**3GPP TSG RAN WG1 #107bis-e R1-22xxxxx**

**e-Meeting, Jan 17th – 25th, 2022**

**Agenda item:** 8.8.2

**Source:** Moderator (Qualcomm)

**Title:** FL summary #1 of PUCCH coverage enhancement

**Document for:** Discussion/Decision

# Introduction

In this document, a summary of companies’ proposals for PUCCH coverage enhancement is provided.

# RRC parameters for PUCCH repetitions

## Proposals discussed in RAN1 107e

First of all, FL would like to remind every company that we need to finalize RRC related aspects in this meeting. Therefore, FL suggest companies to be more constructive and flexible on RRC related issues.

**RRC parameter “PUCCH-nrofSlots-r17”**

The following FL proposal was almost agreeable in RAN1 107e expect one company had some concerns. FL would like to check if the concern still remains. If so, how can we address the concern to wrap up this issue.

**FL proposal 1: In column J of RRC parameter “PUCCH-nrofSlots-r17”, add a note as the following:**

* **Note: a PUCCH resource not configured with PUCCH-nrofSlots-r17 can attain the value of 1 according to when the Rel-15/16 parameter nrofSlots is not configured.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | Support |
| Intel | We are fine with FL proposal 1.  |
| vivo | Fine with the FL proposal. |
| Sharp | Support |
| Panasonic | We are fine with the FL proposal 1. |
| CATT | Agree. |
| LG | Support FL’s proposal. It is our understanding that the case when both of PUCCH-nrofSlots-r17 and nrofSlots are not configured, PUCCH is not repeated. |

**RRC parameter “PUCCH-DMRS-Bundling”**

In last RAN1 meeting, we narrow down to the following two options.

* **Option 2: The RRC parameter “PUCCH-DMRS-Bundling” is per UL BWP**
* **Option 3: The RRC parameter “PUCCH-DMRS-Bundling” is per PUCCH resource format**

A down-selection (maybe a hard binary decision) has to be made in this meeting between these two options. Before that, FL would like to collect companies’ views/votes as below.

 **FL question 1: which one of the below two options should be supported, and why?**

* **Option 2: The RRC parameter “PUCCH-DMRS-Bundling” is per UL BWP**
* **Option 3: The RRC parameter “PUCCH-DMRS-Bundling” is per PUCCH resource format**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Option 2 | As per existing agreements, we should strive for common design for PUSCH/PUCCH with DMRS bundling as much as possible. Exception could exist of course, but we do not see a valid technical use case to justify such exception for this aspect. |
| Intel | Option 2 | As previously mentioned, if this is configured per PUCCH resource format and when a new PUCCH resource is generated for overlapped dynamic HARQ-ACK and CSI, this would mean dynamic enabling/disabling DMRS bundling for PUCCH repetition, which is against the previous agreement.  |
| Sharp | Option 2 | It was agreed that dynamic signaling/adaptation to enable/disable DMRS bundling for PUCCH repetition is not supported in Rel-17. |
| Panasonic | Option 2 | Since PUCCH resource/format can be dynamically changed, Option 3 means dynamic indication of enabling/disabling DMRS bundling is supported. Since dynamic indication is not supported for PUSCH, to have unified operation (i.e., only semi-static configuration) is better. |
| CATT | Option 2 | Additionally, *PUCCH-DMRS-Bundling* does not apply to PUCCH format 0, since it is sequence-based and without DMRS. |
| LG | Prefer option 2. | Considering the previous agreement in RAN1#105-e that “strive for common design of the time domain window for PUSCH/PUCCH with DMRS bundling as much as possible”, DMRS bundling of PUCCH should be remained to be same with that of PUSCH unless there is a critical issue.For the common design between DMRS bundling of PUSCH and PUCCH, “PUCCH-DMRS-Bundling” should be per UL BWP which is aligned to DMRS bundling for PUSCH. |

**RRC parameter “PUCCH-TimeDomainWindowLength”**

In last RAN1 meeting, we narrow down to the following two options.

* **Option 2: The RRC parameter “PUCCH-TimeDomainWindowLength” is per UL BWP**
* **Option 3: The RRC parameter “PUCCH-TimeDomainWindowLength” is per PUCCH resource format**

A down-selection (maybe a hard binary decision) has to be made in this meeting between these two options. Before that, FL would like to collect companies’ views/votes as below.

 **FL question 2: which one of the below two options should be supported, and why?**

* **Option 2: The RRC parameter “PUCCH-TimeDomainWindowLength” is per UL BWP**
* **Option 3: The RRC parameter “PUCCH-TimeDomainWindowLength” is per PUCCH resource format**

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| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Option 2 | See above. |
| Intel | Option 2 | Same comment for PUCCH-DMRS-Bundling |
| Sharp | Option 2 | In AI 8.8.1.3, it was agreed that the window length L is configured per UL BWP and we should strive for common design as much as possible. |
| Panasonic | Option 2 | Since PUCCH resource/format can be dynamically changed, Option 3 means dynamic indication of window length of configured TDW is supported. Since there was a conclusion that dynamic indication of the window length of the configured TDW by DCI is not supported, we think Option 2 is aligned to this conclusion. |
| CATT | Option 2 | Additionally, *PUCCH-DMRS-Bundling* does not apply to PUCCH format 0, since it is sequence-based and without DMRS. |
| LG | Prefer option 2. | Same comment with previous question. |

## New proposals

R1-2200153 Proposal 3: Inter-bundling frequency hopping can be explicitly configured for PUSCH and PUCCH via introducing a new candidate alternative in frequency hopping configuration related IEs in PUSCH-Config and a new frequency hopping IE in PUCCH-FormatConfig, respectively.

R1-2200502 Proposal 3: Hopping interval for PUCCH should be configured per UL BWP.

R1-2200488 Proposal 2: Adopt the following table for the RRC parameters for PUCCH and PUSCH frequency hopping interval.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **WI code** | **Sub-feature group** | **Parameter name in the spec** | **New or existing?** | **Description** | **Value range** | **Default value aspect** | **Per (UE, cell, TRP, …)** | **UE-specific or Cell-specific** |
| NR\_cov\_enh-Core | DM-RS bundling for PUCCH | *PUCCH-Frequencyhopping-Interval* | New | Number of consecutive slots for UE to perform inter-slot frequency hopping with inter-slot bundling for PUCCH | ENUMERATED {1, 2, 4, 8} for paired spectrum and SUL band,ENUMERATED {1, 5, 10, 20} for unpaired spectrum | 　*PUCCH-TimeDomainWindowLength* | in PUCCH-Config | UE-specific |
| NR\_cov\_enh-Core | DM-RS bundling for PUSCH | *PUSCH-Frequencyhopping-Interval* | New | Number of consecutive slots for UE to perform inter-slot frequency hopping with inter-slot bundling for PUSCH | ENUMERATED {1, 2, 4, 8} for paired spectrum and SUL band,ENUMERATED {1, 5, 10, 20} for unpaired spectrum | 　*PUSCH-TimeDomainWindowLength* | in PUSCH-Config | UE-specific |

Given we have to finalize the RRC parameters related design in this RAN1 meeting, on this issue, FL would like to kick off the discussion directly based on R1-2200488 Proposal 2, which is a very comprehensive proposal already.

**FL question 3: What is your feedback/comment to the following proposal:**

**R1-2200488 Proposal 2: Adopt the following table for the RRC parameters for PUCCH and PUSCH frequency hopping interval.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **WI code** | **Sub-feature group** | **Parameter name in the spec** | **New or existing?** | **Description** | **Value range** | **Default value aspect** | **Per (UE, cell, TRP, …)** | **UE-specific or Cell-specific** |
| NR\_cov\_enh-Core | DM-RS bundling for PUCCH | *PUCCH-Frequencyhopping-Interval* | New | Number of consecutive slots for UE to perform inter-slot frequency hopping with inter-slot bundling for PUCCH | ENUMERATED {1, 2, 4, 8} for paired spectrum and SUL band,ENUMERATED {1, 5, 10, 20} for unpaired spectrum | 　*PUCCH-TimeDomainWindowLength* | in PUCCH-Config | UE-specific |
| NR\_cov\_enh-Core | DM-RS bundling for PUSCH | *PUSCH-Frequencyhopping-Interval* | New | Number of consecutive slots for UE to perform inter-slot frequency hopping with inter-slot bundling for PUSCH | ENUMERATED {1, 2, 4, 8} for paired spectrum and SUL band,ENUMERATED {1, 5, 10, 20} for unpaired spectrum | 　*PUSCH-TimeDomainWindowLength* | in PUSCH-Config | UE-specific |

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | The spirit of the proposal is fine with us; however, we think that a decision on the value range should be made after we finalize the discussion in Section 4.2, i.e., details on how frequency hopping intervals are determined.  |
| Intel | We are generally fine with the proposal. However, * It is not clear to us whether we need consecutive. Suggest to remove “Number of ~~consecutive~~ slots”
* for the default value, we need to first reach consensus for bundling size first.
 |
| vivo | We are fine to add these two parameters.While the value range should be FFS, in our understanding, the same value range for the interval can be applied for both TDD/FDD.Besides, for PUCCH, *PUCCH-Frequencyhopping-Interval* should be configured per PUCCH resource*.* |
| Sharp | We are generally fine with the proposal but suggest to change “inter-slot bundling” in description to “DMRS bundling”. |
| Panasonic | The value rage of {1, 5, 10, 20} for unpaired spectrum should be starting point of discussion. The length of frequency hopping interval and configured TDW should support the length aligned with *dl-UL-TransmisisonPeriodicity*, which takes the value of {ms0p5, ms0p625, ms1, ms1p25, ms2, ms2p5, ms5, ms10} and {ms3, ms4}. This is because if hopping interval and configured TDW length are the same as the period of TDD {DL+S+UL} slots, hopping pattern can be same regardless of hopping pattern is determined by physical slot or relative slot indices. {1, 5, 10, 20} for unpaired spectrum can support the length aligned with the value of {ms0p5, ms0p625, ms1, ms1p25, ms2, ms2p5, ms5, ms10}. |
| CATT | Generally fine with the proposal. Preferably, candidate numbers for hopping interval should be unified between paired (& SUL) and unpaired spectrums. |
| LG | Before introducing RRC parameter, it should be discussed that the hopping intervals for PUCCH/PUSCH repetitions with DMRS bundling is derived based on parameters or configured by new RRC parameters, which is represented in FL question 8. Moreover it is quite unclear to us that why “1” should be supported for the value range since it is equivalent to the Rel-17 frequency hopping. |

# Dynamic PUCCH repetition factor indication

## Dynamic PUCCH repetition factor indication for HARQ-ACK of first SPS PDSCH associated with the activation DCI and SPS release DCI

Regarding whether dynamic PUCCH repetition factor indication is applicable to HARQ-ACK for first SPS PDSCH associated with the activation DCI and SPS release DCI, the following FL conclusion was proposed in RAN1#106bis.

FL proposed conclusion 1: In NR Rel-17, for HARQ-ACK for SPS PDSCH, it is clarified that the dynamic PUCCH repetition factor indication mechanism agreed in RAN1 106e applies to HARQ-ACK corresponding to the SPS release DCI

* FFS whether dynamic PUCCH repetition factor indication mechanism is applied to HARQ-ACK for the first SPS PDSCH associated with the activation DCI.

However, it was not agreeable in RAN1 107e mainly due to controversial views on the FFS. A few companies think the FFS is actually a Rel-15 maintenance issue.

Given Rel-15 maintenance should be handled in other AI, therefore, the following FL proposal is made to capture the current situation of the discussion and wrap up this topic.

**FL proposal 2: In NR Rel-17, for HARQ-ACK for SPS PDSCH, it is clarified that the dynamic PUCCH repetition factor indication mechanism agreed in RAN1 106e applies to HARQ-ACK corresponding to the SPS release DCI**

* **Note: It is still open whether dynamic PUCCH repetition factor indication mechanism is applied to HARQ-ACK for the SPS activation DCI. Several companies request clarification of Rel-15/16 spec before resolving this open issue.**

Comments to the above FL proposal can be provided in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | In our view, SPS activation DCI and SPS release DCI are part of the same “family” of DCI. They are both not associated to a PDSCH (since the latter is configured via RRC). We are not comfortable with the idea of decoupling the two issues, since this would create even more confusion. If this is what it takes, let us clarify Rel-15/16 spec first. |
| Intel | We are fine to make conclusion for the SPS release DCI, which should be not controversial. However, for activation DCI, clarification on Rel-15 behavior is needed and our view is that this is based on PRI + CCE to determine the PUCCH resource. We suggest to also make conclusion that dynamic PUCCH repetition factor indication for HARQ-ACK of SPS PDSCH which is not associated with or activated by a DCI is not supported |
| Panasonic | We are fine with FL proposal 2. |
| CATT | OK. As well explained by Apple in the previous meeting, this is an issue left over from history. Although after exchanging views in several rounds, we think SPS activation DCI should be viewed as dynamic grant. So dynamic PUCCH repetition factor indication will be applied to HARQ-ACK SPS activation DCI by natural, without spec change.  |

## Other proposals

There are a few other proposals in submitted contributions to this agenda, which are listed as below.

R1-2200423 Proposal 2: Support the existing mechanism in 38.213 Sec. 9.2.3 when number of resources per PUCCH resource set is up to 32.

* Combine existing mechanisms based on PRI, NCCE and nCCE,0 to indicate the PUCCH resource with repetition factor within a PUCCH resource set up to 64 PUCCH resources

FL’s initial assessment is that the discussion of those proposals can be deprioritized, comparing to proposals in Section 2.1 and 2.2. But companies are welcome to provide comments to the above proposals in the following table.

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| --- | --- |
| **Company name** | **Comment** |
|  |  |
|  |  |

# DMRS bundling across PUCCH repetitions

The second objective of this agenda item is to “specify mechanism to support DMRS bundling across PUCCH repetitions.” Under this objective, a few topics are addressed in companies’ contributions. The topics are summarized as below.

## PUCCH TDW design details

In RAN1 107e, the following agreement was made.

**Agreement**

**For PUCCH DMRS bundling, when appliable, reuse the procedure developed for PUSCH DMRS bundling to determine configured TDW(s) and actual TDW(s).**

* **FFS: events for PUCCH actual TDW(s)**

On the FFS, the input from companies are the following.

R1-2200054 Proposal 1: The agreed events for PUSCH actual TDWs should be also applicable to PUCCH actual TDW.

* Dropping/cancellation based on Rel-15/16 collision rules;
* DL slot or DL reception/monitoring based on semi-static DL/UL configuration for unpaired spectrum;
* Other uplink transmission in the middle of two PUSCH/PUCCH transmissions;
* Gap between two PUSCH/PUCCH transmissions exceeds 13 symbols;
* TA adjustment;
* Frequency hopping;
* UL beam switching for multi-TRP operation.

R1-2200468 Proposal 1: Same events can be reused and defined for PUCCH actual TDW(s)

R1-2200089 Proposal 11: PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as an event.

R1-2200614: Proposal 1: The configured TDW determination of the PUCCH should reuse the configured TDW determination based on the available slot of the PUSCH.

Given CR R1-2112967 actual captured the events which would break the power consistency and phase continuity for PUCCH/PUSCH repetitions, FL’s initial assessment is that the proposal in R1-2200054 and R1-2200468 are already captured in Rel-17 specification.

Next, FL would like to collect comments/feedback to R1-2200089 Proposal 11 and R1-2200614 Proposal 1.

**FL question 4: What is your view/feedback to the following two proposals**

**R1-2200089 Proposal 11: PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as an event.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | Ok. |
| Intel | We are fine with the proposal.  |
| vivo | Support this proposal. |
| Sharp | Support |
| Panasonic | We support the proposal. |
| CATT | OK. |
| LG | According to the definition of event, i.e., events which cause power consistency and phase continuity not to be maintained, PUCCH repetition with different sets of power control parameters in multi-TRP operation should be an event. Since the UE behavior is different whether it is dynamic or semi-static event, it needs to be clarified. |

**R1-2200614: Proposal 1: The configured TDW determination of the PUCCH should reuse the configured TDW determination based on the available slot of the PUSCH.**

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| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | Agree with the spirit of the proposal but the wording needs to be improved to avoid confusion. Suggest the following: “*The configured TDW determination procedure for the PUCCH should only be based on counting on the slots determined as available for the PUCCH and reuse the logic of the configured TDW determination procedure based on the available slot of the PUSCH*”. |
| Intel | We are fine with the proposal. We suggest to add if applicable to the proposal. **If applicable, the configured TDW determination of the PUCCH should reuse the configured TDW determination based on the available slot of the PUSCH,**  |
| vivo | Similar with as Nokia. |
| Sharp | Support. However, it is already captured in Rel-17 specification. |
| Panasonic | We support the proposal. |
| CATT | OK. |
| LG | Support. |

## Inter slot freq hopping enhancement with DMRS bundling

In RAN1 107e, the following agreement was made for inter-slot frequency hopping.

**Agreement**

For the interaction between inter-slot frequency hopping and DMRS bundling for PUCCH/PUSCH repetitions, a UE performs the “hopping intervals determination”, “configured TDW determination”, and “actual TDW determination” in a sequential ordering, based on the following option 1.

* Option 1: “hopping intervals determination” -> “configured TDW determination” -> “actual TDW determination”
	+ DMRS bundling shall be restarted at the beginning of each frequency hop
	+ DMRS bunding is per actual TDW
	+ FFS: Frequency hopping pattern is determined by physical slot indices.
		- FFS: different FH pattern determination for PUCCH and PUSCH
		- FFS: details of FH pattern design
	+ Support separate RRC configuration(s) for hopping interval and configured TDW length.
		- if hopping interval is not configured, the default hopping interval is the same as the configured TDW length
			* FFS: if both hopping interval and TDW length are not configured
		- Note: hopping interval is only determined by the configuration of hopping interval if hopping interval is configured

There are still three FFS that need to be address. Companies’ input for each FFS are summarized as following.

### FFS: different FH pattern determination for PUCCH and PUSCH

R1-2200054 Observation 1: It seems not a critical issue to have different FH pattern for PUCCH and PUSCH.

R1-2200153 Proposal 2: Frequency hopping patterns for both PUCCH and PUSCH are determined based on physical slot indices separately.

R1-2200163 Proposal 1: Frequency hopping pattern is not determined by physical slot indices, and a UE configured for DM-RS bundling determines the frequency hopping intervals for a set of PUCCH/PUSCH transmissions based at least on the starting slot of the set of PUCCH/PUSCH transmissions for which DM-RS bundling is activated

R1-2200208 Proposal 1: For DMRS bundling for PUCCH transmission with repetitions, the frequency hopping pattern is determined based on a relative slot index as in Rel-16.

R1-2200239 Proposal 1: Available slot should be used for determination of FH pattern for PUCCH and PUSCH (counting based on available slots), if hopping interval is not configured.

R1-2200304 Proposal 2: Frequency hopping pattern for DMRS bundling across PUCCH transmissions is determined based on physical slot indices.

R1-2200322 Proposal 1: Either of following option is taken.

* Option 1: Frequency hopping pattern is determined by physical slot indices for both PUSCH and PUCCH.
	+ The length aligned with dl-UL-TransmissionPeriodicity should be supported for the length of hopping interval and configured TDW.
* Option 2: Frequency hopping pattern is determined by physical slot indices for PUSCH and is determined by relative slot indices for PUCCH.
	+ The length aligned with dl-UL-TransmissionPeriodicity should be supported for the length of hopping interval and configured TDW.
* Option 3: Frequency hopping pattern is determined by physical slot indices if hopping interval is configured. Frequency hopping pattern is determined by relative slot indices if hopping interval is not configured.

R1-2200337 Proposal 3: Frequency hopping pattern is determined by physical slot indices.

Hopping interval can be implicitly determined by number of repetitions.

Same rules for both PUCCH/PUSCH frequency hopping.

R1-2200382 Proposal 3:

* For inter-slot frequency hopping with inter-slot bundling
	+ For PUSCH repetition, frequency hopping pattern is determined based on physical slot index.
	+ For PUCCH repetition, frequency hopping pattern is determined based on relative physical slot index.

R1-2200468 Proposal 3: Frequency hopping pattern can be determined by physical slot indices.

R1-2200488 Proposal 1: Frequency hopping pattern for inter-slot frequency hopping with inter-slot bundling is determined by physical slot indices.

R1-2200502 Proposal 1: If a hopping interval $H$ is configured, UEs with the hopping pattern should be multiplexed independently from starting slots of PUSCH transmissions of the UEs.

R1-2200591: Proposal 2:

Frequency hopping pattern should be determined by physical slot indices.

R1-2200591: Proposal 3:

The frequency hopping pattern could be different between PUCCH and PUSCH. But the determination rule can be unified to reduce the specification impact and simplify the implementation.

R1-2200614 : Proposal 3: The frequency hopping pattern for inter-slot frequency hopping is determined only by physical slot index.

R1-2200636 Proposal 1: For Rel-17 inter-slot frequency hopping with inter-slot bundling, Rel-15/16 inter-slot frequency hopping pattern design is reused as much as possible.

* + Physical slot index is used for PUSCH.
	+ Relative physical slot index is used for PUCCH.

Based on companies’ input, majority support that the frequency hopping pattern for both PUCCH/PUSCH with DMRS bundling is determined by physical slot index, with the following benefits

* Unified solution for PUCCH and PUSCH on TDD, FDD, and SUL
* More friendly to multi-user multiplexing

However, there are also different views. For example, several companies prefer using physical slot index for PUSCH while relative slot index for PUCCH (which seems to follow current Rel-15/16 spec).

Before making a recommend proposal, FL would like to collect more input, especially on what are the technical benefits to adopt different solutions for PUCCH and PUSCH.

**FL question 5: Do you prefer a unified rule/procedure to determine frequency hopping for PUCCH/PUSCH with DMRS bundling. If not, what are the benefits to adopt different rules for PUCCH/PUSCH?**

* **Note: The unified determination rule/procedure still allow to generate different frequency hopping patterns for PUCCH and PUSCH, e.g., different hopping intervals.**

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| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Yes, upon condition. | If a unified rule is agreed, it should be based on relative slot index (first repetition is on slot “0” and so on). This allows to enjoy the largest benefit brough by JCE, especially if the hopping interval duration is a divisor of the cTDW duration, while not sacrificing the frequency diversity. Conversely, we do not see any technical benefit in having a unified solution based on physical slot index. This would be very detrimental for the performance of JCE in most cases. Some companies state that this would be friendlier to multi-user multiplexing, however this would hardly be the case in practice. Indeed, to enjoy such benefits all UEs would need to be configured with the same hopping interval length. This would impose such hard constraints on NW’s scheduler and limit benefits of JCE so largely then we doubt it would ever been pursued as an objective in an actual deployment. We invite all companies to seriously think about this aspect. More details can be found in R1-2200163. |
| Intel | No. It is not necessary | Our view is that it is more appropriate to extend the existing mechanism as defined in Rel-15, to minimize the spec impact and implementation effort. Following this design principle, for PUSCH, frequency hopping pattern is determined based on physical slot index while for PUCCH, frequency hopping is determined based on relative physical slot index.  |
| vivo | YES |  |
| Sharp | Yes | We should strive for common design of inter-slot frequency hopping with DMRS bundling as much as possible. |
| Panasonic | We are open whether to use unified rule/procedure between PUCCH and PUSCH. | To adopt different rules for PUCCH and PUSCH has similar behavior as in Rel.15/16. |
| CATT | Yes |  |
| LG | Yes. | According to the following agreement in RAN1#104-e, unified rule/procedure should be supported to determine frequency hopping for PUCCH/PUSCH with DMRS bundling.Agreements: Subject to the prerequisite of DMRS bundling for PUCCH repetitions, enhance inter-slot frequency hopping pattern for PUCCH repetitions with DMRS bundling. * FFS: details in inter-slot frequency hopping pattern enhancement, e.g., additional frequency hopping patterns than Rel-16.
* Strive for common design for PUSCH/PUCCH with DMRS bundling as much as possible
 |

**FL question 6: if a unified rule/procedure is preferred, is the following proposal agreeable?**

* **Proposal: For PUCCH/PUSCH repetitions with DMRS bundling, the inter-slot frequency hopping pattern is determined by physical slot index.**

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| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Not agreeable. | Please see above. |
| Intel | No |  |
| vivo | NO | For inter-slot frequency hopping, the RB index is determined by physical slot index, while it can not be simply reused for frequency hopping per multiple slots. For example, in frame structure DDDDD DDSUU, the frequency hopping interval is 2 slots, and PUCCH/PUSCH is repeated 4 times, i.e., repeated in the last two slots in two consecutive frames. Since the slot index is counted within a frame, the starting RB index for frequency hop in the first frame and the second frame will be the same if the starting RB is determined by the physical slot index. Hence, for inter-slot frequency hopping with DMRS bundling, the starting RB index for each frequency hop can not be determined by slot index. |
| Sharp | We are generally fine with the proposal but suggest to revise as the following:Proposal: For PUCCH/PUSCH repetitions with DMRS bundling, the inter-slot frequency hopping pattern is determined by **at least** physical slot index. | We agree that multiple UEs with new frequency hopping are multiplexed regardless of starting slot of PUSCH/PUCCH repetitions for each UE. However, in terms of the number of slots in a radio frame, the new frequency hopping pattern should be determined by physical slot index and SFN. For example, the number of slots in a radio frame when $μ$ = 0 is only 10 slots even if the number of repetitions is more than 10 slots. |
| Panasonic | Agreeable if the length aligned with *dl-UL-TransmisisonPeriodicity* is supported. | If hopping interval and configured TDW length are the same as the period of TDD {DL+S+UL} slots, hopping pattern can be same regardless of hopping pattern is determined by physical slot or relative slot indices. |
| CATT | Yes | The question raised by vivo can be easily tackled by using frame number to distinguish the slots in different frames. |
| LG | Yes. |  |

**FL question 7: If separate rules/procedures to determine frequency hopping for PUCCH/PUSCH with DMRS bundling are preferred, is the following proposal agreeable?**

* **Proposal: For inter-slot frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling**
	+ **For PUSCH repetitions, frequency hopping pattern is determined based on physical slot index.**
	+ **For PUCCH repetitions, frequency hopping pattern is determined based on relative physical slot index**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Acceptable as a middle ground. | This is not our first preference |
| Intel | Support | Same comment as above.  |
| vivo | No | As we commented for FL question 6, FH pattern based on physical slot index may result in NO FH, when the repetitions cross the frame boundary.The same rule can be applied for PUCCH and PUSCH repetitions. |
| Panasonic | Agreeable if the length aligned with *dl-UL-TransmisisonPeriodicity* is supported. | If hopping interval and configured TDW length are the same as the period of TDD {DL+S+UL} slots, hopping pattern can be same regardless of hopping pattern is determined by physical slot or relative slot indices. |
| CATT | OK |  |

### FFS: details of FH pattern design

R1-2200054 Proposal 2: Further enhancement of frequency hopping pattern is not necessary.

R1-2200089 Proposal 5: For frequency hopping with DMRS bundling, the starting RB is determined by the interval index

* The first hopping interval starts from the first PUSCH/PUCCH repetition, and has a number of slots according to configured interval length or configured TDW length.
* New frequency hopping interval is created if there are remaining repetitions not covered by previous intervals.

R1-2200114 Proposal 2: For PUSCH/PUCCH repetition, frequency hopping pattern is determined by the legacy rules for inter-slot frequency hopping for PUCCH repetition defined in Rel-15/16.

* The UE performs frequency hopping per frequency hopping interval.
* The frequency hopping interval indicated to the UE containing the first PUSCH/PUCCH transmission has number 0 and each subsequent frequency hopping interval until the UE transmits all PUSCH/PUCCH repetitions is counted regardless of whether or not the UE transmits the PUSCH/PUCCH in the frequency hopping interval.

R1-2200163 Proposal 2. Define frequency hopping interval in case of DM-RS bundling constrained to being either equal to the length of the configured TDW or a divisor of the length of the configured TDW.

R1-2200208 Proposal 2:

For DMRS bundling for PUCCH transmission with repetitions, the frequency hopping interval can be larger than one slot.

R1-2200208 Proposal 3:

For DMRS bundling for PUCCH transmission with repetitions, further discuss whether the number of hops is larger than two.

R1-2200280 Proposal 5: For the inter-slot frequency hopping with DMRS bundling for PUSCH/PUCCH:

* + Hopping offsets are determined by the physical slot index and frequency hopping interval

R1-2200322 Proposal 2: Frequency hopping pattern based on physical slot indices is realized as following.

* The starting RB during slot $n\_{s}$ is given by
	+ $RB\_{start}\left(n\_{s}\right)=\left\{\begin{matrix}RB\_{start}&\left⌊n\_{s}/N\_{FH}\right⌋ mod 2=0\\\left(RB\_{start}+RB\_{offset}\right) mod N\_{BWP}^{size}&\left⌊n\_{s}/N\_{FH}\right⌋ mod 2=1\end{matrix}\right.$
		- $n\_{s}$ is the current slot number within a radio frame
		- $RB\_{start}$ is the starting RB within the UL BWP as calculated from the resource block assignment information
		- $RB\_{offset}$ is the frequency offset in RBs between the two frequency hops
		- $N\_{FH}$ is the length of hopping interval

R1-2200322 Proposal 3: Frequency hopping pattern based on relative slot indices is realized as following.

* The starting RB during slot $n\_{s}^{'}$ is given by
	+ $RB\_{start}\left(n\_{s}^{'}\right)=\left\{\begin{matrix}RB\_{start}&\left⌊{n\_{s}^{'}}/{N\_{FH}}\right⌋ mod 2=0\\\left(RB\_{start}+RB\_{offset}\right) mod N\_{BWP}^{size}&\left⌊{n\_{s}^{'}}/{N\_{FH}}\right⌋ mod 2=1\end{matrix}\right.$
		- $n\_{s}^{'}$ is the relative slot number. The slot indicated to the UE for the first PUSCH/PUCCH repetition has number 0 and each subsequent slot until the UE transmits the PUSCH/PUCCH in $K$ slots is counted regardless of whether or not the UE transmits the PUSCH/PUCCH in the slot.

R1-2200502 Proposal 2: If a hopping interval $H$ is configured, the hopping pattern should be determined as:

$$RB\_{start}\left(n\_{f},n\_{s,f}^{μ}\right)=\left\{\begin{array}{c}RB\_{start}, \&\left⌊(N\_{slot}^{frame,μ}n\_{f}+n\_{s,f}^{μ})/H\right⌋ mod 2=0\\\left(RB\_{start}+RB\_{offset}\right) mod N\_{BWP}^{size}, \&\left⌊(N\_{slot}^{frame,μ}n\_{f}+n\_{s,f}^{μ})/H\right⌋ mod 2=1\end{array}\right.$$

R1-2200614 Proposal 6: The bundle size can be same as or different from the time domain window size.

R1-2200636 Proposal 2: Following methods can be further considered to maximize the gain of joint channel estimation in case of both hopping interval (i.e., L’) and configured TDW length (i.e., L) are configured:

* + Alt 1: A UE does not expect to be configured as hopping interval (i.e., L’) > configured TDW length (i.e., L).
	+ Alt 2: Hopping interval (i.e., L’) is used for determination of configured TDW length if configured hopping interval value of L’ is larger than configured TDW length value of L.

R1-2200658 Proposal 2:

* Enhanced frequency hopping designs for PUCCH and PUSCH include the following:
	+ Frequency hopping offsets are determined from a hopping index that is calculated from the (physical) slot number, where the hopping index changes once every N slots, the index can attain up to M values, and the hopping pattern has a configurable time shift (in the unit of slots).
		- Increased hopping offsets over Rel-15 are supported, e.g. M=4,
	+ UE capability for support for the Rel-17 frequency hopping pattern is independent from that of joint channel estimation

There are three major open issues regarding the details of the FH pattern design.

* Issue 1: How to decide frequency hopping interval, i.e., derived by other parameters such as configured TDW or explicated configured by a new RRC parameter(e.g., R1-2200153 Proposal 3)?
* Issue 2: Whether increase the number of frequency offset over Rel-15/16 are supported?
* Issue 3: What is the exact equation to decide hopping pattern?

For issue 3, the solution depends on the decision for questions in Section 3.2.1. FL suggest to put the discussion on issue 3 on hold until the open issues in Section 3.2.1 are resolved. For issue 1 and 2, FL would like to collect companies’ answers to the following two questions as below.

**FL question 8: The hopping intervals for PUCCH/PUSCH repetitions with DMRS bundling should be derived based on parameters or configured by new RRC parameters?**

|  |  |
| --- | --- |
| **Company name** | **Answer** |
| Nokia/NSB | In our view existing agreements stipulate that hopping intervals for PUCCH/PUSCH should be configured, and a fallback mechanism should exist in case they are not configured. We are not sure that having a mechanism exclusively based on a derivation of the FH interval duration respects existing agreements. Having said this, we also think that existing agreements allow a derivation based on a new RRC parameter, e.g., such new RRC parameter could be the ratio between FH interval and TDW duration, to ensure that an integer number of complete FH intervals is present in each TDW and that performance of JCE is maximized.  |
| Intel | According to the agreement from last meeting, a new RRC parameter is needed:* Support separate RRC configuration(s) for hopping interval and configured TDW length
 |
| vivo | It seems already discussed in last meeting, if hopping interval is configured, it is a new parameter by nature. If hopping interval is not configured it is derived from the configured TDW |
| Sharp | Hopping interval should be configured by new RRC parameters. |
| Panasonic | Hopping intervals should be derived based on *Frequencyhopping-Interval* in Section 2.2 and/or configured TDW length. |
| CATT | To FL’s Question 8, using an explicit RRC parameter to configure hopping interval is clear and preferred. Additionally, default value may be determined (e.g. in Section 4.2.3) if the explicit RRC parameter is absent.To clarify, ‘how to inform the UE to perform inter-bundling hopping’ seems to be one missing piece for this feature… Our suggestion (R1-2200153 Proposal 3) is by explicit RRC configuration, e.g. to add ‘*interBundling*’ in ‘*frequencyHopping’* IE in *PUSCH-Config* for PUSCH. For PUCCH, it depends on whether it is per BWP configured or per format configured. |
| LG | To align with the default value for the hopping interval, which is same with the configured TDW length, it should be derived based on parameters, especially configured TDW length. |

**FL question 9: For frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling, should Rel-17 increase the number of frequency offset over what are supported in Rel-15/16?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | No need. |  |
| Intel | No | Increasing the number of frequency offsets for inter-slot frequency hopping is out of the scope for PUSCH/PUCCH coverage enhancement.  |
| vivo | No |  |
| Sharp | No need |  |
| Panasonic | No.  | Although we understand it improve the performance, we think it is rather optimization given the end of WI. |
| CATT | We do not see strong need. |  |
| LG | No | We do not think have enough time to introduce something new considering all we have for frequency hopping of DMRS bundling now is sequential ordering of TDW and hopping interval. It should be deprioritized or at least revisit after offset determination, hopping pattern and configuration is settled. |

### FFS: if both hopping interval and TDW length are not configured

R1-2200114 Proposal 3: If both hopping interval and configured TDW are not configured, the default hopping interval is equal to half of the duration of all PUSCH/PUCCH repetitions.

R1-2200153 Proposal 1: The default hopping interval is equal to the default window length of the configured TDW, i.e. the minimum of maximum duration and the duration of all PUSCH/PUCCH transmissions, if neither of hopping interval or configured TDW length is configured.

R1-2200163 Proposal 3. Set the frequency hopping interval length equal to the configured TDW length, in the case the configured TDW length is not configured, and the frequency hopping interval is not configured

R1-2200239 Proposal 2: If both hopping interval and TDW length are not configured, default value for configured TDW length (= hopping interval) is used.

R1-2200280 Proposal 1: When both hopping interval and TDW length are not configured, down select between:

* Half of default configured TDW length can be used as frequency hopping interval, which is 1/2\*min (maximum duration, duration of all PUSCH repetitions).
* Not allowed this case.

R1-2200322 Proposal 4: If both hopping interval and TDW length are not configured,

* If DMRS-budling is enabled, default hopping interval should be same as the default TDW length.
* If DMRS-budling is not enabled, Rel.15/16 hopping pattern should be applied.

R1-2200468 Proposal 4: If both hopping interval and TDW length L are not configured, the first step is to determine the default value of L = min (maximum duration, duration of all PUSCH repetitions), then the hopping interval can be the same as the default TDW length L.

R1-2200502 Proposal 6: When hopping interval and window length L are not configured, a half of the configured TDW should be equal to the default hopping interval to achieve both frequency hopping gain and DMRS bundling gain.

R1-2200521 Proposal 1: If both hopping interval and TDW length are not configured, hopping interval is determined by L = min (maximum duration, duration of all PUSCH repetitions) and L = min (maximum duration, duration of all PUCCH repetitions) for PUSCH and PUCCH, respectively.

R1-2200614 Proposal 5: In case the joint channel estimation is enabled and frequency hopping is indicated without a hopping interval and configured TDW, the default value for configured TDW should be applied as a default value for the hopping interval.

R1-2200636 Proposal 3: If both hopping interval (i.e., L’) and configured TDW length (i.e., L) are not configured, hopping interval is determined as a single slot, i.e., Rel-15/16 inter-slot frequency hopping can be reused.

Based on the input from companies, there are four options to solve this issue of default hopping interval, if both hopping interval and TDW length are not configured.

* **Option 1: half duration of PUCCH/PUSCH repetitions**
* **Option 2: default window length of the configured TDW**
* **Option 3: half of default window length of the configured TDW**
* **Option 4: a single slot (fallback to Rel-15/16 inter-slot frequency hopping)**

FL would like to collect more input on this topic, especially the pros and cons for each option.

**FL question 10: Which one of the above 4 option you prefer, and why?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Option 2. | Existing agreement stipulates that if hopping interval is not configured, the default hopping interval is the same as the configured TDW length. Given that we also have a default TDW length if the latter is not configured, the most straightforward behavior is to set the default FH internal length equal to the default TDW length. Any other decision seems rather arbitrary to us, with no solid justification. |
| Intel | We are fine with Option 1 or 3 | For the case when configured TDW is equal to the number of repetitions and if default bundling size for inter-slot frequency hopping is equal to the number of repetitions or configured TDW size, this would indicate that inter-slot frequency hopping with inter-slot bundling is not enabled. Using half of the configured TDW or the number of repetitions would enable inter-slot frequency hopping with inter-slot bundling |
| vivo | Option 2 | It has been agreed that the default frequency hopping interval is the configured TDW length. Furthermore, based on agreements in AI 8.8.1.3, if TDW length is not configured, the default TDW length is min (maximum duration, duration of all PUSCH/PUCCH repetitions). Hence, when neither hopping interval nor TDW length is configured, the frequency hopping interval is min (maximum duration, duration of all PUSCH/PUCCH repetitions) |
| Sharp | Option 3 | At least, the UE should achieve frequency diversity for PUSCH/PUCCH with frequency hopping. |
| Panasonic | Option 2 if DMRS-budling is enabled.Option 4 if DMRS-budling is not enabled |  |
| CATT | Option 2 | This is a straight forward option. No need to make this issue too complicated. If a specific value is needed, the gNB shall configure the hopping interval explicitly. |
| LG | Prefer option 2. | It is quite clear to us by combining two default behaviors, i.e., “if hopping interval is not configured, the default hopping interval is the same as the configured TDW length” and “if L is not configured, the default value of L = min (maximum duration, duration of all PUSCH repetitions)”. We are running out of time and still have things to wrap up, it will be the simplest solution without spec impact. |

## Frequency hopping for TBoMS

There are a few proposals to support frequency hopping for TBoMS, which are listed as below.

R1-2200519 Proposal 3:

* In case of DMRS bundling, inter-slot frequency hopping with inter-slot bundling is supported for TBoMS.
	+ Frequency hopping pattern for TBoMS is determined based on physical slot index.
* For repetition of a single TBoMS transmission, inter-repetition frequency hopping is supported.

R1-2200152 Proposal 4: Inter-slot frequency hopping with inter-slot bundling is supported for TBoMS at least for the case when DMRS bundling is applied.

R1-2200466 Proposal 3: Support intra-TB frequency hopping for TB processing over multi-slot PUSCH.

R1-2200604 Proposal 8: The bundling of inter-slot frequency hopping should be supported for TBoMS.

As these are new proposals submitted in this meeting, FL would like to collect feedback on these proposals before making a recommendation.

**FL question 11: Should inter-slot frequency hopping with DMRS bundling supported for TBoMS, and why?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Yes | In our view, there does not seem to be any agreed restriction on the application of JCE to TBoMS. Therefore, we do not see why inter-slot frequency hopping with DMRS bundling should not be supported for TBoMS. However, this should come with no specific optimization targeting TBoMS.  |
| Intel | Yes | Share similar view as Nokia. |
| vivo | YES | The same mechanism for inter-slot FH with DMRS bundling for type-A PUSCH repetition can be reused for TBoMS. New mechanisms should be avoided. |
| Sharp | Yes |  |
| Panasonic | Yes | The same mechanism as PUSCH repetition Type A should be supported. |
| CATT | Yes | Combination of TBoMS, DMRS bundling and inter-bundling hopping can extend the coverage as much as possible. This seems not a big issue since the TDRA of TBoMS is based on repetition type A-like mechanism. |
| LG | Only if those for PUSCH repetition type A is reused. | For the TDW determination procedure, following is agreed in agenda 8.8.1.3 during previous meeting.**Agreement*** The TDW determination procedure agreed for PUSCH repetition type A is reused, when applicable, for PUSCH repetition type B and TBoMS with or without repetition.
* No additional specification enhancements for PUSCH repetition type B and TBoMS

It is our understanding that actual TDW is determined based on the events which include frequency hopping, and configured/actual TDW is determined after hopping interval determination.Therefore it is natural that inter-slot frequency hopping for TBoMS is supported only when inter-slot frequency hopping for PUSCH repetition type A is reused. |

## Other proposals

R1-2200280: Proposal 1: Candidate values of Frequency hopping interval can be any integer value that is equal or large than 1.

R1-2200280: Proposal 2: PUCCH, PUSCH repetition type A, TBoMS and PUSCH repetition type B can have separate configurations of inter-slot FH with DMRS bundling interval.

R1-2200423 Proposal 1: If DMRS bundling is supported, specify conditions under which phase continuity is kept for a PUCCH with DMRS bundling overlapping in one (or more) occasions with a second PUCCH without DMRS bundling.

FL’s initial assessment is that the discussion of those proposals can be deprioritized, comparing to proposals in Section 3.1, 3.2, 3.3. But companies are welcome to provide comments to the above proposals in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comment** |
|  |  |
|  |  |

# Power control and TA with PUCCH repetitions

Based on companies input in contributions, we could strive for a common design of power control and TA handling for PUCCH and PUSCH repetitions. Therefore, we could hold on the discussion on this topic until progress made in agenda 8.8.1.3.

# References

|  |  |  |
| --- | --- | --- |
| [R1-2200054](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200054.zip) | Discussion on PUCCH coverage enhancement | Huawei, HiSilicon |
| [R1-2200089](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200089.zip) | Remaining issues on PUCCH enhancements | vivo |
| [R1-2200114](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200114.zip) | Discussion on remaining issues for coverage enhancements for PUCCH | ZTE |
| [R1-2200153](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200153.zip) | Remaining issues on PUCCH enhancements | CATT |
| [R1-2200163](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200163.zip) | PUCCH coverage enhancements | Nokia, Nokia Shanghai Bell |
| [R1-2200208](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200208.zip) | PUCCH enhancements | Samsung |
| [R1-2200239](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200239.zip) | PUCCH enhancements for coverage enhancement | NTT DOCOMO, INC. |
| [R1-2200280](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200280.zip) | Discussion on PUCCH enhancements | Spreadtrum Communications |
| [R1-2200304](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200304.zip) | PUCCH enhancements | Qualcomm Incorporated |
| [R1-2200322](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200322.zip) | Discussion on the interaction between inter-slot frequency hopping and DMRS bundling | Panasonic Corporation |
| [R1-2200337](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200337.zip) | PUCCH enhancements for coverage | OPPO |
| [R1-2200382](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200382.zip) | Remaining details on PUCCH enhancements | Intel Corporation |
| [R1-2200423](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200423.zip) | Further discussion on PUCCH coverage enhancement | Apple |
| [R1-2200468](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200468.zip) | Discussion on PUCCH enhancements | xiaomi |
| [R1-2200488](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200488.zip) | Remaining issues on inter-slot frequency hopping with inter-slot bundling for PUCCH and PUSCH | China Telecom |
| [R1-2200502](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200502.zip) | PUCCH coverage enhancement | Sharp |
| [R1-2200521](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200521.zip) | Discussions on PUCCH enhancements | InterDigital, Inc. |
| [R1-2200591](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200591.zip) | Remaining issues on PUCCH enhancements | CMCC |
| [R1-2200614](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200614.zip) | Discussions on coverage enhancement for PUCCH | LG Electronics |
| [R1-2200636](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200636.zip) | Remaining issues on PUCCH enhancements for coverage enhancement | WILUS Inc. |
| [R1-2200658](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200658.zip) | Remaining Issues for PUCCH Dynamic Repetition and DMRS Bundling | Ericsson |