3GPP TSG-RAN WG1 Meeting #107-e R1-2111466

e-Meeting, 11th – 19th November, 2021

Agenda Item: 8.2.3

Source: Moderator (Ericsson)

Title: FL Summary for [107-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:

[107-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4 with checkpoints for agreements on November 15 and 19 – Steve (Ericsson)

# 2 Handling of PUCCH Resource Set Index 15 Prior to Dedicated PUCCH Configuration

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Sony [9] | **Proposal 1: For PUCCH resource set index 15, select** $X=N\_{RB}$**.** |
| ZTE [5] | **Proposal 1: For PUCCH resource set index 15, Alt-a:** $X=N\_{RB}$**X=N\_RB should be adopted.** |
| Futurewei [3] | ***Proposal 1. If a fractional value X is considered for scaling the PRB offset of PUCCH resource set 15, it is better to absorb X into the floor(***$∙$***) operation, i.e.,*** $\left⌊N\_{BWP}^{size}∙X/4\right⌋$***.*** ***Proposal 2. If a value X independent of*** $N\_{RB}$ ***is considered for scaling the PRB offset of PUCCH resource set 15, it is recommended that X=1 is adopted.***  |
| Intel [12] | **Proposal 1: For resource set index 15,** $X=N\_{RB}$**.****Proposal 2: It is left to gNB implementation to avoid any error case related to a potential RB shortage issue.** |
| Ericsson [10] | Proposal 1 In the RAN1#106bis-e agreement on construction of PUCCH resource sets prior to dedicated PUCCH configuration, support scaling value X = 1 for PUCCH resource set index 15 (Alt-b in the agreement). |
| CATT [7] | Proposal 3 For PUCCH resource set index 15 which has reserved enough PRB offset for inter-cell frequency division multiplexing, it is prefer to support$ X=1$. |
| Nokia [6] | ***Proposal 1:*** *Alt-a (*$X=N\_{RB})$ *is applied also with PUCCH resource set index 15.* |
| Apple [14] | ***Proposal 1:*** *For the construction of PUCCH resource sets prior to dedicated PUCCH configuration, X = 1 for PUCCH resource set index 15.* * *It will be up to gNB implementation to configure the values of* $N\_{BWP}^{size}$ *and* $N\_{RB}$ *to ensure that there are enough PUCCH resources.*
 |
| Qualcomm [17] | **Proposal 1: For index 15 in table 9.2.1, we support Alt-a to use same procedure as other indexes to construct common PUCCH resource.** |
| LGE [15] | **Proposal #1: Adopt the following CR where X=**$N\_{RB}$ **for PUCCH resource set index 0 to 14 and X=1 for the PUCCH resource set index 15:**

|  |
| --- |
| If $\left⌊{r\_{PUCCH}}/{8}\right⌋=0$ 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 $RB\_{BWP}^{offset}∙X+\left(\left⌊{r\_{PUCCH}}/{N\_{CS}}\right⌋\right)∙N\_{RB}$ and the lowest PRB index of the PUCCH transmission in the second hop as $N\_{BWP}^{size}-RB\_{BWP}^{offset}∙X-\left(1+\left⌊{r\_{PUCCH}}/{N\_{CS}}\right⌋\right)∙N\_{RB}$, where $N\_{CS}$ is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes, and $X=1$ if *pucch-ResourceCommon* indicates index 15 and $X=N\_{RB}$ otherwise-     the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as $r\_{PUCCH}modN\_{CS}$If $\left⌊{r\_{PUCCH}}/{8}\right⌋=1$ 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 $N\_{BWP}^{size}-RB\_{BWP}^{offset}∙X-\left(1+\left⌊{\left(r\_{PUCCH}-8\right)}/{N\_{CS}}\right⌋\right)∙N\_{RB}$ and the lowest PRB index of the PUCCH transmission in the second hop as $RB\_{BWP}^{offset}∙X+\left(\left⌊{\left(r\_{PUCCH}-8\right)}/{N\_{CS}}\right⌋\right)∙N\_{RB}$, where $X=1$ if *pucch-ResourceCommon* indicates index 15 and $X=N\_{RB}$ otherwise-     the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as $\left(r\_{PUCCH}-8\right)modN\_{CS}$ |

 |
| Huawei [2] | ***Proposal 1: For PUCCH resource set index 15, the PUCCH resources are determined in the same way as that of PUCCH resource set indices 0…14. (Alt-a:*** $X=N\_{RB}$***)*** |
| NTT DOCOMO [16] | **Proposal 1: For PUCCH before dedicated PUCCH configuration, PRB offset definition for PUCCH resource set index 15 should be the same as index 0-14 for multiple PRB allocation (Alt-a in the agreement at RAN1#106bis-e meeting).** |
| vivo [4] | **Proposal 1: For the FFS, down select to one of the alternatives for PUCCH resource set index 15, we support alt-a:** $X=N\_{RB}$**.** |

## Summary of Handling of PUCCH Resource Set Index 15

Based on company contributions, two alternatives are identified for handling of PUCCH resource set index 15 used prior to dedicated PUCCH configuration, where X is the scaling value agreed in the CR in RAN1#106bis-e

* Alt-1: X = NRB
	+ Sony, ZTE, Intel, Nokia, Qualcomm, Huawei, NTT DOCOMO, vivo
* Alt-2: X = 1
	+ CATT, Futurewei(?), Ericsson, Apple, LGE

Companies supportive of Alt-1 generally say that any error cases that occur can be handled by gNB implementation, and that a consistent scaling principle is desired for all PUCCH resource set indices.

Some companies supportive of Alt-2 observe that according to the Rel-15 design intention, PUCCH resources in set 15 are designed to hop within the center NBWP/2 RBs of the BWP, i.e., the RB offset creates an "RB offset area" of NBWP/4 RBs at the low and high ends of the BWP that are not used (see Figure 1 from [15] below). Furthermore in Rel-15, the second hop for the first 8 resources in the set is designed to have a larger RB index than the first hop and vice versa for the last 8 resources in the set. These companies oberve that if X = NRB, the frequency hopping steps into the RB offset area and the hopping pattern reverses, i.e., the second hop is at a lower frequency than the first hop for the first 8 resources (see Figures 2 and 3 from [15] below).



RB offset area

Figure 1. An example of PUCCH resource configuration for the case of NRB=1



Figure 2. An example of PUCCH resource configuration for the case of NRB=2



Figure 3. An example of PUCCH resource configuration for the case of NRB=3

Hence the trade-off between Alt-1 and Alt-2 seems to be the following:

* Alt-1: Same scaling value X = NRB for all PUCCH resource sets 0 .. 15, but for set 15
	+ Different hopping pattern compared to sets 0..14
	+ RB offset area (NBWP/4 RBs) on each end of BWP is occupied, contrary to Rel-15
* Alt-2: Different scaling value X = 1 used for set 15 compared to sets 0 .. 14, but for set 15
	+ Same hopping pattern as for sets 0 .. 14
	+ RB offset area (NBWP/4 RBs) on each end of BWP is not occupied, as per Rel-15

## **Question #1: What is your view on the above trade-offs between Alt-1 and Alt-2?**

Please provide your view on Question #1 above in addition to your preference for Alt-1 or Alt-2. Please also indicate if your position is flexible.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator | We need to down-select to one of Alt-1 and Alt-2 in this meeting. However, before doing so, it seems relevant to discuss the trade-offs between the two approaches identified above.The moderator points out that the issue is not whether or not PUCCH resources step outside the BWP; that error case is already handled by the below conclusion from RAN1#106bis-e for both Alt-1 and Alt-2. The issue is rather about the hopping pattern and whether or not the "RB offset" area is occupied. Conclusion:* For a common PUCCH resource set prior to dedicated PUCCH resource configuration, for some values of r\_PUCCH, the corresponding PUCCH resource may not be fully contained within the initial UL BWP. The UE does not expect to receive a PRI and determine a value of r\_PUCCH for which the corresponding PUCCH resource is not fully contained within the initial UL BWP
* It is left to gNB implementation to avoid such an error case, i.e., this is not explicitly captured in specifications
 |
| Nokia, NSB | We have a sligh preference for Alt-1 as we want to maintain a consistent scaling principle for all PUCCH resource set indices. |
| Huawei, HiSilicon | Our preference is Alt-1, for simplicity. Considering the large carrier frequencies and bandwdiths the WI focuses on, we do not expect any noticeable performance difference of either alternative.  |
| OPPO | We prefer Alt-1 based on the consistent scaling principle. In our opinion, the issues on the hopping pattern reverses and RB offset area is occupied already exist for PUCCH resource set indices 0-14. For example, for PUCCH resource set 14 in Rel-15, the "RB offset area" of 4 RBs at the low and high ends of the initial BWP are designed not to be used. However, in 60GHz band, when the initial UL BWP is 100 MHz(i.e. 66RBs) and the number of RBs for PUCCH resource is 13RBs, the "RB offset area" is occupied for PUCCH resource index r\_PUCCH = 0,1,2,3. In addition, the hopping pattern also reverses. |
| Qualcomm | We want to point out that “RB offset“ area may be occupied even with some other index value. In other words, it is not unique to index=15. Consider a 100Mhz/120kHz SCS (~65RBs) UL BWP, with index=2 and N\_RB=16, both the top and bottom “reserved RB offset“ area (which is 3\*16=48 RBs) will be occupied. In this case, the hopping pattern already changed from Rel-15 , as for r\_pucch=3,4,5, the first hop RBs are loccated in the top half, while the second hop RBs are in the bottom half.We dont see a performance loss with the changed hopping pattern. And we don‘t see a reason for multi-RB common PUCCH, it needs to following same pattern as 1-RB common PUCCH.As we mentioned in our contribution, index 12-14 has the same configuration of First symbol, Number of symbols, initial CS set as index 15, and should already offer enough flexiblity to configure common PUCCH resource.Our biggest concern against special handling of index=15 is that UE/gNB needs to have corresponding logic to just handle one index value, which inceases both speicification effort and chip design/testing effort. We think two design for one problem is not necessary and we think index=15 should only apply to N\_RB=1.We prefer Alt-a. |
| Intel | We prefer Alt-1 as this alternative allows to mantain a consistent scaling principle across all the PUCCH resource sets. Furthermore, we share same view as OPPO, and in our understanding similar issue regarding the hopping patter exists for some numerologies, offset and PUCCH resources index r\_PUCCH for all other PUCCH resource sets as well, so there is no need to optimize at this point for a single PUCCH resource set. |
| Apple | We prefer Alt-2 but are flexible. |
| InterDigital | We prefer Alt-1 as we believe that keeping the consistent scaling principle is more important than handling/optimizing some corner cases such as reverted hopping patterns.  |
| Lenovo, Motorola Mobility | We slightly prefer Alt1 for simplicity.  |
| Sony | Our preference is Alt-1. |
| Futurewei | Our preference for X=1 was based on the concern about whether or not PUCCH resources step outside the BWP; but if the issue is rather about the hopping pattern, we also don’t think it pertains only to the resource set index 15, thus in this case there seems to be no other viable option except for Alt-1.  |
| LG Electronics | We agree with the Moderator’s analysis and prefer Alt-2.With Alt-1, the intention of PUCCH resource set index 15 to provide RB offset area (NBWP/4 RBs) on each end of BWP does not hold any longer. From the perspective of specification impact, as we proposed TP in [15], the impact can be minimized by adding just two sentences on top of the endorsed draft 213 CR.If we go with Alt-1, it can be considered to restrict that UE does not expect PUCCH resource set index 15 is configured for N\_RB>1. |
| NTT DOCOMO | Our preference is Alt-1. We think the agreed scaling principle for PUCCH resource set index 0-14 would still work for index 15 even if N\_RB=2 or 3, and do not see the need to restrict N\_RB as 1 only. Thus, we support consistent scaling principle for index 0-15, and leave the actual number up to implementation. |
| vivo | We prefer Alt-1. In our opinion, frequency hopping is aimed to achieve the frequency diversity gain regardless the hopping pattern. So we don’t think it should be restricted. Moreover, for Alt-1, the specification doesn’t need more modification with consistent design for all the PUCCH set index. |
| ZTE, Sanechips | We prefer Alt-1, which maintain the same scheme as index 0~14 and have less spec impact. |
| Transsion | We prefer Alt-1 for simplicity. |
| Samsung | We prefer Alt-1 for a unified design. Without a significant issue observed, it would be good to keep unified solution to benefit both UE and gNB’s implementation.  |
| Moderator | Company support is as follows:* Alt-1
	+ Nokia, Huawei, OPPO, Qualcomm, Intel, Apple (2nd choice), Interdigital, Lenovo, Sony, Futurewei, NTT DOCOMO, ZTE, Samsung, Ericsson (2nd choice)
* Alt-2
	+ LGE, Apple (1st choice), Ericsson (1st choice),CATT

Companies supporting Alt-1 prefer a consistent scaling approach for all PUCCH resource set indices. Some companies observe that for PUCCH resource set indices other than 15 with non-zero RB offsets, the RB offset area is used and the hopping pattern reverses as well, albeit for a larger number of RBs than for set index 15.One company supporting Alt-2 suggests that PUCCH resource set index 15 should be restricted to only N\_RB = 1; however, two companies supporting Alt-1 do not think that PUCCH resource set index 15 should be restricted to only N\_RB = 1. One of these companies observes that even for N\_RB = 2 or 3 the PUCCH resources are still contained within the active BWP, and another company observes that frequency diversity is still obtained, even if the hopping pattern reverses.@LGE and @Apple: Given the overwhelming support for Alt-1, and the technical reasoning provided above, are you willing to compromise and support Proposal #2 below.@All: Please only responsd if you have a concern with Proposal #2 below |
| Apple | We can be flexible and are fine with the proposal |
| Futurewei | Not a direct concern with Proposal #2, which seems okay; but it can be good to solve the difference in views on whether frequency diversity is still obtained even if hopping pattern reverse. It seems that N\_RB up to 3 is fine for the resource set index 15, while if it turns out that N\_RB has to be at most 1, this resource set is quite restrictive itself.  |
| LG Electronics | We can accept Proposal #2 for the sake of progress. |
| ZTE, Sanechips | We support this proposal. |
| Intel | We support this proposal. |

### **Proposal #2 (PUCCH resource set index 15)**

In the RAN1#106bis-e agreements on construction of PUCCH resource sets prior to dedicated PUCCH configuration, the following is supported for PUCCH resource set index 15 in Table 9.2.1-1:

* $X=N\_{RB}$

# 3 Sequence Design for Multi-RB PUCCH

## 3.1 Sequence Design for DMRS of Multi-RB PF1

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| vivo [4] | **Proposal 2: The DMRS for enhanced PF1 supports a single sequence of length equal to the total number of mapped REs of the PUCCH-DMRS resource is used.** |

### Summary of Sequence Design for DMRS of Multi-RB PF1

vivo [4] observes that it is not clear whether the below RAN1#106-e agreement for multi-RB PF0/1 also applies to the DMRS of PF1.

Agreement (RAN1#106-e):

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 checked the current draft CR for 38.211 [18] prepared by the 38.211 editor, and indeed, Section 6.4.1.3.1.1 on DMRS for PF1 has not been updated to include the case of NRB > 1.

Hence the moderator makes the following proposal to ensure that the next version of the 38.211 draft CR will capture this.

### **Proposal #1 (Sequence design for DMRS of multi-RB PF1)**

For DMRS of enhanced PF1 support a single sequence of length equal to the total number of mapped REs of of the PUCCH resource is used. The spreading factor for DMRS of enhanced PF1 is defined in the same way as Rel-16.

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

Please provide your company view on Proposal #1.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator | Support Proposal #1 |
| Nokia, NSB | We support the Proposal #1 |
| Huawei, HiSilicon | We support Proposal #1. |
| OPPO | We support Proposal#1. |
| Qualcomm | We support Proposal#1. |
| Intel | We support this proposal. |
| Apple | We suppport Proposal #1. Moderator should fix typo “of of“ |
| InterDigital | We are fine with Proposal #1. |
| Lenovo, Motorola Mobility | We support Proposal #1 |
| Sony | Support the FL proposal. |
| Futurewei | We support the Proposal #1.  |
| LG Electronics | Support Proposal #1 as a conclusion. |
| NTT DOCOMO | We support Proposal #1. |
| vivo | We support Proposal #1 as an agreement given there is expected spec impact. |
| ZTE, Sanechips | We support Proposal #1. |
| Transsion | We support Proposal #1. |
| Moderator | There seems to be consensus on Proposal #1, hence the moderator will recommend for email endorsement |
| Samsung | We support Proposal #1.  |
| CATT | We support Proposal #1. |

## 3.2 Sequence Design for DMRS of Multi-RB PF4

There are no company contributions on this topic; however, when the moderator checked the draft CR for 38.211 [18] for the issue discussed in Section 3.1 above, the moderator discovered that Section 6.4.1.3.3.1 of 38.211 on DMRS for PF4 contains the following:

The reference-signal sequence $r\_{l}\left(m\right)$ shall be generated according to



where $M\_{sc}^{PUCCH,s}$ is given by clause 6.3.2.6.3 and $r\_{u,v}^{\left(α,δ\right)}(m)$ depends on the configuration:

- if the higher-layer parameter *dmrs-UplinkTransformPrecodingPUCCH* is configured, and ${π}/{2}$-BPSK is used for PUCCH, $r\_{u,v}^{\left(α,δ\right)}(m)$ is given by clause 5.2.3 with $δ=0$ and $c\_{init}$ given by clause 6.4.1.3.2.1. The sequence group $u$ and the sequence number $v$ depend on the sequence hopping in clause 6.3.2.2.1.

- otherwise, $r\_{u,v}^{\left(α,δ\right)}(m)$ is given by clause 6.3.2.2 and the cyclic shift $α$ varies with the symbol number and slot number according to clause 6.3.2.2.2 with

- $m\_{0}=0$ for PUCCH format 3 without interlaced mapping;

- $m\_{0}$ obtained from Table 6.4.1.3.3.1-1 with the orthogonal sequence index $n$ given by clause 6.3.2.6.3 for PUCCH format 3 with interlaced mapping and PUCCH format 4.

This text says that if ${π}/{2}$-BPSK is used for PF4, then the DMRS sequence is defined in Section 5.2.3 which defines Type-2 low PAPR sequences which are based on ${π}/{2}$-BPSK symbols. This is in contrast to Type-1 low PAPR sequences which are based on Zadoff-Chu sequences. The moderator observes that use of Type-2 low PAPR sequences conflicts with the below RAN1 agreement from RAN1#104bis-e:

Agreement (RAN1#104bis-e):

For DMRS of enhanced PF4, a Type-1 low PAPR sequence of length equal to the total number of mapped REs of 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).

Based on this observation, the moderator poses the following question regarding whether or not pi/2-BPSK should be supported for enhanced PF4, i.e., if NRB > 1. Depending on company views, we can either make a new agreement or conclusion capturing the RAN1 consensus so that the next version of the 38.211 draft CR can capture the consensus.

### **Question #2 What is your view on whether or not** ${π}/{2}$**-BPSK should be supported for enhanced PF4, i.e., when** NRB > 1**?**

Please provide your company view on Question #2.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | We are ok to support ${π}/{2}$-BPSK for PF4 with Type-2 low PAPR sequences.  |
| Huawei, HiSilicon | We are uncertain about the usefulness of ${π}/{2}$-BPSK in this case. It may be applicable where coverage is an issue, but this modulation format has not been part of the RAN1 evaluations.  |
| OPPO | We are OK to support pi/2-BPSK for enhanced PF4. |
| Qualcomm | As it is UE capability to support pi/2 BPSK, it doesn’t hurt to support it for multi-RB PF4. We are open to support it as UE capability. |
| Intel | We are OK to support ${π}/{2}$-BPSK for PF4 for enhanced PF4. |
| Apple | We are fine with supporting pi/2 BPSK as a UE capability for enhanced PF4. |
| InterDigital | As pi/2-BPSK has its own benefits, we are fine to support pi/2-BPSK for enhanced PF4.  |
| Lenovo, Motorola Mobility | We are Ok to support ${π}/{2}$-BPSK for PF4 |
| Futurewei | We are OK with ${π}/{2}$-BPSK for PF4. |
| LG Electronics | Support of ${π}/{2}$-BPSK seems to be an issue of whether the following FG 16-6b is supported for FR2-2 or not.

|  |  |  |
| --- | --- | --- |
| 16-6b | Low PAPR DMRS for PUCCH | For PUCCH format 3 and PUCCH format 4 with transform precoding and with pi/2 BPSK modulation |

If this FG is also supported for FR2-2, ${π}/{2}$-BPSK can be applicable not only to PF4 but also PF3. |
| NTT DOCOMO | We are fine to support pi/2-BPSK for PF4 DMRS with multiple PRB as per Rel-16 specification. Thus, the agreement can be modified to support type-2 low PAPR sequence generation with pi/2-BPSK modulation. |
| vivo | We are OK to support ${π}/{2}$-BPSK for ePF4 and also think the issue raised by LG should be considered. On whether to support low-PAPR sequence type 2 as ePF4 DMRS with ${π}/{2}$-BPSK, we believe the same motivation still holds. Given type 2 sequence and ${π}/{2}$-BPSK have better PAPR, we think it’s benefit at least for coverage.However, one thing we’d like to note is that for the low-PAPR sequence type2, it does not support user multiplexing for PUCCH format 4 with ${π}/{2}$-BPSK . |
| ZTE, Sanechips | In our understanding, for enhanced PUCCH format 4 whose DMRS using type-1 sequence can be configured with pi/2-BPSK. |
| Transsion | We are OK with ${π}/{2}$-BPSK for PF4 with Type-2 low PAPR sequences. |
| Moderator | Multiple companies seem to be okay with supporting pi/2-BPSK for PF4 when NRB > 1 which implies that Type 2 sequence is used for DMRS. Some companies suggest that this should be a UE capability, and one company has a concern that Type 2 sequences have not been part of the evalulations so far.The moderator thinks that still more discussion is needed before a conclusion can be drawn. This is based on the following two comments:* LGE observes that support of pi/2-BPSK is a UE capability (FG 16-6b) and that this capability applies to both PF3 and PF4.
* vivo observes that with Type 2 sequences, PUCCH format 4 with pi-/2-BPSK does not support user multiplexing. This seems to be true according to Section 6.4.1.3.3.1 of 38.211 on DMRS for PF4 (shown above). As can be seen from this section, when pi/2-BPSK is used, no cyclic shifts are defined for DMRS. This means that despite the fact that the UCI for PF4 can only be configured with spreading factor 2 and 4 (not 1), in practice only 1 user can be supported. If 2 users were multiplexed, then the performance would be poor due to interference in the channel estimation since the DMRSs of the two users would not be orthogonal.

If what vivo observes is true that PF4 with pi/2-BPSK does not support user multiplexing, and based on the observation from LGE that pi/2-BPSK is defined for both PF3 and PF4, it is not clear that multi-RB PF4 with pi/2-BPSK (restricted to only 1 user) offers any beneficial functionality compared to PF3 with pi/2-BPSK, since the latter supports multiple RBs and also supports only 1 user. Furthermore, if only 1 user can be supported for PF4 with pi/2-BPSK, the use of spreading factor 2 for UCI needlessly reduces the PUCCH payload by a factor of 2 compared to PF3 with the same number of RBs.  |

### **Question #3 Do you agree with vivo's observation that in the current specifications, user-multiplexing for PF4 is not supported when** ${π}/{2}$**-BPSK is used?**

### **Question #4 If the answer to Question #3 is yes, does multi-RB PF4 with** ${π}/{2}$**-BPSK offer any additional functionality compared to PF3 with** ${π}/{2}$**-BPSK, considering that both formats can be configured with multiple RBs?**

Please provide your company view on Questions #3 and #4.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| CATT | Q3: Yes it seems true that user-multiplexing is not supported for PF4Q4:Agree with moderator that no additional benefit is offered by PF4 with pi/2-BPSK. |
| Apple | Q3: yesQ4: agree |
| Futurewei | Q3: Agree that in the current specification, user-multiplexing for PF4 is not supported when pi/2-BPSK is usedQ4: It does not seem that multi-RB PF4 with pi/2-BPSK offer additional benefit over PF3 with pi/2-BPSK.  |
| LG Electronics | Q3: Yes.Q4: The same question can hold also for the case of 1-RB PF3 and 1-RB PF4 in Rel-16. However, we don’t see any differentiation of the applicability of pi/2-BPSK to PF3 and PF4. Therefore, we prefer to take the same approach for pi/2-BPSK also for FR2-2. One slight difference between PF3 and enhanced multi-RB PF4 is whether RB size can be adjusted based on UCI payload size or not. In summary, we can follow the same logic for pi/2-BPSK in FR2-2 with Rel-16 NR. |
| ZTE, Sanechips | Q3:Yes.Q4:There seems to be no difference between multi-RB PF4 with pi/2-BPSK and PF3 with pi/2-BPSK. |
| NTT DOCOMO | Q3: We have a different understanding on this. In our understanding, according to the current specification, if *dmrs-UplinkTransformPrecodingPUCCH* is configured, type-2 low PAPR sequence would be used and user-multiplexing is not supported. Otherwise, i.e., *dmrs-UplinkTransformPrecodingPUCCH* is not configured, type-1 low PAPR sequence would be used and user-multiplexing can be supported even for PF4 with pi/2-BPSK. Therefore, in the current specification, whether to use type-1 or 2 low PAPR sequence to use and whether to support user-multiplexing for PF4 with pi/2-BPSK can be switched associated with *dmrs-UplinkTransformPrecodingPUCCH*. |
| vivo | Q3: Yes, of course. With type 2 low PAPR sequence as DMRS, multi-RB PF4 with pi/2-BPSK will not support user multiplexing.Regarding NTT DOCOMO’s comment to support type 1 low PAPR sequence as DMRS for multi-RB PF4 with pi/2-BPSK, we’d like to share some background on why they introduced type 2 low PAPR sequence. For transform precoded OFDM, it was identified that when pi/2-BPSK modulation is used, then the PAPR of the PUSCH or PUCCH is lower than that of the associated DMRS (type 1 sequence) which is a problem as different OFDM symbols will have different PAPR. So if we were to support type 1 sequence as DMRS for multi-RB PF4 with pi/2-BPSK, we’re not sure about the benefit of PAPR associated with pi/2-BPSK to begin with.In sumamry, the benefit of low PAPR of pi/2-BPSK is obtainable when used with type 2 sequence as DMRS for ePF4 but rstricted to 1 UE. It’s not clear to us whether the benefit of low PAPR of pi/2-BPSK is still obtainable when type 1 sequence is used as DMRS for ePF4.Q4: we don’t think it provide new functionality.  |
| Intel | Q3: Yes – User-multiplexing is not supported for PF3 when pi/2-BPSK is used.Q4:Agree with the moderator, and that this will not provide any new functionality.  |

# 4 Potential Coverage Imbalance between PF2/3 and PF4

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| ZTE [5] | **Proposal 2: Considering the limited time for Rel-17 B52.6GHz, the discussion on potential problem of coverage performance should be deferred.**  |
| OPPO [8] | **Proposal 2: For PF2/3 in 60GHz band, 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.** |
| Nokia [6] | ***Observation 1:*** *On potential coverage imbalance between enhanced PUCCH formats 2/3 and PUCCH format 4, it has not been shown that PF2/3 cause a coverage limitation.* |
| Qualcomm [17] | **Proposal 3: In Rel-17, no further discussion on potential coverage imbalance between PF2/3 and PF4.** |
| Interdigital [13] | ***Observation 3:*** *Potential coverage imbalance issue can be handled by gNB configuration with the flexibility given by the current specification.****Proposal 1:*** *Keep the current design for PUCCH formats in NR 52-71.*  |

## Summary of Potential Coverage Imbalance

The summary from the discussion in RAN1#106bis-e was as follows [1]:

|  |  |
| --- | --- |
| Moderator | Companies views are mixed. Some companies do not see an issue with coverage imbalance. Many companies view that the current agreements support a functional feature and prefer not to revisit prior agreements. Some companies which to revisit the conclusion on the maximum payload for PF4 if there is consensus to do so. Several companies point out that changes to PF2/3 are out of scope for this WI.From the moderator's point of view, the only viable option is to re-visit the conclusion on the maximum payload size for enhanced (multi-RB) PF4. However, there is not consensus to do so.FL Recommendation: De-prioritize this issue due to lack of consensus. |

Given the state of the discussion in the last meeting, and the new company contributions on the topic for this meeting suggesting to not further discuss, the moderator proposes to de-priortize this topic for Rel-17 given the limited time left in the WI.

Of course companies are always free to provide their view, and if you which to do so, please provide it here.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator Recommendation | De-prioritize this topic for Rel-17. |
| Nokia, NSB | We support the FL recommendation |
| Huawei, HiSilicon | We support to de-prioritize this topic for Rel-17. |
| OPPO | As we stated in our contribution, the coverage performance will be substantially degraded if the number of RBs used for PF2/3 varies dynamically based on PUCCH payload. Specifically, as shown in our simulation results, the MIL loss ranges from 1.2dB to 13.5dB depending on the number of RBs compared with N\_RB=16. Considering it has been agreed that the actual number of RBs for enhanced PF4 does not vary dynamically based on PUCCH payload, the similar agreement can be made for PF2/3 with little spec impact. |
| Qualcomm | We agree to de-prioritize this topic for Rel-17 |
| Intel | We support to de-prioritize this topic for Rel.17, and furthermore we beleive that this is out of scope for this AI. |
| Apple | We support the FL’s recommendation |
| InterDigital | We are fine with the Moderator recommendation. |
| Lenovo, Motorola Mobility | We support de-prioritizing this topic given the limited time for the WI |
| Sony | Support the FL proposal. |
| Futurewei | We are fine with de-prioritizing this issue.  |
| LG Electronics | Support to deprioritize this issue.. |
| NTT DOCOMO | We support the FL recommendation. |
| vivo | Agree with FL’s recommendation. |
| ZTE, Sanechips | We support the FL’s suggestion. |
| Transsion | We agree with the FL’s recommendation. |
| Samsung | We agree with moderator’s assessment.  |
| Moderator | Given that all but one company wish to de-prioritize this issue, and that PF2/3 enhancement is out ouf scope from the WID, the moderator recommendation still holds. Please comment further only if you have servious concerns. |
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# 5 Potential Assistance Info Provided to gNB

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| ZTE [5] | **Proposal 3: There is no need for UE to report beamforming gain to gNB.** |
| Futurewei [3] | ***Proposal 3. Discuss further the necessity of an explicit assistance information for gNB to determine*** $N\_{RB}$ ***such as beamforming gain.***  |
| Intel [12] | **Proposal 3: A UE operating in shared spectrum is expected to report its TX beamforming gain via either Msg3 PUSCH or PRACH resource partitioning.** |
| CATT [7] | **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.** |
| Nokia [6] | ***Observation 2:*** *UE assistance information for PUCCH resource configuration is an optimisation that should be deprioritized at this phase of WI.*  |
| Qualcomm [17] | **Proposal 2: In Rel-17, Assistance Info on number of RBs for multi-RB PF 0/1 is not supported.** |
| Interdigital [13] | ***Proposal 2:*** *No potential assistance information and power control enhancement are supported in Rel-17.* |

## Summary of Potential Assistance Information Provided to gNB

The summary from the discussion in RAN1#106bis-e was as follows [1]:

|  |  |
| --- | --- |
| Moderator | Some companies view that assistance information could be useful, while others do not see a strong motivation. Many companies view is that this issue should be de-prioritized due to little remaining time in the WI.FL Recommendaton: De-prioritize this issue |

Given the state of the discussion in the last meeting, and the new company contributions on the topic for this meeting suggesting that provision of assistance info should not be supported, the moderator proposes to de-priortize this topic for Rel-17 given the limited time left in the WI.

Of course companies are always free to provide their view, and if you which to do so, please provide it here.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator Recommendation | De-prioritize this topic for Rel-17. |
| Nokia, NSB | We support the FL Recommendation |
| Huawei, HiSilicon | We support to de-prioritize this topic for Rel-17. |
| Qualcomm | We support to de-prioritize this topic for Rel-17 |
| Intel | As for this topic, we would like to highlight again a few point to justify its technical need:* As companies have noticed, there is a large dependency between the number of PRbs required by a UE to achieve a specific MIL and the UE’s transmit beamforming gain, which is unknown by the gNB.
* Based on our evaluation, when there is a mistmatch between the gNB’s assumption on UE’s transmit beamforming gain and the actual UE’s capability, this would lead to a big loss in terms to MIL, and this loss could be quite substaintial if the gNB assumes a much larger UE’s transmit beamforming gain (e.g., 6dB) than the real UE’s transmit beamforming gain (e.g., 0 dB).

In the figure below, as an exampe it is shown the achievable MIL performance at 120 kHz SCS when the UE’s TxBF is the same as that assumed by the gNB (transparent bars) and achievable MIL performance when the UE’s TxBF is different than what assumed by the gNB. Chart  Description automatically generated For certain UE EIRP and UE’s output power, **the MIL loss is ~5dB**.* While it could be argued that a gNB could potentially take always a pessimistic approach and assume the UE’s beamforming gain is 0 dBi, this will come at the cost of a very inefficient spectrum utilization with reduce multiplexing capability, especially since it is quite likely that UEs may employ directional transmissions which require/utilize much higher beamforming gains, whose effectively require much smaller number of PRBs to achieve same coverage. In this matter, the Table below shows the number of PRBs that may need to be configured to achieve maximum MIL when the beamforming gain is 0dBi (first value in black) or 6dBi (second value in red) for different values of UEs EIRP and output power.

The table highlights that by using a pessimistic approach the impact in terms of spectrum efficiency may be quite large, and **a UE may be configure to use up to more than 5 times the number of PRBs that may require**. With that said, given that we still have a full meeting ahead of us, we beleive that if RAN1 is willing to solve this issue there is indeed enough time to make progress and solve it. Also we will like to remind the group that in **Rel.18 there won’t be any WI specific to improve further this design**, and this issue will continue to sussist and could not be solved anymore. Considering that setting the proper number of PRBs for the enhanced PF0/1 and 4 is fundamental to benefit from the enhancements made in this AI, and given the aforementioned penalties that the design will incur in, we really thing that RAN1 should discuss this topic, and converge into a solution. In this matter, as discussed in our tdoc (R1-2111485), this could be effectively solved through one of the following options:1. Option 1: PRACH resource partitioning -> the PRACH preambles could be divided into groups, where each group is associated to a specific UE’s TX beamforming gain. When the gNB detects a specific preamble by knowing in which group this may belong to, it would effectively know the UE’s TX beamforming gain.
2. Option 2: Explicit indication using Msg3 -> Msg3 can be used to explicitly report the UE’s TX beamforming gain. For instance, Tx beamforming gain for a UE can be carried by MAC-CE or piggybacked on Msg3 PUSCH.
 |
| Apple | We are fine with the FL’s recommendation for Rel-17 |
| Lenovo, Motorola Mobility | We support de-prioritizing this topic given the limited time for the WI |
| Sony | Support the FL proposal. |
| Futurewei | Support to de-prioritize this topic for Rel-17. |
| LG Electronics | Support to deprioritize this issue.. |
| NTT DOCOMO | We are fine with the FL recommendation. |
| vivo | Agree with FL’s recommendation. |
| ZTE, Sanechips | We support the FL’s suggestion. |
| Transsion | We agree with the FL’s recommendation. |
| Samsung | We agree with moderator’s assessment.  |
| Moderator | Given that all but one company wish to de-prioritize this issue, the moderator recommendation still holds. Please comment further only if you have serious concerns. |
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# 6 PUCCH Power Control

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| ZTE [5] | **Proposal 4: It is proposed not to discuss the power control of PUCCH until RAN4 determines some parameters such as PSD limitation and the maximum conduct power.** |
| CATT [7] | **Proposal 4 It is needed to modify the maximum transmission power in the PUCCH power control formula for different configured number of RBs.** |

### Summary of PUCCH Power Control

The summary from the discussion in RAN1#106bis-e was as follows [1]:

|  |  |
| --- | --- |
| Moderator | Many companies do not see a need for a change to the power control formula wit the rationale that similar PSD issues exist also in the 5/6 GHz bands, and specifica enhancements were not deemed necessary there. Several companies feel the issue should be further discussed.FL Recommendation: De-prioritize this topic for this meeting |

Given the state of the discussion in the last meeting, and the new company contributions on the topic for this meeting suggesting that any change to power control may depend on RAN4 decisions that will occur in later RAN4 meetings, the moderator proposes to de-priortize this topic, at least for now.

Of course companies are always free to provide their view, and if you which to do so, please provide it here.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator Recommendation | De-prioritize this topic |
| Nokia, NSB | We support the FL Recommendation |
| Huawei, HiSilicon | We support to de-prioritize this topic for Rel-17. |
| Qualcomm | We support to de-prioritize this topic for Rel-17 |
| Apple | We suport de-prioritizing this topic for Rel-17 (not just this meeting) |
| InterDigital | We are fine with the moderator recommendation. |
| Lenovo, Motorola Mobility | We support Moderator’s recommendation |
| Sony | Support the FL proposal. |
| Futurewei | Support the proposal as the issue depends on RAN4 decision. |
| LG Electronics | Support to deprioritize this issue.. |
| NTT DOCOMO | We support the FL recommendation. |
| vivo | Agree with FL’s recommendation. |
| ZTE, Sanechips | We support the FL’s suggestion. |
| Transsion | We agree with the FL’s recommendation. |
| Samsung | We agree with moderator’s assessment.  |
| Moderator | Given that all companies agree to de-prioritize this issue, the moderator recommendation still holds. Please comment further only if you have concerns. |
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# 7 RRC / SIB1 Parameter Issues

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Nokia [6] | ***Proposal 2:*** *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

One company proposes to clarify that the value range for the SIB1 parameter that configures the number of RBs for PUCCH resources prior to dedicated PUCCH configuration. According to the moderator's understanding, the value range 1 .. 16 is already captured in the RRC parameter spreadsheet provided to RAN2 [19], hence there shouldn't be a need to further discuss.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| NR\_ext\_to\_71GHz | PUCCH | nrofPRBs | New | Number of PRB for for PUCCH resource sets before dedicated PUCCH resource configuration | {1,…,16} | PUCCH-ConfigCommon |

# References

1. R1-2110499, "FL Summary #2 for [106bis-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4," Moderator (Ericsson), RAN1#106bis-e, October 2021.
2. R1-2110829 Enhancement on PUCCH formats Huawei, HiSilicon
3. R1-2110874 Discussion on Enhancements of PUCCH formats for Beyond 52.6GHz FUTUREWEI
4. R1-2111000 Remaining issues on PUCCH enhancements for NR operation from 52.6GHz to 71GHz vivo
5. R1-2111076 Discussion on the PUCCH enhancements for 52.6 to 71GHz ZTE, Sanechips
6. R1-2111197 Remaining items for enhanced PUCCH formats 0/1/4 Nokia, Nokia Shanghai Bell
7. R1-2111243 Enhancements for PUCCH formats for up to 71GHz operation CATT
8. R1-2111309 Discussion on enhancements for PUCCH format 0/1/4 OPPO
9. R1-2111387 Views on enhancements for PUCCH formats 0/1/4 Sony
10. R1-2111465 PUCCH enhancements Ericsson
11. R1-2111466 FL Summary for Enhancements for PUCCH formats 0/1/4 Ericsson
12. R1-2111485 Discussion on PUCCH enhancements for extending NR up to 71 GHz Intel Corporation
13. R1-2111834 Discussions on enhancements for PUCCH formats 0/1/4 InterDigital, Inc.
14. R1-2111863 Discussion on Enhancements for PUCCH formats 0\_1\_4 Apple
15. R1-2112047 Enhancements for PUCCH formats 0/1/4 to support NR above 52.6 GHz LG Electronics
16. R1-2112098 PUCCH format 0/1/4 enhancements for NR from 52.6 to 71 GHz NTT DOCOMO, INC.
17. R1-2112205 Enhancements for PUCCH for NR in 52.6 to 71GHz band Qualcomm Incorporated
18. R1-2112431, "draft CR Introduction of extensions to 71 GHz," Ericsson, RAN1#107-e, November 2021.
19. R1-2110573, "Consolidated higher layer parameter list for Rel-17 NR," Moderator(Ericsson), RAN1#106bis-e, October 2021.