3GPP TSG RAN WG1 #106bis-e R1-21xxxxx

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

**Agenda item: 5.1**

**Source: Moderator (China Telecom)**

**Title: [106bis-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

|  |  |
| --- | --- |
|  | **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

|  |  |
| --- | --- |
|  | **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

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

and

|  |  |
| --- | --- |
|  | **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

|  |  |
| --- | --- |
|  | **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:

[106bis-e-NR-R17-TxSwitching-01] Email discussion on RAN1 Aspects for RF requirements for NR frequency range 1 (FR1) – Jianchi (China Telecom)

* 1st check point: October 14
* Final check point: October 19

# Email discussion (1st round)

## Determination of the state of Tx chains for 2Tx-2Tx switching

In RAN1#106-e, it was discussed how to handle the case that the state of Tx chains after Tx switching is not unique for UL CA option 2 for 2Tx-2Tx chains and the following agreement was achieved.

**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.

**Companies’ views [3] - [9] on each option are summarized in the table blow.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Option 1** | **Option 2** | **Option 3** |
| **Huawei, HiSilicon (R1-2108743)** | The network can flexibly adjust the UE behavior according to the actual situation, without requiring a new RRC parameter. | The network cannot adjust the UE behavior according to the actual situation. | |
| **ZTE (R1-2108839)** | coupling the default state with *uplinkTxSwitchingPeriodLocation* is not necessary from our perspective.  Which carrier is more important is typically decided by operator, not decided by the parameter *uplinkTxSwitchingPeriodLocation*. | since UE supports both 1-port and 2-port transmission on carrier2 and carrier1 under Case2 and Case3, respectively, to avoid unnecessary switching between 1-port and 2-port transmission, it is more appropriate to predefine the target case as Case2 and Case3. | |
| **vivo (R1-2108949)** | to couple the Tx state with the presence of uplink switching gap does not provide meaningful gain in practice but put constraint for gNB when configuring the presence of uplink switching gap between carriers | Option 2 could maximum the utilization of UL MIMO (i.e. 2Tx) on one carrier in the slot immediately after the Tx switching, but it would cause additional delay or resource overhead if 1Tx PUSCH or PUCCH is scheduled on the other carrier immediately after the Tx switching (as 0Tx is assumed). | Option 3 is more balanced between the two carriers and therefore preferred |
| **OPPO (R1-2109050)** | Whether the carrier is configured with *uplinkTxSwitchingPeriodLocation* as true or false is usually depending on the available UL resources, rather than on the importance of the carrier(s). | For a UE can support 2Tx-2Tx, gNB usually prefers to boost the data rate via utilizing the maximum capability of UE. Thus, gNB is likely to continue transmit 2-port PUSCH in this carrier/band, or switch back to another carrier/band to transmit 2-port PUSCH. Thus, Option 2 is the most efficient in most typical cases. | It is beneficial the case where gNB schedules UE with 1-port transmission switching between two carriers/bands. It should not be the typical case for a UE supporting 2Tx-2Tx UL Tx switching. |
| **China Telecom (R1-2109246)** | if a UE is configured with 2Tx-2Tx UL Tx switching, it means that this UE can be scheduled with 2Tx transmission on any of the two carrier with high probability. | | |
| **CMCC (R1-2109269)** | the “signaling” solution looks like the best one but it is already ruled out for Rel-17. Then the second-best solution is to exam the actual Tx switching application scenarios on major operators’ network and take decision accordingly. If for most of the time/scenarios, 2Tx is the righteous choice, then assuming 2Tx will be most efficient. | | |
| **Qualcomm (R1-2110163)** | the UL switching period is configured typically with the carrier with more UL slots, which doesn’t mean the carrier is less important | Option 2 somewhat incompatible with the feature of PUCCH carrier switching because it can result in a state switch for every successive PUCCH transmission when there is no PUSCH. | Option 3 tries to prioritize 1Tx on each band which is friendly to Pcell. |
| **Summary** | **Supported by Huawei, HiSilicon** | **Supported by ZTE, China Telecom, OPPO, CMCC** | **Supported by Qualcomm, vivo** |

In addition, R1-2108949 proposed option 4, configured between Option 2 and Option3 by a new RRC parameter.

* **Option 4:** 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.

R1-2109246 proposed the details for 2Tx-2Tx switching between two uplink carriers and 2Tx-2Tx switching between two uplink bands.

* 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, i.e.,
  + If the current state of Tx chains is 0Tx on carrier 1 and 2Tx on carrier 2, and if the next UL transmission is 1-port transmission on carrier 1, the state of Tx chains after Tx switching is 2Tx on carrier 1 and 0Tx on carrier 2.
  + If the current state of Tx chains is 2Tx on carrier 1 and 0Tx on carrier 2, and if the next UL transmission is 1-port transmission on carrier 2, the state of Tx chains after Tx switching is 0Tx on carrier 1 and 2Tx on carrier 2.
* For UL-CA Option2, if UL Tx switching is triggered for 1-port transmission on at least one carrier on a band 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 band is assumed, i.e.,
  + If the current state of Tx chains is 0Tx on band A and 2Tx on band B, and if the next UL transmission is 1-port transmission on band A, the state of Tx chains after Tx switching is 2Tx on band A and 0Tx on band B.
  + If the current state of Tx chains is 2Tx on band A and 0Tx on band B, and if the next UL transmission is 1-port transmission on at least one carrier on band B, the state of Tx chains after Tx switching is 0Tx on band A and 2Tx on band B.

**FL comments:** It seems companies acknowledge that either option can work. Option 1 has the flexibility to configure the state of Tx chains but it has to couple with *uplinkTxSwitchingPeriodLocation*, and it seems most companies has concerns on the coupling. It is mentioned by companies that for UE configured with 2Tx-2Tx UL Tx switching, it means that this UE can be scheduled with 2Tx transmission on any of the two carrier with high probability, thus, Option 2 is the most efficient in most typical cases. Option 3 may avoid the switching gap in some cases, it is friendly to Pcell and more balanced between the two carriers, but it may not be the typical case for a UE supporting 2Tx-2Tx UL Tx switching. Based on companies’ views and analysis on each option, FL suggests to consider option 4 proposed by vivo, which keeps flexibility while it is not coupled with *uplinkTxSwitchingPeriodLocation*.

**Proposal:**

* 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.

Companies are encouraged to provide comments on the above proposal.

|  |  |
| --- | --- |
| **Company** | **Views** |
|  |  |
|  |  |
|  |  |
|  |  |

## 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.

**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.

**Companies’ views [3] - [9] on each option are summarized in the table blow.**

|  |  |  |
| --- | --- | --- |
|  | **Option 1** | **Option 2** |
| **Huawei, HiSilicon (R1-2108743)** | The counting of maximum number of antenna ports has no impact on the effective non-codebook operation, but only on the determination of operation mode which is used to determine the proper gap that a UE needs. | When new parameters are introduced, problems may arise. If a new RRC parameter is introduced, then it may end up with conflicting RRC parameters, for example, 2Tx-2Tx are configured to the UE by existing MIMO parameter, but the new RRC parameter indicates 1Tx-2Tx mode. |
| **ZTE (R1-2108839)** | network and UE has to consider the SRS for “noncodebook” as 2Tx.  The current spec supports non-codebook based 1Tx PUSCH transmission with configuration of one single port SRS resource but the above proposal seems to preclude such operation. It’s also confusing to say 2 antenna ports are counted in this case even 1-port SRS is configured.  we need to clarify whether configured SRS resources in inactive BWPs/cell should be counted as well. In any case, it is too complicated to require UE and network to sync up counting in different protocol layers. | If a new RRC parameter is introduced, network and UE can directly determine whether the SRS for “noncodebook” should be 1Tx or 2Tx. |
| **vivo (R1-2108949)** | Between the two options, the key controversy is how to count the UE Tx state (i.e. 1Tx or 2Tx) when an SRS resource with usage “non-codebook” is configured for a carrier. It is understood that for non-codebook based UL transmission, it is up to UE implementation to use either 1Tx or 2Tx. We think such UE implementation flexibility should be maintained in the UL Tx switching feature, which is allowed by Option1, since the worst case is assumed by gNB.  our understanding is that 2 antenna ports are assumed only for the purpose of determining UE Tx switching mode, it does not affect the UE implementation on using 1Tx or 2Tx for the real transmission. | In Option 2, the UE implementation (1Tx or 2Tx) for non-codebook based UL transmission is controlled by the NW, which is different from the case without UL Tx switching, therefore not desirable. |
| **OPPO (R1-2109050)** | Option 1 is more complicated compared to Option 2. That is to say, Option 1 may lead to more implementation complexity for UE. Moreover, Option 1 will make the specification obscure and not friendly to the readers. | There might be some concern on the introduction of new RRC parameter in Option 2. The additional signaling overhead of one RRC parameter is neglectable. |
| **Qualcomm (R1-2110163)** | When the SRS resource is configured with non-codebook, 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.  The current option 1 may have smaller time period as number of antenna ports could be changed/configured with MAC-CE. | Option 2 to introduce a new RRC IE in principle as this is the most efficient way.  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. |
| **Summary** | **Supported by Huawei, HiSilicon, vivo** | **Supported by ZTE, OPPO, Qualcomm** |

**FL comments:** It seems companies have different understandings. The key points are summarized based on FL understanding below.

1) For option 1, 2 antenna ports are assumed only for the purpose of the determination of operation mode (1Tx-2Tx switching or 2Tx-2Tx switching). It has no impact on the effective non-codebook operation and it does not affect the UE implementation on using 1Tx or 2Tx for the real transmission.

2) Option 1 may lead to more implementation complexity for UE.

3) For option 2, the UE implementation (1Tx or 2Tx) for non-codebook based UL transmission is controlled by the NW, which is different from the case without UL Tx switching.

4) For option 2, if a new RRC parameter is introduced, then it may end up with conflicting RRC parameters, for example, 2Tx-2Tx are configured to the UE by existing MIMO parameter, but the new RRC parameter indicates 1Tx-2Tx mode.

Before moving forward, it is necessary to align the understandings. Companies are encouraged to provide views on the above summary.

|  |  |
| --- | --- |
| **Company** | **Views** |
|  |  |
|  |  |
|  |  |
|  |  |

## 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. The latest proposed conclusion in RAN1#106-e is as follows:

**Proposed Conclusion:**

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

R1-2110163 proposed the following.

* 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.

R1-2109050 proposed the followings.

* Alt.1: No further discussion in Rel-17
* Alt.2: Make a simple conclusion as below
  + For Rel-17 Tx switching, no additional specification enhancement to support 1-port transmission via DCI format 0\_1

FL would like to check if companies can live with any of the above alternatives.

|  |  |
| --- | --- |
| **Company** | **Views** |
|  |  |
|  |  |
|  |  |
|  |  |

## Back-to-back switching with SRS switching

In RAN1#106-e, following two options were discussed, but no consensus were reached.

**Option 1:**

* When SRS carrier switching is configured, a maximum of 3 switches (2 for SRS and 1 for UL Tx switching) are supported in 14 consecutive symbols corresponding to the SCS of SRS.

Note: it is applicable to both Rel-16 UL Tx switching and Rel-17 UL Tx switching.

**Option 2:**

* For a UE configured with UL Tx switching on two uplinks and configured with SRS carrier switching for a third uplink, if a uplink transmission is scheduled after a SRS carrier switching occurrence and the time interval between the first symbol of the uplink transmission and the last symbol of SRS transmission is less than or equal to an interval of 13 symbols plus the RF retuning time required by SRS carrier switching, then the last symbol of PDCCH scheduling the uplink transmission should be no later than at symbol L, where the time interval between symbol L and the first symbol of SRS transmission is larger than symbols plus the RF retuning time.
  + In case of different SCS between the uplink transmission and the SRS transmission, the 13 symbols are with respect to the smaller SCS.

Note: it is applicable to both Rel-16 UL Tx switching and Rel-17 UL Tx switching.

Companies are encouraged to continue the discussion.

|  |  |
| --- | --- |
| **Company** | **Views** |
|  |  |
|  |  |
|  |  |
|  |  |

## CA based SRS carrier switching

In RAN1#106-e, following TP was discussed in [106-e-NR-Maintenance-Others-02].

|  |
| --- |
| **<Unchanged parts are omitted – 38.214>**  A UE can be configured with SRS resource(s) on a carrier *c1* with slot formats comprised of DL and UL symbols and not configured for PUSCH/PUCCH transmission. For carrier *c1*, the UE is configured with higher layer parameter *srs-SwitchFromServCellIndex* and *srs-SwitchFromCarrier* the switching from carrier *c2* which is configured for PUSCH/PUCCH transmission. During SRS transmission on carrier *c1* (including any interruption due to uplink or downlink RF retuning time [11, TS 38.133] as defined by higher layer parameters *switchingTimeUL* and *switchingTimeDL* of *SRS-SwitchingTimeNR*), the UE temporarily suspends the uplink transmission on carrier *c2*, and also the uplink transmission on carrier *c3* if the UE is configured with *uplinkTxSwitching-r16* for uplink switching between uplink carrier *c2* and *c3*.  **<Unchanged parts are omitted – 38.214>** |

R1-2110163 had following proposals.

* **Proposal:** In the prioritization for SRS switching considers the state of carriers configured with UL Tx switching jointly. As an example, if SRS switching is configured between CC2 and CC3 then in the prioritization the state of CC1 also needs to be considered if CC1 and CC2 are configured with UL Tx switching.
* **Proposal:** Define requirements allowing dropping transmissions on a CC due to SRS transmission on another CC, even if this CC is not configured with SRS switching, as long as the CC is configured with UL Tx switching.
* **Proposal:** Choose one of the following options:
  + During the SRS transmission on CC3 and the interruption time caused by RF tuning, UE is not expected to be scheduled or configured with other transmission requiring UL Tx switching
  + Define rules on the order in which the UE state vs. dropping decisions are being made

Companies are encouraged to provide views on the above TP and proposals in R1-2110163.

|  |  |
| --- | --- |
| **Company** | **Views** |
|  |  |
|  |  |
|  |  |
|  |  |

## TP

R1-2108743 provided TP for the uplink switching between two bands for SUL and the uplink switching between two bands for UL CA option 1.

R1-2108839 provided TP for 2Tx-2Tx switching between two uplink carriers for UL CA, 1Tx-2Tx/2Tx-2Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B for UL CA.

**FL comments:**

* Regarding the TP for2Tx-2Tx switching between two uplink carriers for UL CA, based on the discussion in the past RAN1 meetings, it seems the key point is whether a new RRC parameter is introduced to differentiate Rel-16 Tx switching or Rel-17 Tx switching. Since the discussion on differentiation between 1Tx-2Tx switching and 2Tx-2Tx switching is ongoing, we need to hold on the discussion on TP.
* Regarding the TP for uplink switching between two bands, it seems the TPs provided by R1-2108743 and R1-2108839 are quite divergent. The main point is whether the current spec description is revised to cover both uplink switching between two uplink carriers and uplink switching between two bands as in R1-2108743 or to introduce separate spec description for uplink switching between two bands as in R1-2108839.

**Companies are encouraged to answer the following question.**

**Question:** Regarding the TP for uplink switching between two bands, which option is preferred?

* **Option 1:** The current spec description is revised to cover both uplink switching between two uplink carriers and uplink switching between two bands in the same paragraphs.
* **Option 2:** Introduce separate paragraphs for spec description for uplink switching between two bands.
* **Option 3:** It’s up to Editor how to capture the agreements on uplink switching between two bands.

|  |  |
| --- | --- |
| **Company** | **Views** |
|  |  |
|  |  |
|  |  |
|  |  |

## UL-CA power-limited handling

R1-2110163 mentioned RAN4 identified an issue of SCell dropping in UL-CA when the power is limited, and send an LS to RAN1 asking a couple of questions on how to address the issue. R1-2110163 proposed the following proposal.

**Proposal:**

* Introduce a higher-layer parameter for relative power offset to reflect the priority difference for concurrent UL transmissions in case of power-limited
* For UL-CA power-limited handling, the UE allocates transmission powers to the concurrent transmissions taking into account the total available power and the relative power offset

**FL comments:** It seems not relevant to Tx switching and depends on the outcome of [106bis-e-NR-AI5-LSs-Prep].

# 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.

# 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. R1-2108743, Discussions on enhancements for UL Tx switching, Huawei, HiSilicon, RAN1#106b-e, October 11th – 19th, 2021.
4. R1-2108839, Remaining issues for Rel-17 UL Tx switching, ZTE, RAN1#106b-e, October 11th – 19th, 2021.
5. R1-2108949, Remaining issues on Rel-17 Tx switching, vivo, RAN1#106b-e, October 11th – 19th, 2021.
6. R1-2109050, Discussion on Rel-17 Tx switching enhancement, OPPO, RAN1#106b-e, October 11th – 19th, 2021.
7. R1-2109246, Remaining issues on Rel-17 uplink Tx switching, China Telecom, RAN1#106b-e, October 11th – 19th, 2021.
8. R1-2109269, Discussion on Rel-17 UL Tx Switching, CMCC, RAN1#106b-e, October 11th – 19th, 2021.
9. R1-2110163, Discussion on R17 UL Tx switching, Qualcomm Incorporated, RAN1#106b-e, October 11th – 19th, 2021.