**3GPP TSG-RAN WG4 Meeting # 112 R4-2412820**

**Maastricht, Netherlands, August 19 – August 23, 2024**

**Agenda item:** 8.1.3

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

**Title:** Topic summary for [112][118] NR\_ENDC\_RF\_Ph4\_part3

**Document for:** Information

# Introduction

This document summarizes the contributions submitted under agenda item 8.1.1.3. 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

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2411456 | Spreadtrum Communications | Proposal 1: We support option 3. Different value for handheld UE and FWA.Proposal 2: 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. |

Proposal 3: We accept option2 that consider the average value of ΔRIB,6R from company proposals for further discussion. |
| R4-2411497 | MediaTek Inc. | Observation 1: Regarding n77/n78/n79/[n104], in WF[2], the range of ΔRIB,6R values are [-3.0~-3.3] dB and [-3.0~-3.2] dB for FWA and handheld UE, respectively. The median values of ΔRIB,6R are -3.15 dB and -3.1 dB for FWA and handheld UE, respectively.Observation 2: Regarding n77/n78/n79/n104, in R4-2407313[3], the ΔRIB,6R values of -3.1 dB and -3.1 dB were proposed for FWA and handheld UE, respectively.Observation 3: Regarding n41, in WF[2], the range of ΔRIB,6R values are [‑3.0~-4.0] dB and [-3.0~-4.0] dB for FWA and handheld UE, respectively. The median values of ΔRIB,6R are -3.5dB and -3.5dB for FWA and handheld UE, respectively. Observation 4: Regarding n41, in R4-2407313[3], the ΔRIB,6R values of -3.4 dB and -3.4 dB were proposed for FWA and handheld UE, respectively.Proposal 1: Based on observations 1 and 3, if there is little difference in ΔRIB,6R values between handheld UE and FWA, to define the same ΔRIB,6R value for handheld UE and FWA. Proposal 2: Regarding n77/n78/n79/n104, based on observations 1 and 2, to define ΔRIB,6R values of [-3.1] dB and [-3.1] dB for FWA and handheld UE, respectively.Proposal 3: Regarding n41, based on observations 3 and 4, to define ΔRIB,6R values of [-3.4] dB and [-3.4] dB for FWA and handheld UE, respectively. |
| R4-2411608 | 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 |

 |
| R4-2411647 | Meta Ireland | Proposal 1: Based on the 2Rx REFSENS requirements, the 6Rx REFSENS levels for HHUE and FWA UE would be specified with the same ΔRIB,6R as follow:

|  |  |
| --- | --- |
| Operating bands | ΔRIB,6R for both FWA and Handheld |
| n77, n78, n79 and n104 | -3.1 dB |
| n41 | - 3.5 dB |

Proposal 2: 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. |
| R4-2411883 | ZTE Corporation, Sanechips | Proposal 1: For ΔRIB,6R, include n77, n78, n79 and n104 into the same group.Proposal 2: The same ΔRIB,6R value is used for handheld UE and FWA.Proposal 3: ΔRIB,6R = -3.5dB for band n41, and ΔRIB,6R = -3dB for n77/n78/n79/n104.Proposal 4: To use average value of ΔRIB,6R from company proposals if there are different values proposed by companies.Proposal 5: When the UE is equipped with six Rx antenna ports* For single carrier REFSEN requirements, additional requirement for four Rx antenna ports and six Rx antenna ports shall be verified in operating bands;
* For Rx requirements other than single carrier REFSEN, the UE shall be verified with six Rx antenna ports and skip both two and four Rx antenna ports requirements in operating bands.
 |
| R4-2412011 | Nokia | Proposal 1: Define separate values of ΔRIB,6R to both FWA and handheld UEs. First define value for FWA.Proposal 2: FWA ΔRIB,6R is as defined in Table 1.

|  |  |
| --- | --- |
| **Operating bands** | **ΔRIB,6R for FWA** |
| n77, n78, n79, [n104] | -3.4 dB |
| n41 | -4.0 dB |

**Table 1: ΔRIB,6R for FWA** |
| R4-2412074 | vivo | Proposal 1：For ΔRIB,6R requirement, include band n104 into the same group with band n77, n78, n79.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 |

 |
| R4-2412405 | LG Electronics | Proposal 1: It is necessary to consider the worst ΔRIB,6R value among n77, n78, n79 and n104, if n104 is included in category n77, n78, n79Proposal 2: it is necessary to consider different ΔRIB,6R value for handheld UE and non-handheld UE and consider the ΔRIB,6R relaxation for non-handheld UE about 0.2 ~0.4 dB. Proposal 3: Proposed ΔRIB,6R values

|  |  |  |
| --- | --- | --- |
| Operating band | Handheld $ΔR\_{IB,6R}$ | Non-handheld $ΔR\_{IB,6R}$ |
| n41 | -3.5 | -3.7 |
| n77, n78, n79, n104 | -3 | -3.4 |

 |
| R4-2412571 | Huawei, HiSilicon | Observation 1: The demand for differentiated 6Rx delta Rib requirements is from UE form factor and operating band which could be further illustrated from RF perspective as follows:* Due to form factor limitation, physical antenna layout in order to accommodate increased Rx number could lead to compromised performance on:
	+ RF isolation, and
	+ Antenna efficiency
* Availability on RF resource could be different per operating band

Proposal 1: Check whether below ΔRIB,6R for the example bands n41, n77/n78, n79 and n104 can be applied for both handheld UE and FWA UE:* -3dB for band n77/78, n79 and n104
* -3.3dB for band n41
 |
| R4-2412610 | Qualcomm France | Proposal 1: If the ΔRIB,6R for n77/n78/n79 is -3.0dB then n104 can belong to the same groupProposal 2: Use same ΔRIB,6R value for handheld UE and FWAProposal 3: Use -3.4dB ΔRIB,6R for n41 and -3.0dB ΔRIB,6R for n77/n78/n79/n104 |
| R4-2412925 | Google | Proposal 1: Considering the frequency range of n104 is much higher than n77/n78/n79, PCB tracing loss and RFFE insertion loss may be 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.Proposal 2: In order to save the cost for 6Rx handheld UE implementation, it is highly possible that n104 can be collocated with WIFI 6G module from implementation perspective. Hence, considering the different implementation complexity for handheld UE and FWA UE, it is proposed to differentiate n104 ΔRIB,6R requirements for handheld UE from FWA UE.Proposal 3: For n77/n78/n79, considering 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 4: 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. |
| R4-2413268 | 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 (MediaTek, Xiaomi, Spreadstrum, Meta, vivo, ZTE, Sanechips, Qualcomm, Ericsson, Nokia, LGE, Huawei, HiSilicon)
	+ Option 2: Treat n104 separately as ultra-high band for 6Rx requirement (Google)
* Recommended WF
	+ Option 1.

**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 depending on performance requirement (Nokia, vivo)
	+ Option 2: Same value for handheld UE and FWA (MediaTek, Xiaomi, Meta, ZTE, Sanechips, Qualcomm, Ericsson, Huawei, HiSilicon)
	+ Option 3: Different value for handheld UE and FWA (Spreadtrum, Google, LGE)
* Recommended WF
	+ Option 2.

### 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: Define ΔRIB,6R for band n41 as -3.4dB, and for bands n77/n78/n79/n104 as -3.1dB (MediaTek)
	+ Option 2: 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: Specify ΔRIB,6R values as follows: (LGE)

|  |  |  |
| --- | --- | --- |
| Operating bands | ΔRIB,6R for Non-Handheld | ΔRIB,6R for Handheld |
| n77, n78, n79, n104  | -3.4 dB | -3.0 dB |
| n41 | -3.7 dB | -3.5 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 - 3.1 dB for n77, n78, n79 and n104
		- ΔRIB,6R is - 3.5 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)
	+ Option 9: Define ΔRIB,6R for n41 as -4.0dB, and for n78/n77/n79/n104 as -3.4dB for FWA (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 (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: ΔRIB,6R = -3.3dB for band n41, and ΔRIB,6R = -3dB for n77/n78/n79/n104 for FWA and handheld UE (Huawei, HiSilicon)
	+ Option 13: ΔRIB,6R = -3.4dB for band n41, and ΔRIB,6R = -3dB for n77/n78/n79/n104 for FWA and handheld UE (Qualcomm)
	+ Option 14: Adopt the average value of ΔRIB,6R for handheld UE from company proposals and specify it for FWA and handheld UE devices based on moderator recommended WFs for Issue 1-1-1 and Issue 1-1-2.

**Table: Averaged values based on proposals**

|  |  |  |
| --- | --- | --- |
| 　 | Operating Bands | ΔRIB,6R (dB) |
| MediaTek | Band n41 | -3.4 |
| Band n77, n78, n79, n104 | -3.1 |
| Xiaomi | Band n41 | -3.2 |
| Band n77, n78, n79, n104 | -3.0 |
| LGE | Band n41 | -3.5 |
| Band n77, n78, n79, n104 | -3.0 |
| Spreadtrum | Band n41 | -3.3 |
| Band n77, n78, n79, n104 | -3.0 |
| Meta | Band n41 | -3.5 |
| Band n77, n78, n79, n104 | -3.1 |
| vivo #1 | Band n41 | -3.0 |
| Band n77, n78, n79, n104 | -3.0 |
| vivo #2 | Band n41 | -3.2 |
| Band n77, n78, n79, n104 | -3.0 |
| ZTE  | Band n41 | -3.5 |
| Band n77, n78, n79, n104 | -3.0 |
| Ericsson | Band n41 | -3.6 |
| Band n77, n78, n79, n104 | -3.2 |
| Google | Band n41 | -3.4 |
| Band n77, n78, n79 | -3.0 |
| Huawei | Band n41 | -3.3 |
| Band n77, n78, n79, n104 | -3.0 |
| Qualcomm | Band n41 | -3.4 |
| Band n77, n78, n79, n104 | -3.0 |
| **Average** | Band n41 | **-3.4** |
| Band n77, n78, n79, n104 | **-3.0** |

* Recommended WF
	+ Option 14.

# Topic #2: SRS antenna switching and ΔTRxSRS

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2411151 | Apple | Proposal 1: For 1T6R SRS antenna switching configuration, the following values can be used for ΔTRxSRS:* For n41, n77, and n78, ΔTRxSRS = 3.9dB
* For n79 and n104 ΔTRxSRS = 5.4dB

Proposal 2: For 2T6R SRS antenna switching configuration, the following values can be used for ΔTRxSRS:* For n41, n77, and n78, ΔTRxSRS =3.2dB
* For n79 and n104, ΔTRxSRS =4.4dB

Proposal 3: For 1T6R-2T6R SRS antenna switching configuration, the following values can be used for ΔTRxSRS:* For n41, n77, and n78, ΔTRxSRS =4.2dB
* For n79 and n104, ΔTRxSRS =5.7dB
 |
| R4-2411457 | Spreadtrum Communications | Proposal 1: There is no need to introduce an additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of n104.Proposal 2: Adopt the value of ΔTRxSRS in Table 1 for 1T6R, 2T6R for PC3.**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 |

Proposal 3: We accept option1 that consider average value of ΔTRxSRS for further discussion. |
| R4-2411647 | Meta Ireland | Proposal 3: RAN4 can define the detailed ΔTRxSRS antenna switching IL values in Table 3. These values will be included in the merged ΔTRxSRS antenna switching IL values in WF [3].**Table 3 Proposed additional SRS Switch IL for n77/n78 and n79**

|  |  |  |
| --- | --- | --- |
|  | **n77/n78 (< 3.5GHz)** | **n79 (4.9GHz)** |
| **t1r6** | 3.7 | 5.0 |
| **t2r6** | 3.0 | 4.1 |
| **t1r6 + t2r6** | 4.4 | 5.9 |
| **t3r6** | 3.0 | 4.1 |
| **t1r6 + t3r6** | 4.5 | 6.1 |

Proposal 4: RAN4 can define the average values of ΔTRxSRS antenna switching IL values from the inputs by interested companies. |
| R4-2411884 | ZTE Corporation, Sanechips | Observation 1: t4r8 is removed, and t3r6 will be under RAN1’s studied.Proposal 1: Apply 4.5dB for n41/n77/n78 and 5.5dB for n79 for t1r6 ΔTRxSRS requirements.Proposal 2: Apply 4dB for n41/n77/n78 and 5dB for n79 for t2r6 ΔTRxSRS requirements.Proposal 3: Apply 5dB for n41/n77/n78 and 6dB for n79 for t1r6-t2r6 ΔTRxSRS requirements.Proposal 4: If introduce an additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of n104 for 6Rx, then it is also needed to revisit the ΔTRxSRS requirement for n104 4Rx.Proposal 5: To use the average value of ΔTRxSRS if there are different values proposed by companies. |
| R4-2412076 | vivo | Proposal 1: For ΔTRxSRS requirements, no need to introduce an additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of n104.Proposal 2: 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, n104 | 5 dB |  4.0 dB  | 6.5 dB |

 |
| R4-2412406 | LG Electronics | Proposal 1: Proposed ΔTRxSRS values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **n41** | **n77/n78** | **n79** | **n104** |
| t1r6 | 3.5 | 4.2 | 5.9 | 6.9 |
| t2r6 | 2.6 | 3 | 4.5 | 5.2 |
| t1r6-t2r6 | 3.7 | 4.3 | 6.3 | 7.5 |

Proposal 2: For Issue 2-1-2: , following options can be considered**Issue 2-1-2: Whether to use different ΔTRxSRS based on operating frequency*** Option 1: Consider the worst case ΔTRxSRS among n79 and n104 for high band ΔTRxSRS value
* Option 2: Add the one more break point for UHB ΔTRxSRS
 |
| R4-2412573 | Huawei, HiSilicon | Observation 1: Additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of band n104 may be needed.Observation 2: The derivation on 6Rx ΔTRxSRS requirement needs to consider real implementation in both phablet and foldable phone. * For a foldable phone, increasing insertion loss can be expected for a diversity branch that lays through the hinge connecting different screens.

Proposal 1: Check if following framework regarding 6Rx ΔTRxSRS requirements can be adopted.* 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.
 |
| R4-2412611 | Qualcomm France | Proposal 1: Add a new ΔTRxSRS value for bands whose FUL\_low is higher than 5GHzProposal 2: Use the following ΔTRxSRS values for 1T6R, 2T6R, and 1T6R-2T6R when the device is power class 3 or power class 5 or power class 1.5 in the band, or when the device is power class 2 in the band and ΔPPowerClass = 3 dB, or when UE indicating Tx diversity capability.

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 4 dB | 4 dB | 4.5 dB |
| Band n79  | 5.5 dB | 5.5 dB  | 6 dB |
| Band n104 | 6.5 dB | 6.5 dB | 7 dB |

Proposal 3: Use the following ΔTRxSRS values for 1T6R, 2T6R, and 1T6R-2T6R when the device is power class 2 in the band and ΔPPowerClass = 0 dB and not indicating Tx diversity capability

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 7 dB | 7 dB | 7.5 dB |
| Band n79  | 8.5 dB | 8.5 dB  | 9 dB |
| Band n104 | 9.5 dB | 9.5 dB | 10 dB |

 |
| R4-2412939 | Google | Proposal 1: Considering that the averaging method is most acceptable way in RAN4 to determine requirement, it is proposed to adopt the average of all proposed values to determine ΔTRxSRS requirement for 6Rx handheld and FWA UE in Rel-19. |
| R4-2413359 | Ericsson | Proposal 1: For ‘t1r6’ AS capability, for bands n41 and n77/78 ΔTRxSRS should be specified as 3.5 dB, while for bands n79 and n104 ΔTRxSRS should be specified as 5.0 dB.Proposal 2: For ‘t2r6’ AS capability, for bands n41 and n77/78 ΔTRxSRS should be specified as 3.5 dB, while for bands n79 and n104 ΔTRxSRS should be specified as 5.0 dB.Proposal 3: For ‘t1r6-t2r6’ AS capability, for bands n41 and n77/78 ΔTRxSRS should be specified as 4.0 dB, while for bands n79 and n104 ΔTRxSRS 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: Whether to consider an additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of n104**

* Proposals
	+ Proposal 1: Do not consider an additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of n104 (Apple, LGE, Spreadtrum, vivo, Ericsson)
	+ Proposal 2: Consider additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of n104 (ZTE, Sanechips, LGE, Huawei, HiSilicon, Qualcomm)
* Recommended WF
	+ TBA.

**Issue 2-1-2: Whether to consider separate ∆TRxSRS values when the device is power class 2 in the band and ΔPPowerClass = 0 dB and not indicating Tx diversity capability**

* Proposals
	+ Proposal 1: Consider separate ∆TRxSRS values when the device is power class 2 in the band and ΔPPowerClass = 0 dB and not indicating Tx diversity capability (Qualcomm)
	+ Proposal 2: Same ∆TRxSRS values.
* Recommended WF
	+ TBA.

### Sub-topic 2-2: ΔTRxSRS values

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

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

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 3.7 dB | 3.0 dB | 4.4 dB |
| Band n79 | 5.0 dB | 4.1 dB  | 5.9 dB |
| Band n104 | - | - | - |

* + 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 | 5.0 dB |  4.5 dB  | 5.0 dB |
| Band 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 |
| Band n104 | 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 |
| Band n104 | - | - | - |

* + Option 5: Use the following values for ΔTRxSRS (LGE) using worst case value for bands whose FUL\_high is lower than the FUL\_low of n79

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 4.2 dB | 3.0 dB | 4.3 dB |
| Band n79 | 5.9 dB | 4.5 dB  | 6.3 dB |
| Band n104 | 6.9 dB | 5.2 dB  | 7.5 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 | 5.5 dB | 5.5 dB  | 6.0 dB |
| Band n104 | 6.5 dB | 6.5 dB | 7.0 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 |
| Band n104 | - | - | - |

* + 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 |
| Band n104 | 5.0 dB | 5.0 dB | 5.5 dB |

* + Option 9: Use the following values for ΔTRxSRS (Apple)

|  |  |  |  |
| --- | --- | --- | --- |
| Operating bands | ΔTRxSRS requirement for t1r6 | ΔTRxSRS requirement for t2r6 | ΔTRxSRS requirement for t1r6-t2r6 |
| Band n41, n77, n78 | 3.9 dB | 3.2 dB | 4.2 dB |
| Band n79 | 5.4 dB | 4.4 dB | 5.7 dB |
| Band n104 | 5.4 dB | 4.4 dB | 5.7 dB |

The following table summarizes the averaged values based on the proposals.

**Table: Averaged values based on proposals**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 　 | Operating Bands | ΔTRxSRS t1r6 (dB) | ΔTRxSRS t2r6 (dB) | ΔTRxSRS t1r6-t2r6 (dB) |
| Meta | Band n41, n77, n78 | 3.7 | 3.0 | 4.4 |
| Band n79 | 5.0 | 4.1 | 5.9 |
| Band n104 | - | - | - |
| Spreadtrum | Band n41, n77, n78 | 3.5 | 3.0 | 3.5 |
| Band n79 | 5.0 | 4.5 | 5.0 |
| Band n104 | 5.0 | 4.5 | 5.0 |
| vivo | Band n41, n77, n78 | 4.0 | 3.5 | 5.5 |
| Band n79 | 5.0 | 4.0 | 6.5 |
| Band n104 | 5.0 | 4.0 | 6.5 |
| ZTE  | Band n41, n77, n78 | 4.5 | 4.0 | 5.0 |
| Band n79 | 5.5 | 5.0 | 6.0 |
| Band n104 | - | - | - |
| LGE | Band n41, n77, n78 | 4.2 | 3.0 | 4.3 |
| Band n79 | 5.9 | 4.5 | 6.3 |
| Band n104 | 6.9 | 5.2 | 7.5 |
| Qualcomm | Band n41, n77, n78 | 4.0 | 4.0 | 4.5 |
| Band n79 | 5.5 | 5.5 | 6.0 |
| Band n104 | 6.5 | 6.5 | 7.0 |
| Huawei | Band n41, n77, n78 | 4.0 | 4.0 | 4.5 |
| Band n79 | 5.5 | 5.5 | 6.0 |
| Band n104 | - | - | - |
| Ericsson | Band n41, n77, n78 | 3.5 | 3.5 | 4.0 |
| Band n79 | 5.0 | 5.0 | 5.5 |
| Band n104 | 5.0 | 5.0 | 5.5 |
| Apple | Band n41, n77, n78 | 3.9 | 3.2 | 4.2 |
| Band n79 | 5.4 | 4.4 | 5.7 |
| Band n104 | 5.4 | 4.4 | 5.7 |
| **Average** | Band n41, n77, n78 | **4.0** | **3.4** | **4.4** |
| Band n79 |  |  |  |
| Band n104 | **5.3** | **4.5** | **5.7** |

* + Option 10: Adopt the average values from companies as summarized below and specify the values for ΔTRxSRS without considering an additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of n104.

**Table: Averaged values based on proposals**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 　 | Operating Bands | ΔTRxSRS t1r6 (dB) | ΔTRxSRS t2r6 (dB) | ΔTRxSRS t1r6-t2r6 (dB) |
| **Average** | Band n41, n77, n78 | **3.9** | **3.5** | **4.5** |
| Band n79, n104 | **5.3** | **4.8** | **5.9** |

* + Option 11: Adopt the average values from companies as summarized below and specify the values for ΔTRxSRS considering an additional breakpoint for bands whose FUL\_high is higher than the FUL\_low of n104.

**Table: Averaged values based on proposals**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 　 | Operating Bands | ΔTRxSRS t1r6 (dB) | ΔTRxSRS t2r6 (dB) | ΔTRxSRS t1r6-t2r6 (dB) |
| **Average** | Band n41, n77, n78 | **3.9** | **3.5** | **4.5** |
| Band n79 | **5.3** | **4.8** | **5.9** |
| Band n104 | **5.7** | **5.0** | **6.3** |

* Recommended WF
	+ Either Option 10 or Option 11 depending on the way forward on Issue 2-1-1.

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

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2411393 | Apple | Observation 1: Common assumptions for Tx EVM are 6% for QPSK/16QAM and 3% for 256QAM.Proposal 1: Postpone discussion on whether to tighten BS EVM requirements after simulation assumptions are agreed and interested companies have reported simulation results and conclusions.Observation 2: As per WID, the specified requirements can be applicable to both handheld UE and FWA devices.Proposal 2: RAN4 should initially define a single set of demodulation requirements that apply to both handheld UE and FWA devices.Proposal 3: RAN4 to confirm that 6-Layer support is an optional feature.Proposal 4: RAN4 to consider the following baseline PDSCH simulation assumptions (table above).Observation 3: MediumB correlation can be used as a very conservative antenna correlation model of the actual antenna correlation that a handheld UE could achieve.Observation 4: Simulation results under our assumed MediumB correlation show that Rank 6 outperforms Rank 4 only at very low MCS where such high-rank transmission is not intended.Observation 5: Under these assumptions, Rank 4 transmission under MediumB correlation achieves full throughput only at very low MCS.Proposal 5: RAN4 to limit to 4 layers the number of MIMO layers in 6Rx unless other simulation assumptions are agreed. |
| R4-2411525 | Nokia | Observation 1: The need to possible tighten the BS EVM requirements depends on the SNR of the final requirement definition, hence should be postponed to RAN4 performance discussion.Proposal 1: Defer the decision of BS EVM requirement tightening to the later RAN4 performance discussion.Observation 2: In order to fully assess the performance of 6Rx a spatial channel model must be used.Observation 3: The RAN4 TDL + antenna correlation model severely overestimates the rank deficiency, or rather ill-conditioning, of the channel matrix and this model shall not be used to evaluate the feasibility of full rank transmissionProposal 2: Demodulation of 6 Rx full rank transmission is feasible for handheld devices.Observation 4: The performance part of this work item has not yet commencedObservation 5: There is an ongoing study item on introduction of a spatial channel model for RAN4 performance requirements.Proposal 3: RAN4 shall discuss the performance requirements for 6Rx once the performance part commences.Observation 6: Reuse of handheld for FWA requirements cannot be decided on initial evaluation of 6 MIMO layer performance as results might change during the performance part in-depth analysis.Proposal 4: Defer decision to use same requirements for handheld UE and FWA to the performance part.Observation 7: RAN4 demodulation performance requirements are not defined per UE deployments.Observation 8: 6Rx will require a band that supports deployments with “maxNumberMIMO-LayersPDSCH” above 4.Observation 9: 6Rx will require signaling to indicate UE support.Proposal 5: RAN4 shall consider 6-layer support as optional feature.Observation 10: 8Rx performance requirements are released independent, but it is premature to assume that it will be the same for 6RxProposal 6: RAN4 shall defer the decision on release independence until the performance part of the work item commences. |
| R4- 2411609 | Xiaomi | Observation 1: It is feasible to support 6Rx with low antenna correlation for folding smartphone.Proposal 1: RAN4 to 6 MIMO layers for 6Rx handheld UE. |
| R4-2411647 | Meta Ireland | Proposal 5: RAN4 can support 6 MIMO layer in this WID based on the performance evaluation campaign for HHUE and FWA depending on the medium/high correlation of ULA and cross polarized MIMO matrices (i.e., 1x6, 2x6 and 6x6 cases compared to 1x4, 2x4 and 4x4 cases) in Dense urban micro (UMi) cellular deployment scenarios. It means that RAN4 need to validate the benefits of 6 MIMO layer compared to 4 MIMO layer according to real antenna correlation according to the device type and existing Tx EVM level at gNB.Proposal 6: In RF perspective, RAN4 need to analyse the additional RF complexity and power consumptions to support 6 MIMO layers in both HHUE and FWA device. |
| R4-2411680 | Qualcomm Incorporated | Observation 1: For a handheld test device that has been optimized for antenna placing and decoupling, the correlation coefficients between pair of antennas is upper bounded by 0.3.Observation 2: Correlation coefficients between any pair of receive antennas are mostly below 0.1 for a handheld device.Observation 3: Commercial device may see even lower correlation values between pairs of receive antennas.Proposal 1: Consider correlation values with correlation coefficient between pairs of antennas to be less than 0.1 for a handheld device. Observation 4: Six receive antennas provide very large throughput gain for SSB RSRP > -80 dBm and -80 dBm<SSB RSRP<-100 dBm in the order of 35% and 45%, respectively.Observation 5: An advanced receiver, such as R-ML receiver can offer noticeable performance improvement over an MMSE receiver for 6Rx devices.Observation 6: The following observations can be made for achievable average number of layers:* Six receive antennas can achieve 5-layer transmission for SSB RSRP > -80 dBm and -80 dBm<SSB RSRP<-100 dBm with sub-optimal MMSE processing.
* Six receive antennas can achieve 6-layer transmission with a R-ML receiver when SSB RSRP > -80 dBm.

Observation 7: Configuration four DMRS symbols per slot (2+2 DMRS case) yields to a performance degradation and should be avoided for 6-layer scenario.Observation 8: Comparing between configuration 1 (i.e., 6Rx/4layer with 1+1 DMRS) and configuration 3, 6Rx/6-layer outperforms 6Rx/4-layer at around SNR = 33 dB and 6Rx/5-layer at around SNR = 42 dB.Observation 9: Comparing between configurations 1 and 3, 6Rx/5-layer starts to consistently outperform 6Rx/4-layer at around SNR = 20 dB.Observation 10: The performance impact is less than 1 dB by having all elements of both 5th and 6th columns and rows of the 6x6 correlation matrix to be 0.25.Observation 11: The performance of 5-layer and 6-layer configurations with six receive antennas is somewhat less sensitive to β value up to 0.25.Observation 12: Compared to 8 transmit antennas, a configuration of 16 transmit antennas can offer significant gain (up of 40% relative throughput improvement) for 6Rx/6-layer. It is expected that configuring 32 transmit antennas will avail even more gain.Observation 13: Negligible losses are observed for a symmetric correlation matrix having correlation coefficient up to 0.2 across all non-diagonal elements.Proposal 2: RAN4 to introduce 6-layer performance requirements for handheld and FWA devices. * FFS whether to use same requirements for handheld and FWA devices.

Proposal 3: RAN4 to introduce 6-layer support for 6Rx devices as an optional feature. |
| R4-2411773 | MediaTek Inc. | Proposal 1: Following the guidance of WID, the feasibility study of 6-layer MIMO for 6Rx should focus on handheld UEs rather than CPE devices.Observation 1: Observations from system-level simulation * Allowing max 6-layer MIMO for 6Rx UE does not bring expected gain over the baseline with max 4-layer MIMO.
* Max 6-layer MIMO suffers more degradation to the dynamic inter-site interference than max 4-layer MIMO
* Max 6-layer MIMO suffers more degradation to channel aging effect than max 4-layer MIMO
* Considering Type-1 DMRS, max 6-layer MIMO requires higher DMRS overhead compared to max 4-layer MIMO, leading to up to 18% lower throughput than max 4-layer MIMO.
* Changing UE antenna distance from 0.3λ to 0.5λ does not make max 6-layer MIMO outperform max 4-layer MIMO
* No big performance difference between BS EVM 0% and 3.5%, because the majority of the UEs operate under SNR<30dB

Proposal 2: RAN4 to further discuss the system-level simulation assumptions for the feasibility study of 6-layer MIMO for 6Rx handheld UEs. |
| R4-2412075 | 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. Observation 9: Under existing BS EVM requirement, the 6 MIMO layer can hardly outperform 4 MIMO layer for 6Rx UE.Proposal 1: At least for handheld UE, do not support 6 MIMO layer for 6Rx. |
| R4-2412352 | OPPO | Observation 1: 6Layer have better performance than 4Layer+2Div when SNR is higher than 20dB in TDL channel model and 30dB in CDL channel model.Proposal 1: Introduce 6Layers as optional feature for UE which supports 6Rx antennas. |
| R4-2412572 | Huawei, HiSilicon | Observation 1: For fixed FRC, RAN4 could simulate serval MCSs for 4 Layers and 6 Layers respectively and compare the maximum Throughput at given SNR. The MCS corresponding to the max Throughput of 4 Layers and that of 6 Layers could be different.Observation 2: For DMRS type 1, 6 Layers will lead to more DMRS overhead compared to 4 Layers, which would limit the throughput gain.Observation 3: Under the conditions with proposed antenna correlation, 4 layers outperforms 6 layers.Proposal 1: RAN4 to use link adaption without OLLA for evaluation as baseline.Proposal 2: RAN4 shall not tighten the BS EVM requirements for 6 MIMO layers feasibility study.Proposal 3: Companies can start with providing reasonable antenna correlation based on e.g. measurement and run the simulation accordingly. Proposal 4: RAN4 to use low correlation (α=0) at BS side.Proposal 5: RAN4 to consider 10dB MIMO isolation when evaluating the 6 MIMO layers feasibility. |
| R4-2412877 | Samsung | Proposal 1: For 6Rx performance evaluation, use TDLA30-10 as the propagation condition and cross polarized (XP/X-pol) antennas correlation modelling with low and medium correlation as the correlation configuration for the starting point.Proposal 2: For 6Rx performance evaluation, use MCS4, MCS13, and MCS19 with different modulation orders as the beginning.Observation 1: For 4 MIMO layers cases, 6Rx could outperform 4Rx antenna cases for the ideal channel conditions with no correlation cases at least, due to the diversity gain of more receiver antennas. Observation 2: For 6Rx antenna cases, 6 MIMO layers cases could outperform 4 MIMO layers cases only at higher SNR value range using ideal channel conditions with no correlation cases.Observation 3: For 6Rx antenna cases with XP medium correlation with MCS13 and MCS19, the performance of 6 MIMO layers cases is even worse than 4 MIMO layers cases.Observation 4: For 6Rx antenna cases with XP medium correlation, the maximum throughput is hard to be achieved for 6 MIMO layers cases with MCS13 and MCS19.Observation 5: For 6Rx antenna cases with XP medium correlation, even the correlation factor downgrades from 0.6 to 0.1, the performance of 6 MIMO layers case is still worse than 4 MIMO layers case.Proposal 3: For handheld UEs with 6Rx antennas, considering correlation will be introduced in realistic deployment, there is no need to introduce requirements for 6 MIMO layers since no benefit could be observed from our initial simulation results. |
| R4-2412928 | Google | 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.Proposal 2: If RAN4 consensus is to support 6 MIMO layer for 6Rx UE, it is proposed that the 6 MIMO layer performance requirement for 6Rx handheld UE should be separated from FWA UE, and that 6 MIMO layer for 6Rx UE should be optional feature from Rel-19. |
| R4-2413269 | Ericsson | Observation 1: The evaluation of demodulation performance is influenced by the assumption of antenna correlation.Observation 2: With the TDLA30-10 low antenna correlation condition, the performance gain with 6 layers over 4 layers for QPSK, 16QAM and 64QAM is observed.Observation 3: With TDLA30-10 medium correlation, the performance gain with 6 layers over 4 layers for low and medium MCS is observed.Proposal 1: Support of MIMO 6 layers should be evaluated considering the impact of antenna correlation and the feasibility and probability of achieving a rank 6 channel in the deployment scenario.Proposal 2: Support of MIMO 6 layers could be considered an optional feature. |

## Open issues summary

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

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

# Topic #4: SRS IL imbalance issue

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2411152 | Apple | Observation 1: Based on its implementation, it seems reasonable that the UE could implement some amount of power pre-compensation on its SRS ports to cope with the effects of SRS AS IL imbalance when there is enough power headroom to do so.Observation 2: The value of ∆TRxSRS may not be accurately determined by the UE due to required high values of PCMAX tolerances.Proposal 1: Solution for IL imbalance issue based on power pre-compensation and reporting:  Case#1: PCMAX\_SRSi ≤ PCMAX\_SRSmin:For this case, the UE has enough power headroom and can perform pre-compensation on the SRS ports. Case #2: PCMAX\_SRSi ≥ PCMAX\_SRSmin:For this case, the UE does not have enough headroom to perform pre-compensation. The UE should report to the NW the amount of power back-off (PCMAX\_SRSi - PCMAX\_SRSmin) for each SRS port as shown in the Table below. The reporting mechanism is triggered when the configured power at each SRS resource reaches PCMAX\_SRSmin.

|  |  |  |
| --- | --- | --- |
| ***Antenna Port*** | ***SRS Port Power Level (At antenna connectors)*** | ***Reported Value to the Network*** |
| 0 | PCMAX\_SRS0 | PCMAX\_SRS0 -PCMAX\_SRSmin |
| 1 | PCMAX\_SRS1 | PCMAX\_SRS1 -PCMAX\_SRSmin |
| 2 | PCMAX\_SRS2 | PCMAX\_SRS2 -PCMAX\_SRSmin |
| 3 | PCMAX\_SRS3 | PCMAX\_SRS3 -PCMAX\_SRSmin |
| 4 | PCMAX\_SRS4 | PCMAX\_SRS4 -PCMAX\_SRSmin |
| 5 | PCMAX\_SRS5 | PCMAX\_SRS5 -PCMAX\_SRSmin |

Proposal 2: The reporting mechanism highlighted above is also applicable to 2RX/4RX/8RX. |
| R4-2411458 | Spreadtrum Communications | Observation 1: When the power deviation exceeds a certain value (e.g., 5dB) due to the limited power of the PA device, it cannot be completely compensated by the UE.Proposal 1: Whether the UE perform power imbalance self-compensation depends on UE implementation.Proposal 2: The compensation of gNB is necessary when UE cannot keep SRS power balanced.Proposal 3: 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 4: 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. |
| R4-2411647 | 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. |
| R4-2411774 | 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: Pre-compensation by UE can directly improve the SNR condition at gNB, while post-compensation by gNB may amplify the errors in the channel estimation.Proposal 1: To handle the SRS IL issue, RAN4 should take UE pre-compensation as the baseline solution, when UE haven’t reached its Tx power limit.Proposal 2: RAN4 to further discuss whether a solution is needed when UE cannot fully pre-compensate the SRS IL.Observation 3: From the system-level simulation results, UE pre-compensation is always better than BS post-compensation in all cases.Observation 4: From the system-level simulation results, using ‘Type-I CSI’ can achieve better performance than ‘SRS-based CSI’ for cell edge UEs. |
| R4-2411884 | ZTE Corporation, Sanechips | Observation 1: Majority companies shows the SRS IL imbalance would cause non-negligible performance degradation according to the past discussions.Proposal 1: Introduce reporting for the SRS IL imbalance issue in Rel-19.Proposal 2: UE power compensation is up to UE implementation, and UE needs to indicate the power compensation behaviour to NW.Proposal 3: 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 4: The SRS IL imbalance reporting mechanism should be also specified for 2Rx, 4Rx and 8Rx. |
| R4-2412012 | Nokia | Proposal 1: RAN4 should not continue the discussion on how to solve the SRS imbalance issue.If proposal 1 is not acceptable thenObservation 1: a deadline should be set to the initial considerations phase. For example, RAN4#112bis.Observation 2: If RAN4 decides to specify requirements for 6-layer MIMO then it may have to be release independent from Rel-19.Observation 3: 6Rx REFSENS without 6-layer MIMO can be release independent from Rel-15. |
| R4-2412094 | 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: The Tx-Rx imbalance related points:* Tx-Rx imbalance matters for SRS antenna switching;
* Rx part do have its own “compensation” of imbalance;
* More factors such as antenna performance may also have impact on Tx-Rx imbalance;
* Bring more uncertainty factors in the network.

Based on the previous discussion, a general proposal is suggested: 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.
* Tx-Rx imbalance 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. |
| R4-2412136 | Samsung | Observation 1: The proposed solutions or issues of SRS IL imbalance such as UE behaviours or network performance degradation has not been discussed sufficiently in RAN4. Observation 2: 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, the meaningless arguments would be repeated to find out 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 are 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 as some networks have the same downlink performance regardless of the imbalance level.Observation 5: It would be not so meaningful capability for some UEs and networks even if RAN4 defines a solution to compensate the gap.Observation 6: In our measurements, it has not been seen the meaningful performance degradation even from the large imbalance gap between antennas under various scenarios with various networks.Observation 7: 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. |
| R4-2412330 | Intel | Observation 1: In Rel-18 discussion there was no consensus among the companies on the legacy UE behavior for SRS IL handling. Observation 2: 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 3: 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 4: 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 38.101-1Observation 5: Rel-18 RAN1 results have indicated that existence of SRS IL imbalance will cause non-negligible performance degradation.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: Specify requirements for Case 1 scenarios with PSRS,PC ≤ PCMAX,L to ensure that legacy UE performs SRS IL compensation. Proposal 2: Specify solutions, UE behavior and requirements for scenarios, when UE has sufficient power to compensate the power imbalance and require UE to perform SRS IL compensation up to the maximum power capabilities. Proposal 3: Further discuss the mechanisms for UE assistance mechanisms to inform network on the actual SRS transmission power imbalance among TX chains and modifications to the configured transmit power equations to require UE to perform at partial SRS IL compensation. |
| R4-2412353 | OPPO | Observation 1: SRS IL reporting doesn’t show much gain comparing to no SRS IL reporting under the realistic UE RFFE /Ant imbalance condition. |
| R4- 2412434 | China Telecom | Observation 1: SRS IL imbalance is non-negligible and reporting mechanism is necessarily to be introduced. Proposal 1: UE should indicate to NW whether it support insertion loss compensation ability.Proposal 2: From complexity point, the static reporting is more feasible. But if we want more accurate report, dynamic method should be considered.Proposal 3: Both static and dynamic SRS IL report need to consider reporting granularity and assistance information. |
| R4-2412574 | Huawei, HiSilicon | Observation 1: SRS transmission power determination can be categorised as following cases.

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| **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 ΔTRxSRS 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 ΔTRxSRS, 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.Proposal 6: As another compromised solution, UE is allowed to indicate whether it enables self-compensation on the SRS IL once the network requests such information, which would benefit the network by adjusting expectation on the antenna switching SRS based PMI estimation. |
| R4-2412966 | Google | Observation 1: From conducted RF antenna connector perspective, although RFFE insertion loss and PCB tracing loss may cause SRS Tx power imbalance issue when performing SRS antenna switching, the SRS-IL imbalance can be reduced a lot by factory RF calibration process for every commercial UE before shipment, which is also the common process in the industry.Observation 2: From OTA perspective, SRS Tx power imbalance at the network side needs to consider not only SRS-IL imbalance but also different antenna implementation. In our understanding, the antenna performance for the MIMO Rx diversity paths would be usually sacrificed because of more protection on main Tx/PRx. So SRS Tx power imbalance may often be occurred in the real live network even if the UE is well calibrated. 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 may not be the critical factor to impact SRS Tx power imbalance from OTA perspective, it is proposed not to introduce any SRS-IL imbalance reporting mechanism for 6Rx UE in Rel-19. |
| R4-2413306 | Lenovo | Observation 1: It is expected that the *difference* between the *configured maximum power* for two ports i and j given by$δ\_{i,j}=$ 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* $$δ\_{i,j}= ∆T\_{RxSRS,j}^{A}-∆T\_{RxSRS,i}^{A} .$$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 $δ\_{1,j}, 2\leq j\leq N$, 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 $δ\_{1,j} for all 1\leq j\leq N$ to the gNB where N is the number of SRS ports, $$δ\_{i,j}=P\_{CMAX,f,c}\left(i\right)-P\_{CMAX,f,c}\left(j\right)$$and the SRS ports are numbered such that $$δ\_{1,j}\geq 0 for all 1\leq j\leq N .$$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. |
| R4-2413360 | Ericsson | Observation 1: According to the current specifications, 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 2: It is recognized that in practice the insertion loss may not be fully accounted for (and thus compensated) for all UE 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 3: In the field, even under static conditions a very large variations (as a function of time) of received SRS power/SNR have been observed per SRS port due to the power setting inaccuracies etc.Observation 4: The SRS IL imbalance without reporting/compensation results in a non-negligible DL MIMO performance loss.Observation 5: “ΔPPowerClass requirement for SRS AS for 4Tx” issue could not be optimally solved without the introduction of reporting of the SRS transmission power or similar.Observation 6: 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: The discussion on “ΔPPowerClass requirement for SRS AS for 4Tx” issue could be merged with the discussion on “SRS IL imbalance” issue if reporting related to the SRS transmission power is agreed to be introduced.Proposal 4: IL imbalance reporting mechanism for SRS AS should include the configured maximum output power per SRS resource, the power headroom per SRS resource and ΔPPowerClass.Proposal 5: 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.Proposal 6: Another way to resolve the SRS IL imbalance reporting issue would be to introduce two types of reporting for a UE: a “baseline” and an “advanced” reporting. The baseline reporting would not require any calibration at the UE and it could include e.g. the PHR and ΔPPowerClass information. The advanced reporting could in addition include the information on e.g. the configured maximum output power. |

## Open issues summary

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

### Sub-topic 4-2: SRS IL imbalance issue solutions