing 3GPP MIMO correlation models to capture the effect of the limited form factor constraint.  Observation 4: For the Rank 6 transmission scenario, there is actually no codebook defined for 6Tx.  Observation 5: As per WID, the specified requirements can be applicable to both handheld UE and FWA devices.  Proposal 2: RAN4 should consider 4Tx-6Rx and 8Tx-6Rx as the antenna configurations for 4-layer and 6-layer transmissions respectively.  Proposal 3: RAN4 should define a single set of requirements, taking handheld UE as the baseline.  Proposal 4: RAN4 should discuss down select between ULA High and ULA Medium MIMO correlation to model the effect of more antennas in a limited form factor.  Proposal 5: RAN4 to consider the following baseline PDSCH simulation assumptions.  **Table 1: Baseline simulation assumptions for PDSCH performance**   |  |  |  | | --- | --- | --- | | Parameter | | Value | | Duplex mode | | FDD/TDD | | TDD pattern | | 7D1S2U  S=6D:4G:4U | | SCS(kHz)/Bandwidth (MHz) | | TDD: 30/40 | | MIMO layer and Antenna configuration | | Rank 4: 4x6  Rank 6: 8x6 | | Propagation condition and antenna correlation | | ULA Medium (α = 0.3, β = 0.9)  ULA High (α = 0.9, β = 0.9) | | MCS | | 256QAM Table: MCS20, MCS22, MCS24 | | PDSCH configuration | Mapping type | Type A | |  | k0 | 0 | |  | Starting symbol (S) | 2 | |  | Length (L) | 12 | |  | PRB bundling type | Static | |  | PRB bundling size | 2 | | PDSCH DMRS configuration | DMRS Type | Type 1 | |  | Number of additional DMRS | 1 | |  | Maximum number of OFDM symbols (maxLength) for DL | Single-symbol / Double-symbol | | TRS configuration | | Symbol#{5, 9} | | PT-RS | | Not configured | | NZP-CSI-RS configuration | | row 6 | | Overhead | | 0 | | N1 and N2 configurations for 8Tx cases | | Use (N1,N2) = (4,1), (O1, O2) = (4,1) | | Coodebook for PDCCH for PDSCH tests with 4Tx and 8Tx | | Keep same number of Tx for PDSCH and PDCCH during PDSCH test. Set “codebookMode” to 1 | | Special slot (S slot) scheduling | | Not schedule PDSCH in special slot | | Number of HARQ Processes | | TDD: 8 | | HARQ ACK/NACK bundling | | Not configured | | Maximum HARQ transmissions | | 4 | | Redundancy version coding sequence | | {0,2,3,1} | | PDSCH & PDSCH DMRS Precoding configuration | | Single Panel Type I, Random precoder selection updated per slot, with equal probability of each applicable i1, i2 combination, and with PRB bundling granularity | | Tx EVM (Explicitly modeled in the simulation) | | 256QAM:3% | | Test metric | | SNR@70% max Throughput |   (Other common parameters, refer to TS 38.101-4: Table 5.2-1: Common test parameters for PDSCH)  Proposal 6: The support of 6 MIMO layers should remain optional. |
| R4-2407698 | MediaTek Inc | Observation 1: Consider reasonable MIMO correlation, the lowest SNR for 6Rx-6Layer to outperform 6Rx-4Layer is expected to be higher than 33dB.  Observation 2: The current BS EVM requirement for 256QAM is 3.5% which corresponds to a 29.1dB SNR upper bound.  Proposal 1: RAN4 should also discuss the need of tightening BS EVM requirement when discussing the feasibility of 6-Layer MIMO for 6Rx UEs. |
| R4-2408031 | Meta Ireland | Proposal 6: RAN4 can support 6 MIMO layer in this WID based on the performance evaluation campaign for HHUE and FWA. It means that the benefits of 6 MIMO layers compared to 4 MIMO layers should first be evaluated and verified and then, RAN4 need further analyse of the impact of the device types in terms of the additional RF load and power consumption. |
| R4-2408125 | vivo | Observation 1: Under high SNR condition, 6 MIMO layer has gain over 4 MIMO layer with fixed MCS and Rank.  Observation 2: When enabling MCS and Rank adaption, 6 MIMO layer has no gain over 4 MIMO layer.  Observation 3: For different Rx correlation, it shares similar trend for the SNR-Throughput cures for 4 and 6 MIMO layers. With poor Rx correlation, it requires better SNR conditions when 6 MIMO layer outperforms 4MIMO layer.  Observation 4: Compared with TDL, it is more challenging to achieve gain for 6 MIMO layer under CDL channel model.  Observation 5: Under high SNR and relatively small MCS (e.g., MCS 13/18), it shows gain for 6 MIMO layer with fixed MCS and Rank.  Observation 6: When enabling MCS and Rank adaption, 4 MIMO layer outperforms 6 MIMO layer.  Observation 7: In the practical deployment, it is more feasible to enable MCS and Rank adaption to adapt the dynamically changed traffic and channel state.  Observation 8: It is more appropriate to evaluate the support of 6 MIMO layer based on the CDL channel model with its specific spatial DoF.  Proposal 1: At least for handheld UE, do not support 6 MIMO layer for 6Rx. |
| R4-2408726 | Nokia | Proposal 2: If RAN4 decides to specify requirements for 6-layer MIMO then it is release independent from Rel-19. |
| R4-2408760 | OPPO | Observation 1: Some UEs on the market already implement 6Rx antennas.  Proposal 1: Confirm it is feasible to support 6Rx for smartphone in high frequency bands.  Observation 2: The design of 6Rx antennas is no more difficult than the Low band 4Rx antennas, the antenna efficiency and correlation can support up to 6Layers from antenna perspective.  Proposal 2: Introduce 6Layer as an optional feature for smartphone/CPE in high frequency bands. |
| R4-2408843 | Qualcomm France | Observation 1: 6L is feasible in smartphone form-factor and provides good gains compared with 4L.  Proposal 1: Specify requirements to support 6 MIMO layers for handheld and FWA devices. |
| R4-2409050 | Google Inc. | Proposal 1: For the handheld UE equipped with 6Rx, considering that 6 MIMO layer may suffer more performance degradation from higher antenna correlation than 4 MIMO layers and that the antenna implementation complexity is very high, it is proposed not to introduce 6 MIMO layer for 6Rx handheld UE in Rel-19. |
| R4-2409091 | ZTE Corporation, Sanechips | Observation 1. The correlation between the transmitter antennas and the receiver antennas will reduce the channel capacity.  Observation 2. The handle UE cannot fully exploit the technical benefits of 6 MIMO layers using 6Rx due to practical physical limitations.  Observation 3. Currently, there is no antenna correlation data can be provided for 6Rx for handle UE.  Proposal 1. 6 MIMO layers are perfectly feasible for FWA devices at least.  Proposal 2. RAN4 shall first evaluate the performance of 6 MIMO layers. And then decide whether need to introduce 6 MIMO layers for the handle UE. |
| R4-2409173 | Huawei, HiSilicon | Observation 1: Antenna correlation matrixes defined in 36.101 and 38.101-4 are for performance testing and can’t reflect the real antenna correlation of a UE device.  Proposal 1: Discuss possible 6Rx realizations and choose typical one to derive antenna correlation for simulation evaluation.  Proposal 2: Consider handheld UE for MIMO layers evaluation. |
| R4-2409459 | Samsung | Observation 1: RAN4 first needs to study the gain and feasibility of 6 MIMO layers in addition to existing 4 MIMO layers considering practical form factors and implementation constraints.  Observation 2: It would be a different story between ‘any space for more antennas’ and ‘enough space for more layers’ for handheld UEs.  Observation 3: Higher MIMO layer does not help to increase the throughput gain as it will lead to the lower order MCS than the legacy MIMO layer case practically.  Observation 4: Legacy antenna performance will be degraded since we observed that the antenna isolation of some pairs between antennas is even less than 10 dB assuming that the same UE capability and form factor, which has no benefit from the additional efforts.  Observation 5: Even if larger handheld form factors are considered, it should be noted that they seldom use multiple RF circuits in each fold dues to RF connection loss and design complexity.  Proposal 1: 6 MIMO layers can be considered restricted to FWA UEs only. |
| R4-2409667 | Ericsson | Observation 1: The evaluation of demodulation performance depends on the antenna correlation assumptions.  Observation 2: With TDLA30-10 low antenna correlation condition, it is observed the performance gain with 6 layers over 4 layers for QPSK and 16QAM.  Observation 3: With TDLA30-10 medium and high antenna correlation conditions, it is not observed the performance gain with 6 layers compared with 4 layers.  Proposal 1: Support of MIMO 6 layers should be evaluated considering the impact of antenna correlation as well as the feasibility and probability of achieving a rank 6 channel in the practical deployment scenario. |

## Open issues summary

### Sub-topic 3-1: General considerations for MIMO layer evaluation for 6Rx UE

**Issue 3-1-1: Tightening BS EVM requirement**

* Proposals
  + Proposal 1: RAN4 should also discuss the need of tightening BS EVM requirement when discussing the feasibility of 6-Layer MIMO for 6Rx UEs (MediaTek)
* Recommended WF
  + TBA

**Issue 3-1-2: 6-Layer Performance Evaluation Assumptions**

* Proposals
  + Proposal 1: For high throughput conditions consider TDLA30-10 and 256QAM modulation as baseline (Apple).
  + Proposal 2: RAN4 should consider 4Tx-6Rx and 8Tx-6Rx as the antenna configurations for 4-layer and 6-layer transmissions respectively (Apple).
  + Proposal 3: RAN4 should discuss down select between ULA High and ULA Medium MIMO correlation to model the effect of more antennas in a limited form factor (Apple).
  + Proposal 4: RAN4 to consider the baseline PDSCH simulation assumptions in R4-2407272 (Apple).
* Recommended WF
  + TBA

**Issue 3-1-3: Whether to use same requirement for handheld UE and FWA**

* Proposals
  + Option 1: Define a single set of requirements, taking handheld UE as the baseline. (Apple)
  + Option 2: Defer decision after evaluation of 6 MIMO layer performance for handheld and FWA devices
* Recommended WF
  + TBA

### Sub-topic 3-2: 6-layer Support

**Issue 3-2-1: 6-layer Support**

* Proposals
  + Option 1: Specify requirements to support 6 MIMO layers for handheld and FWA devices (OPPO, Qualcomm)
  + Option 2: Specify requirements to support 6 MIMO layers for FWA devices only (vivo, Google, Samsung)
  + Option 3: Decision on support of 6 MIMO layers for handheld is deferred until performance level differences in comparison with 4 MIMO layers are known based on evaluations considering realistic antenna correlation assumptions and deployment scenarios (Apple, Meta, ZTE Corporation, Sanechips, Huawei, HiSilicon, Ericsson)
* Recommended WF
  + TBA

Huawei: Option 3 is the way forward. The discussion should involve demod people. Here we can focus on simulation assumption.

OPPO: Option 3 is OK for us. Antenna corelation assumption depends on UE vendor input.

Samsung: Option 3. We would like to consider real antenna assumption.

ZTE: Option 3 is only for handheld UE. For 6-layer, FWA UE can support 6-layer. For handheld UE we are open to discussion.

Verizon: Prefer option 1.

Vivo: Simulation assumptions are not aligned.

Mediatek: According the WID, RAN4 has feasibility study based on FWA and handheld. We focus on how to kick of the study, system level or link level.

Apple: we go with option 3. It means the proper analysis. In addition, how to set the requirement. We are talking about handheld UE as baseline.

Qualcomm: In principle we are OK with option 3. We should not limit to antenna correlation. We can decide it in our demodulation study.

Nokia: Similar as Qualcomm. It should be discussed in Demod room. Spatial channel modelling.

Intel: for FWA, 8Rx has been supported. So 6Rx is feasible for FWA. For handheld, we can do the analysis. Confused on comments that UE antenna correlation will be provided by companies. How can we converge? We should not preclude the good implementation.

CHTTL: Support Verizon and option 1 only. This WI focuses on handheld UE.

Qualcomm: We do not propose combine spatial channel model with the 6-layer study. To Intel, the correlation model is not realistic. We believe that the evaluation should take the real antenna correlation into account.

Moderator: option 3 seems agreeable.

Tentative Agreement:

* Decision on support of 6 MIMO layers for handheld is deferred until performance level differences in comparison with 4 MIMO layers are known based on evaluations considering realistic antenna correlation assumptions and deployment scenarios
  + Performance evaluation will be conducted in the demodulation session

**Issue 3-2-2: 6-layer Support as optional feature**

* Proposals
  + Option 1: Introduce 6 MIMO layers support as an optional feature (Apple, OPPO)
* Recommended WF
  + TBA

**Issue 3-2-3: Release independence of 6-layer Support**

* Proposals
  + Proposal 1: If RAN4 decides to specify requirements for 6-layer MIMO then it is release independent from Rel-19 (Nokia)
* Recommended WF
  + TBA

# Topic #4: SRS IL imbalance issue

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2407071 | Apple | Observation 2: The value of ∆TRxSRS relaxation will be higher for 6Rx compared to 4Rx due to the increase in UE integration complexity when more Rx paths are added.  Observation 3: Based on its implementation, it seems reasonable that the UE could implement some amount of compensation on its SRS ports to cope with the effects of SRS AS IL imbalance.  Proposal 2: We support Option 1, depending on UE implementation.  Observation 4: The value of ∆TRxSRS may not be accurately determined by the UE due to required high values of PCMAX tolerances.  Observation 5: Implementing SRS AS IL imbalance compensation would require UE factory calibration. As a result, UE test time and cost will increase.  Based on the UE implementation challenges enumerated above, we can make the following proposal:  Proposal 3: For Case 1 (not near max Tx power) power compensation seems like a viable solution to address the SRS AS IL imbalance, and implementing this feature remains challenging. RAN4 could further discuss how a feature can be specified under such constraints, and we recommend that this discussion proceed with the assumption that the feature would remain optional and shall depend on UE implementation. For Case 2 and Case 3 a clear path forward is not yet evident, and further discussions related to the feasibility of possible solutions are needed. |
| R4-2407699 | MediaTek Inc | Observation 1: Additional UE transmit power reduction due to IL, if not compensated, will degrade DL performance due to lower SNR in gNB channel estimation on SRS for determining DL precoder.  Observation 2: Compensation by UE can directly improve the SNR condition at gNB, while compensation by gNB may amplify the errors in the channel estimation.  Proposal 1: To handle the SRS IL issue, RAN4 should take UE self-compensation as the baseline solution, when UE haven’t reached its Tx power limit.  Proposal 2: RAN4 to further discuss a solution when UE cannot fully compensate the SRS IL.  Observation 3: Results from [4] show that at mid-high CNR, relying on gNB SRS power imbalance compensation via signalled power offsets is inferior in terms of improving DL performance compared to the “zero imbalance” .scenario. In this scenario we assume that the UE would likely have Tx power available to compensate potential SRS power imbalance by itself.  Observation 4: Results from [4] show that, at low CNR, the benefit of gNB SRS power imbalance compensation via signalled power offsets is negligible in terms of benefit to DL performance.  Observation 5: Results show that, there is no DL performance benefit in the UE reporting SRS offset values and gNB performing compensation of IL compared to the UE performing IL compensation alone.  Observation 6: Results show that, for UEs operating at low SINR and Tx power limited cases, Type 1 CSI-RS based CSI reporting enables superior DL performance when compared to SRS-based CSI reporting when the Tx port contains IL. |
| R4-2407990 | LG Electronics | Observation 1: The ∆TRxSRS values can be considered as the maximum magnitude of the SRS IL imbalance of the UEs.  Observation 2: The maximum SRS signal power imbalance can be considered as ∆TRxSRS, but the actual SRS transmitted signal power imbalance may vary depending on the PEMAX,c, PPowerClass and ∆TRxSRS values according to the configured maximum output power equation in Table 1.  Proposal 1: It is necessary to study the SRS signal imbalance impact considering the PEMAX,c, PPowerClass and ∆TRxSRS values. |
| R4-2407994 | Spreadtrum Communications | Proposal 1: If UE reports statically, UE needs to indicate compensation behaviour to NW.   * If the UE does not perform self-compensation, the UE should report a two-dimensional table which contains the fixed insertion loss mapping to NW according to the different SRS antenna switching capabilities. * If the UE does perform self-compensation but still cannot keep the power balanced, UE could configure a power threshold in case that beyond this value, UE could report Q (Q is equal to max power –power threshold) two-dimensional tables which contains the fixed insertion loss mapping according to the different SRS antenna switching capabilities.   Proposal 2: If UE reports dynamically, UE report the difference value of each diversity branch output power to NW according to the SRS period (including periodic, semi-persistent and aperiodic) in real time. |
| R4-2408031 | Meta Ireland | Proposal 7: If the system performance is not affected by the SRS IL offset, RAN4 does not need to report SRS IL offset to compensate SRS power imbalance. |
| R4-2408069 | China Telecom | Observation 1: UE may not compensate all the SRS IL due to limit power headroom regardless of the UE implementation.  Proposal 1: An SRS IL imbalance reporting mechanism should be adopted to handle the mismatch between UE and NW when UE cannot compensate the total IL.  Proposal 2: IL imbalance reporting is necessary, and further discuss whether static or dynamic way should be adopted.  Proposal 3: Both static and dynamic SRS IL report need to consider reporting granularity and assistance information.  Proposal 4: For dynamic way, clear trigger condition should be specified in RAN4. |
| R4-2408122 | vivo | Observation 1: Dynamic antenna switching is widely used, and the impact to the perceivable IL has to be considered.  Observation 2: Currently there is no “mandatory compensation” requirement or behaviour defined or implied for UE.  Observation 3: Rx IL Loss may still need further consideration.  Proposal 1: Discuss some general understandings may be helpful to make progress, e.g.:   * Widely used Dynamic antenna switching have to be considered. * Currently there is no “mandatory compensation” requirement or behaviour for UE. * Rx IL Loss may still need further consideration.   Observation 4: Current WID scope and impacted TS/TR doesn’t involve RAN1.  Proposal 2: RAN4 should avoid RAN1 impact as much as possible, and should not conclude a scheme with RAN1 impact without confirmation from RAN/RAN1.  Proposal 3: Do not consider UE self-compensation and UE reporting IL loss at the same time, if reporting is considered. |
| R4-2408356 | ZTE Corporation, Sanechips | Proposal 1: Static reporting is up to UE implementation, and UE needs to indicate the power compensation behaviour to NW if UE reports statically.  Proposal 2: Dynamic reporting for actual SRS IL reporting for each SRS‑TxSwitch pattern, and several thresholds associated with capability class for the actual SRS IL reporting can be considered.  Proposal 3: The SRS IL imbalance reporting mechanism should be also specified for 2Rx, 4Rx and 8Rx. |
| R4-2408614 | Intel Corporation | Observation 1: Rel-18 RAN1 results have indicated that existence of SRS IL imbalance will cause non-negligible performance degradation.  Observation 2: In Rel-18 discussion there was no consensus among the companies on the legacy UE behavior for SRS IL handling.  Observation 3: The legacy UE behavior is based on current specifications of the SRS power control mechanism in TS 38.213 and based on configured maximum output Tx power in TS 38.101-1.  Observation 4: For Case 1 (non near max Tx power) scenario the UE is supposed to always compensate any SRS insertion in SRS transmissions based on TS 38.213.  Observation 5: For Case 2 (near max Tx power) scenario the UE behavior in terms of SRS IL is not fully specified and UE may or may not necessarily be required to perform SRS IL compensation up to its maximum power capabilities based on TS 38.101-1  Observation 6: For power-limited scenarios gNB is unaware whether UE applies SRS IL compensation and is not aware on the amount of applied compensation.  Proposal 1: Further discuss SRS IL for 6RX type of devices taking into consideration:   * SRS insertion loss requirements for 6RX UEs * SRS IL impact on performance * SRS insertion loss compensation * UE assistance on SRS insertion loss (power imbalance)   Proposal 2: Specify requirements for Case 1 scenarios with PSRS,PC ≤ PCMAX,L to ensure that UE performs SRS IL compensation.  Proposal 3: Specify UE behavior and requirements for scenarios, when UE has sufficient power to compensate the power imbalance (Case 2) and require UE to perform SRS IL compensation up to the maximum power capabilities.  Proposal 4: Further discuss the mechanisms for UE assistance mechanisms to inform network on the actual SRS transmission power imbalance among TX chains. The methods in WF R4-2317621 can be used as the basis for further analysis. |
| R4-2408726 | Nokia | Proposal 1: RAN4 should not continue the discussion on how to solve the SRS imbalance issue. |
| R4-2408762 | OPPO | Observation 1: IL imbalances also exist in Rx paths which may reduce the impacts of SRS IL imbalance in Tx part.  Proposal 1: When evaluate the gain of SRS IL reporting, the Rx IL imbalance need to be also considered.  Observation 2: UE can compensate the SRS IL among different antennas before PA max power is reached, and it is UE implementation dependent.  Observation 3: The mapping between SRS resource and physical antennas might change due to e.g. hand blocking.  Proposal 2: UE compensation issue and SRS IL changes due to hand blocking need to be considered if SRS IL is reported. |
| R4-2408842 | Qualcomm France | Observation 1: While there are some performance gains in SRS Imbalance indication, there are a lot of uncertainties and assumptions which impact the actual gain.  Observation 2: Probably the largest gain is achieved in case where UE does not compensate the additional SRS IL delta even there would be power reserve remaining. |
| R4-2409053 | Google Inc. | Observation 1: From conducted RF antenna connector perspective, SRS-IL imbalance can be reduced a lot by factor RF calibration process for every commercial UE before shipment, which is also the common process in the industry.  Observation 2: From OTA perspective, even if the UE is well calibrated, the SRS-IL imbalance among each SRS Tx on the associated Rx paths may still be existed due to different antenna implementation. On the other hand, the received power for SRS Tx antenna switching transmission at the network side may be varying very fast due to the multipath fading channel effect. Hence, SRS-IL imbalance among each SRS Tx on the associated Rx paths may also varying very fast even if the UE is in the stationary mode.  Proposal 1: Considering that SRS-IL imbalance can be reduced a lot by factor RF calibration process from conductive perspective and that SRS-IL imbalance offset is difficult to be obtained from OTA perspective, it is proposed not to introduce any SRS-IL imbalance reporting mechanism for 6Rx UE in Rel-19. |
| R4-2409175 | Huawei, HiSilicon | Observation 1: SRS transmission power determination can be categorised as following cases.   |  |  |  | | --- | --- | --- | | **Case #1** | **For all SRS resources within the set, none of PSRS equals to PCMAX** | **The estimated path loss could be relatively small, e.g. cell centre** | | **Case #2** | **For all SRS resources within the set, some of PSRS equals to PCMAX** | **The estimated path loss could still be not so high while some of the diversity branches becomes MOP limited due to ∆TRxSRS, or P-MPR dominated scenario (not in the scope), e.g. mildly away from cell centre** | | **Case #3** | **For all SRS resources within the set, all of PSRS equals to PCMAX** | **The estimated path loss could be high and all diversity branches becomes MOP limited due to ∆TRxSRS, or P-MPR dominated scenario (not in the scope), e.g. cell middle/edge** |   Observation 2: Unlike antenna switching SRS transmission, DL reception would not require Rx switching. Consequently, IL of each Rx path should be within the same level given that it can be realized by similar PCB trace pattern and RF component selection.  Observation 3: RAN4 has never discussed about per branch REFSENS since no exceptional but reasonable RF implementation can be provided to prove the necessity of it.  Proposal 1: Clarify that for PSRS calculation as defined in TS 38.213, PCMAX is a value determined by UE according to the definition in TS 38.101-1, where ∆TRxSRS has already been counted respective to each SRS occasion, but not the range [PCMAX, L, PCMAX, H] itself.  Proposal 2: The following scenario can be considered as the target for SRS IL reporting:   * For all SRS resources within the set, all of PSRS equals to PCMAX   + In this scenario, the estimated path loss could be high and all diversity branches becomes MOP limited due to ∆TRxSRS, or P-MPR dominated scenario (not in the scope), e.g. cell middle/edge   Proposal 3: Tx/Rx-Rx imbalance should not be considered for the discussion on SRS IL reporting.  Proposal 4: Given that specification defines the Tx power should be equally distributed across SRS ports for each SRS transmission, per SRS resource IL reporting would be sufficient.  Proposal 5: If dynamic reporting can be considered for SRS IL reporting, network configurable threshold related to e.g. historical change of PSRS can be considered in order to give the network authority for handling SRS IL reporting frequency. |
| R4-2409460 | Samsung | Observation 1: Similar discussion happened in Rel-18 both in RAN4 and RAN1 having no outcome due to the lack of a clear or workable solution considering the practical deployment between UE and network.  Observation 2: Based on the history, the most important thing is that RAN4 should identify the issue of the IL imbalance across SRS ports clearly from the real network operations. Otherwise, RAN4 may repeat the meaningless arguments on the solution for the undefined problem as previous discussions in Rel-18.  Observation 3: RAN4 first needs to justify what the issue is regarding the IL imbalance across SRS ports as there is a lot of sources affects both downlink and uplink performance related to the multiple SRS ports.  Proposal 1: RAN4 should discuss and conclude whether the IL imbalance issue needs to be handled in the specification based on the real network check and measurements before moving forward to the solutions.  Observation 4: SRS power imbalance impact is pretty much dependent on the networks, which implies that the issue can be handled by implementation.  Observation 5: In our measurement, it have not been seen the meaningful performance degradation even from the large imbalance gap between antennas under various scenarios with various networks.  Observation 6: Introducing new capability for IL imbalance reporting would be a meaningless solution for improving accuracy of the downlink channel estimation.  Proposal 2: At the current stage, the SRS IL imbalance does not affect the practical system performance, nor any enhancement to resolve the issue would work effectively. |
| R4-2409736 | Lenovo | Observation 1: It is expected that the difference between the configured maximum power for two ports i and j given by  δi,j= PCMAX,f,c (i) - PCMAX,f,c (j)  is fixed and is independent of the RB allocation and is equal to the actual difference in SRS insertion loss so that  δi,j = - .  Observation 2: For a UE that compensates SRS insertion losses, the gNB can determine the transmit power for any SRS port from the set of insertion loss differences δi,j,2≤j≤N, and a power headroom report for port 1 (that includes maximum configured power), so long as port 1 has the smallest insertion loss.  Observation 3: For a UE that does not compensate the SRS insertion losses, the gNB can determine the power difference between any two SRS ports from the set of insertion loss differences, and thus correct the SRS based channel estimates without the need for a power headroom report for SRS port 1.  Proposal 1: The UE should signal the set of values δ1,j for all 1≤j≤N to the gNB where N is the number of SRS ports,  δi,j = PCMAX,f,c (i)- PCMAX,f,c (j)  and the SRS ports are numbered such that  δ1,j ≥0 for all 1≤j≤N .  These values only need to be signaled when there is a change in the mapping or numbering of the antenna ports.  Proposal 2: The UE should indicate whether it compensates the actual SRS insertion losses for each SRS port up to the configured maximum power for the port.  Proposal 3: For a UE that indicates that it compensates the actual SRS insertion loss for each SRS port, the gNB can determine the SRS transmit power for each SRS port by configuring the UE to transmit a power headroom report, including the maximum configured power, for the SRS port having the smallest insertion loss. |
| R4-2409759 | Ericsson | Observation 1: The SRS IL imbalance without reporting/compensation results in a non-negligible performance loss.  Observation 2: The UE shall compensate for the IL below the maximum configured output power for a resource, as the insertion loss is not accounted for in the SRS power control equations.  Observation 3: It is recognized that in practice the insertion loss may not be fully accounted for (and thus compensated) in implementations. That is a reason to introduce SRS IL imbalance reporting since the behavior of different UE implementations is almost impossible to predict for the network.  Observation 4: Since the UE behavior when it comes to the compensation of the additional IL of a given Rx branch is unpredictable, reporting of the actual insertion loss (or IL imbalance) per branch is in general insufficient for the accurate DL CSI estimation (it is unclear how the network would use this information).  Proposal 1: Introduce reporting for the SRS insertion loss imbalance issue in Rel-19.  Proposal 2: The introduced solution for the SRS insertion loss imbalance issue should be applicable to all 2Rx/4Rx/6Rx/8Rx cases.  Proposal 3: IL imbalance reporting mechanism for SRS AS should include both the configured maximum output power per SRS resource and the power headroom per SRS resource.  Proposal 4: The PH used for the SRS resource can be a Type 3 but used for a new MAC-CE “SRS resource power report” and can be used also for a carrier configured for PUSCH transmission. |

## Open issues summary

### Sub-topic 4-1: General considerations for SRS IL imbalance issue

**Issue 4-1-1: Whether to solve SRS IL imbalance issue in Rel-19**

* Proposals
  + Option 1: RAN4 should not continue the discussion on how to solve the SRS IL imbalance issue (Meta, Nokia, Google, Samsung)
  + Option 2: Continue to pursue a solution to the SRS IL imbalance issue.
* Recommended WF
  + TBA

**Issue 4-1-2: Initial Considerations for SRS IL imbalance issue**

* Proposals
  + Proposal 1: To handle the SRS IL issue, RAN4 should take UE self-compensation as the baseline solution, when UE haven’t reached its Tx power limit (MediaTek)
  + Proposal 2: RAN4 to further discuss a solution when UE cannot fully compensate the SRS IL (MediaTek)
  + Proposal 3: It is necessary to study the SRS signal imbalance impact considering the PEMAX,c, PPowerClass and ∆TRxSRS values (LGE)
  + Proposal 4: Discuss some general understandings may be helpful to make progress considering the following, e.g.: (vivo)
    - Widely used Dynamic antenna switching have to be considered.
    - Currently there is no “mandatory compensation” requirement or behaviour for UE.
    - Rx IL Loss may still need further consideration.
  + Proposal 5: RAN4 should avoid RAN1 impact as much as possible, and should not conclude a scheme with RAN1 impact without confirmation from RAN/RAN1 (vivo)
  + Proposal 6: Do not consider UE self-compensation and UE reporting IL loss at the same time, if reporting is considered (vivo)
  + Proposal 7: Static reporting is up to UE implementation, and UE needs to indicate the power compensation behaviour to NW if UE reports statically (ZTE, Sanechips).
  + Proposal 8: Dynamic reporting for actual SRS IL reporting for each SRS TxSwitch pattern, and several thresholds associated with capability class for the actual SRS IL reporting can be considered (ZTE, Sanechips).
  + Proposal 9: The introduced solution for the SRS insertion loss imbalance issue and SRS IL imbalance reporting mechanism should be specified for 2Rx, 4Rx, 6Rx, and 8Rx (ZTE, Sanechips, Ericsson).
  + Proposal 10: Further discuss SRS IL for 6RX type of devices taking into consideration (Intel):
    - SRS insertion loss requirements for 6RX UEs
    - SRS IL impact on performance
    - SRS insertion loss compensation
    - UE assistance on SRS insertion loss (power imbalance)
  + Proposal 11: Further discuss the mechanisms for UE assistance mechanisms to inform network on the actual SRS transmission power imbalance among TX chains. The methods in WF R4-2317621 can be used as the basis for further analysis (Intel)
  + Proposal 12: When evaluate the gain of SRS IL reporting, the Rx IL imbalance need to be also considered (OPPO).
  + Proposal 13: UE compensation issue and SRS IL changes due to hand blocking need to be considered if SRS IL is reported (OPPO).
  + Proposal 14: Clarify that for PSRS calculation as defined in TS 38.213, PCMAX is a value determined by UE according to the definition in TS 38.101-1, where ∆TRxSRS has already been counted respective to each SRS occasion, but not the range [PCMAX, L, PCMAX, H] itself. (Huawei, HiSilicon)
  + Proposal 15: Tx/Rx-Rx imbalance should not be considered for the discussion on SRS IL reporting (Huawei, HiSilicon).
  + Proposal 16: Introduce reporting for the SRS insertion loss imbalance issue in Rel-19 (Ericsson).
* Recommended WF
  + TBA

### SRS IL imbalance issue solutions

**Issue 4-2-1: Candidate solutions for the SRS IL imbalance issue**

* Proposals
  + Proposal 1: Support Option 1 from WF in R4-2406585, depending on UE implementation (Apple)
    - For Case 1 (not near max Tx power) power compensation seems like a viable solution to address the SRS AS IL imbalance, and implementing this feature remains challenging. RAN4 could further discuss how a feature can be specified under such constraints, and we recommend that this discussion proceed with the assumption that the feature would remain optional and shall depend on UE implementation. For Case 2 and Case 3 a clear path forward is not yet evident, and further discussions related to the feasibility of possible solutions are needed.
  + Proposal 2: If UE reports statically, UE needs to indicate compensation behaviour to NW (Spreadtrum)
    - If the UE does not perform self-compensation, the UE should report a two-dimensional table which contains the fixed insertion loss mapping to NW according to the different SRS antenna switching capabilities.
    - If the UE does perform self-compensation but still cannot keep the power balanced, UE could configure a power threshold in case that beyond this value, UE could report Q (Q is equal to max power –power threshold) two-dimensional tables which contains the fixed insertion loss mapping according to the different SRS antenna switching capabilities.
  + Proposal 3: If UE reports dynamically, UE report the difference value of each diversity branch output power to NW according to the SRS period (including periodic, semi-persistent and aperiodic) in real time (Spreadtrum).
  + Proposal 4: An SRS IL imbalance reporting mechanism should be adopted to handle the mismatch between UE and NW when UE cannot compensate the total IL (China Telecom).
  + Proposal 5: IL imbalance reporting is necessary, and further discuss whether static or dynamic way should be adopted (China Telecom).
  + Proposal 6: Both static and dynamic SRS IL report need to consider reporting granularity and assistance information (China Telecom).
  + Proposal 7: For dynamic way, clear trigger condition should be specified in RAN4 (China Telecom).
  + Proposal 8: Specify requirements for Option 1 Case 1 scenarios from WF in R4-2406585 with PSRS,PC ≤ PCMAX,L to ensure that UE performs SRS IL compensation (Intel).
  + Proposal 9: Specify UE behavior and requirements for scenarios, when UE has sufficient power to compensate the power imbalance (Option 1 Case 2 from WF in R4-2406585) and require UE to perform SRS IL compensation up to the maximum power capabilities (Intel).
  + Proposal 10: The following scenario can be considered as the target for SRS IL reporting: (Huawei, HiSilicon)
    - For all SRS resources within the set, all of PSRS equals to PCMAX
    - In this scenario, the estimated path loss could be high and all diversity branches becomes MOP limited due to ∆TRxSRS, or P-MPR dominated scenario (not in the scope), e.g. cell middle/edge
  + Proposal 11: Given that specification defines the Tx power should be equally distributed across SRS ports for each SRS transmission, per SRS resource IL reporting would be sufficient (Huawei, HiSilicon).
  + Proposal 12: If dynamic reporting can be considered for SRS IL reporting, network configurable threshold related to e.g. historical change of PSRS can be considered in order to give the network authority for handling SRS IL reporting frequency (Huawei, HiSilicon).
  + Proposal 13: The UE should signal the set of values when there is a change in the mapping or numbering of the antenna ports (Lenovo).
  + Proposal 14: The UE should indicate whether it compensates the actual SRS insertion losses for each SRS port up to the configured maximum power for the port (Lenovo).
  + Proposal 15: For a UE that indicates that it compensates the actual SRS insertion loss for each SRS port, the gNB can determine the SRS transmit power for each SRS port by configuring the UE to transmit a power headroom report, including the maximum configured power, for the SRS port having the smallest insertion loss (Lenovo).
  + Proposal 16: IL imbalance reporting mechanism for SRS AS should include both the configured maximum output power per SRS resource and the power headroom per SRS resource (Ericsson).
  + Proposal 17: The PH used for the SRS resource can be a Type 3 but used for a new MAC-CE “SRS resource power report” and can be used also for a carrier configured for PUSCH transmission (Ericsson).
* Recommended WF
  + TBA