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. |
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## 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. |
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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. |
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# 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.**

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|  | 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.

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| --- | --- | --- |
|  | 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.

# References

1. RP-202088, New WID proposal: RF requirements enhancement for NR frequency range 1 (FR1) in Rel-17, Huawei, HiSilicon, China Telecom, RAN #89e, Sep. 2020.
2. RP-210899, Revised WID: RF requirements enhancement for NR frequency range 1 (FR1), Huawei, HiSilicon, RAN #91e, Mar. 2021.
3. R1-2110795, Discussions on enhancements for UL Tx switching, Huawei, HiSilicon, RAN1 #107-e, November 11th – 19th, 2021.
4. R1-2110904, Remaining issues for Rel-17 UL Tx switching, ZTE, RAN1 #107-e, November 11th – 19th, 2021.
5. R1-2110972, Remaining issues on Rel-17 Tx switching enhancements, vivo, RAN1 #107-e, November 11th – 19th, 2021.
6. R1-2111288, Discussion on Rel-17 Tx Switching enhancement, OPPO, RAN1 #107-e, November 11th – 19th, 2021.
7. R1-2111933, Discussion on the remaining problems of supporting Tx switching between two uplink carriers, Huawei, HiSilicon, RAN1 #107-e, November 11th – 19th, 2021
8. R1-2112188, Discussion on Rel-17 UL Tx switching, Qualcomm Incorporated, RAN1 #107-e, November 11th – 19th, 2021.
9. R1-2111193, Recommendations for RAN1 RRC Parameter Preparation, Ericsson, RAN1#107-e, November 11th – 19th, 2021.