3GPP TSG-RAN WG1 Meeting #106bis-e R1-2109436

e-Meeting, 11th – 19th October, 2021

Agenda Item: 8.2.3

Source: Moderator (Ericsson)

Title: FL Summary for [106bis-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4

Document for: Discussion, Decision

# 1 Introduction

This document summarizes the contributions made under the “Enhancements for PUCCH Formats 0/1/4” agenda item of the Rel-17 work item "Extending current NR operation to 71 GHz."

The following email thread is assigned for discussion of this topic:

[106bis-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4 with checkpoints for agreements on October 14 and 19 – Steve (Ericsson)

# 2 PUCCH Resource Set Prior to RRC Configuration

## 2.1 Potential RB Shortage

The following table provides a summary of company proposals on this topic:

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| **Company** | **Company Proposals** |
| Intel [11] | **Proposal 4: RAN1 should further discuss possible enhancements to PUCCH resource sets before dedicated PUCCH resource configuration such as additional starting symbol or OCC index similarly as done in Rel.16 NR-U.** |
| Qualcomm [17] | **Proposal 3: Based on construction process in example 1, a common PUCCH resource is invalid if some of its occupied RBs is outside the initial UL BWP. gNB should never schedule UE with such a resource, and UE shall treat it as an error case when it is scheduled to use such a common PUCCH resource.**  **Proposal 4: Based on construction process in example 1, if one of common resource with r\_pucch>=8 uses some RBs occupied by common resource with r\_pucch<8, this resource should be invalidated by spec. gNB should never schedule UE with such a resource, and UE shall treat it as an error case when it is scheduled to use such a common PUCCH resource.** |
| Futurewei [3] | ***Observation 1. The prior Note on no further enhancement on RB shortage issue was included by the agreement at the time of the discussion when the maximum number of RBs were 12/3/2 for 120/480/960kHz SCS were preliminary, while the numbers were finalized one meeting afterwards. It has not been discussed whether it is needed for the RB shortage issue to be revisited under the newly allowed maximum RB numbers 16/16/16 for 120/480/960kHz SCS.***  ***Proposal 2. The increase of the maximum number of RBs can make the RB shortage problem substantially worse, so it is warranted to confirm whether or not RAN1 wish to address the RB shortage problem.***  ***Observation 2. Alt-4 in the relevant discussion in RAN1#105-e is expected to remain as a feasible option such that 16 PUCCH resources can be made available if additional OCCs and/or SLIVs are introduced for some rows of the table. Alt-5 can also alleviate the RB shortage issue by not allowing large PRB offsets when multiple RBs are configured.*** |
| LGE [15] | **Proposal #4: To address the potential shortage of PUCCH resources for the initial PUCCH resource set resulting from using multi-PRB to transmit PUCCH formats 0 and 1, consider the following alternatives:**   * **Alt. 1: Use only valid resources in the frequency domain** * **Alt. 2: Support additional starting symbol and OCC index**   **Proposal #5: Considering the available number of RBs in the initial BWP and more than 1 RB allocated for an initial PUCCH resource, discuss how to configure the hopping distance to obtain hopping gain equally for each initial PUCCH resource.** |
| Ericsson [8] | **Observation 1 According to previous agreements, the following enhancements for PUCCH resource sets prior to RRC configuration are out-of-scope:**   * + **Introduction of additional time domain starting positions and/or additional OCCs**   + **Support of a new RE mapping scheme (e.g., sub-PRB interlaced mapping)**   + **Equalization of hopping distance for the PUCCH resources within a set** |
| OPPO [6] | **Proposal 2: The potential RB shortage issue prior to RRC configuration can be handled by gNB implementation.** |
| Nokia [9] | ***Observation:*** *Further enhancements for PUCCH resource sets to mitigate RB shortage or to equalize frequency hopping distance should not be considered.* |
| Samsung [10] | **Proposal 2: RAN1 shall not re-open the discussion on the RB shortage issue before RRC connection.** |
| ZTE [4] | **Observation 1: RB shortage issue can be resolved through appropriate gNB configuration of BWP and RB number.**  **Proposal 1: No further enhancements on RB shortage issue should be considered.** |

### Summary of Potential RB Shortage

Company views on whether or not to re-open discussion on potential RB shortage issue

* Do not re-open discussion:
  + Qualcomm, Ericsson, OPPO, Nokia, Samsung, ZTE
* Further discuss:
  + Intel, Futurewei, LGE

Several companies point out that even if there could be an RB shortage issue for some combinations of values of {indicated row index of Table 9.2.1-1, indicated number of RBs, configured initial UL BWP size, indicated PUCCH resource index r\_PUCCH}, such ccombinations can be avoided by gNB implementation. Several companies also refer to the following note from an Agreement in RAN1#105-e that implies that there should be no further enhancements to address a potential RB shortage issue. Some companies point out that this note was agreed when it had not yet been agreed to increase the maximum number of RBs for a PUCCH resource from 12 to 16, and thus have increased concerns on RB shortage.

* Note: No further enhancements on RB shortage issue and frequecy hopping distance issue should be considered for PUCCH resource sets prior to RRC configuration

As per normal working procedure, consensus will be needed on any enhancement to address a potential RB shortage issue. Given that there is not even consensus to discuss the issue, it appears unlikely that consensus on potential enhancements could be agreed. Given the situation, the moderator proposes the following conclusion.

### **Conclusion #1 (Potential RB Shortage)**

* Do not re-open the discussion potential RB shortage and frequency hopping distance issues for PUCCH resource sets prior to RRC configuration.

Please provide your company view on Conclusion #1. Please consider that we should try to avoid spending valuable time on issues that have little chance of consensus.

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| **Company** | **View/Position** |
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## 2.2 PUCCH Resource Set Construction

The following table provides a summary of company proposals on this topic:

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| **Company** | **Company Proposals** |
| Intel [11] | **Proposal 1: Independently of the PUCCH resource set the number of RBs used for each PUCCH resource is the same as that configured through SIB1.**  **Proposal 2: The first PRB index for each PUCCH resource is function of the offset provided in Table 9.2.1-1, but also the number of RBs, , over which the PUCCH transmission spans.**  **Proposal 3: TP1 is supported.**  --------------------------------------------TP#1 for Section 9.2.1 in TS 38.213 -----------------------------------------------  If and a UE is provided a PUCCH resource by pucch-ResourceCommon and is not provided useInterlacePUCCH-PUSCH in BWP-UplinkCommon  - the UE determines the first PRB index of the PUCCH transmission in the first hop as and the first PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes and is the number of PRBs for the PUCCH transmission.  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by pucch-ResourceCommon and is not provided useInterlacePUCCH-PUSCH in BWP-UplinkCommon  - the UE determines the first PRB index of the PUCCH transmission in the first hop as and the first PRB index of the PUCCH transmission in the second hop as  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as |
| Qualcomm [17] | **Proposal 3: Based on construction process in example 1, a common PUCCH resource is invalid if some of its occupied RBs is outside the initial UL BWP. gNB should never schedule UE with such a resource, and UE shall treat it as an error case when it is scheduled to use such a common PUCCH resource.**  **Proposal 4: Based on construction process in example 1, if one of common resource with r\_pucch>=8 uses some RBs occupied by common resource with r\_pucch<8, this resource should be invalidated by spec. gNB should never schedule UE with such a resource, and UE shall treat it as an error case when it is scheduled to use such a common PUCCH resource.**  [Moderator Note] "construction process in example 1" refers to Example Construction 1 in Section 7.2 of [1] |
| Futurewei [3] | ***Proposal 1. The equations in the Example Construction 1 by FL for addressing different rows in Table 9.2.1-1 is sufficient to calculate the lowest PRB indices as a function of the N\_RB and the RB offset.***  [Moderator Note] Example Construction 1 contained in Section 7.2 of [1] |
| NTT DOCOMO [12] | *Proposal 1: How to design PUCCH resources before dedicated PUCCH configuration should be discussed based on the following three alternatives for frequency domain resource configuration considering multi-PRB allocation for PF0/1.*   * *Alt.1:*   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * + the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * + the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as * *Alt.2-1:*   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as * *Alt.2-2:*   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * + the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as     Fig.1: An example for Alt.1 of PUCCH resource sets before dedicated PUCCH configuration    Fig.2: An example for Alt.2-1 of PUCCH resource sets before dedicated PUCCH configuration    Fig.3: An example for Alt.2-2 of PUCCH resource sets before dedicated PUCCH configuration  [Moderator Note] Alt-1 corresponds to Example Construction 1 contained in Section 7.2 of [1] |
| LGE [15] | **Proposal #2: The PRB indices for enhanced PUCCH format 0/1 prior to RRC configuration can be obtained by following options:**   * **Option 1: Directly use the NRB value indicated by SIB1 to calculate the PRB indices** * **Option 2: The parameter X for the PRB offset scaling is configured separately and use it together with the NRB value to calculate the PRB indices.**   Option 2:  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  -     the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes  -     the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  -     the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as  [Moderator Note] Option 1 corresponds to Example Construction 1 in Section 7.2 of [1].  **Proposal #3: Discuss whether special handling for the PUCCH resource set index 15 is necessary or not.** |
| Sony [13] | **Proposal 1: Support moderator’s Proposal 10 from RAN1#106-e meeting. The lowest-indexed RB of each PUCCH resource is a function of the and RB offset provided by Table 9.2.1-1 and can be computed according to Example Construction 1.**  [Moderator Note] Example Construction 1 contained in Section 7.2 of [1]  **Observation 1: The network can select and so as to ensure that the lowest-indexed RB of each PUCCH resource is within the initial UL BWP. Alternatively, operations in 38.213 Section 9.2.1 can be performed modulo .** |
| Ericsson [8] | **Proposal 2 For 120 and 480 kHz SCS, reuse the Rel-15 PUCCH configuration table 9.2.1-1 for configuration of PUCCH resource sets prior to RRC configuration for enhanced (multi-RB) PUCCH formats 0/1**   * + **As previously agreed, the number of RBs for each PUCCH resource in a set is *N*RB which is signaled in SIB1**   + **The lowest-indexed RB for each PUCCH resource is a function of *N*RB**   + **The following example change to Rel-16 specifications can be recommended to the editor of 38.213 to use at his discretion**   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as |
| CATT [7] | Option1: The gNB uses SIB1 to configure an index of PUCCH resource sets which is associated with the number of RBs similar to the table in [3].  **Table 9.2.1-1: PUCCH resource sets before dedicated PUCCH resource configuration**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **Index** | **PUCCH format** | **First symbol** | **Number of symbols** | **Number of RBs** | **PRB offset** | **Set of initial CS indexes** | | 0 | 0 | 12 | 2 | 1 | 0 | {0, 3} | | 1 | 0 | 12 | 2 | 1 | 0 | {0, 4, 8} | | 2 | 0 | 12 | 2 | 12 | 3 | {0, 4, 8} | | 3 | 1 | 10 | 4 | 1 | 0 | {0, 6} | | 4 | 1 | 10 | 4 | 1 | 0 | {0, 3, 6, 9} | | 5 | 1 | 10 | 4 | 12 | 2 | {0, 3, 6, 9} | | 6 | 1 | 10 | 4 | 12 | 4 | {0, 3, 6, 9} | | 7 | 1 | 4 | 10 | 1 | 0 | {0, 6} | | 8 | 1 | 4 | 10 | 1 | 0 | {0, 3, 6, 9} | | 9 | 1 | 4 | 10 | 12 | 2 | {0, 3, 6, 9} | | 10 | 1 | 4 | 10 | 12 | 4 | {0, 3, 6, 9} | | 11 | 1 | 0 | 14 | 1 | 0 | {0, 6} | | 12 | 1 | 0 | 14 | 1 | 0 | {0, 3, 6, 9} | | 13 | 1 | 0 | 14 | 12 | 2 | {0, 3, 6, 9} | | 14 | 1 | 0 | 14 | 12 | 4 | {0, 3, 6, 9} | | 15 | 1 | 0 | 14 | 1 |  | {0, 3, 6, 9} |   The values in the table indicates number of RBs for 120 kHz SCS. For 480 or 960 kHz SCS, the values should be scaled by 1/4 or 1/8. If the value for 480 or 960 kHz SCS is not an integer, it needs to be rounded up.  **Proposal 3 For common PUCCH resource sets, the gNB needs to indicate the number of RBs for PUCCH format 0/1/4 of 120 kHz SCS. For 480 or 960 kHz SCS, the values can be scaled by 1/4 or 1/8.**  **Proposal 4 The PRB offset value also needs to be scaled by the number of RBs for inter-cell frequency division multiplexing, which ensure that the multi-RB PUCCH resources in the set do not overlap each other.**  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as |
| OPPO [6] | **Proposal 1: The UE can determine the PRB index and the initial cyclic shift index in the PUCCH resource sets prior to RRC configuration based on the simple modification in 38.213 Section 9.2.1.** |
| Nokia [9] | ***Proposal 2:*** *PUCCH resource RBs are defined so that RBs of the PUCCH resources in the cell-specific resource set are not partially overlapping. The lowest PRB indexes of PUCCH resource frequency hops are defined as and as for the first 8 PUCCH resource indexes and with and as for the last 8 PUCCH resource indexes.* |
| Apple [16] | ***Proposal 1:*** *Adopt Example Construction 1 in [12] for the PUCCH resource sets before dedicated PUCCH resource configuration*   * *The UE assumes that the number of RBs indicated in SIB1 can be used with any row of table 9.2.1-1 of 38.213* * *Modify the specification in 38.213 Section 9.2.1 for frequency hopping with the introduction of the multi-RB PUCCH enhancement.*   + *Turn off frequency hopping in the case that N\_RB is on the order of the bandwidth* |
| Samsung [10] | **Proposal 1: Before RRC connection, support the starting RB for a PUCCH resource based on the indicated number of RBs.**  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as |
| ZTE [4] | For the details of PUCCH resource, the determination of the lowest or starting PRB indexes in [3] can be discussed further.  **Proposal 2: No further enhancements on frequency hopping distance issue should be considered.** |
| Interdigital [14] | ***Observation 1:*** *Different number of RBs for each row enables supporting a different number of RBs for different PUCCH formats, different first symbols, different numbers of symbols and different sets of initial CS indexes. However, the indication method actually reduces flexibility as number of RBs should be associated with each row.*  ***Observation 2:*** *Need of supporting different number of RBs for each PUCCH resource set is doubted as it can be further resolved by UE specific RRC configuration.*  ***Proposal 1:*** *It is preferred to support same number of RBs for all PUCCH resource sets* |
| vivo [5] | **Proposal 1: For PUCCH, the lowest PRB index of PUCCH is dependent on the NRB:** |
| Huawei [2] | ***Proposal 1: For 120 and 480 kHz SCS, UE determines PUCCH resources prior to RRC configuration based on the general extension (Example Construction 1).***  [Moderator Note] Example Construction 1 contained in Section 7.2 of [1] |

### Summary of Construction of PUCCH Resource Set Prior to RRC

In RAN1#106-e, the following construction of PUCCH resource sets prior to RRC configuration was discussed (see Section 7.2 of [1]), and this was referred to as "Example Construction 1."

**Example Construction 1**:

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as 

Based on the proposals listed above from company contributions, there appears to be quite strong support for Example Construction 1 which is based on using Table 9.2.1-1 in 38.213 "as is" with N\_RB indicated in SIB1 (as previously agreed). Some companies support a variation of Example Construction 1 in which is scaled by a value other than N\_RB (e.g., by N\_RB / 2, by a configurable value X, or no scaling at all) [12] [15]. One company [7] proposes a variation whereby Example Construction 1 is used, but Table 9.2.1 is hardwired with a different value in each row (N\_RB = 1 or 12). The existing SIB1 parameter that indicates the row index of Table 9.2.1-1 would then implicitly indicate the number of RBs. However, it is the moderator's understanding that the intention of the following agreement from RAN1#106-e is that a new SIB1 parameter would directly indicate the number of RBs.

Agreement:

* For PUCCH resource sets prior to RRC configuration, support a parameter in SIB1 that indicates the number of RBs for enhanced (multi-RB) PUCCH format 0/1

A summary of the above company is as follows:

* Alt-1: Support Example Construction 1 based on using the existing Table 9.2.1-1 "as is" with N\_RB indicated by a new parameter in SIB1:
  + Intel, Qualcomm, Futurewei, NTT DOCOMO (Alt-1), Sony, Ericsson, OPPO, Nokia, Apple, Samsung, ZTE(?), Interdigital (?), vivo, Huawei
* Alt-2: Variation of Alt-1 in which the RB offset in Table 9.2.1-1 ) is scaled by a value other than N\_RB
  + Scale by fixed value (e.g., N\_RB / 2 or no scaling)
    - NTT DOCOMO (Alt 2-1, 2-2)
  + Scale by configurable value X
    - LGE
* Alt-3: Support Example Construction 1 using a modification of Table 9.2.1-1 where a fixed value of N\_RB is hardwired per row of the table and N\_RB is implicitly indicated by the existing SIB1 parameter that indicates the row index of Table 9.2.1-1
  + CATT

Based on the strong support for Alt-1, it is proposed that Alt-1 is agreed, but with an FFS point on whether or not the RB offset is scaled by a value other than N\_RB, i.e., Alt-2.

An additional FFS can be added based on that several companies observe that there can be two potential error cases for some combinations of {indicated row index of Table 9.2.1-1, indicated number of RBs, configured initial UL BWP size, indicated PUCCH resource index r\_PUCCH}. The error cases are

* Case 1: Some of the RBs of a PUCCH resource fall outside the initial UL BWP
* Case 2: A PUCCH resource with r\_PUCCH ≥ 8 can overlap the RBs of a PUCCH resource with r\_PUCCH < 8.

Companies have suggested that such potential error cases can be handled by one of the following approaches:

1. By implantation the gNB can avoid configurations where Case 1 and 2 could happen, e.g., [6],[13]
2. The UE behavior can be specified for Case 1 and/or Case 2, e.g., [17]

### **Proposal #1 (PUCCH Resource Set Construction Prior to RRC)**

* Reuse the existing Rel-15/16 PUCCH configuration Table 9.2.1-1 in 38.213 for configuration of PUCCH resource sets prior to RRC configuration for multi-RB PUCCH formats 0/1
* As previously agreed, the number of RBs for each PUCCH resource in a set is N\_RB which is signaled in SIB1
* The lowest-indexed RB for each PUCCH resource is a function of N\_RB
* The following example change to 38.213 Section 9.2.1 can be recommended to the editor of 38.213 to use at the editor's discretion (subject to resolution of the below FFS on the value of X)

---- Start ----

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as 

---- End ----

* FFS: Supported value of X. Down-select to one of the following alternatives:
  + Alt-1: X = N\_RB
    - Note: This alternative is mathematically equivalent to Example Construction 1 discussed in RAN1#106-e.
  + Alt-2a: X is a fixed value less than N\_RB, e.g., 1, N\_RB / 2, …
  + Alt-2b: X is configurable, e.g., via SIB1
* FFS: Whether it should be left to gNB implementation to avoid the following potential error cases, or whether/how UE behavior should be specified for these cases:
  + Case 1: Some of the RBs of a PUCCH resource fall outside the initial UL BWP
  + Case 2: An indicated PUCCH resource with r\_PUCCH ≥ 8 can overlap the RBs of a PUCCH resource with r\_PUCCH < 8.

Please provide your company view on Proposal #1.

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| **Company** | **View/Position** |
| Moderator | Question to CATT: Due to almost unanimous support for Alt-1 or Alt-2 and the agreement from last meeting on the SIB1 parameter indicating N\_RB, can CATT compromise and accept Proposal #1?  Question to Apple: Is it still necessary to further discuss potential disabling of frequency hopping, or is it sufficient that the gNB avoid potential error cases by implementation?  Question to All: Please include your view on the FFS points. If possible, we can try to converge in this meeting. |
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# 3 Cyclic Shift Definition for PF0/1

The following table provides a summary of company proposals on this topic:

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| **Company** | **Company Proposals** |
| Qualcomm [17] | As multi-RB PF0 is extended to a longer base sequence length, for the cyclic shift varying as a function of the symbol and slot number, Eq. 1 should be updated to following Eq.2 where M is the number of RBs occupied by the PUCCH. Note that for multi-RB PUCCH format 0 on FR2-2, as it is contiguous RB assignment, =0.  Eq. 2  In following sub-sections, we like to present our views on for PF0 and for PF0/1 on FR2-2.  **Proposal 1: for a M-RB PF0, information bearing Cyclic shifts are chosen as below:**   * **For 1-bit A/N, use {0, 6}\*M** * **For 2-bit A/N, use {0, 3, 6, 9}\*M** * **For 1-bit A/N + SR, use {0, 3, 6, 9}\*M** * **For 2-bit A/N + SR, use {0, 1, 3, 4, 6, 7, 9, 10}\*M**   **Proposal 2: for a M-RB PF0/1, value range of initial Cyclic shifts should be extended with one of following options:**   * **Option 1: extend it to [0, 1, … , 12M-1].** * **Option 2: extend it to [0, 1, … , 10, 11]\*M**   **Proposal 5: For a common PUCCH resource M-RB PF 0/1, the UE determines the initial cyclic shift index where is the i-th CS index from the set of initial CS indexes, and *i* is determined as for and as for .** |
| vivo [5] | **Proposal 2：For a single sequence of length equal to the total number of mapped REs of the PUCCH resource, the cyclic shift should be adapted with the length of the sequence.**  However, for a single long sequence with all RE mapped within a PRB, the cyclic shift should be additionally dependent on the number of PRBs like formula 2. Meanwhile, the value of and should also depend on the For example, the sequence length is 24 when the PRB number is 2. The value range of should be 0～23 for dedicated PUCCH resources, the candidate values of for common PUCCH resource in Table 1-1 and the candidate values of in Table 1-2 to Table 1-5 should all multiply by 2.  ---Formula 2  Table 1 Copy of Table 9.2.1-1 and Table 9.2.3-3&4 and Table 9.2.5-1&2 from TS 38.213[4]  **Table 1**-1 Copy of Table 9.2.1-1: PUCCH resource sets before dedicated PUCCH resource configuration   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Index | PUCCH format | First symbol | Number of symbols | PRB offset | Set of initial CS indexes | | 0 | 0 | 12 | 2 | 0 | {0, 3} | | 1 | 0 | 12 | 2 | 0 | {0, 4, 8} | | 2 | 0 | 12 | 2 | 3 | {0, 4, 8} | | 3 | 1 | 10 | 4 | 0 | {0, 6} | | 4 | 1 | 10 | 4 | 0 | {0, 3, 6, 9} | | 5 | 1 | 10 | 4 | 2 | {0, 3, 6, 9} | | 6 | 1 | 10 | 4 | 4 | {0, 3, 6, 9} | | 7 | 1 | 4 | 10 | 0 | {0, 6} | | 8 | 1 | 4 | 10 | 0 | {0, 3, 6, 9} | | 9 | 1 | 4 | 10 | 2 | {0, 3, 6, 9} | | 10 | 1 | 4 | 10 | 4 | {0, 3, 6, 9} | | 11 | 1 | 0 | 14 | 0 | {0, 6} | | 12 | 1 | 0 | 14 | 0 | {0, 3, 6, 9} | | 13 | 1 | 0 | 14 | 2 | {0, 3, 6, 9} | | 14 | 1 | 0 | 14 | 4 | {0, 3, 6, 9} | | 15 | 1 | 0 | 14 |  | {0, 3, 6, 9} |   **Table 1**-2 Copy of Table 9.2.3-3: Mapping of values for one HARQ-ACK information bit to sequences for PUCCH format 0   |  |  |  | | --- | --- | --- | | HARQ-ACK Value | 0 | 1 | | Sequence cyclic shift |  |  |   **Table 1**-3 Copy of Table 9.2.3-4: Mapping of values for two HARQ-ACK information bits to sequences for PUCCH format 0   |  |  |  |  |  | | --- | --- | --- | --- | --- | | HARQ-ACK Value | {0, 0} | {0, 1} | {1, 1} | {1, 0} | | Sequence cyclic shift |  |  |  |  |   **Table 1**-4 Copy of Table 9.2.5-1: Mapping of values for one HARQ-ACK information bit and positive SR to sequences for PUCCH format 0   |  |  |  | | --- | --- | --- | | HARQ-ACK Value | 0 | 1 | | Sequence cyclic shift |  |  |   **Table 1**-5 Copy of Table 9.2.5-2: Mapping of values for two HARQ-ACK information bits and positive SR to sequences for PUCCH format 0   |  |  |  |  |  | | --- | --- | --- | --- | --- | | HARQ-ACK Value | {0, 0} | {0, 1} | {1, 1} | {1, 0} | | Sequence cyclic shift |  |  |  |  | |

### Summary of Cyclic Shift Definition for PF0/1

Two companies have proposed that the cyclic shift definition for PF0/1 should be modified to take into account the length of the sequence for multi-RB PUCCH.

The moderator would like to point out that this seems to conflict with the highlighted part of the following agreement:

Agreement:

For enhanced PF0/1 support a single sequence of length equal to the total number of mapped Res of of the PUCCH resource is used. Cyclic shifts for PF0/1 are defined in the same way as Rel-16 for the case that *useInterlacePUCCH-PUSCH* is not configured.

* Note: this is Alt-1 from the RAN1#104 agreement

The moderator's understanding of this agreement is that by using the cyclic shift definition in Rel-16, two PUCCH resources using different cyclic shifts will be orthogonal on a per-PRB basis. It is not clear why the cyclic shift should be redefined accounting for the full sequence length, and if there would be a benefit of doing so. Can there be a performance degradation due to channel variation over the full sequence length? With the Rel-16 definition, the channel variation is expected to be much less over 1 PRB than over the full sequence length.

### **Question #1: Is it sufficient to reuse the Rel-16 cyclic shift defintition for enhanced (multi-RB) PF0/1 (as previously agreed), or is there a need/benefit of redefining the cyclic shift accounting for the full base sequence length over multiple RBs as proposed in [5],[17]?**

Please provide your view on Question #1.

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| **Company** | **View/Position** |
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# 4 Potential Coverage Imbalance between PF2/3 and PF4

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Futurewei [3] | ***Observation 3. One remaining concern is that whether PF2/3 is expected to deliver a satisfactory coverage performance, especially for PF3 when more than 115 bits are associated, even if it uses 16 as the maximum number of RBs, given that it has not been studied in this agenda.***  ***Proposal 3. It is more reasonable that the UCI payload limit is not restricted for enhanced PF4 in case the unenhanced PF3 turns out not being capable of delivering good coverage when 16 RBs is used for FR2-2*** |
| OPPO [6] | **Proposal 4: For PF2/3, the actual number of RBs used for a PUCCH transmission is equal to NRB, i.e., the actual number of RBs does not vary dynamically based on PUCCH payload.** |

### Summary of Potential Coverage Imbalance

Two companies have proposed modifications to address a potential coverage imbalance between PF2/3 and PF4. While PF2/3 supports large payloads and multiple RBs (up to 16), the number of RBs varies dynamically with the payload. In contrast, for enhanced (multi-RB) PF4, the payload is restricted to a maximum of 115 bits (as concluded last meeting) and the number of RBs (up to 16) does not vary dynamically with the PUCCH payload (as agreed in RAN1#104-e). Hence, the concern is that if the PUCCH payload is larger than 115 bits, and one is forced to use PF2/3, the coverage may not be optimized since the actual number of RBs may be less than the configured value.

Conclusion:

For enhanced (multi-RB) PF4, maintain the same maximum UCI payload limit as in Rel-15/16 (115 bits).

Agreement:

* The configured number of RBs for enhanced PF 0/1/4 is denoted NRB
  + The minimum value of NRB is 1 for PF 0/1/4 for all subcarrier spacings
  + The maximum value of NRB depends on subcarrier spacing
    - FFS: maximum value for each SCS and each of PF0/1/4
  + FFS: Allowed values of NRB within the [min/max] range
  + FFS: Details of indication of NRB by cell-specific (for PF0/1) and dedicated signaling (PF0/1/4)
  + FFS: Whether or not multiplexing of users with misaligned RB allocations is supported, where "misaligned" also includes users with different # of RBs.
  + For PF4:
    - The actual number of RBs used for a PUCCH transmission is equal to NRB, i.e., the actual number of RBs does not vary dynamically based on PUCCH payload
    - NRB fulfils the following: where is a set of non-negative integers
* Note: if frequency hopping is enabled, NRB is the number of RBs per hop
* Note: decisions on the maximum value of NRB for each SCS and PUCCH format shall take into account link budgets based at least on the agreed evaluation assumptions

One company [3] proposes to increase the maximum PUCCH payload for PF4 to be larger than 115 bits. Another company [6] proposes to enhance PF2/3 such that the number of RBs does not vary dynamically with the PUCCH payload.

The moderator observes that PF2/3 enhancements are not in scope according to the WID; however, the moderator questions whether or not by gNB implementation, the maximum coding rate for PF2/3 could be configured low enough to ensure that 16 PRBs are used, thus alleviating coverage concerns? The proposal to increase the maximum payload size for PF4 is certainly in scope; however, it would revert the conclusion from the prior meeting. As always, if there is consensus to do so, we could try for a new agreement.

### **Question #2: Do you agree that there is a potential coverage imbalance issue between PF2/3 and enhanced (multi-RB) PF4, and if so, should this be addressed?**

Please provide your view on Question #2.

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| **Company** | **View/Position** |
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# 5 Potential Assistance Info Provided to gNB

The following table provides a summary of company proposals on this topic:

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| --- | --- |
| **Company** | **Company Proposals** |
| Intel [11] | **Observation 3: If the gNB is not aware of the correct UE’s transmit beamforming gain, by using a pessimistic approach and assuming that the UE’s transmit beamforming gain is 0 dBi, the gNB may configure up to more than 5 times the number of PRBs that would be otherwise needed.**  **Proposal 5: RAN1 should discuss a proper framework to implicitly or explicitly indicate the UE’s beamforming gain to the gNB.** |
| CATT [7] | 1. For RRC connected UEs, it is beneficial to update the number of RBs with the change of PUCCH transmission power.   **Proposal 1 For RRC connected UEs, a PHR for PUCCH can be introduced to help gNB to calculate the number of RBs.**  **Proposal 2 For initial accessed UEs, information could be reported in MSG3 to help gNB to determine the number of RBs.** |

### Summary of Potential Assistance Information Provided to gNB

Two companies have proposed to support provision of assistance information to the gNB such that could potentially help for configurating an appropriate number of RBs for PF0/1/4. In [11], the assistance information is an indication of the UE's tranmit beamforming gain (the TxBF quantity used in prior evaluations of MIL). In [7], the assistance information is in the form of a power headroom (PHR) report for PUCCH.

### **Question #3: Do you agree that it is needed/beneficial to provide some form of assistance information to the gNB to aid in configuration of the number of RBs for PUCCH?**

Please provide your company view on Question #3.

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| **Company** | **View/Position** |
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# 6 PUCCH Power Control

The following table provides a summary of company proposals on this topic:

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| --- | --- |
| **Company** | **Company Proposals** |
| CATT [7] | **Observation 2 PUCCH power control is based on the maximum transmission power of the user equipment, which only depends on the user's capability.**  **Proposal 5 It is needed to modify the maximum transmission power in the PUCCH power control formula for different configured number of RBs.**  In R16, PUCCH power control is related to the maximum transmission power of the user, which only depends on the user's capability. However, for 52.6GHz~71GHz, the transmission power limit is also variable when the number of RB is variable. So the maximum transmission power for different RB number will also change accordingly. If the maximum power for different RB configurations is the same, the transmitted power on each RB may be higher than the PSD limit. So it is needed to modify the PUCCH power control formula. For 52.6GHz~71GHz, the formula may change as below:  where  - is the UE maximum output power for the configured number of RBs for a PUCCH resource  -  is the maximum output power defined in [8-1, TS 38.101-1], [8-2, TS38.101-2] and [8-3, TS38.101-3] for carrier  of primary cell  in PUCCH transmission occasion  - is calculated by the PSD limit and the configured number of RBs for a PUCCH resource. The PSD is defined for 1 RB power limit. |

### **Summary of PUCCH Power Control**

One company has raised a potential issue regarding the PUCCH power control formula. In [7] it is proposed to alter the formula to account for multiple RBs and a potential PSD limit. The moderator observes that PSD limits are not relevant in all regulatory regions.

### **Question #4: Do you agree that it is needed to modify the PUCCH power control formula in 38.213 Section 7.2 in order to account for multiple RBs and a potential regulatory PSD limit as described in [7]?**

Please provide your company view on Question #4.

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| **Company** | **View/Position** |
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# 7 RRC / SIB1 Parameter Issues

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| LGE [15] | **Proposal #1: It needs to clarify whether the number of RBs for enhanced PUCCH format 0, 1, and 4 can be configured differently per PUCCH resource. If RAN1 can confirm that the previous RAN1 agreement implies the number of RBs for enhanced PUCCH format 0, 1, and 4 can be configured differently per PUCCH resource, the note in the comments for row 11/12/13 in RRC parameters table for extending NR to 52.6-71GHz should be modified as follows:**   |  | | --- | | Agreement:  The maximum configured number of RBs, N\_RB, for enhanced PF 0/1/4 is given by 16 RBs for 480 and 960 kHz SCS (same as for 120 kHz SCS).  Note: RAN2 may need to determine eventually where this RRC parameter is added.  Note: It is possible to put this in PUCCH resource~~, but RAN1 agreement is the # of RB is configured per format~~ | |
| Ericsson [8] | Prior to RRC configuration, a set of cell-specific PUCCH resources are configured via SIB1 for the initial UL BWP (of the PCell). The parameter *pucch-ResourceCommon* indicates the configuration by pointing to a row index 0..15 of Table 9.2.1-1 in 38.213. The hierarchy of this parameter in 38.331 is as follows:  *SIB1 🡺 ServingCellConfigCommonSIB 🡺 UplinkConfigCommonSIB 🡺 BWP-UplinkCommon 🡺 PUCCH-ConfigCommon 🡺 pucch-ResourceCommon*  The parameter *pucch-ResourceCommon* is present only for the initial UL BWP (BWP#0) configuration provided by SIB1, i.e., for the PCell; it is absent for other BWPs. Only PUCCH formats 0 and 1 can be configured prior to RRC, and we see no reason to change this for the 52.6 – 71 GHz band.  pucch-ResourceCommon INTEGER (0..15) OPTIONAL, -- Cond InitialBWP-Only   |  |  | | --- | --- | | **Conditional Presence** | **Explanation** | | *InitialBWP-Only* | The field is mandatory present in the [*PUCCH-ConfigCommon*](#TPUCCHConfigCommon) of the initial [BWP](#TBWP) (BWP#0) in SIB1. It is absent in other BWPs. |   Additionally, we observe that according to RAN1 and RAN level agreements, initial access (i.e., on PCell) is supported only for 120 and 480 kHz SCS. Hence 960 kHz SCS is not needed for the initial UL BWP. Hence we propose:  **Proposal 1 For PUCCH resource sets prior to RRC configuration, support only 120 and 480 kHz SCS.** |
| Nokia [9] | ***Proposal 1:*** *For the SIB1 parameter that configures the number of RBs for a cell-specific PUCCH resource set, the value range contains all integer values in the range [1 .. N\_RB\_Max], where N\_RB\_Max is the maximum number of RBs.* |

### **Summary of RRC / SIB1 Parameter Issues**

Several companies have provided issues related to RRC and SIB1 parameters:

1. In [15] it is proposed to clarify that the number of RBs can be configured differently for each PUCCH resource
2. In [8] it is proposed to capture that PUCCH resource sets prior to RRC configuration are supported for 120 and 480 kHz only
3. In [9] it is proposed to clarify the value range for the SIB1 parameter that configures the number of RBs for the PUCCH resources prior to RRC

For the 2nd and 3rd issues, the moderator proposes that these are discussed in the following email thread on RRC parameters:

[106bis-e-R17-RRC-60GHz] Email discussion on Rel-17 RRC parameters for supporting NR from 52.6 GHz to 71 GHz – Jing (Qualcomm)

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

For the 1st issue, it seems like some discussion is needed in this email thread first, and then subsequent discussion can occur in the RRC parameter email thread.

In Rel-15 (and Rel-16 without interlacing), the number of RBs for PF2/3 is configured per PUCCH resource. There is an RRC parameter within the PUCCH resource definition for each of PUCCH formats 2 and 3 separately where the number of RBs is configured (see below extract from the IE *PUCCH-Config* from 38.331). For example, the gNB could configure one PF2 resource with X1 RBs, a 2nd PF2 resource with X2 RBs, and a 3rd PF3 resource with X3 RBs.

PUCCH-Resource ::= SEQUENCE {

pucch-ResourceId PUCCH-ResourceId,

startingPRB PRB-Id,

intraSlotFrequencyHopping ENUMERATED { enabled } OPTIONAL, -- Need R

secondHopPRB PRB-Id OPTIONAL, -- Need R

format CHOICE {

format0 PUCCH-format0,

format1 PUCCH-format1,

format2 PUCCH-format2,

format3 PUCCH-format3,

format4 PUCCH-format4

}

}

PUCCH-format0 ::= SEQUENCE {

initialCyclicShift INTEGER(0..11),

nrofSymbols INTEGER (1..2),

startingSymbolIndex INTEGER(0..13)

}

PUCCH-format1 ::= SEQUENCE {

initialCyclicShift INTEGER(0..11),

nrofSymbols INTEGER (4..14),

startingSymbolIndex INTEGER(0..10),

timeDomainOCC INTEGER(0..6)

}

PUCCH-format2 ::= SEQUENCE {

nrofPRBs INTEGER (1..16),

nrofSymbols INTEGER (1..2),

startingSymbolIndex INTEGER(0..13)

}

PUCCH-format3 ::= SEQUENCE {

nrofPRBs INTEGER (1..16),

nrofSymbols INTEGER (4..14),

startingSymbolIndex INTEGER(0..10)

}

PUCCH-format4 ::= SEQUENCE {

nrofSymbols INTEGER (4..14),

occ-Length ENUMERATED {n2,n4},

occ-Index ENUMERATED {n0,n1,n2,n3},

startingSymbolIndex INTEGER(0..10)

}

In RAN1#106-e we made the following agreement

Agreement:

* Support an RRC parameter to configure the number of RBs for a PUCCH resource for each of enhanced PUCCH formats 0, 1, and 4
* The parameter is provided by dedicated signaling (per UE) per BWP

While it may not be 100% clear from this agreement, it was the moderator's intention when drafting the proposal in the last meeting that the same principle should be followed for Rel-17. To clarify, the moderator proposes the following.

### **Proposal #2 (Number of RBs per PUCCH resource)**

* Update the following RAN1#106-e agreement to clarfiy that the number of RBs can be configured separately per PUCCH resource

Update of RAN1#106-e Agreement:

* Support an RRC parameter to configure the number of RBs ~~for a~~ per PUCCH resource for each of enhanced PUCCH formats 0, 1, and 4
* The parameter is provided by dedicated signaling (per UE) per BWP
* Update the description of the RRC parameter accordingly within the RRC parameter email thread

Please provide your company view on Proposal #2

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator | The moderator's recommendation is to support Proposal #2 as this was the moderator's intention when drafting the original proposal. This is consistent with the way the number of RBs is configured for PF2/3 in Rel-15 and Rel-16 (without interlacing). |
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# 8 UE Capability Issues

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| OPPO [6] | **Proposal 3: Reporting UE capability or maximum supported number of RBs in RRC\_CONNECTED should be supported.** |

### **Summary of UE Capability Issues**

One company proposes that a UE capability reporting is supported for the maximum number of RBs for a PUCCH resource for RRC connected mode.

The moderator proposes that this discussion is handled in the following email thread on UE capability issues.

[106bis-e-R17-UE-features-60GHz-01] Email discussion UE features for supporting NR from 52.6 GHz to 71 GHz – Ralf (AT&T)

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

# References

1. R1-2108624, "FL Summary #3 for [106-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4," Moderator (Ericsson), RAN1#106-e, August 2021.
2. R1-2108769 Enhancement on PUCCH formats Huawei, HiSilicon
3. R1-2108784 On Enhancement of PUCCH Resource Set for 52.6GHz to 71GHz FUTUREWEI
4. R1-2108936 Discussion on the PUCCH enhancements for 52.6 to 71GHz ZTE, Sanechips
5. R1-2108961 Discussions on PUCCH enhancements for NR operation from 52.6GHz to 71GHz vivo
6. R1-2109072 Discussion on enhancements for PUCCH format 0/1/4 OPPO
7. R1-2109210 Enhancements for PUCCH formats for up to 71GHz operation CATT
8. R1-2109435 PUCCH enhancements Ericsson
9. R1-2109444 Remaining items for enhanced PUCCH formats 0/1/4 Nokia, Nokia Shanghai Bell
10. R1-2109478 Enhancements for PUCCH format 0/1/4 for NR from 52.6 GHz to 71 GHz Samsung
11. R1-2109600 Discussion on PUCCH enhancements for extending NR up to 71 GHz Intel Corporation
12. R1-2109667 PUCCH format 0/1/4 enhancements for NR from 52.6 to 71 GHz NTT DOCOMO, INC.
13. R1-2109779 Additional considerations on enhancements for PUCCH formats 0/1/4 Sony
14. R1-2109905 Discussions on enhancements for PUCCH formats 0/1/4 InterDigital, Inc.
15. R1-2109963 Enhancements for PUCCH formats 0/1/4 to support NR above 52.6 GHz LG Electronics
16. R1-2110023 Discussion on Enhancements for PUCCH formats 0/1/4 Apple
17. R1-2110174 Enhancements for PUCCH for NR in 52.6 to 71GHz band Qualcomm Incorporated