3GPP TSG-RAN WG1 Meeting #107-e R1-2200403

e-Meeting, 11th – 19th November, 2021

Agenda Item: 8.2.3

Source: Moderator (Ericsson)

Title: FL Summary for [107bis-e-R17-52-71GHz-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:

[107bis-e-R17-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4 – Steve (Ericsson)

* 1st check point: January 20
* Final check point: January 25

# 2 Sequence Design for DMRS of Multi-RB PF4

The following agreement was made in RAN1#107-e:

**Agreement**

* For DMRS of enhanced (multi-RB) PF4, Type-2 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource is supported if *dmrs-UplinkTransformPrecodingPUCCH* is configured and *pi2BPSK* is configured for the PUCCH resource.
* FFS: For DMRS of enhanced (multi-RB) PF4, whether or not Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource is supported if *pi2BPSK* is configured for the PUCCH resource.
  + If Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource is not supported for DMRS of enhanced (multi-RB) PF4 in FR2-2 if *pi2BPSK* is configured for the PUCCH resource, it will be separately discussed whether to support FG 16-6b in FR2-2 in UE feature discussion.
* Update the prior agreement from RAN1#104bis-e as follows:

Agreement (RAN1#104bis-e):

* + For DMRS of enhanced PF4, if *pi2BPSK* is not configured for the PUCCH resource, a Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource is used. Cyclic shifts are defined in the same was as Rel-15/16 for PF4 (Alt-1 in agreement from RAN1#104-e).

The open issue is whether or not Type-1 low PAPR sequences (in addition to the already supported Type-2 low PAPR sequences) are supported for enhanced (multi-RB) PF4 when pi/2-BPSK is configured for the PUCCH resource. The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Sony [5] | **Proposal 1: To minimize standardization effort, for DMRS of enhanced (multi-RB) PF4, use Type-1 low PAPR sequences of length equal to the total number of mapped REs of the PUCCH resource whenever *dmrs-UplinkTransformPrecodingPUCCH* is set to *false* and *pi2BPSK* is set to *true.***  **Proposal 2: Avoiding the flag combination *dmrs-UplinkTransformPrecodingPUCCH* = *false*, *pi2BPSK* = *true* is up to the network*.*** |
| Futurewei [13] | ***Proposal 1. Not to support Type-1 low PAPR sequence when pi2BPSK is configured for multi-RB PUCCH format 4.*** |
| Ericsson [12] | 1. For DMRS of an enhanced (multi-RB) PF4 resource, Type-1 low PAPR sequences are not supported if *pi2BPSK* is configured for the PUCCH resource. |
| OPPO [10] | **Proposal 1: For DMRS of enhanced PF4, Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource should be supported if *pi2BPSK* is configured for PUCCH.** |
| vivo [4] | **Proposal 1: For DMRS of enhanced (multi-RB) PF4, Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource should not be supported when N\_RB>1 if *pi2BPSK* is configured for the PUCCH resource.** |
| ZTE [9] | **Proposal 1: For DMRS of enhanced(multi-RB) PF4, if pi/2 BPSK is configured, Type-1 low PAPR sequence can be supported.** |
| Nokia [6] | ***Proposal 1:*** *Combination of -BPSK modulation and Type-1 low PAPR sequence as DMRS is supported for enhanced PUCCH format 4.* |
| Huawei [2] | ***Proposal 1: For DMRS of enhanced (multi-RB) PF4, Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource is not supported if* -BPSK *is configured for the PUCCH resource.*** |
| Samsung [7] | **Proposal: Don’t support Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource, if *pi2BPSK* is configured for the PUCCH resource.**   * **No spec impact.** |
| NTT DOCOMO [8] | **Proposal 1:** Type-1 low PAPR sequence should be supported for DMRS of PF4 when /2-BPSK modulation is used and *dmrs-UplinkTransformPrecodingPUCCH* is not configured**.** |
| Interdigital [3] | ***Proposal 1:*** *Support Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource if pi/2-BPSK is used for PUCCH format 4 without transform precoding.* |
| Intel [11] | **Proposal 1: Do not support Type-1 low PAPR sequence for DMRS of multi-RB PUCCH format 4 when pi2BPSK is configured.** |
| LGE [14] | **Proposal #1: For DMRS both of PF3 and enhanced (multi-RB) PF4, Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource is supported if *pi2BPSK* is configured for the PUCCH resource.**  **Proposal #2: Adopt the following text proposal in TS 38.211 Section 6.4.1.3.3.1.**   |  | | --- | | 6.4.1.3.3 Demodulation reference signal for PUCCH formats 3 and 4  6.4.1.3.3.1 Sequence generation  The reference-signal sequence shall be generated according to    where is given by clause 6.3.2.6.3 and depends on the configuration:  - if the higher-layer parameter *dmrs-UplinkTransformPrecodingPUCCH* is configured, and -BPSK is used for PUCCH, is given by clause 5.2.3 with and given by clause 6.4.1.3.2.1. The sequence group and the sequence number depend on the sequence hopping in clause 6.3.2.2.1.  - otherwise, ~~for PUCCH format 3, PUCCH format 4 with =1, and PUCCH format 4 with >1 when -BPSK is not used for PUCCH,~~ is given by clause 6.3.2.2 and the cyclic shift varies with the symbol number and slot number according to clause 6.3.2.2.2 with  - for PUCCH format 3 without interlaced mapping;  - obtained from Table 6.4.1.3.3.1-1 with the orthogonal sequence index given by clause 6.3.2.6.3 for PUCCH format 3 with interlaced mapping and PUCCH format 4. | |

Company views on this topic are split:

* Do not support Type-1 low PAPR sequences for DMRS when pi/2-BPSK is configured
  + Futurewei, Ericsson, vivo, Huawei, Samsung, Intel
* Support Type-1 low PAPR sequences for DMRS when pi/2-BPSK is configured
  + Sony, OPPO, ZTE, Nokia, NTT DOCOMO, Interdigital, LGE

Arguments for supporting the combination of Type-1 + pi/2-BPSK are as follows

* Combination is supported in Rel-16 for PF3 and PF4 with N\_RB = 1, so support for PF4 with N\_RB > 1 offers design uniformity. If desired, the gNB can choose not to configure Type-1 in combination with pi/2-BPSK.
* User-multiplexing supported if pi/2-BPSK configured and Type-1 sequences are used

Arguments against supporting the combination are as follows:

* Three companies (Sony, vivo, Huawei) have provided evaluation results, all showing that if Type-1 sequences are used for DMRS, then the CM/PAPR in the OFDM symbols occupied by DMRS is significantly larger than the OFDM symbols with UCI. In contrast, when Type-2 sequences are used for DMRS, the CM/PAPR is balanced between DMRS and UCI symbols. Hence the combination of Type-1 + pi/2-BPSK does not allow for a low PAPR design, and thus does not provide a coverage benefit.
* User multiplexing has lower priority than coverage as previously agreed

Clearly, there is a lack of consensus on whether or not Type-1 low PAPR sequences should be supported when pi/2-BPSK is configured for multi-RB PF4, i.e., when . It is recommended to further discuss the following two proposals in this meeting to see if there is an opportunity to converge. For reference, please see the analysis in Appendix A and B of this summary for how the DMRS sequence type is determined based on the relevant RRC parameters defined in 38.331 and the relevant spec text in 38.211.

## **Proposal #2.1 (Do not support Type-1 + pi/2-BPSK)**

* For DMRS of enhanced (multi-RB) PF4, do not support Type-1 low PAPR sequences if *pi2BPSK* is configured for the PUCCH resource.
* No change to 38.211 Section 6.4.1.3.3.1 is needed

## **Proposal #2.2 (Support Type-1 + pi/2-BPSK)**

* For DMRS of enhanced (multi-RB) PF4, support Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource is supported if *pi2BPSK* is configured for the PUCCH resource
* Adopt TP#1 implementing this proposal:

>>> Text Proposal (TP#1) for 38.211, Section 6.4.1.3.3.1 >>>

\*\*\* Unchanged text omitted \*\*\*

6.4.1.3.3.1 Sequence generation

The reference-signal sequence shall be generated according to



where is given by clause 6.3.2.6.3 and depends on the configuration:

- if the higher-layer parameter *dmrs-UplinkTransformPrecodingPUCCH* is configured, and -BPSK is used for PUCCH, is given by clause 5.2.3 with and given by clause 6.4.1.3.2.1. The sequence group and the sequence number depend on the sequence hopping in clause 6.3.2.2.1.

- otherwise, ~~for PUCCH format 3, PUCCH format 4 with =1, and PUCCH format 4 with >1 when -BPSK is not used for PUCCH,~~  is given by clause 6.3.2.2 and the cyclic shift varies with the symbol number and slot number according to clause 6.3.2.2.2 with

- for PUCCH format 3 without interlaced mapping;

- obtained from Table 6.4.1.3.3.1-1 with the orthogonal sequence index given by clause 6.3.2.6.3 for PUCCH format 3 with interlaced mapping and PUCCH format 4.

**Table 6.4.1.3.3.1-1: Cyclic shift index for PUCCH format 3 with interlaced mapping and PUCCH format 4.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Orthogonal sequence index** | **Cyclic shift index** | | |
|  |  |  |
| 0 | 0 | 0 | 0 |
| 1 | - | 6 | 6 |
| 2 | - | - | 3 |
| 3 | - | - | 9 |

\*\*\* Unchanged text omitted \*\*\*

>>> End Text Proposal >>>

Please provide your company view on Proposal #2.1 and Proposal #2.2 and additionally if your position is flexible.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | As discussed in our contribution, we support Proposal #2.2, as it results in uniform design for different PUCCH formats and simplifies standards. However, we can also be flexible if majority of companies sees this otherwise. |
| LG Electronics | Support Proposal #2.2.  For the evaluation results provided by the companies supporting Proposal #2.1, it is noted that the same results can be observed for PF3 (i.e., the Type-2 low PAPR sequence in PF3, would have better CM/PAPR performance than the Type-1 low PAPR sequence) because there are no practical differences between PF3 and multi-RB PF4.  However, compared to PF3, the enhanced (multi-RB) PF4 provides more user multiplexing capacity by using orthogonal cover code and can achieve better coverage gain since the configured RB size won’t be adjusted based on actual UCI payload size. With this regard, if Type-1 low PAPR sequence can be applied to PF3 in FR2-2, Type-1 low PAPR sequence should also be able to be applied to enhanced (multi-RB) PF4.  In addition, it is worth noting that TP in Proposal #2.2 is exactly the same as Rel-16 specification. |
| Sony | We prefer Proposal #2.2 (Support Type-1 + pi/2-BPSK). As explained in the moderators’s summary, this combination is supported in Rel-16 for PF3 and PF4 and, further, in the current version of R17 for PF3 and PF4 and (see Appendix B). We therefore do not see the point of not supporting it for PF4 with ; the network can always choose to not configure the UE with this particular parameter combination. |
| OPPO | We support Proposal #2.2. Supporting Type 1 low PAPR sequence + pi/2-BPSK does not conflict with Type 2 low PAPR sequence + pi-BPSK. Then, the switch between Type-1 and Type-2 low PAPR sequence, i.e. whether or not user-multiplexing is supported, can be associated with higher-layer parameter *dmrs-UplinkTransformPrecodingPUCCH*. In our view, this is the legacy design principle as in R16 and there is no spec impact. |
| vivo | We support Proposal 2.1.  We disagree with the argument from companies that Type-1 low PAPR sequence + pi/2-BPSK should be supported for PF4 when PF3 support that. PF3 is not in the scope of this WI and the WID does not task us to desgin PF4 following PF3. Given the technical concerns raised, we do not understand why put something into the specification if there’s no benefit.  On the argument of user multiplexing, we don’t understand why the network has to configure Type-1 sequence + pi/BPSK for PF4 when Type-1 sequence for PF4 can be configured w/o pi/BPSK. We believe pi/BPSK is mainly for coverage usage and hence arguing multiplexing along with pi/2-BPSK is a bit stretch and does not make sense.  On the argument of providing options for network to configure, we’d like to reminder thus group the principle we took during WI for this agenda. There were multiple options/alternaives proposed (e.g., sequence, RE mapping) during WI and the decision is to only take one option rather that specifying multiple options where alternative option actually has benefit. For this corner case, we don’t see why now providing multiple options is justified when there’s no benefit/usage scenario of the alternative. |
| CATT | We support Proposal 2.1.  Beside the point summarized by the moderator, we want to pointed out the current maintenance phase is not meant for introducing new features. |
| Futurewei | We prefer Proposal 2.1.  For the reasons from proponents for supporting this combination/new feature, at least the second reason “User-multiplexing supported if pi/2-BPSK configured and Type-1 sequences are used” is not siginificant due to the prior agreement that user-multiplexing has low priority. For the first reason ‘Combination is supported in Rel-16 for PF3 and PF4 with N\_RB = 1, so support for PF4 with N\_RB > 1 offers design uniformity..’, we do not find it convincing enough to have this feature supported, since ‘uniformity’ seems to be claimed between Rel-16 (multi-RB) PF3 and Rel-17 multi-RB PF4.  Also, given the simulations that show if Type-1 sequences are used for DMRS, the CM/PAPR in the OFDM symbols occupied by DMRS is significantly larger than the OFDM symbols with UCI, the reason for supporting this feature is further weakened. We would like to hear if there is additional reason for having to make agreement on supporting this feature. |
| Samsung | We prefer Proposal 2, although our position is flexible. What we try to emphasize is, maintenance phase should shoot for minimum changes to the specificaiton especially when it’s already complete. |
| InterDigital | As we clarified in our contribution, we support Proposal 2.2. We don’t see any reason to introduce additional restriction to PF4. |
| Intel | We prefer proposal #2.1.  As mentioned within the moderator’s summary, there is no technical advantage in supporting Type-1 low PAPR sequences if *pi2BPSK* is configured for the PUCCH resource besides allow to increase user multiplexing capability, which however has been concluded within this AI to be of marginal importance. With that said, and considering the spec impact that supporting Type-1 low PAPR sequences if *pi2BPSK* is configured for the PUCCH resource may have, we prefer proposal #2.1. |
| Apple | We prefer Proposal 2.1. given that there is no technical advantage in introducing this and we are in the maintenance phase, proposal 2.1 seems to be the best choice of the two proposals. |
| NTT DOCOMO | We support Proposal#2.2.  As summarized by moderator, both type-1 and type-2 low PAPR sequence has pros and cons in terms of coverage and user-multiplexing when pi/2-BPSK is used. In Rel-16, both sequences are supported and can be switched by *dmrs-UplinkTransformPrecodingPUCCH*. In addition, Type-1 low PAPR sequence is supported even for single PRB PF4 and multi-PRB PF3, thus, we don’t see the need to preclude the support for multi-PRB PF4.  Therefore, following Rel-16 specification, we suggest keeping this configurability for multi-PRB PF4. |

# 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 [13] | ***Proposal 2. By removing the maximum payload size for enhanced multi-RB PF4 or by disallowing the actual number of RBs be dynamic for PF3 would bring benefit for alleviating the coverage imbalance issue.*** |
| Moderator | Given that this issue has been de-prioritized for two meetings now due to lack of support, and only one company has made a proposal in this meeting, the moderator suggests that this issue be closed now that we are in maintenance phase. |
| Nokia, NSB | We agree with the moderator’s assessment. |
| LG Electronics | Agree with Moderator’s suggestion. |
| Sony | Support the moderator’s proposal. |
| vivo | Agree with moderator. |
| CATT | Agree with moderator. |
| InterDigital | Fine with the moderator’s proposal. |
| Intel | We agree with the moderator’s conclusion. |
| Apple | We are fine with the moderator’s proposal. |
| NTT DOCOMO | We support moderator’s view. |

# References

1. R1-2111466, "FL Summary for [107-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4," Moderator (Ericsson), RAN1#107-e, November 2022.
2. R1-2200046 Remaining issues of PUCCH enhancement for 52-71GHz spectrum Huawei, HiSilicon
3. R1-2200061 Remaining issues for enhanced PUCCH formats 0/1/4 InterDigital, Inc.
4. R1-2200679 Remaining issues on PUCCH enhancements for NR operation from 52.6GHz to 71GHz vivo
5. R1-2200175 Remaining issues on enhancements for PUCCH formats 0/1/4 Sony
6. R1-2200185 Finalization of enhanced PUCCH formats 0/1/4 Nokia, Nokia Shanghai Bell
7. R1-2200194 Maintenance on enhancements for PUCCH format 0/1/4 for NR from 52.6 GHz to 71 GHz Samsung
8. R1-2200228 Remaining issues on PUCCH format 0/1/4 enhancements for NR in FR2-2 NTT DOCOMO, INC.
9. R1-2200261 Remaining issues on the PUCCH enhancements for 52.6 to 71GHz ZTE, Sanechips
10. R1-2200326 Discussion on remaining issue for enhancements for PUCCH format 0/1/4 OPPO
11. R1-2200368 Discussion on PUCCH enhancements for extending NR up to 71 GHz Intel Corporation
12. R1-2200402 PUCCH enhancements Ericsson
13. R1-2200446 Remaining issues on PUCCH formats enhancements for beyond 52.6GHz FUTUREWEI
14. R1-2200566 Enhancements for PUCCH formats 0/1/4 to support NR above 52.6 GHz LG Electronics

# Appendix A – Parameters for configuring pi/2-BPSK and DMRS sequence type

According to 38.331 (see extracts from *PUCCH-Config* below) the following two parameters are defined for configuring pi/2-BPSK and the DMRS sequence type for PF3 and PF4

* The parameter *pi2BPSK* may be only be present for PF3 and PF4 (absent for PF1 and PF2)
* The parameter *dmrs-UplinkTransformPrecodingPUCCH* may only be present if *pi2BPSK* is configured for both PF3 and PF4 (if both formats are configured) or if *pi2BPSK* is configured for either PF3 or PF4 (if only one format is configured).

dmrs-UplinkTransformPrecodingPUCCH-r16 ENUMERATED {enabled} OPTIONAL, -- Cond PI2-BPSK

PUCCH-FormatConfig ::= SEQUENCE {

interslotFrequencyHopping ENUMERATED {enabled} OPTIONAL, -- Need R

additionalDMRS ENUMERATED {true} OPTIONAL, -- Need R

maxCodeRate PUCCH-MaxCodeRate OPTIONAL, -- Need R

nrofSlots ENUMERATED {n2,n4,n8} OPTIONAL, -- Need S

pi2BPSK ENUMERATED {enabled} OPTIONAL, -- Need R

simultaneousHARQ-ACK-CSI ENUMERATED {true} OPTIONAL -- Need R

}

|  |
| --- |
| ***PUCCH-Config* field descriptions** |
| ***dmrs-UplinkTransformPrecodingPUCCH***  This field is used for PUCCH formats 3 and 4 according to TS 38.211, Clause 6.4.1.3.3.1. |

|  |
| --- |
| ***PUCCH-FormatConfig* field descriptions** |
| ***pi2BPSK***  If the field is present, the UE uses pi/2 BPSK for UCI symbols instead of QPSK for PUCCH. The field is not applicable for format 1 and 2. See TS 38.213 [13], clause 9.2.5. |

|  |  |
| --- | --- |
| **Conditional Presence** | **Explanation** |
| *PI2-BPSK* | The field is optionally present, Need R, if *format3* and/or *format4* are configured and *pi2BPSK* is configured in each of them. It is absent, Need R otherwise. |

# Appendix B – DMRS sequence type

According to the current version of 38.211 (v17.7.0) Section 6.4.1.3.3.1 (see extract below), the following table summarizes what DMRS sequence type is used for PF4 based on the two RRC parameters described in Appendix A. As can be seen, for multi-RB PF4, the sequence type is unspecified if *pi2BPSK* is configured but *dmrs-UplinkTransformPrecodingPUCCH* is absent. In other words the combination of sequence Type-1 + pi/2-BPSK is not supported according to current specifications.

Table 1: Sequence type used for DMRS of PF4

|  |  |  |
| --- | --- | --- |
| ***dmrs-UplinkTransformPrecodingPUCCH*** | ***pi2BPSK*** | **Low PAPR Sequence Type** |
| Present | Present | Type-2 for 1 |
| Present | Absent | Invalid configuration according to the conditional presence defined in 38.331 |
| Absent | Present | * Type-1 for PF4 with 1 * Unspecified for PF4 with >1 |
| Absent | Absent | Type-1 for 1 |

6.4.1.3.3.1 Sequence generation

The reference-signal sequence shall be generated according to



where is given by clause 6.3.2.6.3 and depends on the configuration:

- if the higher-layer parameter *dmrs-UplinkTransformPrecodingPUCCH* is configured, and -BPSK is used for PUCCH, is given by clause 5.2.3 with and given by clause 6.4.1.3.2.1. The sequence group and the sequence number depend on the sequence hopping in clause 6.3.2.2.1.

- otherwise, for PUCCH format 3, PUCCH format 4 with =1, and PUCCH format 4 with >1 when -BPSK is not used for PUCCH, is given by clause 6.3.2.2 and the cyclic shift varies with the symbol number and slot number according to clause 6.3.2.2.2 with

- for PUCCH format 3 without interlaced mapping;

- obtained from Table 6.4.1.3.3.1-1 with the orthogonal sequence index given by clause 6.3.2.6.3 for PUCCH format 3 with interlaced mapping and PUCCH format 4.

**Table 6.4.1.3.3.1-1: Cyclic shift index for PUCCH format 3 with interlaced mapping and PUCCH format 4.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Orthogonal sequence index** | **Cyclic shift index** | | |
|  |  |  |
| 0 | 0 | 0 | 0 |
| 1 | - | 6 | 6 |
| 2 | - | - | 3 |
| 3 | - | - | 9 |