**3GPP TSG RAN WG1 #112bis-e R1-23xxxxx**

**E-meeting, April 17th – April 26th, 2023**

**Agenda Item: 5**

**Source: Moderator (China Telecom)**

**Title: [112bis-e-LS-03] FL summary of email discussion on reply LS for Rel-18 Tx switching**

**Document for: Discussion**

1. Introduction

This contribution is a summary of the following email discussion in response to RAN4 LS in R1-2302266 for Rel-18 Tx switching.

[112bis-e-LS-03] Email discussion for response to RAN4 LS in [R1-2302266](file:///C%3A%5CUsers%5Cyouns%5COneDrive%5CDocuments%5C3GPP%5CRAN1%20tdocs%5CTSGR1_112b-e%5CDocs%5CR1-2302266.zip) by April 21 – Jianchi (China Telecom).

1. Summary of contributions in RAN1#112bis-e

In contributions [2-13], following proposals were made.

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| Huawei, HiSilicon, [2, 13] | ***Observation 1:*** *In Rel-16, when a UE receives two DCI’s before T0-Toffset, only one UL Tx switching is triggered for both the UL transmission scheduled by two DCIs if the UL transmissions on the two bands are at least partially overlapped in time domain, otherwise two UL Tx switching are performed.****Observation 2:*** *In Rel-17, it has been supported that the two Tx chains are switched simultaneously for one triggered UL Tx switching.****Proposal:*** *Confirm that Rel-16 and Rel-17 mechanism of Tx switching can be directly reused in Rel-18 UL Tx switching among 3 or 4 bands.** *For dual UL, two UL transmissions that overlap in time triggers only one UL Tx switching.*
* *If the two Tx chains are switched for one triggered UL Tx switching, the UE should be capable to switch both Tx chain simultaneously.*
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| vivo, [3] | Answer: Yes, it is possible that two Tx chains are switched concurrently between two different band pairs and with overlapping switching period. |
| CATT, [4] | **Observation 1:** From the perspective of RAN1, RAN4’s question of ‘two Tx chains are switched concurrently between two different band pairs’ only refer to the case a UE is triggered to perform TX switching for two different band pairs before the start of earlier UL transmissions of ‘switch-to’ band.**Proposal 1:** From RAN1 perspective, when the two Tx chains are switched concurrently between two different band pairs, the switching periods for Tx switching between different band pairs are overlapping and start with the same symbol. |
| ZTE, [5] | ***Proposal 1:*** *If the two Tx chains are triggered to switch between two different band pairs (e.g., band A + band C->band B + band D), and when the two UL transmissions (including both CG PUSCH and DG PUSCH) after TX switching are at least partially overlapped in time domain, UE perform it as one TX switching involving more than 2 bands.** *If the later PUSCH transmission in the two UL transmissions after TX switching is DG PUSCH, UE expects that the DCI scheduling the later PUSCH transmission is no later than the following:*
	+ *Alt.1: T0,1- max {Toffset1, Toffset2}*
		- *Alt.2: the earlier time between {T0,1- Toffset1, T0,2- Toffset2}*
	+ *T0,1 and T0,2 are the start of the earlier transmission and later transmission in the two UL transmissions after TX switching, respectively. Toffset1 and Toffset2 are the corresponding processing time of the earlier UL transmissions and later UL transmission, respectively.*

*Otherwise, UE performs it as two separate Tx switching.* |
| Intel, [6] | **Proposal 1*** From RAN1 perspective, it is possible that the two Tx chains are switched concurrently between two different band pairs and with overlapping switching period.
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| Xiaomi, [7] | **Answer:**Generally speaking, RAN1 thinks it is possible that the two Tx chains are switched concurrently between different band pairs. In RAN1#111 e-meeting, RAN1 achieved the following agreement, which supports UL Tx switching between any two switching cases belonging to 3 bands case and 4 bands case respectively.

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| **Agreement**For dual UL, if UE supports concurrent transmission on all band pairs and supports up to 2 ports UL transmission on all the bands in the band combination, all possible switching cases with 1T-1T and 2T are assumed* In case of 3 bands, 6 switching cases ({2T,0T,0T}, {0T,2T,0T}, {0T,0T,2T}, {1T, 1T, 0T}, {1T, 0T, 1T}, {0T, 1T, 1T}) are assumed
* In case of 4 bands, 10 switching cases ({2T,0T,0T,0T}, {0T,2T,0T,0T}, {0T,0T,2T,0T}, {0T,0T,0T,2T}, {1T,1T,0T,0T}, {1T,0T,1T,0T}, {1T,0T,0T,1T}, {0T,1T,1T,0T}, {0T,1T,0T,1T}, {0T,0T,1T,1T}) are assumed
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Based on the above agreement, the two examples raised by RAN4 have been already supported:* Example #1: In the case of 3-band Tx switching, the switching is performed from 1T+1T on band A and B to 2T on band C. To be specific, RAN1 supports UL Tx switching between {1T, 1T, 0T} and {0T, 0T, 2T}, {1T, 0T, 1T} and {0T, 2T, 0T}, {0T, 1T, 1T} and {2T, 0T, 0T}, which aligns with RAN4’s example.
* Example #2: In the case of 4-band Tx switching, the switching is performed from 1T+1T on band A and B to 1T+1T on band C and D. To be specific, RAN1 supports UL Tx switching between {1T,1T,0T,0T} and {0T,0T,1T,1T}, {1T,0T,1T,0T} and {0T,1T,0T,1T}, {1T,0T,0T,1T} and {1T,0T,0T,1T}, which aligns with RAN4’s example.

Regarding whether the switching period is overlapping or not, RAN1 only specifies the switching period length and the located carrier. The time location of switching period in time domain is up to UE implementation. Therefore, it is possible that the two Tx chains are switched concurrently between two different band pairs and with overlapping switching period. |
| Spreadtrum, [8] | 1. ***RAN1 replies to RAN4 that it is possible that the two Tx chains are switched concurrently between two different band pairs and with overlapping switching period.***
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| Apple, [9] | **Reply to the question:** From RAN1 perspective, for the cases involving switching of the two Tx chains between two different bands (example#1: A(1Tx)+B(1Tx) -> C(2Tx) and example#2: A(1Tx)+B(1Tx) -> C(1Tx)+D(1Tx)), there can be two possibilities:* If a single switching instance is determined for the switching of the two Tx chains, then a single switching period (maximum among the band pairs) is applied, i.e. there is no overlapping switching period. Within that single switching period, whether the two Tx chains switch concurrently between the two different bands pairs or not is a UE implementation.
* If two switching instances are determined for the switching of the two Tx chains, then two corresponding switching periods are applied. The overlap of the two switching periods should not be possible and consequently, the two Tx chains are not switched concurrently between the two different band pairs
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| Qualcomm, [10] | **Observation: the two switching cases in the RAN4 LS are allowed from RAN1 perspective.****Proposal: For the following exemplary switch, the switching gap is summation of the per band pair switching period** * **For the Example #1: In the case of 3-band Tx switching, the switching is performed from 1T+1T on band A and B to 2T on band C, the switching gap is summation of {Tswitch\_A\_C, Tswitch\_B\_C}**
* **For Example #2: In the case of 4-band Tx switching, the switching is performed from 1T+1T on band A and B to 1T+1T on band C and D, the switching gap is summation of {max(Tswitch\_A\_C, Tswitch\_B\_C), max(Tswitch\_A\_D, Tswitch\_B\_D).**
* **Tswitch\_X\_Y is the UE reported switching period for band pair X, Y**
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| OPPO, [11] | ***Proposal 1: To add the following inputs to the reply LS to [1].*** * ***There is no RAN1 agreement that explicitly addresses the possibility of concurrent switching and overlapping switching periods.***
* ***It is worthwhile to note that, although there was assumption of overlapping switching periods in the past RAN1 discussion, the RAN4 LS in R4-2217741 may help to build up that assumption.***
* ***The possibility of concurrent switching and overlapping switching periods may differ among band pairs.***
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| NTT DOCOMO, [12] | **Proposal 1:****RAN1 first needs to agree on following clarifications to reply RAN4 LS*** **When a UE is triggered to perform TX switching between a band pair, and the start of the UL transmission after TX switching is T0, UE uses grants received before T0-Toffset to determine how to perform switching, where Toffset is the UE processing procedure time defined for the uplink transmission triggering.**
	+ **To determine the Toffset which is composed of N2andTswitch*,* the minimum SCS among the downlink carriers where DCI triggers the UL transmission for Tx switching is used as *µDL* and the minimum SCS among the UL carriers after Tx switching is used as *µUL* to determine N2,additionally, the minimum SCS among the UL carriers involved in Tx switching is used as *µUL* to determine Tswitch**
	+ **If the two Tx chains are triggered to switch between two different band pairs (e.g., band A + band C->band B + band D), and when the two UL transmissions after TX switching are at least partially overlapped in time domain, UE perform it as one TX switching involving more than 2 bands**

**Proposal 2:****RAN1 replies to RAN4 question with following feedbacks.*** **In example #1, it is RAN1 understanding that there should be only one UL Tx switching to perform 2T transmission on band C after 1T+1T transmissions on band A and B. The switching period in this case is determined based on maximum of {switching period for band pair A-C, switching period for band pair B-C}.**
* **In example #2, it is RAN1 understanding that whether there is only one Tx switching for two Tx chains or there are two Tx switchings (one switching for each Tx chain) is dependent on the trigger timing (T0, Toffset) and overlap in time domain between two 1T transmissions after two Tx chain switching(s), and RAN1 made following agreement.**
	+ **[When a UE is triggered to perform TX switching between a band pair, and the start of the UL transmission after TX switching is T0, UE uses grants received before T0-Toffset to determine how to perform switching, where Toffset is the UE processing procedure time defined for the uplink transmission triggering.]**
		- **[To determine the Toffset which is composed of N2andTswitch*,* the minimum SCS among the downlink carriers where DCI triggers the UL transmission for Tx switching is used as *µDL* and the minimum SCS among the UL carriers after Tx switching is used as *µUL* to determine N2,additionally, the minimum SCS among the UL carriers involved in Tx switching is used as *µUL* to determine Tswitch]**
		- **[If the two Tx chains are triggered to switch between two different band pairs (e.g., band A + band C->band B + band D), and when the two UL transmissions after TX switching are at least partially overlapped in time domain, UE perform it as one TX switching involving more than 2 bands]**
* **There is another example “Example #3: In the case of 3-band Tx switching, the switching is performed from 2T on band A to 1T+1T on band B and C”, and in example #3, it is RAN1 understanding that whether there is only one Tx switching for two Tx chains or there are two Tx switchings (one switching for each Tx chain) is dependent on the trigger timing (T0, Toffset) and overlap in time domain between two 1T transmissions after two Tx chain switching(s) same as in example #2.**
* **It is also RAN1 understanding that whether UE actually performs concurrent switching on two Tx chains or performs sequential switching on two Tx chains is up to UE implementation as long as switchings on two Tx chains are completed within reported switching period duration in case of one UL Tx switching.**
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1. Discussion

In [1], RAN4 asked the following question to RAN1.

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| **In addition, RAN4 would like to ask RAN1 one question:** From RAN1 perspective, is it possible that the two Tx chains are switched concurrently between two different band pairs and with overlapping switching period? Two examples are given below:* Example #1: In the case of 3-band Tx switching, the switching is performed from 1T+1T on band A and B to 2T on band C.
* Example #2: In the case of 4-band Tx switching, the switching is performed from 1T+1T on band A and B to 1T+1T on band C and D.
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**Moderator comments:** Based on contributions, at least there is common understanding in RAN1 that two example scenarios #1 and #2 mentioned in RAN4 LS are supported from RAN1 perspective. In addition, [12] proposed to add one more example scenario #3 for the completeness to reply to RAN4 question. Moderator would like to ask companies to provide views on proposed clarification on example scenarios related to RAN4 question.

### **Proposal 1**

### **1st round**

In the reply LS to RAN4, RAN1 confirms following three example scenarios related to RAN4 question are supported from RAN1 perspective.

* Example #1: In the case of 3-band Tx switching, the switching is performed from 1T+1T on band A and B to 2T on band C.
* Example #2: In the case of 4-band Tx switching, the switching is performed from 1T+1T on band A and B to 1T+1T on band C and D.
* Example #3: In the case of 3-band Tx switching, the switching is performed from 2T on band A to 1T+1T on band B and C.

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**Moderator comments:** Regarding RAN4’s question “is it possible that the two Tx chains are switched concurrently between two different band pairs and with overlapping switching period?”. It seems it is related to the issue on ambiguity between one Tx switching and two Tx switchings which has been discussed extensively in past RAN1 meetings. The latest proposal in [14] is as follows.

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| * When a UE is triggered to perform TX switching between a band pair, and the start of the UL transmission after TX switching is T0, UE uses grants received before T0-Toffset to determine how to perform switching, where Toffset is the UE processing procedure time defined for the uplink transmission triggering.
	+ - To determine the Toffset which is composed of N2andTswitch*,* the minimum SCS among the downlink carriers where DCI triggers the UL transmission for Tx switching is used as *µDL* and the minimum SCS among the UL carriers after Tx switching is used as *µUL* to determine N2,additionally, the minimum SCS among the UL carriers involved in Tx switching is used as *µUL* to determine Tswitch
		- If the two Tx chains are triggered to switch between two different band pairs (e.g., band A + band C->band B + band D), and when the two UL transmissions after TX switching are at least partially overlapped in time domain, UE perform it as one TX switching involving more than 2 bands
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**Moderator comments:** According to the discussion in [14], whether there is only one Tx switching for two Tx chains or there are two Tx switchings (one switching for each Tx chain) is dependent on the timeline and overlap in time domain between two 1T transmissions after two Tx chain switching(s), while the timeline may also include a couple of factors such as T0, Toffset, CG or DG, maximum or summation of the switching periods based on the contributions summarized in section 2. As per the following guidance from Chair, the discussion on potential RAN1 specification impact will be handled in agenda item 9.18, while we will focus on the answer to RAN4 question in agenda item 5.

The discussion on potential RAN1 specification impact to be handled under the email discussion(s) on draft CR(s) for Rel-18 MC-Enh in agenda item 9.18. For the RAN4 questions to RAN1, to be handle in agenda item 5.

**Moderator comments:** Then, looking back at the RAN4 question, RAN4 is asking the possibility of concurrent switching of two Tx chains between two different band pairs. For Example #1, it seems companies acknowledge that there is only one Tx switching, since 2 Tx chains are on the same band after Tx switching. For Example #2, whether there is one Tx switching or two Tx switchings will be discussed in agenda item 9.18. It seems companies acknowledge that one Tx switching is regarded as long as conditions are met, e.g., timeline, overlap in time domain. Example #3 is similar with Example #2. If there is one Tx switching, UE can perform concurrent switching of two Tx chains. Some companies may argue that if there is sufficient time between end of the transmission on switch-from bands (A and B) and start of the transmission on switch-to band (C), it may be possible UE implementation to perform switching on one Tx chain first and then perform switching on another Tx chain. But it does not preclude the possibility of concurrent switching of two Tx chains asked by RAN4.

Regarding the “with overlapping switching period” in RAN4 question, from moderator understanding, it refers to switching periods for different band pairs reported by UE. If there is only one Tx switching, the effective switching period is derived based on the following LS from RAN4. The concurrent switching of two Tx chains between two different band pairs can be performed during an effective switching period derived by switching periods for different band pairs reported by UE.

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| **LS** **R1-2300029/** **R4-2220548****Issue 2: Ambiguity issue when two Tx chains are switched between two different band pairs**For Rel-18 UL Tx switching among 4 bands, when switching from 1T+1T on band A and B to 1T+1T on band C and D is performed, and it is not clear whether UE performs Tx switching {from band A to C + B to D} or {from band A to D + B to C}, RAN4 agreed that:* As baseline UE assumption, no need to resolve the ambiguity issue of the switching pattern for each Tx chain and determine the switching gap based on the worst case by default, i.e., neither of the two Tx chains is expected to be used for transmission during the maximum of the four switching periods, i.e., max {Tswitch\_A-C, Tswitch\_B-D, Tswitch\_A-D, Tswitch\_B-C}.

Note: Tswitch\_A-C, Tswitch\_B-D, Tswitch\_A-D, Tswitch\_B-C are the switching periods reported by the UE for band pair A&C, B&D,A&D and B&C, respectively. |

**Moderator comments:** Note that RAN4 is discussing advanced UE capability that UE is capable of uplink transmission during the time period of longer switching period minus shorter switching period for the band pair with shorter switching period [15]. Then ,whether the concurrent switching of two Tx chains between two different band pairs can be performed during overlapping switching periods for different band pairs reported by UE, e.g., advanced UE capability, is up to RAN4.

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| **Issue 1-4-3 in [15]:**Time mask for one transmitter switching between band X and band Z, and between band Y and band Z, where UE is capable of uplink transmission on band Y during time period of {switching period #1 - switching period #2}, i.e., the UE indicates [*TBD-1*] in the capability [*TBD tx-on-non-affected-band*] |

### **Proposal 2**

### **1st round**

In the reply LS to RAN4, the answer to RAN4 question is as follows:

* RAN1 confirms that it is possible that the two Tx chains are switched concurrently between two different band pairs for the following three examples.
	+ Example #1: In the case of 3-band Tx switching, the switching is performed from 1T+1T on band A and B to 2T on band C.
	+ Example #2: In the case of 4-band Tx switching, the switching is performed from 1T+1T on band A and B to 1T+1T on band C and D.
	+ Example #3: In the case of 3-band Tx switching, the switching is performed from 2T on band A to 1T+1T on band B and C.
* It is RAN1 understanding it is possible that the concurrent switching of two Tx chains between two different band pairs can be performed during an effective switching period derived by switching periods for different band pairs reported by UE according to RAN4 LS [R1-2300029/R4-2220548].
	+ Whether the concurrent switching of two Tx chains between two different band pairs can be performed during overlapping switching periods for different band pairs reported by UE, e.g., subject to different UE capability, is up to RAN4.
* The conditions of concurrent switching of two Tx chains between two different band pairs are still under discussion in RAN1.

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1. Reference
2. R1-2302266 LS on Rel-18 Multi-carrier enhancement for NR RAN4, China Telecom
3. R1-2302386 Discussion on UL Tx switching across 3 or 4 bands in Rel-18 Huawei, HiSilicon
4. R1-2302446 Draft LS reply on Rel-18 Multi-carrier enhancement for NR vivo
5. R1-2302639 Discussion on RAN4 LS on Rel-18 Multi-carrier enhancement for NR CATT
6. R1-2302754 [Draft] Reply LS on Rel-18 Multi-carrier enhancement for NR ZTE
7. R1-2302777 Discussions on reply LS on Rel-18 multi-carrier enhancement Intel Corporation
8. R1-2302955 [Draft] Reply LS on Rel-18 Multi-carrier enhancement for NR xiaomi
9. R1-2303165 Discussion of RAN4 LS on Rel-18 Multi-carrier enhancement for NR Spreadtrum Communications
10. R1-2303462 Draft reply LS to RAN4 on Rel-18 multi-carrier enhancements for NR Apple
11. R1-2303562 Draft Reply to LS on RAN4 LS on Multi-Carrier enhancement for NR Qualcomm Incorporated
12. R1-2303629 Discussion on RAN4 LS for multi-carrier enhancement OPPO
13. R1-2303689 Discussion on reply LS on Multi-carrier enhancement for NR NTT DOCOMO, INC.
14. R1-2303856 Draft reply LS on UL Tx switching across 3 or 4 bands in Rel-18 Huawei, HiSilicon
15. R1-2302221 Summary#3 of discussion on multi-carrier UL Tx switching scheme Moderators (NTT DOCOMO, INC.)
16. R4-2303693 WF on Multi-carrier enhancements for NR China Telecom