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

**e-Meeting, August 16th – 27th, 2021**

**Agenda item: 5.1**

**Source: Moderator (China Telecom)**

**Title: [106-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:

[106-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: August 19
* 2nd check point: August 25
* 3rd check point: August 27

# Email discussion (1st round)

## 2Tx-2Tx switching between two uplink carriers

#### 2.1.1 Determination of the state of Tx chains for UL CA option 2

In RAN1 #105e, it was discussed how to handle the case that the state of Tx chains after Tx switching may not be unique for UL CA option 2 and the following agreement was achieved.

**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.

R1-2106500 proposed: If the state of Tx chains after UL Tx switching is not unique, the state of Tx chains with the most of Tx chains on the most important uplink carrier is assumed, e.g. the one carrier with *uplinkTxSwitchingPeriodLocation* configured as false. R1-2106729, R1-2107122, R1-2107211 proposed if the state of Tx chains after Tx switching is not unique, the state of Tx chains supporting 2Tx transmission on one carrier is assumed. R1-2107970 proposed if the state of Tx chains after Tx switching is not unique, 1Tx on carrier 1 and 1Tx on carrier 2 is assumed. R1-2107308 mentioned several options to handle this issue, and prefer that if the state of Tx chains after Tx switching is not unique, 1Tx on carrier 1 and 1Tx on carrier 2 is assumed.

1. Prioritize one carrier in the sense that allow at least one Tx chain on that carrier and two Tx chains when possible
   * One example is to prioritize Pcell or Spcell which would be configured with UCI and other important channels.
2. Prioritize one switching case
   * One example is to prioritize Case 1 which is more balanced for both carriers.
3. Define rules with pre-conditions
   * One example is to define per channel rules
     1. if the scheduling on target cell is PUSCH, it prefers Case 3 -> Case 2 with 0P+1P, and Case 2 -> Case 3 with 1P+0P
     2. if the scheduling on target cell is PRACH/PUCCH, it prefers Case 3 -> Case 1, and Case 2 -> Case 1, as single port should be sufficient for those channels and the rest port could be on another carrier for future Tx.

Based on companies’ contributions, following proposal is proposed:

**Proposal 1: Down select one of the following options:**

* **Option 1: If the state of Tx chains after UL Tx switching is not unique, the state of Tx chains with the most of Tx chains on the most important uplink carrier is assumed, e.g. the one carrier with *uplinkTxSwitchingPeriodLocation* configured as false.**
  + Support: Huawei, HiSilicon
* **Option 2: If the state of Tx chains after UL Tx switching is not unique, the state of Tx chains supporting 2Tx transmission on one carrier is assumed.**
  + Support: ZTE, China Telecom, OPPO
* **Option 3: If the state of Tx chains after UL Tx switching is not unique, 1Tx on carrier 1 and 1Tx on carrier 2 is assumed.**
  + Support: Qualcomm, vivo

Companies are encouraged to provide views on the above options.

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We are fine with Option 2. |
| ZTE | We support Option2.  For Option1, RAN1 may need to further discuss the definition of “most important uplink carrier”, which is time consuming since different companies may have different understandings on this issue, especially considering the different band combinations. Regarding the carrier with uplinkTxSwitchingPeriodLocation configured as false, it may also be the important carrier. For example. FDD+TDD CA, the TDD carrier is configured uplinkTxSwitchingPeriodLocation as false, but this doesn’t mean FDD carrier is less important. The reason is mainly because that TDD carrier has less UL symbols.  Between Option2 and Option3, Option2 allows UE to transmit both 1-port and 2-port transmission without unnecessary UL Tx switching, which can improve the overall system performance. Thus, Option2 is preferred. |
| Huawei, HiSilicon | We prefer Option 1.  Compared to Option 2, Option 1 can have more flexibility, but without requiring a new RRC parameter.  @ZTE, it is not time consuming bug only reuse the existing RRC parameter. According to current spec, the carrier configured with RRC *uplinkTxSwitchingPeriodLocation* as false is more important than the other carrier because its transmission is kept in case of overlapping with any transmission on the other carrier. Your example seems self-contradict because a gNB would not configure the TDD carrier as true to drop any overlapping transmission while the gNB regards the TDD carrier is more important.  Compared to Option 3, Option 1 can use 2Tx to guarantee performance. | |
| Qualcomm | We support Option 3.  For Option 1, we don’t agree with the intention. Our understanding is the UL switching period is configured typically with the carrier with more UL slots, which doesn’t mean the carrier is less important. Take for example the case of a FDD carrier (CC1) + a TDD carrier (CC2), CC1 could be configured with switching period because CC2 has fewer UL slots. Meanwhile, CC1 is with better chance to be the PCell due to the better propagation performance. In this example, CC1 is more important as it carries PUCCH and other important UL transmission.  Among Option 2 and 3, we prefer Option 3 as this is more balance for both carriers as it provides equal transmission opportunity when switching ambiguity occurs. |

#### 2.1.2 TP for UL CA option 1

**FL comments: Regarding the TP corresponding to the agreed switching mechanism for 2Tx-2Tx UL Tx switching between two uplink carriers for UL CA option 1. The latest proposal in RAN1 #105e is as follows:**

**Proposal 2: Adopt the following TP to TS 38.214 in principle.**

* **Note: whether new UE capability *“BandCombination-UplinkTxSwitch-R17”* will be introduced is up to RAN2.**
* **FFS potential new RRC parameters.**

|  |
| --- |
| **<Unchanged parts are omitted – 38.214>** **6.1.6.2 Uplink switching for carrier aggregation** For a UE indicating a capability for uplink switching with *BandCombination-UplinkTxSwitch* [or *BandCombination-UplinkTxSwitch-R17*] for a band combination, and if it is for that band combination configured with uplink carrier aggregation:  - If the UE is configured with uplink switching with parameter *uplinkTxSwitching*, when the UE is to transmit in the uplink based on DCI(s) received before or based on a higher layer configuration(s):  - When the UE is to transmit a 2-port transmission on one uplink carrier and if the preceding uplink transmission is a 1-port transmission on another uplink carrier, then the UE is not expected to transmit for the duration of on any of the two carriers.  - When the UE is to transmit a 1-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 on any of the two carriers.  - For the UE configured with *uplinkTxSwitchingOption* set to 'switchedUL', when the UE is to transmit a 1-port transmission on one uplink carrier and if the preceding uplink transmission was a 1-port transmission on another uplink carrier, then the UE is not expected to transmit for the duration of on any of the two carriers.  - When the UE is to transmit a 2-port transmission on one uplink carrier and if the preceding uplink transmission was a 2-port transmission on another uplink carrier, then the UE is not expected to transmit for the duration of on any of the two carriers.  - For the UE configured with *uplinkTxSwitchingOption* set to 'dualUL', when the UE is to transmit a 2-port transmission on one uplink carrier and if the preceding uplink transmission was a 1-port transmission on the same uplink carrier and the UE is under the operation state in which 2-port transmission cannot be supported in the same uplink carrier, then the UE is not expected to transmit for the duration of on any of the two carriers.  **<Unchanged parts are omitted – 38.214>** |

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We are fine with FL proposal |
| ZTE | There are still some issues not clear from our perspective.  The above TP assumes that Rel-16 and Rel-17 UL Tx switching share the same RRC configuration parameter *uplinkTxSwitchingOption*, which hasn’t been explicitly discussed yet. We prefer to explicitly discuss this issue or add a tentative RRC parameter in the TP for now.  Also, the newly added bullet in the above TP is only for Rel-17 UL Tx switching, but not for Rel-16. We prefer to make this clear.  Thus, the following is proposed from our perspective.  - For the UE configured with *uplinkTxSwitchingOption* set to 'switchedUL' or configured with *[RRC\_R17\_CA Option1\_2carrier]*, when the UE is to transmit a 1-port transmission on one uplink carrier and if the preceding uplink transmission was a 1-port transmission on another uplink carrier, then the UE is not expected to transmit for the duration of on any of the two carriers.  - For the UE configured with *[RRC\_R17\_CA Option1\_2carrier] or [RRC\_R17\_CA Option2\_2carrier]*, when the UE is to transmit a 2-port transmission on one uplink carrier and if the preceding uplink transmission was a 2-port transmission on another uplink carrier, then the UE is not expected to transmit for the duration of on any of the two carriers. |
| Huawei, HiSilicon | We are fine with the proposal. But don’t see any need to introduce new RRC parameter at this stage because in the proposed TP the same UE behaviour is associated with both existing RRC parameter and the proposed new RRC parameter. |
| Qualcomm | From RAN1#105-emeeting, there were some debates on RRC IEs including whether to have a new RRC parameter like “uplinkTxSwitchingOption-R17". Repeating our views in RAN1 105-emeeting, we propose to make all technical agreements first and try to translate them to TPs later. Meanwhile, we think at least specification should clearly say this 2 Tx – 2 Tx switching is Rel-17 capability. |
| FL | Based on companies’ comments, let’s discuss the TP later. |

#### 2.1.3 TP for UL CA option 2 (on hold)

R1-2106729 proposed TP for UL CA option 2.

**FL comments: It is still under discussion how to handle the case if the state of Tx chains after UL Tx switching is not unique for UL CA option 2. This sub-section is tentatively on hold.**

## Uplink Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B

In RAN1 #104b-e, the following conclusion was reached.

**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.

In RAN1 #105e, the basic principle for uplink Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B was discussed. The latest proposal was as follows:

* For inter-band UL-CA and SUL, for Rel-17 1Tx-2Tx/2Tx-2Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B, the contiguous uplink carriers on band B should be considered as a single uplink carrier for the purpose of UL Tx switching, i.e.
  + FFS: with respect to the determination of uplink switching triggering, the presence of transmission occasion on any one uplink carrier on Band B is equivalent to the presence of transmission occasion on any other uplink carrier(s) on Band B.
  + FFS: no uplink switching is triggered if the presence of transmission occasion is on one uplink carrier on Band B and the preceding uplink transmission occasion is on other uplink carrier(s) on Band B.
  + FFS: In evaluating the antenna ports for determination of UL Tx switching, the larger ports number among the scheduling for CC2 and CC3 on band B is used.

In this meeting, R1-2106500, R1-2107308 continued to propose the basic mechanism. R1-2106729, R1-2106925, R1-2107122, R1-2107211, R1-2107388, R1-2107970 proposed the detailed switching mechanism for SUL, UL CA option 1 and option 2. R1-2106500, R1-2106729 provided TPs.

**FL comments: Considering the situation of the discussion in RAN1 #105e and it seems the majority support to discuss the detailed switching mechanism, suggest to discuss the detailed switching mechanism in this meeting. The corresponding TPs can be discussed later.**

**Proposal 3:**

* **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.**

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We are fine with FL proposal |
| ZTE | Ok with the above proposal. |
| Huawei, HiSilicon | Prefer to reuse the existing specified/updated mechanism. But we are fine with FL proposal. |
| Qualcomm | We are fine with FL’s proposal. |

**Proposal 4:**

* **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.**

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We are fine with FL proposal |
| ZTE | Ok with the above proposal. |
| Huawei, HiSilicon | We are fine with FL proposal. |
| Qualcomm | We are fine with FL’s proposal. |

**Proposal 5:**

* **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.**

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We are fine with FL proposal |
| ZTE | Ok with the proposal. |
| Huawei, HiSilicon | We are fine with FL proposal. |
| Qualcomm | We are fine with FL’s proposal.  However, we’d like to note that the current way of progressing this topic is a bit inefficient.  We could just make a simple agreement saying the following:  “When a carrier is configured with both intra-band carrier aggregation and UL Tx switching then for the purposes of UL switching state determination for that carrier, the maximum number of ports used for uplink transmission on any carrier in the same band is considered to be occurring on the carrier.”  Based on the above, the 38.214 editor can have a CR with the necessary changes. Instead of doing this, we keep coming up with separate agreements in multiple meetings, all saying the same. |
| FL | @Qualcomm, we tried to discuss the basic principle in RAN1 #105e, but it seems companies have different understandings and it is difficult to achieve consensus. With the detailed switching mechanisms and agreements, from FL understanding, editor can still make only necessary changes. |

## Operation with downgraded MIMO setting and/or CA setting

R1-2106500 proposed that if UE support UL Tx switching with two contiguous carriers on Band B, the UE can be configured and operated with one carrier on Band B as a downgraded UL Tx switching and had the following proposal.

**Proposal 6: Confirm the following,**

* **If UE support UL Tx switching with two contiguous carriers on Band B, the UE can be configured and operated with one carrier on Band B as a downgraded UL Tx switching.**

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We are fine with FL proposal |
| ZTE | First of all, our first preference is still to discuss this issue under UE feature discussion.  If majority companies prefer to discuss it now, then we have the following detailed comments.  The main bullet is not clear. We are not sure why we use “confirm” here and what’s to be confirmed.  We propose to update the proposal as following.  ***Proposal:*** *If UE support UL Tx switching with two contiguous carriers on Band B, the UE can be configured and operated with UL Tx switching with one carrier on Band B ~~as a downgraded UL Tx switching~~.* |
| Huawei, HiSilicon | We are fine with the proposal.  @ZTE, it is to confirm the legacy understanding on CA procedure. It is not proposing anything new. If the FL proposal is not acceptable, do you mean a new CA procedure or restriction of gNB configuration for this case is needed? For example, these three carriers must be configured and activated by a gNB at the same time? Rather than allowing to activate them one by one? |
| Qualcomm | This proposal was discussed in RAN1 #105-emeeting. We still don’t understand why we need to discuss this even though we are in the early discussion of R17 UL Tx switching. We don’t even have the agreement on some basic behavior for the 3CC case - e.g. the triggering mechanism, how to evaluate the Tx ports for UL CA, etc.  Before we can clearly understand the Rel-17 UL Tx switching specification structure, we can’t agree or disagree this proposal.  We propose to postpone this discussion until we have clear understanding on how Rel-17 UL Tx switching is structured.  We think that the fallback cases can be covered with explicit UE capability report. But anyway, this becomes clearer once the Rel-16 vs Rel-17 capability reporting is agreed at the end of the release. |

R1-2106500 proposed the number of ports of configured SRS resources on an uplink completely determines the maximum Tx chain required on the uplink, which can also easily differentiate 2Tx-2Tx from 1Tx-2Tx, and had the following proposal.

**Proposal 7:**

* **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 both 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.**

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We are fine with FL proposal. |
| ZTE | We propose to introduce a RRC parameter to explicitly differentiate 1Tx-2Tx vs 2Tx-2Tx switching mode if necessary.  The above proposal 7 may not work in the following two cases  1) if non-codebook bases transmission is configured, number of SRS ports cannot determine whether it is 1Tx or 2Tx since each SRS is always 1 port. Two 1-port SRS resources are used for two ports PUSCH transmission.  2) if different maximum number of ports are configured for the two carriers on Band B. For example, 2-ports is configured on carrier1 and carrier3, while only 1 port is configured on carrier2.  Besides, UE may need to check all the SRS configurations for all the carriers. An explicit RRC signalling can avoid such cross-carrier checking. |
| Huawei, HiSilicon | We are fine with the proposal.  Since Rel-15, for a carrier that a UE is capable of 2Tx transmission, a gNB is allowed to configure 1-port transmission on the carrier for the UE. This principle gives the gNB freedom to work out the best service strategy for the UE. The same principle is applied to UL Tx switching also.  @ZTE Thank you for your comments. Regarding your last comment, in the FL proposal, it is already RRC parameters for a UE to check, which the UE shall check through always. Regarding your second comment, it has been resolved by the FL proposal by the “maximum number” of antenna ports.  Regarding your first comment, we feel any non-codebook based PUSCH transmission is considered as two port transmission and there is no different understanding within this group. Therefore, the proposal can be refined simply with one additional subbullet,  **Proposal 7-rev:**   * **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 both 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 2 antenna ports are counted for the SRS resource during the determination of operation mode.** |
| Qualcomm | We support the views expressed by ZTE. |

## 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. In RAN1 #104b-e, RAN1 #105-e, RAN1 #106-e, some companies raised this issue in Rel-17 again. Based on the discussion in RAN1 #105-e, we can focus on the following two alternatives.**

**Alt 1: supported by ZTE, Qualcomm**

* **For UL CA option 2, DCI format 0\_1 can be used to schedule a UL transmission on carrier 2 when nrofSRS-Ports is configured as 2 antenna ports and state of Tx chains is 1 Tx on carrier 1 and 1Tx on carrier 2.**
  + **It’s up to implementation how DCI format 0\_1 to be used.**

**Alt 2: supported by Huawei, HiSilicon, CATT, OPPO**

* **1-port transmission via DCI format 0\_1 for UL CA option 2 is not considered for Rel-17 Tx switching.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We prefer to Alt.2 because it is out of scope in R17 WID. |
| ZTE | In Rel-17 UL Tx switching, all carriers can support 1-port and 2-port UL transmission. In case the state of Tx chains is 1 Tx on carrier 1 and 1Tx on carrier 2, if nrofSRS-Ports is configured as 2, only fallback DCI can be used to schedule 1-port PUSCH transmission, which is too restrictive.  For this issue, Alt.1 is to allow DCI format 0\_1 to schedule 1-port PUSCH in this case. We are also open to other solutions as long as it can reduce the restriction mentioned above. |
| Huawei, HiSilicon | Alt. 2 is the only option. It is not new proposal and too much time has been wasted on introducing the new MIMO scheme since Rel-16 discussions. |
| Qualcomm | We support the views expressed by ZTE. |

## Back-to-back switching with SRS switching

R1-2107308 mentioned that in Rel-16 UL Tx switching, UE is restricted to support one switch per one slot. However, the switching location could be anywhere inside the slot. For example, if the switch is triggered by SRS transmission, the switching location could be in the middle or even later part of the slot. Therefore, if there is an expected switch on the SRS transmission carrier, there would be two switches in 14 consecutive symbols even these two switches still belong to two slots. Now, when we consider SRS carrier switching and if the UL Tx switching is triggered by SRS carrier switching which means there would be 4 switches (2 for SRS and 2 for UL Tx switch) in 14 consecutive symbols! From UE implementation perspective, we definitely want to avoid this case as too many symbols are costed as switch gap.

UL

DL

DL

Tx Switch

CC1

UL

CC2

DL

DL

CC3

RF tuning

UL

4 switches within 14 consecutive symbols

SRS

RF tuning

SRS

Tx switch

**Figure: illustrative figure on 4 switches in 14 consecutive symbols**

**Proposal 8:**

* **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.**

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We think the proponent to clarify it for Rel-17 WID in RAN plenary because we can’t find out any objective of Rel17 WID related to this proposal.  This proposal is related to SRS carrier switching together with UL Tx switching in Rel-16 and first of all it is better to discussion about it in Rel-16 AI.  In our understanding, gNB can schedule UE for SRS transmission based on UE capability on SRS-*SwitchingTimeNR*. So as shown in the above figure, UE can execute SRS transmission on CC2and CC3 and then go back to CC1. So the motivation isn’t clear to us. |
| Huawei, HiSilicon | If a succeeding uplink transmission is scheduled after a SRS carrier switching occurrence, the UE can directly switch to the carrier of the succeeding uplink transmission to avoid unnecessary frequent Tx switching. Thus we can still meet the requirements of R16 without introducing additional restriction on the number of switching.  More details and proposal can be found in R1-2106501. |
| Qualcomm | We are supportive |
|  |  |

## CA based SRS carrier switching

**FL comments: This issue is discussed in AI 7.2.12.**

# Email discussion (2nd round)

## 2Tx-2Tx switching between two uplink carriers

**Proposal 1: Down select one of the following options:**

* **Option 1: If the state of Tx chains after UL Tx switching is not unique, the state of Tx chains with the most of Tx chains on the most important uplink carrier is assumed, e.g. the one carrier with *uplinkTxSwitchingPeriodLocation* configured as false.**
  + Support: Huawei, HiSilicon
  + Have concerns: ZTE, Qualcomm
* **Option 2: If the state of Tx chains after UL Tx switching is not unique, the state of Tx chains supporting 2Tx transmission on one carrier is assumed.**
  + Support: ZTE, China Telecom, OPPO, CATT
* **Option 3: If the state of Tx chains after UL Tx switching is not unique, 1Tx on carrier 1 and 1Tx on carrier 2 is assumed.**
  + Support: Qualcomm, vivo

**FL comments: Companies’ views are summarized for proposal 1 above. Concerns on option 1 are raised. Considering the majority support option 2, FL suggests to take option 2 as an agreement.**

**Revised Proposal 1:**

* **For a UE configured with UL CA Option 2 and with 2Tx-2Tx UL Tx switching between two uplink carriers, if the state of Tx chains after UL Tx switching is not unique, the state of Tx chains supporting 2Tx transmission on one carrier is assumed.**

Companies are encouraged to provide views on the above revised proposal 1.

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We support revised proposal 1. |
| OPPO | support |
| CMCC | Support the revised proposal 1.  It articulates the purpose of enhancing the UL throughput by enjoying 2Tx transmission as much as possible. |

## Uplink Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B

**FL comments: Proposal 3/4/5 are stable. Please refrain from any further comments.**

**Proposal 3:**

* **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.**

**Proposal 4:**

* **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.**

**Proposal 5:**

* **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.**

## Operation with downgraded MIMO setting and/or CA setting

**FL comments: Companies are encouraged to provide further comments on proposal 6.**

**Proposal 6: Confirm the following,**

* **If UE support UL Tx switching with two contiguous carriers on Band B, the UE can be configured and operated with one carrier on Band B as a downgraded UL Tx switching.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We are fine with this proposal. |
| OPPO | We agree the principle. However, our first preference is to postpone this until the solution for R17 UL Tx swtihign is clear so that we can double check whether there is any inconsistency or not for the downgraded case. Having said that, we can live with it if majority companies support it |
| CMCC | May we clarify, in what sense that this is “downgraded”? Is it because UE could have been using 2Tx for both carriers in Band B but only uses 1 carrier in reality? |

**FL comments: Companies are encouraged to provide further comments on proposal 7-v2.**

**Proposal 7-v2:**

* **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 both 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 2 antenna ports are counted for the SRS resource during the determination of operation mode.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We are fine with proposal 7 |
|  |  |
|  |  |

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

**FL comments: This issue has been discussed for a long time since Rel-16. FL suggests to make the following conclusion.**

**Conclusion:**

* **No consensus on specified solutions can be reached to support 1-port transmission via DCI format 0\_1 for UL CA option 2 for Rel-17 Tx switching in RAN1.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | We support making this conclusion on 1-port transmission via DCI format 0\_1 for UL CA option 2 |
| OPPO | * DCI format 0\_1 can support 1-port transmission if the associated SRS is of single port. Thus, we suggest to use “further enhancement” * We also don’t further enhance the transmission scheduled by DCI format 0\_2   Thus, some changes are suggested as below   * **No consensus on ~~specified solutions~~ further enhancement can be reached to support 1-port transmission via DCI format 0\_1 and DCI format 0\_2 for UL CA option 2 for Rel-17 Tx switching in RAN1.** |
|  |  |

## Back-to-back switching with SRS switching

**FL comments: Companies are encouraged to provide further comments on proposal 8 in R1-2107308 and proposal 9 in R1-2106501.**

**Proposal 8:**

* **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.**

**Proposal 3:**

**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.**

|  |  |
| --- | --- |
| **Company** | **Views** |
| CATT | In principal, we are fine with proposal 9. We suggest firstly focusing on transmission interval rule on TX switching +SRS carrier switching. So we would like to modify proposal 9 as below:  **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 no 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.** |
|  |  |
|  |  |

# 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. R4-2107847, Reply LS on Rel-17 uplink Tx switching, RAN4, China Telecom, RAN4 #99-e, 19 - 27 May, 2021
4. R1-2106500, Discussions on enhancements for UL Tx switching, Huawei, HiSilicon, RAN1 #106-e, August 16th – 27th, 2021.
5. R1-2106729, Discussion on Rel-17 UL Tx switching, ZTE, RAN1 #106-e, August 16th – 27th, 2021.
6. R1-2106925, Discussion on Rel-17 enhancements for UL TX switching, CATT, RAN1 #106-e, August 16th – 27th, 2021.
7. R1-2107122, Discussion on Rel-17 uplink Tx switching, China Telecom, RAN1 #106-e, August 16th – 27th, 2021.
8. R1-2107211, Discussion on Rel-17 Tx Switching enhancement, OPPO, RAN1 #106-e, August 16th – 27th, 2021.
9. R1-2107308, Discussion on Rel-17 UL switching, Qualcomm Incorporated, RAN1 #106-e, August 16th – 27th, 2021.
10. R1-2107388, Discussion on Rel-17 UL Tx switching, CMCC, RAN1 #106-e, August 16th – 27th, 2021.
11. R1-2107970, Discussion on Rel-17 Tx switching enhancements, vivo, RAN1 #106-e, August 16th – 27th, 2021.