3GPP TSG RAN WG1 #107-e R1-21xxxxx

**e-Meeting, November 11th – 19th, 2021**

**Agenda item: 5.1**

**Source: Moderator (China Telecom)**

**Title: [107-e-NR-R17-TxSwitching-01] Summary of email discussion on Rel-17 uplink Tx switching**

**Document for: Discussion**

# Introduction

In RAN #89 e-meeting, a new Rel-17 WID of “RF requirements enhancement for NR frequency range 1 (FR1)” [1] was approved and was revised in RAN #91 e-meeting [2], including following objectives.

* Specify UE requirements to enable Tx switching between different cases across carriers based on SUL and NR inter-band uplink CA for UE supporting maximum two concurrent transmissions
  + Specify UE requirements to enable Tx switching between cases
    - The scenarios include
      * For Tx switching based on SUL band combination, or uplink CA band combination

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|  | **Number of Tx chains in WID (carrier 1 + carrier 2)** |
| Case 2 | 0T+2T |
| Case 3 | 2T+0T |

* + - * For Tx switching based on uplink CA band combination

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|  | **Number of Tx chains in WID (carrier 1 + carrier 2)** |
| Case 1 | 1T+1T |
| Case 2 | 0T+2T |
| Case 3 | 2T+0T |

* + - Specify the following RAN4 requirements for above scenarios
      * Length of switching period
      * Time mask RF requirements
      * Uplink interruption and downlink interruption (RRM) requirements, if needed
    - Minimize the impacts on RAN1
      * Update RAN1 uplink switching for carrier aggregation and supplementary uplink
    - Minimize the impacts on RAN2
      * Update the RRC signaling to indicate the switching period location and length
      * Update the UE capabilities
  + Specify UE requirements to enable Tx switching between cases, where 1 carrier on band A and 2 contiguous aggregated carriers on band B, and band A is for SUL or non-SUL and band B is a non-SUL band
    - The scenarios include
      * For Tx switching based on SUL band combination, or uplink CA band combination

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|  | **Number of Tx chains in WID (band A + band B)** |
| Case 1 | 1T+1T |
| Case 2 | 0T+2T |

and

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|  | **Number of Tx chains in WID (band A + band B)** |
| Case 2 | 0T+2T |
| Case 3 | 2T+0T |

* + - * For Tx switching based on uplink CA band combination

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|  | **Number of Tx chains in WID (band A + band B)** |
| Case 1 | 1T+1T |
| Case 2 | 0T+2T |
| Case 3 | 2T+0T |

* + - Specify the following RAN4 requirements for above scenarios
      * Length of switching period
      * Time mask RF requirements
      * Uplink interruption and downlink interruption (RRM) requirements, if needed
    - Minimize the impacts on RAN1
      * Update RAN1 uplink switching for carrier aggregation and supplementary uplink
    - Minimize the impacts on RAN2
      * Update the RRC signaling to indicate the switching period location and length
      * Update the UE capabilities

Note 1: Only addressing the case of co-located and synchronized network deployment for the two UL carriers.

Note 2: Only addressing the case of single TAG for the two UL carriers for SUL and for UL CA.

Note 3: The UE is configured with two different uplink carrier frequencies.

This contribution is a summary of the following email discussion:

[107-e-NR-R17-TxSwitching-01] Email discussion on RAN1 Aspects for RF requirements for NR frequency range 1 (FR1) – Jianchi (China Telecom)

* Including any Rel-17 RRC signalling aspects
* 1st check point: November 15
* Final check point: November 19

# Email discussion (1st round)

## Differentiation between 1Tx-2Tx switching and 2Tx-2Tx switching

In RAN1#106-e, it was discussed whether to use existing RRC parameter or introduce a new RRC parameter to differentiate 1Tx-2Tx switching and 2Tx-2Tx switching. The following agreement has been achieved.

**Agreements: Down select one of the following options in RAN1 #106bis-e**

**Option 1:**

* For a UE configured with UL Tx switching via *uplinkTxSwitching*, the maximum number of antenna ports among all configured P-SRS/A-SRS and activated SP-SRS resources is used to determine the operation mode, i.e. either 1Tx-2Tx switching mode or 2Tx-2Tx switching mode.
* 2Tx-2Tx switching mode: when the maximum number is 2 for all uplinks configured with *uplinkTxSwitching*
* 1Tx-2Tx switching mode: when the maximum number is 1 for any one uplink configured with *uplinkTxSwitching*
* the switching gap duration for a triggered uplink switching is equal to the switching time capability value reported for the switching mode
  + Note: If the switching time capability value for 1Tx-2Tx switching mode is not reported by the UE, the value reported for 2Tx-2Tx switching mode is applied.
* If any of the above SRS resources is configured with usage “noncodebook”, then the max number of 2 antenna ports are counted for the SRS resources during the determination of operation mode.
  + FFS how to determine the number of antenna ports for SRS resources.

Support: Huawei, HiSilicon, vivo

**Option 2:**

* For a UE configured with UL Tx switching via *uplinkTxSwitching*, a new RRC parameter is used to indicate 1Tx-2Tx switching mode or 2Tx-2Tx switching mode.

In RAN1 #106b-e, option 2 is updated as follows.

**Option 2:**

* For a UE configured with UL Tx switching via *uplinkTxSwitching*, a new RRC parameter is used to indicate 1Tx-2Tx switching mode or 2Tx-2Tx switching mode.
* Note 1: gNB would not configure 1Tx-2Tx mode where the assumed 1Tx CC is also configured with non-codebook based MIMO.
* Note 2: The new RRC configuration would not conflict with other active RRC configurations on Tx states.
* Note 3: This RRC parameter is used to differentiate the table (mapping between UL transmission ports and Tx chain) and switching delay for 1Tx-2Tx vs 2Tx-2Tx for UE, and it doesn’t imply any restriction on application of non-codebook transmission together with UL Tx switching.

Support: ZTE, vivo, OPPO, Qualcomm

Companies are encouraged to provide further views on the above options.

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| **Company** | **Views** |
| Qualcomm | We support Option 2 which provides a clear way to indicate the switching mode. Meanwhile, we think Option 1 is with following issues.   * When the SRS resource is configured with noncodebook, both 1-port and 2-ports are allowed while the exact port number would be configured by network. From current option 1, our feeling is the proponents want to preclude the 1 port case. It would be better if the proponents can clarify. * The frequency for switching mode determination. Our understanding is this should be at least a RRC message circle, and therefore a new RRC IE as in Option 2 could serve this purpose very well. However, the current option 1 may have smaller time period as number of antenna ports could be changed/configured with MAC-CE. * Option 1 only checks the SRS antenna port number which might NOT fully reveal the Tx chain status. For example, 1T4R of SRS antenna switching on single carrier may be implemented with different RF architectures based on UE’s design. For some UE design, one RF chain only has 1T2R, 1T4R would require 2 separate RF chains and both RF chains need to camp on that carrier for 1T4R. However, current Option 1 would recognize this as 1 Tx and thus implement shorter switching time. |
| ZTE | From our perspective, Option1 has multiple issues need to be clarified, e.g.,  1) Option1 needs to take both RRC configuration and MAC-CE contents into consideration when determining the mode, it complicates the network and UE implementation. Also, it may cause dynamic change of the switching mode between 1Tx-2Tx vs 2Tx-2Tx via MAC-CE activating/deactivating SP-SRS.  2) Detailed timeline of Option1, e.g., if DCI scheduling PUSCH is received before the MAC-CE activating SP-SRS and the scheduled PUSCH is after the MAC-CE.  One claimed concern Option2 is that, network has to avoid conflict configuration. However, this is always the case. Network has to avoid for any case for any WI. This should not be a showstopper of Option2.  Furthermore, according to the following guidance from RAN2 LS R1-2001513/R2-2002378, RAN1 should avoid defining functionality that has no RRC configuration but is dependent on capability bits. Defining a RRC parameter to differentiate 1Tx-2Tx and 2Tx-2Tx is well aligned with RAN2’s guidance.   |  | | --- | | **5 Avoid defining functionality that has no RRC configuration but is dependent on capability bits.**  The specification should not be written so that the network determines what configuration it can use for a UE implicitly by the reported UE capabilities. Instead, the gNB should always configure the UE explicitly by DL RRC signalling, respecting the reported capabilities.  A problematic case in Rel-15 was the UL/DL MIMO layers, which resulted in a late-stage introduction of explicit MIMO signalling support by RAN2 (maxLayersMIMO-Indication). |     At this stage, it is more appropriate to pick a clean solution with majority support, i.e., Option2. |
| OPPO | Support Option 2 since it is the simpler and cleaner solution |
| Huawei, HiSilicon | We support Option 1.  For Option 2, a new RRC parameter can conflict with existing RRC parameters, a clarification like Option 1 is inevitable. It is unclear in Note2 of Option 2 that what active RRC configuration is involved and how to determine a conflict. From this perspective, Option 2 requires a consensus on Option 1 first. For example, Option 2 would have these specification impacts “The UE is not expected to be configured with switch time of 1Tx-2Tx, when the max number of antenna ports for SRS resources is 2.” This redundant RRC parameter only increases signaling overhead and possible conflicts. Therefore, Option 2 is far from good enough.  In 2-port SP-SRS Scenario，Option 2 would cause problem. If the new RRC parameter indicates the 1Tx-2Tx, the UE cannot work after the MAC-CE activates the 2-port SP-SRS due to the conflicting RRC indication. If the new RRC parameter indicates the 2Tx-2Tx, this method is not different from directly predefining to use the longest switching time.  @ZTE, Not sure why RAN2 guidance is quoted. It is quite clear that Option 1 is reusing the existing RRC configurations instead of UE capability.  @OPPO, in our understanding, Option 2 looks simple only because it hides all the clarifications done by Option 1 within Note 2, which can cost misunderstanding between gNB and UEs. |
| vivo | Option 1 and the updated Option 2 is now equivalent in terms of functionality from our understanding, while companies had different flavour on how it is to be specified. We are flexible to take either one of them and prefer to take a decision without repeated discussion again. |

## 1-port transmission via DCI format 0\_1 for UL CA option 2

This issue was intensively discussed in Rel-16. Many compromised proposals were discussed but unfortunately no consensus was reached.

**Proposed Conclusion:**

**Alt 1:**

* For Rel-17 Tx switching between Band A and Band B, no additional specification impact to support 1-port transmission via DCI format 0\_1 for UL CA option 2 when maximum *nrofSRS-Ports* among the carriers on Band B is configured as 2 antenna ports and the state of Tx chains is 1 Tx on Band A and 1Tx on Band B.

**Alt 2:**

* For Rel-17 Tx switching between Band A and Band B, no additional specification impact to support 1-port transmission via DCI format 0\_1 for UL CA option 2.

Companies are encouraged to check whether can live up with one of the alternatives.

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| **Company** | **Views** |
| Qualcomm | We support Alt 1.  This UL Tx switching feature has two most important parts – when to switch and how to switch. This conclusion is on the 1st part – when to switch. In the proposed conclusion, the port number determination “when maximum nrofSRS-Ports among the carriers on Band B is configured as 2 antenna ports and the state of Tx chains is 1 Tx on Band A and 1Tx on Band B” is the most critical issue, as gNB & UE may interpret codebook as different Tx status.  Rel-17 allows 2 ports scheduling for both bands, which makes the status determination more complicated than Rel-16. This port number categorization is thus with higher importance and necessity. As the conclusion would help to reduce the potential scheduling ambiguity, we would propose companies to be more constructive to make the necessary progress.  We had long time discussion and unfortunately, we can’t converge to one proposal. To make progress, we compromise to above FL proposed conclusion without specification impact, which leave the port number categorization to implementation. |
| ZTE | We support Alt.1.  This issue has been discussed for several meeting and was almost agreed in previous meetings. It would be good if we can converge on Alt.1. |
| Huawei, HiSilicon | As a compromise, we can accept Alt 2.  Since the discussion has last more than 16 months, we don’t prefer any further discussion. If it is not acceptable, we request a conclusion to say no consensus on this issue or no consensus to further discuss it, which pretty reflects the real RAN1 situation. |
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## RRC parameters

In RAN1 #106b-e, it was agreed to introduce a new RRC parameter to configure the state of chain if the state of Tx chains after the UL Tx switching is not unique for 2Tx-2Tx switching for UL-CA option 2. Recommendations for RAN1 RRC Parameter are given in [9].

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| **WI code** | **Sub-feature group** | **Parameter name in the spec** | **New or existing?** | **Description** | **Value range** | **Default value aspect** | **Per (UE, cell, TRP, …)** | **UE-specific or Cell-specific** |
| NR\_RF\_FR1\_enh-Core | Uplink Tx switching enhancements | *uplinkTxSwitchingTxState* | new | For UL-CA option 2 and 2Tx-2Tx switching, indicate the state of chain if the state of Tx chains after the UL Tx switching is not unique. |  |  |  | UE-specific |

Companies are encouraged to provide views on the above RRC parameter, especially for the value range and default value.

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| **Company** | **Views** |
| Qualcomm | We support FL’s recommendation.  Just one clarification question on the value range, is it the intent to leave it blank at this meeting? Otherwise, it could be filled with e.g. {1Tx, 2Tx} per our understanding. |
| ZTE | We propose the following contents for the value range.  **Value range: *1T1T*, *0T2T***  When the UE transmitted 1-port or 2-port transmission on one carrier on one band followed by no transmission on this carrier and 1-port transmission on the other carrier on another band,  if the UE was configured with *1T1T* for subsequent switching consideration the UE shall consider this as if 1-port transmission was transmitted on both uplinks  if the UE was configured with *0T2T* for subsequent switching consideration, the UE shall consider this as if 2-port transmission took place on the transmitting carrier.  **Default value could be *0T2T* from our perspective.** |
| OPPO | Support in principle |
| Huawei, HiSilicon | In term of overhead, value range would better be {0 or 1} instead of string set {1T1T, 0T2T}. Then as usual the description can assign 0/1 to 1T1T/0T2T. Or up to RAN2 decision and we only provide the corresponding RAN1 agreement in the comment column which should be clear enough. |

# Email discussion (2nd round)

## Differentiation between 1Tx-2Tx switching and 2Tx-2Tx switching

**FL comments:** Per Chair’s guidance, let’s focus on the discussion on option 2.

**Proposal:**

* For a UE configured with UL Tx switching via *uplinkTxSwitching*, a new RRC parameter is used to indicate 1Tx-2Tx switching mode or 2Tx-2Tx switching mode.
* Note 1: gNB would not configure 1Tx-2Tx mode where the assumed 1Tx CC is also configured with non-codebook based MIMO.
* Note 2: The new RRC configuration would not conflict with other active RRC configurations on Tx states.
* Note 3: This RRC parameter is used to differentiate the table (mapping between UL transmission ports and Tx chain) and switching delay for 1Tx-2Tx vs 2Tx-2Tx for UE, and it doesn’t imply any restriction on application of non-codebook transmission together with UL Tx switching.

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| **Company** | **Views** |
| Qualcomm | We support FL’s proposal. |
| ZTE | We support FL’s proposal. |
| Huawei, HiSilicon | Thank Mr. Chairman and FL very much for the proposal.  However, we cannot agree it for the following concerns that have been raised for long time but never received any answers.   * There are legacy RRC parameters indicating 1Tx-2Tx or 2Tx-2Tx. A new RRC parameter will cause conflict with them. Such conflict should be avoided with clearly description as the proposed Option 1 below. * The UE behaviour is the same for both 1Tx-2Tx switching and 2Tx-2Tx switching, at least quite obvious for UL-CA Option 1 and SUL. A new RRC parameter is redundant since the same UE behaviour has been associated by legacy RRC parameter. Its introduction has never been justified. * There is no table in the current spec as the Note 3 says. It cannot justify any new RRC parameter.   Our suggestion is to clarify the Note2 above with Option 1 below first, then it becomes clearer to check if new RRC parameter is still required.  **Option 1:**   * For a UE configured with UL Tx switching via *uplinkTxSwitching*, the maximum number of antenna ports among all configured P-SRS/A-SRS and activated SP-SRS resources is used to determine the operation mode, i.e. either 1Tx-2Tx switching mode or 2Tx-2Tx switching mode. * 2Tx-2Tx switching mode: when the maximum number is 2 for all uplinks configured with *uplinkTxSwitching* * 1Tx-2Tx switching mode: when the maximum number is 1 for any one uplink configured with *uplinkTxSwitching* * the switching gap duration for a triggered uplink switching is equal to the switching time capability value reported for the switching mode   + Note: If the switching time capability value for 1Tx-2Tx switching mode is not reported by the UE, the value reported for 2Tx-2Tx switching mode is applied. * If any of the above SRS resources is configured with usage “noncodebook”, then the max number of 2 antenna ports are counted for the SRS resources during the determination of operation mode.   + FFS how to determine the number of antenna ports for SRS resources. |
| Qualcomm | Thanks for the great efforts of Mr. Chairman and FL, we support the way forward proposed by Mr. Chairman to take Option 2 as agreement.  In response to Huawei’s comments   * We can’t find any existing RRC IE to differentiate the 1Tx-2Tx and 2Tx-2Tx. Maybe Huawei could point out which and how it serves such purpose. At least we can’t find any clues according to past discussion. * The new RRC IE proposed by Option 2 is only used to indicate the switching time related to the different switching modes, which would not be expected to be used for other purpose (e.g. changing the UE switching behaviour). From this consideration, it would not cause conflict with other activated RRC configurations on Tx states and the note 2 of Option 2 clearly indicates this. * The table in note 3 refers to the agreements in Chairman’s notes and would be translated into specs via CR. This should be very clear.   Beyond the above response, we think Option 1 still has some implementation issues as below:   * Option 1 only checks the SRS antenna port number which might NOT fully reveal the Tx chain status. For example, 1T4R of SRS antenna switching on single carrier may be implemented with different RF architectures based on UE’s design. For some UE design, one RF chain only has 1T2R, 1T4R would require 2 separate RF chains and both RF chains need to camp on that carrier for 1T4R. However, current Option 1 would recognize this as 1 Tx and thus implement shorter switching time. * When the SRS resource is configured with noncodebook, both 1-port and 2-ports are allowed while the exact port number would be configured by network. From current option 1, our feeling is the proponents want to preclude the 1 port case. It would be better if the proponents can clarify. * The frequency for switching mode determination. Our understanding is this should be at least a RRC message circle, and therefore a new RRC IE as in Option 2 could serve this purpose very well. However, the current option 1 may have smaller time period as number of antenna ports could be changed/configured with MAC-CE.   As above considerations, we support Mr. Chairman’s proposal to take Option 2 as agreement. |
| ZTE | Response to Huawei’s comment  1) For the first bullet in Huawei’s comments, we don’t think the legacy SRS configurations can be used to differentiate 1Tx-2Tx and 2Tx-2Tx, at least the timeline issue as we commented in last round should be clarified and the dynamic switching between 1Tx-2Tx and 2Tx-2Tx should be avoided.  2) For the second bullet in Huawei’s comments, we think the main motivation is to indicate different switching delay for UE (i.e., whether it is switching delay for 1Tx-2Tx or 2Tx-2Tx).  3) For the third bullet in Huawei’s comments, Note3 is just for information. All companies understand the table here refers to the table we agreed in previous meetings. If you feel this note is not clear enough, please make changes to note3 if necessary. From our perspective, the Note3 is clear as it is. |
| Qualcomm |  |
| Huawei, HiSilicon | @ZTE Thank you for confirmation the motivation as indicating different switching delay. We don’t see a timeline issue since they are the legacy RRC parameters, but we can save it for offline discussions.  Without the new RRC parameter, the Rel-17 UL Tx switching mechanism works well with the existing RRC parameters. But with the new RRC parameter, the potential conflicts with existing RRC parameters must be clarified. Also its definition on 1Tx-2Tx mode has to be clarified well in order not to put new confusion on current supported operation configurations.  Additionally, the new RRC parameter does not link to any new UE behaviour, for example, ALL of new Rel-17 UE behaviours for SUL have been captured in the following excerpts of endorsed R1-2112489, the change is very small, meaning that the new RRC parameter looks very redundant here and no idea where to add it.  R1-2112489:    We really doubt the necessity of the new RRC parameter, but for progress, we can compromise with the following revised proposal, where necessary clarifications shall be added,  Additional reasoning for changes:   * Note 2 shall be clarified by the first sub-bullet about what conflict should be avoided. * For a UE capable of 2Tx-2Tx switching, if 1Tx-2Tx switching mode is configured, then both the following cases that have been supported by legacy configurations should be allowed, a) the UE is configured with 2Tx UL-MIMO on band A but no UL-MIMO on band B, b) the UE is configured with no UL-MIMO on band A but 2Tx UL-MIMO on band B. * Default value: Since it has been agreed in RAN2 that a UE capable of Rel-17 2Tx-2Tx must report support of 1Tx-2Tx switching, if the RRC parameter is absent, then its default value is 1Tx-2Tx switching mode.   **Possible Agreement**   * For a UE capable of 2Tx-2Tx switching and configured with UL Tx switching via *uplinkTxSwitching*, to differentiate the switching delay for 1Tx-2Tx switching from that for 2Tx-2Tx switching, a new RRC parameter is used to indicate 1Tx-2Tx switching mode or 2Tx-2Tx switching mode. * If 1Tx-2Tx mode is derived by the new RRC parameter, then at least on one uplink (or one uplink band in case of intra-band) configured with *uplinkTxSwitching*, the maximum number of antenna ports among all configured P-SRS/A-SRS and activated SP-SRS resources should be 1 and non-codebook based UL MIMO is not configured. * The new RRC parameter is optional and if it is absent, its default value is 1Tx-2Tx switching mode. * In a configured switching mode, the switching gap duration for a triggered uplink switching is equal to the switching time capability value reported for the switching mode. * Note 1: gNB would not configure 1Tx-2Tx mode where the assumed 1Tx CC is also configured with non-codebook based MIMO. * ~~Note 2: The new RRC configuration would not conflict with other active RRC configurations on Tx states.~~ * Note 3: This RRC parameter ~~is used to differentiate the table (mapping between UL transmission ports and Tx chain) and switching delay for 1Tx-2Tx vs 2Tx-2Tx for UE, and it~~ doesn’t imply any restriction on application of non-codebook transmission together with UL Tx switching. |
| H3C | We are fine with the FL proposal with HW and ZTE’s modification as below:  **Possible Agreement**     For a UE capable of 2Tx-2Tx switching and configured with UL Tx switching via uplinkTxSwitching, to differentiate the switching delay for 1Tx-2Tx switching from that for 2Tx-2Tx switching, a new RRC parameter is used to indicate 1Tx-2Tx switching mode or 2Tx-2Tx switching mode.  ‐   The new RRC parameter is optional and if it is absent, its default value is 1Tx-2Tx switching mode.  ‐   In a configured switching mode, the switching gap duration for a triggered uplink switching is equal to the switching time capability value reported for the switching mode.  ‐   Note 1: gNB would not configure 1Tx-2Tx mode where the assumed 1Tx CC is also configured with non-codebook based MIMO.  ‐   Note 2: ~~The new RRC configuration would not conflict with other active RRC configurations on Tx states.~~   If 1Tx-2Tx mode is derived by the new RRC parameter, **~~then at least on one uplink (or one uplink band in case of intra-band) configured with uplinkTxSwitching,~~** the maximum number of antenna ports among all configured P-SRS/A-SRS and activated SP-SRS resources should be 1 **on the 1Tx** **carrier ~~and non-codebook based UL MIMO is not configured~~**~~.~~  ‐   Note 3: This RRC parameter ~~is used to differentiate the table (mapping between UL transmission ports and Tx chain) and switching delay for 1Tx-2Tx vs 2Tx-2Tx for UE, and it~~doesn’t imply any restriction on application of non-codebook transmission together with UL Tx switching. |

## 1-port transmission via DCI format 0\_1 for UL CA option 2

**FL comments:** Per Chair’s guidance, let’s focus on the discussion on the following proposed conclusion.

**Proposed conclusion:**

* For Rel-17 Tx switching between Band A and Band B, there is no consensus to introduce additional specification support for 1-port transmission via DCI format 0\_1 for UL CA option 2.

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| **Company** | **Views** |
| Qualcomm | Thanks for the efforts from Mr. Chairman and FL.  We don’t agree with the proposed conclusion.  As a compromise, we can accept Alt.2 from the 1st round discussion. Since that was agreed by Huawei, this would need to be confirmed by ZTE only. |
| ZTE | For progress, we can compromise to the previous Alt.2.  **Alt 2:**   * For Rel-17 Tx switching between Band A and Band B, no additional specification impact to support 1-port transmission via DCI format 0\_1 for UL CA option 2. |
| Huawei, HiSilicon | Given more than one-year discussion, it is the only way to go. We are OK with it. |
| FL | Thanks Qualcomm, ZTE for the flexibility. Then, it seems the following proposed conclusion can be acceptable for everyone.  **Proposed conclusion:**   * For Rel-17 Tx switching between Band A and Band B, no additional specification impact to support 1-port transmission via DCI format 0\_1 for UL CA option 2. |

## RRC parameters

**FL comments:** Based on companies’ views, my suggestion is to take {1T, 2T} as the value range and 2T as the default value, while 0T2T may cause confusion that only carrier 2 or band B supports 2Tx. To address the concern from Huawei, we can keep these values in square brackets. The table is updated in red.

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| **WI code** | **Sub-feature group** | **Parameter name in the spec** | **New or existing?** | **Description** | **Value range** | **Default value aspect** | **UE-specific or Cell-specific** | **Comment** |
| NR\_RF\_FR1\_enh-Core | Uplink Tx switching enhancements | *uplinkTxSwitchingTxState* | new | For UL-CA option 2 and 2Tx-2Tx switching, indicate the state of chain if the state of Tx chains after the UL Tx switching is not unique. | [{1T, 2T}] | [2T] | UE-specific | **Agreement:**   For UL-CA Option2, if UL Tx switching is triggered for 1-port transmission on a carrier and the state of Tx chains after the UL Tx switching is not unique, introduce a new RRC parameter to configure between 1) and 2)  ‐ 1) The state of Tx chains supporting 2Tx transmission on the carrier is assumed.  ‐ 2) 1Tx on carrier 1 and 1Tx on carrier 2 is assumed. |

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| **Company** | **Views** |
| Qualcomm | We support FL’s proposal. |
| ZTE | We are ok with the FL’s proposal. |
| Huawei, HiSilicon | Small revision *uplinkTxSwitchingdualULTxState*, since it is only applicable to Option 2 “dualUL”.  As commented before, we feel the agreement in column comment is clear enough. Prefer not to add anything to value range or default value. But we can live with it for the progress. |
| FL | It seems the following table for the RRC parameter is stable. |
| H3C | We are fine with FL proposal |

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| **WI code** | **Sub-feature group** | **Parameter name in the spec** | **New or existing?** | **Description** | **Value range** | **Default value aspect** | **UE-specific or Cell-specific** | **Comment** |
| NR\_RF\_FR1\_enh-Core | Uplink Tx switching enhancements | *uplinkTxSwitchingdualULTxState* | new | For UL-CA option 2 and 2Tx-2Tx switching, indicate the state of chain if the state of Tx chains after the UL Tx switching is not unique. | [{1T, 2T}] | [2T] | UE-specific | **Agreement:**   For UL-CA Option2, if UL Tx switching is triggered for 1-port transmission on a carrier and the state of Tx chains after the UL Tx switching is not unique, introduce a new RRC parameter to configure between 1) and 2)  ‐ 1) The state of Tx chains supporting 2Tx transmission on the carrier is assumed.  ‐ 2) 1Tx on carrier 1 and 1Tx on carrier 2 is assumed. |

# Agreements at RAN1#106b-e

**Agreement:**

* For UL-CA Option2, if UL Tx switching is triggered for 1-port transmission on a carrier and the state of Tx chains after the UL Tx switching is not unique, introduce a new RRC parameter to configure between 1) and 2)
  + 1) The state of Tx chains supporting 2Tx transmission on the carrier is assumed.
  + 2) 1Tx on carrier 1 and 1Tx on carrier 2 is assumed.

# Agreements at RAN1#106-e

**Agreements:**

* **For SUL and UL CA option 1, if 1Tx-2Tx UL Tx switching or 2Tx-2Tx UL Tx switching between 1 carrier on band A and 2 carriers on band B is configured, the switching period is only applicable when the UL transmissions are switched between band A and band B.**

**Agreements:**

* **For inter-band UL CA, if 1Tx-2Tx UL Tx switching between 1 carrier on band A and 2 carriers on band B is configured is configured:**
* **For option 2 of mapping between UL transmission ports and Tx chain**
  + **The switching period is only applicable in the following cases:**
    - **If the current state of Tx chains is 1 Tx on band A and 1Tx on band B, the next UL transmission has a 2-port transmission on at least one carrier on band B.**
    - **If the current state of Tx chains is 0 Tx on band A and 2Tx on band B, the next UL transmission has a 1-port transmission on the carrier on band A.**
  + **For other cases, the state of Tx chains of last UL transmission is assumed.**

**Agreements:**

* **For inter-band UL CA, if 2Tx-2Tx UL Tx switching between 1 carrier on band A and 2 carriers on band B is configured:**
* **For option 2 of mapping between UL transmission ports and Tx chain**
  + **The switching period is only applicable in the following cases:**
    - **If the current state of Tx chains is 1Tx on band A and 1Tx on band B, the next UL transmission has a 2-port transmission on the carrier on band A or at least one carrier on band B.**
    - **If the current state of Tx chains is 0Tx on band A and 2Tx on band B, the next UL transmission has a 1-port or 2-port transmission on the carrier on band A.**
    - **If the current state of Tx chains is 2Tx on band A and 0Tx on band B, the next UL transmission has a 1-port or 2-port transmission on at least one carrier on band B.**
  + **For other cases, the state of Tx chains of last UL transmission is assumed.**

**Agreements: Down select one of the following options in RAN1#106b-e:**

* **Option 1:** For UL-CA Option2, if UL Tx switching is triggered for 1-port transmission on a carrier and the state of Tx chains after the UL Tx switching is not unique, then
  + 1Tx on carrier 1 and 1Tx on carrier 2 is assumed if the carrier is configured with *uplinkTxSwitchingPeriodLocation* as true.
  + the state of Tx chains supporting 2Tx transmission is assumed on the carrier if the carrier is configured with *uplinkTxSwitchingPeriodLocation* as false.
* **Option 2:** For UL-CA Option2, if UL Tx switching is triggered for 1-port transmission on a carrier and the state of Tx chains after the UL Tx switching is not unique, then the state of Tx chains supporting 2Tx transmission on the carrier is assumed.
* **Option 3:** For UL-CA Option2, if UL Tx switching is triggered for 1-port transmission on a carrier and the state of Tx chains after the UL Tx switching is not unique, then 1Tx on carrier 1 and 1Tx on carrier 2 is assumed.

**Agreements: Down select one of the following options in RAN1 #106bis-e**

**Option 1:**

* **For a UE configured with UL Tx switching via *uplinkTxSwitching*, the maximum number of antenna ports among all configured P-SRS/A-SRS and activated SP-SRS resources is used to determine the operation mode, i.e. either 1Tx-2Tx switching mode or 2Tx-2Tx switching mode.**
* **2Tx-2Tx switching mode: when the maximum number is 2 for all uplinks configured with *uplinkTxSwitching***
* **1Tx-2Tx switching mode: when the maximum number is 1 for any one uplink configured with *uplinkTxSwitching***
* **the switching gap duration for a triggered uplink switching is equal to the switching time capability value reported for the switching mode**
  + **Note: If the switching time capability value for 1Tx-2Tx switching mode is not reported by the UE, the value reported for 2Tx-2Tx switching mode is applied.**
* **If any of the above SRS resources is configured with usage “noncodebook”, then the max number of 2 antenna ports are counted for the SRS resources during the determination of operation mode.**
  + **FFS how to determine the number of antenna ports for SRS resources.**

**Option 2:**

* **For a UE configured with UL Tx switching via *uplinkTxSwitching*, a new RRC parameter is used to indicate 1Tx-2Tx switching mode or 2Tx-2Tx switching mode.**

# Agreements at RAN1#105-e

**Agreements:**

* For a UE configured with higher layer parameter *supplementaryUplink* and with 2Tx-2Tx UL Tx switching between two uplink carriers, the mechanism of uplink switching specified in S6.1.6.3 of TS 38.214 is reused.

**Agreements:**

* For a UE configured with UL CA Option 1 and with 2Tx-2Tx UL Tx switching between two uplink carriers, the mechanism of uplink switching specified in S6.1.6.2 of TS 38.214 is reused with the following add-on.
* When the UE is to transmit a 2-port transmission on one uplink carrier and if the preceding uplink transmission is a 2-port transmission on another uplink carrier, then the UE is not expected to transmit for the duration of NTx1-Tx2 on any of the two carriers.

**Agreements:**

* For inter-band UL CA, if 2Tx-2Tx UL Tx switching between two uplink carriers is configured:
* For option 2 of mapping between UL transmission ports and Tx chain
  + The switching period is only applicable in the following cases:
    - If the current state of Tx chains is 1Tx on carrier 1 and 1Tx on carrier 2, the next UL transmission has a 2-port transmission on either carrier 1 or carrier 2.
    - If the current state of Tx chains is 0Tx on carrier 1 and 2Tx on carrier 2, the next UL transmission has a 1-port or 2-port transmission on carrier 1.
    - If the current state of Tx chains is 2Tx on carrier 1 and 0Tx on carrier 2, the next UL transmission has a 1-port or 2-port transmission on carrier 2.
  + For other cases, the state of Tx chains of last UL transmission is assumed.
* Note: For SUL, UL CA option 1 and UL CA option 2, in RAN1 understanding, no spec change to power configuration and power control.

**Agreement:**

* For a UE configured with 2Tx-2Tx UL Tx switching between two uplink carriers and configured with UL CA Option 2, if the state of Tx chains after UL Tx switching is not unique, a rule to determine the state of Tx chains after Tx switching is to be specified.
  + FFS: The state of Tx chains with the most of Tx chains on the most important uplink carrier is assumed, e.g. the carrier with *uplinkTxSwitchingPeriodLocation* configured as false.

# Agreements at RAN1#104b-e

**Agreements:**

* **For Rel-17 2Tx-2Tx switching between two uplink carriers, the mapping between UL transmission ports and Tx chain for SUL and UL CA Option 1 is defined as follows.**

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** in WID (carrier 1 + carrier 2) | Number of **antenna ports** for UL transmission (carrier 1 + carrier 2) |
| Case 2 | 0T+2T | 0P+2P, 0P+1P |
| Case 3 | 2T+0T | 2P+0P, 1P+0P |

**Agreements:**

* **For Rel-17 2Tx-2Tx switching between two uplink carriers, the mapping between UL transmission ports and Tx chain for UL CA Option 2 is defined as follows.**

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** in WID (carrier 1 + carrier 2) | Number of **antenna ports** for UL transmission (carrier 1 + carrier 2) |
| Case 1 | 1T+1T | 1P+0P, 1P+1P, 0P+1P |
| Case 2 | 0T+2T | 0P+2P, 0P+1P |
| Case 3 | 2T+0T | 2P+0P, 1P+0P |

**Conclusion:**

* For uplink Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B,
  + If the state of Tx chains is 1Tx on Band A and 1Tx on Band B, 1Tx is available simultaneously on both uplink carriers on band B for a UE.
  + If the state of Tx chains is 0Tx on Band A and 2Tx on Band B, 2Tx are available simultaneously on both uplink carriers on band B for a UE.

**Agreement:**

* Send LS to RAN4 asking following question:
  + Question: For UL Tx switching in a band pair of a band combination, whether or not the switching time reported by a UE for 2Tx-2Tx switching can be different from that reported by the UE for 1Tx-2Tx switching.

**Agreement:**

For Rel-17 1Tx-2Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B, the mapping between UL transmission ports and Tx chain for SUL and UL CA Option 1 is defined as follows.

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** in WID (band A + band B) | Number of **antenna ports** for UL transmission (band A (carrier 1) + band B (carrier 2 + carrier 3)) |
| Case 1 | 1T+1T | 1P+(0P+0P) |
| Case 2 | 0T+2T | 0P+(2P+0P), 0P+(0P+2P), 0P+(2P+2P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P), 0P+(1P+2P), 0P+(2P+1P) |

**Agreement:**

For Rel-17 2Tx-2Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B, the mapping between UL transmission ports and Tx chain for SUL and UL CA Option 1 is defined as follows.

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** in WID (band A + band B) | Number of **antenna ports** for UL transmission (band A (carrier 1) + band B (carrier 2 + carrier 3)) |
| Case 2 | 0T+2T | 0P+(2P+0P), 0P+(0P+2P), 0P+(2P+2P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P), 0P+(1P+2P), 0P+(2P+1P) |
| Case 3 | 2T+0T | 2P+(0P+0P), 1P+(0P+0P) |

**Agreement:**

For Rel-17 1Tx-2Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B, the mapping between UL transmission ports and Tx chain for UL CA Option 2 is defined as follows.

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** in WID (band A + band B) | Number of **antenna ports** for UL transmission (band A (carrier 1) + band B (carrier 2 + carrier 3)) |
| Case 1 | 1T+1T | 1P+(0P+0P), 1P+(1P+0P), 1P+(0P+1P), 1P+(1P+1P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P) |
| Case 2 | 0T+2T | 0P+(2P+0P), 0P+(0P+2P), 0P+(2P+2P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P), 0P+(1P+2P), 0P+(2P+1P) |

**Agreement:**

For Rel-17 2Tx-2Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B, the mapping between UL transmission ports and Tx chain for UL CA Option 2 is defined as follows.

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** in WID (band A + band B) | Number of **antenna ports** for UL transmission (band A (carrier 1) + band B (carrier 2 + carrier 3)) |
| Case 1 | 1T+1T | 1P+(0P+0P), 1P+(1P+0P), 1P+(0P+1P), 1P+(1P+1P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P) |
| Case 2 | 0T+2T | 0P+(2P+0P), 0P+(0P+2P), 0P+(2P+2P), 0P+(1P+0P), 0P+(0P+1P), 0P+(1P+1P), 0P+(1P+2P), 0P+(2P+1P) |
| Case 3 | 2T+0T | 2P+(0P+0P), 1P+(0P+0P) |

**Conclusion:**

* For uplink Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B, whether Tx switching between 2Tx on Band A and 1Tx on Band A+1Tx on Band B for UL CA option 1 and SUL is included in WID could be clarified by RAN plenary or RAN4.

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