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** |
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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** |
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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** |
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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.**

|  |  |  |
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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 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.

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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) |
| 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.

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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 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.

|  |  |  |
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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) |
| 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.