3GPP TSG-RAN WG1 Meeting #106-e R1-2107774

e-Meeting, 16th – 27th August, 2021

Agenda Item: 8.2.3

Source: Moderator (Ericsson)

Title: FL Summary for [106-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 "Supporting NR from 52.6GHz to 71 GHz."

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

[106-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4 with checkpoints for agreements on August 19, 24, 27 – Steve (Ericsson)

The following is an outline of the summary:

2 Maximum Number of RBs for Enhanced PF0/1/4 discussion

3 Configuration of Number of RBs Proposals

4 Sequence Construction for Enhanced PF0/1 discussion

5 RE Mapping for Enhanced PF0/1/4 for 120 kHz SCS Proposal + discussion

6 Payload Limitation and Rate Matching for PF4

6.1 Maximum UCI Payload for PF4 Conclusion

6.2 Rate Matching for PF4 Proposal

7 PUCCH Resource Set Prior to RRC Configuration

7.1 Indication of Number of RBs DISCUSSION

7.2 PUCCH Resource Set Construction DISCUSSION

# 2 Maximum Number of RBs for Enhanced PF0/1/4

The following agreements were made in RAN1#104bis-e:

Agreement:

* The maximum values for the configured number of RBs, NRB, for enhanced PF0/1/4 are at least:
	+ 12 RBs for 120 kHz SCS
	+ 3 RBs for 480 kHz SCS
	+ 2 RBs for 960 kHz SCS
* FFS: Whether or not the above values need to be revised to support larger values (and any associated signaling impact), e.g., to support lower UE Tx beamforming gain and/or larger UE EIRP and conducted power limits for different UE power classes, different from those in the agreed evaluation assumptions

Agreement:

For addressing the FFS from the prior agreement in RAN1#104bis-e on the maximum values for the configured number RBs, send an LS to RAN4 asking for feasible maximum values for UE\_EIRP and UE\_P for operation in 52.6-71 GHz.

RAN4 has sent reply LS that summarizes the discussion that has occurred so far within RAN4 [4] on UE power classes. RAN4 has provided the following answer to RAN1's question in the original LS [1]:

**Answer**

RAN4 can confirm that the current regulatory limits, i.e. max EIRP and max TRP, are higher than the above values**.** We further note that for the 52.6 to 71 GHz frequency range, regulations in some regions also specify a maximum spectral power density (EIRP).

Regarding what minimum peak EIRP value RAN4 will specify for a power class in this frequency range, it is premature to answer at this stage. RAN4 will continue discussing the power classes, reference UE type, antenna array size, and design considerations to make this assessment. While power class performance is TBD, an FWA UE is expected to yield the highest minimum peak EIRP, and it may be specified around 25 dBm or higher. However, further study is needed to confirm this and provide an exact minimum peak EIRP value. A power ranging from minimum peak EIRP to below the regulatory maximum EIRP limit, is technically valid for the UE to transmit out.

For additional context, different radiated output powers in 38.101-2 are summarized in the table below. Please note that there are no conducted output power requirements defined for FR2 in RAN4 specifications.

**Table 1.** FR2 minimum peak EIRP requirements

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Power class** | **Max TRP****[dBm]** | **FR2 band** | **Min peak EIRP****[dBm]** | **Max EIRP****[dBm]** |
| Power class 1Fixed wireless access UE | 35 | n257/n258/n261 | 40.0 | 55 |
| n260 | 38.0 |
| Power class 2Vehicular UE | 23 | n257/n258/n261 | 29.0 | 43 |
| Power class 3Handheld UE | 23 | n257/n258/n261 | 22.4 | 43 |
| n260 | 20.6 |
| n259 | 18.7 |
| n262 | 16.0 |
| Power class 4High-power non-handheld UE | 23 | n257/n258/n261 | 34.0 | 43 |
| n260 | 31.0 |
| Power class 5Fixed wireless access UE | 23 | n257 | 30.0 | 43 |
| n258 | 30.4 |

TRP: Total **Radiated** Power

EIRP: Effective Isotropic **Radiated** Power

Considering RAN4 is in the early stages of our discussions, this is the information we can provide at this time. Further guidance will be provided as power class discussions progress in RAN4.

The main open issue is whether or not the maximum number of RBs should be increased beyond the agreed values of 12/3/2 for 120/480/960 kHz SCS accounting for the above feedback from RAN4.

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel | **Proposal 1: The maximum number of PRBs over which a PUCCH format 0/1/4 may span is increased based on either option 1 or option 2:*** **Option 1: The maximum number of PRB is at least 40 RBs, 18 RBs, 8 RBs for 120, 480, and 960 kHz SCS, respectively.**
* **Option 2: The maximum number of PRB is at least 20 RBs, 12 RBs, 4 RBs for 120, 480, and 960 kHz SCS, respectively.**

**Proposal 3: RAN1 should discuss a proper framework to implicitly or explicitly indicate the UE’s beamforming gain to the gNB.** |
| Futurewei | ***Proposal 1. Support 22RBs/6RBs/3RBs as the maximally allowed numbers for 120kHz/480kHz/960kHz for enhanced PF0/1/4 of B52/FR2-2, taken the RAN4 feedback further into account.***  |
| vivo | **Proposal 1: When considering the revision of maximum number of RBs, the coverage (maximum isotropic loss (MIL)) should be mainly considered, including the RE mapping method, sequence type, UE power class.** |
| CATT | **Proposal 1 Two sets of maximum values for enhanced PF0/1/4 can be used. The smaller set can be used to reduce the bandwidth, while the larger set can be used to improve the coverage.** |
| ZTE | **Proposal 1: The maximum number of PRBs can be 32 according to the regulation requirements of majority regions with compatibility.** |
| NTT DOCOMO | ***Proposal 1:*** *For the evaluation assumption of enhanced PUCCH format 0/1/4, larger maximum UE conducted power/EIRP should be considered as additional assumption in RAN1.* |
| Nokia | ***Proposal 1:*** *The maximum values for the configured number of RBs for enhanced PF0/1/4 are either the agreed 12/3/2 RBs for 120/480/960 kHz SCS or are extended to 16 RBs and 4 RBs for 120 and 480 kHz SCS, respectively.*  |
| Apple | ***Proposal 1: T****he maximum value of N\_RB should be based on the currently agreed values of 12, 3 and 2 for 120 kHz SCS, 480 kHz SCS and 960 kHz SCS respectively.*  |
| LGE | **Proposal #4: Although UE types with larger EIRP in RAN4 LS reply are considered, it is not necessary to increase the NRB values larger than 12/3/2 for 120/480/960 kHz SCS, respectively.** |
| OPPO | **Proposal 1: When EU regulatory power limit is applied, the maximum values for the configured number of RBs, NRB, for enhanced PF0/1/4 are:*** **32 RBs for 120 kHz SCS**
* **8 RBs for 480 kHz SCS**
* **4 RBs for 960 kHz SCS**

**Proposal 2: When US regulatory power limit is applied, the maximum values for the configured number of RBs, NRB, for enhanced PF0/1/4 are:*** **32 RBs for 120 kHz SCS**
* **8 RBs for 480 kHz SCS**
* **4 RBs for 960 kHz SCS**

**Proposal 3: When South Korea regulatory power limit is applied, the maximum values for the configured number of RBs, NRB, for enhanced PF0/1/4 are:*** **16 RBs for 120 kHz SCS**
* **4 RBs for 480 kHz SCS**
* **2 RBs for 960 kHz SCS**
 |
| Samsung | **Proposal 1: RAN1 can consider up to 16 PRBs as maximum number of PRBs, considering UE\_P can be larger than 21dBm but much smaller than 25 dBm min peak EIRP provided by RAN4.**  |
| Huawei | ***Proposal 1: The maximum number of PRBs for the PUCCH is:**** ***For 120 kHz SCS: 32***
* ***For 480 kHz SCS: 8***
* ***For 960 kHz SCS: 4***
 |
| Interdigital | ***Proposal 1:*** *It is preferred to hold the discussion on max(NRB) until receiving RAN4’s response on the LS.*Moderator note: Note that RAN4 has provided a response (see [1]); however, given that discussions in RAN4 are still at an early stage, the LS reply is not conclusive on all questions asked by RAN1. |
| Ericsson | **Proposal 7 RAN1 should wait for further feedback from RAN4 on feasible pairs of (UE\_EIRP, U\_P) values for the 52.6 – 71 GHz band before concluding on whether or not to increase the maximum number of RBs beyond 12 / 3 / 2.** |

The following extract from [8] summarizes the the reply LS from RAN4 quite succinctly (the moderator has done some light editing to provide context):

According to reply LS from RAN4 [1], RAN4 can confirm the regulatory limits max EIRP and max TRP can be higher than the values quoted in the RAN1 LS (i.e., UE\_EIRP = 25 dBm and UE\_P = 21 dBm), and min peak EIRP for FWA UE can be around 25dBm. A power ranging from minimum peak EIRP to below the regulatory maximum EIRP limit, is technically valid for the UE to transmit out. Therefore, UE\_EIRP can be larger than 25dBm. Regarding UE\_P, RAN4 does not specify requirement for conducted power, but TRP may be used as a reference for determining UE\_P. min peak EIRP is typically much larger than TRP due to antenna gain. Therefore, with 25dBm min peak EIRP for FWA UE in 60GHz, TRP is most likely smaller than 25dBm, though it can be higher than 21dBm.

Maximum transmission power is limited by the minimum of (UE\_EIRP-Tx BF gain) and (UE\_P-CM), the transmission power is limited by UE\_P rather than UE\_EIRP when UE\_EIRP is above a threshold, e.g. > 25dBm. As analysed above, UE\_P may be slightly larger than 21 dBm.

To add to this, some companies have observed that the required number of RBs scales inversely with the Tx beamforming gain (TxBF), and thus RAN1 should use TxBF = 0 dBi (instead of 6 dBi) as a "worst case" for defining the number of RBs. So, if either TxBF = 0 dBi and/or RAN4 agrees on a min Peak EIRP > 25 dBm, it will most likely be the conducted power UE\_P that is the limiting factor, not EIRP.

Based on the analytical expressions for the required PUCCH bandwidth discussed in RAN1#104bis-e (see FL summary [2]), if EIRP is not limiting then the number of RBs as a function of UE\_P and CM is given as follows (table extracted from [11] where CM = 2 is assumed), where the values in red are what have been agreed so far in RAN1:

Table 5: Maximum number of RBs as a function of $x=UE\\_P-CM$

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **x** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** |
| **120 kHz** | 12 | 14 | 18 | 22 | 28 | 35 | 44 | 56 | 70 |
| **480 kHz** | 3 | 4 | 5 | 6 | 7 | 9 | 11 | 14 | 18 |
| **960 kHz** | 2 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 9 |

Hence, the open issue to discuss is whether or not RAN1 should consider a value of UE\_P larger than 21 dBm (x = 19 assuming CM = 2) for defining the maximum number of RBs. Some companies observe that further feedback from RAN4 on power classes (including TRP/EIRP definitions) may come too late in the WI for RAN1 to do anything about it, hence RAN1 should decide on a reasonable value now.

Multiple companies have also pointed out that it is the US regulatory region that requires the largest number of RBs, and the above table assumes this.

Based on various combinations of the above observations, companies have provided the following candidate values for the maximum number of RBs:

* 40 / 18 / 8 (Intel, Option 1)
* 32 / 8 / 4 (OPPO, Huawei)
* 32 / ? / ? (ZTE)
* 28 / 7 / 4 (CATT, assuming CM = 2 dB)
* 22 / 6 / 3 (Futurewei)
* 20 / 12 / 4 (Intel, Option 2)
* 16 / 4 / ? (Nokia)
* 16 / ? / ? (Samsung)
* 12 / 3 / 2 (Apple, LGE)

Given the rather wide spread of proposals, clearly further discussion is needed.

**Proposal 1 Further discuss potentially increasing the maximum number of RBs above the current agreed values 12 / 3 / 2 for 120 / 480 / 960 kHz SCS, respectively.**

## 2.1 <1st Round Comments>

Please provide your company view on Proposal 1 including answering the following questions to help focus the discussion.

**Question 1**: Based on the RAN4 LS reply, is it your understanding that a limit on UE\_P will primarily determine the maximum number of RBs rather than a limit on UE\_EIRP?

**Question 2**: For determining the maximum number of RBs, should RAN1 consider an additional combination of (UE\_EIRP, TxBF) values other than what has been considered so far (25 dBm, 6 dBi)? If yes, then what combination of values should be considered?

**Question 3**: For determining the maximum number of RBs, should RAN1 consider an additional value of UE\_P > 21 dBm? If yes, then what value should be considered?

**Question 4**: Should RAN1 try to conclude now on a maximum values for N\_RB or wait for further RAN4 feedback?

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | Although increasing the number of PRBs in principle increases PUCCH coverage, we are not convinced that the coverage of PUCCH formats 0/1/4, which are used for transmitting only a limited number of bits, is necessarily the bottle neck for system coverage at 60 GHz spectrum. Therefore one should be cautious in increasing the number of PRBs beyond of what is already agreed.  |
| vivo | We are okay with proposal 1. Q1: In the FL summary, it mentioned that “some companies have observed that the required number of RBs scales inversely with the Tx beamforming gain (TxBF), and thus RAN1 should use TxBF = 0 dBi (instead of 6 dBi) as a "worst-case" for defining the number of RBs.” We don’t agree with this argument as it may work for some region(s). The regulation power limits by region are listed in Tables 3 in Section 2.3 of R1-2102127 in the RAN1 104-e meeting. In the US, the TxBF affects the Pmax\_EIRP; while in South Korea, the TxBF affects the Pmax\_EIRP and Pmax\_PSD. Specifically, the number of RBs scales in direct ratio with TxBF in South Korea when the UE\_EIRP is above a threshold. For example, when UE\_EIRP = 25dBm, UE\_P = 21dBm, TxBF = 6dBi, CM = 2, the maximum number of RBs is 12 for SCS 120kHz, while 14 with TxBF changes to 7dBi in the South Korea and no change in the US. However, the maximum number of RBs would not change if the TxBF changes to 0dBi without any other assumption change in all regions.So, it is not correct to always assume the UE\_P will primarily determine the maximum number of RBs rather than a limit on UE\_EIRP without a specific value.Q2 and Q3: in our opinion, the additional combination of (UE\_EIRP, TxBF, UE\_P) values can be (43, 6, 23) at least as in existing FR2 if we do not want to wait for RAN4’s further reply.Q4: we prefer not to wait for further RAN4 feedback if later than the next meeting to make a decision. |
| ZTE, Sanechips | We are fine with Proposal 1.A1: Yes. We share similar understanding with FL on RAN4’s reply LS.A2: Yes. TxBF should be 0dBm.A3: Yes. 25 dBm could be considered.A4. RAN1 should try to make a consensus on additional value set of {UE\_EIRP, UE\_P, TxBF}, if no consensus, RAN1 could wait for further RAN4 feedback. |
| Huawei/HiSilicon | We think a decision can be made in RAN1 given the current status of RAN4. The impact of different number of PRBs to the design of the PUCCH is not critical, since the PUCCH formats are/will be scalable in bandwidth. Thus, the same signal structure could be used regardless of the selected maximum values for the PRBs. RAN1 should choose a set of values (larger than 12/3/2), e.g., 32/8/4, that allows sufficient flexibility for the deployment and to guarantee future proofness.  |
| Lenovo, Motoroloa Mobility | We tend to agree with Nokia that the number of PRBs should not be increased beyond what is already agreed. We are also okay to wait for RAN4 feedback before making the final conclusion |
| Apple | We are fine with Proposal 1. Given that TRP can be used as a proxy for UE\_P and given the values of TRP indicated by RAN4, we can consider using the values of TRP in the estimation of N\_RB.Q1: Yes. Agree with the FLQ2: RAN1 should consider additional values of UE\_EIRP to account for different UE power classes. From our analysis, at least for the United States, the maximum number of RBs is invariant with a change in the TxBF. We can use 0 dB as a reference.Q3: RAN1 can consider additional values of UE\_P. Given the use of TRP as a proxy for UE\_P, we can set it to 23 dBm.Q4: RAN1 should make a decision given that we have only a few meetings left to complete the design. There are some decisions that are contingent on this one. |
| Intel | * Q1: Our understanding is indeed that UE\_P may be dominat on UE\_EIRP to determine the number of PRBs
* Q2: As shown by the analysis conducted by companies, the maximum number of PRBs increases as the UE’s TX beamforming gain decreases, so RAN1 should consider 0 dBi for UE’s TX beamforming gain as worse case. As for the UE\_EIRP, since FR2-1 would be used as a baseline for RAN4 to define new UE power classes, the highest EIRP supported in FR2-1 should be supported which corresponds to 55 dBm for UE power class 1, which is devoted to fixed wireless, which should be also supported for above 52.6 GHz. So to answer the initial questions (0 dBi, 55 dBm) should be considered.
* Q3: In our opinion 21 dBm is very limitative as UE’s output power, and a larger value should be supported as a worse case scenario used to identify the highest number of PRBs to support. As indicated above, our understanding is that RAN4 would use FR2-1 as a baseline to define power classes for FR2-2. For this reason the highest supported TRP should be considered, which correspond to 35 dBm for UE power class 1.
* Q4: our understanding from RAN4 reply is that it may be quite challenging for RAN4 to conclude on the definition of power classes for above 52.6 GHz carrier frequency soon, and it is more likely that RAN4 will conclude after the conclusion of this WI. Since this topic may be a bottleneck for progress within this WI, we believe that RAN1 should try to convey assuming the worse case scenarios and FR2-1 as a baseline.

  |
| CATT1 | For Q1 we don’t think a limit on UE\_P will primarily determine the maximum number of RBs rather than a limit on UE\_EIRP. Q2: additional combination is neededQ3:additional value is neededQ4:we can always try to reach some consensus in ran1. If failed then may be we need to wait for ran4. |
| Sony | We are okay with proposal 1.Q1: We have similar views to Vivo, i.e., both UE\_P and UE\_EIRP can be the limiting factor that determines the maximum number of RBs, depending on the region and assumed values of UE\_EIRP, UE\_P and TxBF.Q2: We are open to consider new values of (UE\_EIRP, TxBF). However, given that RAN4 has not suggested specific values in its reply to RAN1 LS, it is not clear how new values of (UE\_EIRP, TxBF) should be selected. For example, it does not seem reasonable to set TxBF=0 dB as a worst case. The value TxBF=6 dBi already accounts for gain losses, compared to the # antenna elements expected at 60 GHz.Q3: Again, it is not clear from RAN4’s response how a new value of UE\_P should be selected.Q4: Consensus on maximum values of N\_RB should be attempted. If not reached, we are okay to wait for the conclusion of ongoing RAN4 discussions on power classes for the 52.6 to 71 GHz frequency range. |

# 3 Configuration of Number of RBs

The following agreement was made in RAN1#104 on the configuration of the number of RBs for enhanced PF0/1/4 by dedicated signaling:

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: $N=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ where $α\_{2},α\_{3},α\_{5}$ 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

The following table provides a summary of company proposals regarding the open issue marked in red:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| vivo | Proposal 5: The number of RBs for enhanced PF0/1/4 and RE mapping structure are indicated by dedicated RRC signaling. |
| CATT | **Proposal 5 The number of RBs for PUCCH format0/1/4 can be cell specific or UE specific configured.****Proposal 6 For RRC connected UEs, the gNB could use RRC configuration or DCI to indicate UE the configured number of RBs.** |
| NTT DOCOMO | ***Proposal 2:*** *For the dedicated PUCCH resources, the number of RBs for PUCCH format 0/1/4 should be indicated via UE dedicated RRC signaling.* |
| LGE | **Proposal #3: The values of NRB after the RRC connection can be configured based on the allowed values of NRB defined in the specification for each PUCCH format/resource by the gNB (UE-dedicated RRC signalling).** |

The following agreement was made in RAN1#104bis-e on the configuration granularity for the number of RBs:

Agreement:

Down select to one of the following two alternatives for the configuration of the number of RBs, $N\_{RB}$, for enhanced PUCCH formats 0/1/4:

* Alt-1:
	+ For enhanced PF0/1
		- Support configuration of all integer values in the range [1 .. max($N\_{RB}$)] for each SCS
	+ For enhanced PF4
		- Support configuration of all integer values in the range [1 .. max($N\_{RB}$)] for each SCS that fulfill the requirement $N\_{RB}=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ where $α\_{2},α\_{3},α\_{5}$ is a set of non-negative integers.
* Alt-2:
	+ Same as Alt-1, but with coarser granularity, i.e., not all integer values of $N\_{RB}$ can be configured
	+ FFS: Which values of $N\_{RB}$ are supported values in the range [1 .. max($N\_{RB}$)]

The following table provides a summary of company proposals on the open issue marked in red:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel | **Proposal 2: For enhanced PUCCH format 0/1 and 4, support configuration a coarse set of integer values within the range [1.. max(**$N\_{RB}$**)] for each SCS. In particular, for PUCCH format 4 the supported values must fulfill the requirement** $N\_{RB}=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ **where** $α\_{2},α\_{3},α\_{5}$ **is a set of non-negative integers. FFS: on the specific values.** |
| vivo | **Proposal 2: For the configuration of the number of RBs,** $N\_{RB}$**, for enhanced PUCCH formats 0/1/4, the alternative 1 is supported if the maximum RB number is not more than 16.** |
| CATT | **Proposal 4 The configurable RB granularity is preferred for the configuration of the number of RBs.** |
| ZTE | **Proposal 2: The allowed values of N\_RB within the range [1, ..., max(**$N\_{RB}$**)]** **can be flexible, Alt-1 (support configuration of all integer values in the range fulfill the requirement) is preferred in PRB number configuration.** |
| NTT DOCOMO | ***Proposal 3:*** *All integer values for PUCCH format 0/1 and all integer values that fulfill the requirement* $N\_{RB}=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ *where* $α\_{2},α\_{3},α\_{5}$ *is a set of non-negative integers for PUCCH format 4 (Alt-1 in RAN1#104bis-e agreement) should be supported.* |
| Nokia | ***Proposal 5:*** *In case of dedicated PUCCH resource configuration, Alt-1 is supported for the configuration of the number of RBs.* |
| Apple | ***Proposal 2:*** *For enhanced PUCCH formats 0/1/4 and the granularity of the configured values should be based on Alt-1 i.e.,* *For enhanced PF0/1, support configuration of all integer values in the range [1 .. max( )] for each SCS. For enhanced PF4, support configuration of all integer values in the range [1 .. max( )] for each SCS that fulfil the requirement where is a set of non-negative integers.* |
| LGE | **Proposal #2: For the allowed values of NRB, the positive integer values between the min/max NRB can be used for PF0/1 while the allowed values of NRB between the min/max NRB for PF4 can be obtained by applying the DFT constraint.** |
| OPPO | **Proposal 6: Support Alt-1 for configuration granularity on number of RBs for UE dedicated RRC configuration.** |
| Samsung | **Proposal 2: Support configuration of all integer values in the range of [1 .. max(**$N\_{RB}$**)] per SCS, for PUCCH format 0/1. Support configuration of all integer values in the range [1 .. max(**$N\_{RB}$**)] for each SCS that fulfills the requirement** $N\_{RB}=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ **where** $α\_{2},α\_{3},α\_{5}$ **is a set of non-negative integers for PUCCH format 4.**  |
| Huawei | ***Proposal 2: Adopt Alt. 1 for the granularity of the configuration of the number of RBs,*** $N\_{RB}$***, for enhanced PUCCH formats 0/1/4.*** |
| Qualcomm | ***Proposal 2:*** *All integer values for PUCCH format 0/1 and all integer values which fulfill the requirement* $N\_{RB}=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ *for PUCCH format 4 (Alt-1) are supported* |
| Spreadtrum | ***Proposal 1: Support the configuration of all integer values in the range of [1…max(NRB)] for the numbers of contiguous RBs for enhanced PUCCH format 0/1/4 for 120/480/960 kHz SCS.*** |
| Ericsson | **Proposal 8 Support Alt-1 in the agreement from RAN1#104bis-e on the granularity of the configuration of the number of RBs, i.e.,*** **For enhanced PF0/1**
	+ **Support configuration of all integer values in the range [1 .. max(**$N\_{RB}$**)] for each SCS**
* **For enhanced PF4**
	+ **Support configuration of all integer values in the range [1 .. max(**$N\_{RB}$**)] for each SCS that fulfill the requirement** $N\_{RB}=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ **where** $α\_{2},α\_{3},α\_{5}$ **is a set of non-negative integers.**
 |

There seems to be consensus that dedicated signaling is needed for the configuration of the number of RBs. On the issue of configuration granularity, here is a summary of the support for the two alternatives:

* Alt-1
	+ vivo, ZTE, NTT DOCOMO, Nokia, Apple, LGE, OPPO, Samsung, Huawei, Qualcomm, Spreadtrum
* Alt-2
	+ Intel, vivo (if N\_RB > 16)

Since the rapporteur will start collecting needed RRC parameters for this WI after RAN1#106-e, it makes sense to agree on what parameters are needed for enhanced (multi-RB) PUCCH formats 0/1/4. In Rel-16, the moderator points out that for PUCCH formats 2 and 3 which support multiple RBs, the number of RBs for a PUCCH resource is configured within the IE *PUCCH-Config* which is used to configure UE specific PUCCH parameters (per BWP).

As pointed out by some companies, the RRC overhead savings from trying to optimize the granularity of N\_RB is quite small. For example, the difference in overhead required to signal 12 values and 32 values is only 1 bit. Considering that there is flexibility needed to configure the bandwidth of a PUCCH resource depending on the regulatory region, SCS, and the deployment scenario, it does not seem worth it to try to save 1 bit which would limit the deployment flexibility.

Based on this, the moderator makes the following two proposals:

**Proposal 6 Agree to the following:**

* 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

**Proposal 7 Agree to the following:**

* For an RRC parameter that configures the number of RBs for a PUCCH resource for each of enhanced PUCCH formats 0, 1, and 4, support a value range of 1 .. N\_RB\_Max in steps of 1 RB where N\_RB\_Max is the maximum number of RBs per SCS value
* FFS: N\_RB\_Max for each SCS value (120, 480, and 960 kHz)

## 3.1 <1st Round Comments>

Please provide your company view on Proposals 6 and 7.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | We support Proposal 6 and Proposal 7. |
| vivo | We support proposal 7. |
| ZTE, Sanechips | We agree with Proposal 6.For Proposal 7, we are generally fine. It might be better to separately consider PF 4 due to the requirement $N\_{RB}=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ where $α\_{2},α\_{3},α\_{5}$ is a set of non-negative integers. |
| Huawei/HiSilicon | We are fine with Proposal 6 and 7. We would also like to remark that optimization of RRC signalling has never been an issue for RAN1. |
| Lenovo, Motoroloa Mobility | We support both Proposals. |
| Apple | We are fine with both proposals |
| Intel | We support proposal 6, but we are not OK with proposal 7. For proposal 7, we would rather prefer to wait until we conclude the discussion related to the maximum number of PRBs to support. If RAN1 agrees to increase the number of PRBs to values larger than those currently agreed, some of the larger values would never be used, and we beleive Alt. 2 would be more suitable. As we noticed from our LLS evaluations, as the number of PRBs increases the MIL tends saturates, and after some PRB value changing the value of PRB would have marginal effect in coverage, so effectively some PRB values would have same effect, and therefore should not be considered.As for the specific text of proposal 7, we believe that this is missing the restriction for PF4 according with only values that fulfill the requirement $N\_{RB}=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ ,where $α\_{2},α\_{3},α\_{5}$ is a set of non-negative integers, should be considered.  |
| CATT | For P7 we think the step (granuality) should be configurable. |
| Sony | We support Proposal 6 and Proposal 7. |

# 4 Sequence Construction for Enhanced PF0/1

The following agreements were made in RAN1#104-e and RAN1#104bis-e:

Agreement:

* For enhanced PF0/1, support Type-1 low PAPR sequences. Further study and strive to select one of the following alternatives:
	+ Alt-1: 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.
	+ Alt-2: A single sequence of length equal to the number of mapped REs per RB of the PUCCH resource is used, and the sequence is repeated in each RB. At least the following scheme is considered for PAPR/CM reduction:
		- Cycling of cyclic shifts across RBs in a similar way as for Rel-16 for PF0/1 for the case that *useInterlacePUCCH-PUSCH* is configured
* At least the following aspects should be considered in the study
	+ Coverage (maximum isotropic loss (MIL)), including
		- Required SNR to fulfil PUCCH detection criterion
		- PAPR/CM as a function of N\_RB
	+ Specification impact

For the PF0/1 sequence, the main open issue is which sequence construction method should be supported:

* Alt-1: A single long sequence
* Alt-2: Sequence repeated in each RB + cyclic shift cycling for PAPR/CM mitigation

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel | **Proposal 6: For PUCCH format 0 and 1, the sequence is generated by using a Type-1 low PAPR sequence****of length equal to the number of subcarriers over which the PUCCH spans across.** |
| Futurewei | ***Proposal 11: For cases with N\_RB < 12, only Alt-1 one is supported, and consider Alt-2 as the only supported alternative for cases with N\_RB ≥ 12, unless it is strongly favored by the majority that only one alternative should be supported for all N\_RB values, in which case we slightly lean towards supporting Alt-1 only.*** |
| vivo | **Proposal 6:** **For enhanced PUCCH format 0/1, the alt 1 of a single sequence of length equal to the total number of mapped REs of the PUCCH resource is preferred.****Proposal 7：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.** |
| CATT | **Proposal 2 The method to reduce the PAPR should be supported if repetitive sequences are adopted.****Proposal 3 For enhanced PUCCH format 0/1 sequence, Alt1 (long sequences) is preferred to keep similar CM for sequences with different lengths.** |
| Lenovo/Motorola Mobility | ***Proposal 2: For NR operation between 52.6 GHz and 71 GHz, PUCCH format 0 transmitted with multiple number of (same) base sequences with different phase shifts should be supported for mapping to multiple RBs******Proposal 3: For NR operation between 52.6 GHz and 71 GHz, Rel 15 based long sequence should be considered for PUCCH formats 0/1 for mapping to multiple RBs******Proposal 4: For NR operation between 52.6 GHz and 71 GHz, PUCCH format 0 should be enhanced to support 2-bit transmission with 1 symbol by mapping to 2 RBs******Proposal 5: For NR operation between 52.6 GHz and 71 GHz, a combination of repetition and longs sequence could be supported for mapping on multiple RBs for PUCCH format 0/1*** |
| ZTE | **Proposal 6: Regarding the PUCCH format 0/1 sequence type selection, Alt1 (a single long sequence) is preferred.** |
| NTT DOCOMO | ***Proposal 5:*** *Alt.1 (a single sequence of length equal to the total number of mapped REs of the PUCCH resource) should be supported for enhanced PUCCH format 0/1.* |
| Nokia | ***Proposal 2:*** *Support Alt-1 sequence construction: a single sequence of length equal to the total number of mapped REs for PUCCH Format 0/1 resources* |
| Sony | **Proposal 1: Since the MIL criterion alone cannot be used to down select between Alt-1 and Alt-2 enhanced PF0/1 sequences, consider UE multiplexing for down selection between Alt-1 and Alt-2.****Proposal 2. Given that in practice, Alt-1 and Alt-2 display the very similar performance in terms of MIL, support Alt-2 to enable efficient multiplexing of UEs with different configured values of** $N\_{RB}$**.**  |
| Apple | ***Proposal 4:*** *For enhanced PF0/1, RAN1 should support Alt 1 i.e. a single Type-1 low PAPR sequence of length equal to the total number of mapped REs of the PUCCH resource. Cyclic shifts for PF0/1 are defined in the same way as Rel-16 for the case that useInterlacePUCCH-PUSCH is not configured.****Proposal 5:*** *RAN1 should use the increased resources used for PF0/1 PUCCH transmission for coverage enhancement and not for a payload increase.* |
| LGE | **Proposal #5: Considering better MIL performance and improved coverage of multi-PRB based initial PUCCH for the specific RB range (e.g., NRB around 12-16), support Alt-2 (a single sequence of length equal to the number of mapped REs per RB with the step size ∆ = 5 for the cycling of cyclic shifts across RBs) for the sequence type for enhanced PUCCH format 0/1 in 60 GHz.** |
| Qualcomm | **Proposal 1: Support Alt-2 for base sequence type when PUCCH format 0/1 occupies more than one RB.** |
| OPPO | **Proposal 7: Adopt long sequence for PUCCH format 0 and format 1 when N\_RB>1.**  |
| Samsung | **Proposal 3: Support Alt-2 (Rel-16 NR-U short sequence with repetition) for PUCCH format 0/1.**  |
| Huawei | ***Observation 6: Using a repeated DMRS sequence of length-12 with phase ramp for CM/PAPR reduction offers better UE multiplexing than a single sequence. The 95-percentile CM is at most 2 dB worse for allocations below 9 PRBs.*** ***Observation 7: When considering the regional limitations, there is no or very small (< 1 dB) difference in maximum transmit power between using a single sequence or a repeated sequence of length-12 with phase ramp for CM/PAPR reduction.***Moderator note: Corresponding proposal is missing; however, the moderator assumes that Huawei proposes Alt-2.Huawei: We see merits of both proposals. |
| Interdigital | ***Proposal 3:*** *It is preferred to support a single sequence of length equal to the total number of mapped REs of the PUCCH resource (Alt-1) for PUCCH format 0/1.* |
| WILUS | * *Proposal 2: For low PAPR sequence for enhanced PUCCH format 0/1 (PF0/1), we support Alt-2 that a single sequence of length equal to the number of mapped REs per RB of the PUCCH resource is used, and the sequence is repeated in each RB with cycling of cyclic shifts across RBs in a similar way as for Rel-16 for PF0/1.*
 |
| MediaTek | Proposal 1: Alternative 1 should be adopted as the base sequence design for enhanced PUCCH format 0/1. |
| Spreadtrum | *Proposal 3: For enhanced PF0/1, Alt -2 should be supported in order to reduce the impact of the specification.* |
| Ericsson | Proposal 9 In the agreement from RAN1#104-e on sequence construction for enhanced PF0/1, support Alt-1, i.e., reuse the Rel-15 rules to select base sequences based on Low-PAPR sequence Type-1 defined in 38.211 Section 5.2.2. Do not support repeated sequences with cyclic shift cycling (Alt-2). |

In the previous meeting, it was decided to wait until there is further input from RAN4 on the maximum number of RBs. As discussed above, at least some feedback has now been received.

The following is a high level summary of company evaluations comparing Alt-1 vs. Alt-2.

|  |  |
| --- | --- |
| **Company** | **Evaluation summary** |
| Intel | * Alt-1 performance in terms of MIL meets or exceeds Alt-2 performance considering a wide range of RBs (1 – 40)
* For 480/960 kHz the gain for Alt-1 vs. Alt-2 is larger than for 120 kHz
 |
| vivo | * Alt-1 performance in terms of MIL meets or exceeds Alt-2 performance for 3 combinations of (UE\_EIRP, UE\_P) considering up to 18 RBs
	+ (25, 21) dBm
	+ (40, 21) dBm
	+ (43, 23) dBm
* For 480/960 kHz the gain for Alt-1 vs. Alt-2 is larger than for 120 kHz
 |
| Lenovo | * Alt-1 and Alt-2 performance in terms of MIL are comparable considering up to 4 RBs and (UE\_EIRP, UE\_P, TxBF) = (40 dBm, 25 dBm, 0 dBi)
 |
| ZTE | * Alt-1 and Alt-2 have comparable MIL performance for 120 kHz considering 12 RB
* Alt-1 has larger MIL than Alt-2 for 480/960 kHz
	+ 1.5 dB gain for 3 RBs for 480 kHz
	+ 1 dB gain for 2 RBs for 960 kHz
 |
| Nokia | * Alt-1 performance meets or exceeds Alt-1 performance considering up to 16/5/4 RBs for 120/480/960 kHz SCS and UE\_EIRP = 25 dBm
	+ 0.3 – 0.9 dB gain for Alt-1 for 2 and 4 RBs in Europe for 120 kHz and in all regions for 480/960 kHz
 |
| Sony | * With (UE\_EIRP, UE\_P, TxBF) = (25 dBm, 21 dBm, 6 dBi):
	+ 120 kHz
		- Larger transmit power achievable for Alt-1 compared to Atl-2 for PUCCH bandwidth up to 100 MHz, except for 15 – 25 MHz bandwidth where Alt-2 allows up to 1 dB larger transmit power
	+ 480 kHz
		- Larger transmit power achievable for Alt-1 compared to Alt-2 for all PUCCH bandwidths up to 60 MHz. For 60 – 100 MHz bandwidth, Alt-2 allows up to 1 dB larger transmit power
	+ 960 kHz
		- Larger transmit power achievable for Alt-1 compared to Alt-2 for all PUCCH bandwidths up to 100 MHz
 |
| Qualcomm | * With (UE\_EIRP, UE\_P, TxBF) = (25 dBm, 21 dBm, 6 dBi)
	+ 120 kHz:
		- Comparable transmit power between Alt-1 and Alt-2 up to 20 RBs, except for 11 – 16 RBs where Alt-2 allows up to 0.3 dB larger transmit power
	+ 480 kHz:
		- Alt-1 can achieve 1.5 dB higher power for 3 RBs (comparable power for 1,2 RBs)
	+ 960 kHz:
		- Alt-1 can achieve 1 dB Db higher power for 2 RBs (comparable power for 1 RB)
* With (UE\_EIRP, UE\_P, TxBF) = (40 dBm, 21 dBm, 6 dBi)
	+ 120 kHz:
		- Comparable transmit power between Alt-1 and Alt-2 up to 20 RBs, except for 11 – 17 RBs where Alt-2 allows 0.3 – 1.5 dB larger transmit power
 |
| OPPO | * 120 kHz (Considered 12 and 32 RBs)
	+ For 12 RBs: comparable MIL for DS = 10, 20 ns. Alt-2 has 0.5 dB gain for 5 ns
	+ For 32 RBs: Alt-1 has 0.5 – 1.5 dB gain depending on DS
* 480 kHz (Considered 3 and 8 RBs)
	+ Alt-1 has 0.5 – 1.5 dB gain depending on OS and number of RBs
* 960 kHz (Considered 2 and 4 RBs)
	+ Alt-1 has 1 – 1.5 dB gain depending on OS and number of RBs
 |
| Huawei | * MIL comparison for 120 kHz considers 4 and 8 RBs
	+ USA
		- Comparable MIL
	+ EU
		- Alt-1 has 0.4 – 1.4 dB gain compared to Alt-2 depending on number of RBs
 |
| Ericsson | * MIL comparison for 480kHz considers up to 3 RBs
	+ US/SK: Alt-1 has 1.5 dB (US) larger MIL for 3 RBs; comparable MIL for 1,2 RBs
	+ Europe: Alt-1 has 0.8 – 1.3 dB (Europe) larger MIL for 2 and 3 RBs; comparable MIL for 1 RB
 |

Moderator observations based on contributions and reported evaluations:

* Spec complexity
	+ Both Alt-1 and Alt-2 can be seen as extensions of Rel-15 or 16, so no real difference in spec complexity
	+ Alt-1: Used for DMRS of PF3 in Rel-15/16
	+ Alt-2: Used for PF0/1 in Rel-16 when interlacing configured
* MIL performance
	+ 120 kHz
		- MIL for Alt-1 is either comparable or exceeds MIL for Alt-2 for a wide range of N\_RB values (up to 40 RBs)
			* The exception is for the case of N\_RB in the range 12 – 16 RBs where Alt-2 can exceed the MIL of Alt-1 if UE\_EIRP is increased
		- In all cases, the difference in MIL between Alt-1 and Alt-2 is within approximately 1.5 dB
	+ 480/960 kHz:
		- MIL for Alt-1 exceeds MIL for Alt-2 over all practical values for N\_RB
		- The difference in MIL between Alt-1 and Alt-2 is within 1.5 dB
* Multiplexing of users with misaligned RB allocations
	+ Some companies observe that Alt-2 offers better opportunities for multiplexing users with misaligned RB allocations, where “misaligned” also includes users with different number of RBs.
	+ Other companies state that user multiplexing is not important in the 52.6 – 71 GHz band and refer to the agreement from RAN1#104bisi-e that user-multiplexing has lower priority as a design criterion compared to MIL

Discussion Point

It seems that the decision point on Alt-1 vs. Alt-2 comes down to a trade-off coverage vs. multiplexing of users with misaligned RB allocations.

* Alt-1:
	+ Better coverage for 480, 960 kHz SCS
	+ Potentially better coverage for 120 kHz for N\_RB less than 12 depending on regulatory region
	+ Degraded coverage for 120 kHz for N\_RB = 12 .. 16 RBs if UE\_EIRP does not limit transmit power
	+ Cannot multiplex users with mialigned RB allocations
* Alt-2:
	+ Can multiplex users with misaligned RB allocations
	+ Better coverage for 120 kHz for N\_RB = 12 .. 16 RBs if UE\_EIRP does not limit transmit power
	+ Degraded coverage for 480, 960 kHz SCS
	+ Potentially degraded coverage for 120 kHz for N\_RB less than 12 depending on regulatory region

The following is a summary of support for Alt-1 and Alt-2

* Alt-1:
	+ Intel, Futurewei (if only 1 alternative selected), vivo, CATT, Lenovo(?), ZTE, NTT DOCOMO, Nokia, Apple, OPPO, Interdigital, MediaTek, Ericsson
* Alt-2:
	+ Futurewei (if both alternatives selected), Lenovo(?), Sony, LGE, Qualcomm, Samsung, ~~Huawei~~, WILUS, Spreadtrum

**Proposal 2 Further discuss down-selection to one of Alt-1 and Alt-2**

## 4.1 <1st Round Comments>

Please provide your company view on Proposal 2, particularly with respect to the above Discussion Point on trade-off between coverage and multiplexing of users with misaligned RB allocations.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | As discussed in our contribution, since the number of UEs served simultaneously via the same beam can be rather limited, we do not see a need for supporting multiplexing of users with misaligned RB allocations with enhanced PUCCH formats 0/1. |
| vivo | We still support alt1.As summaried by FL, alt 1 has better coverage for 480, 960 kHz SCS than alt 2. Regarding 120kHz SCS, similar MIL is observed for alt 1 and alt 2. The debate is on multiplexing capability or multiplexing users with misaligned RB allocations. As a step forward of proposal 2, we propose to first agree with support alt 1 for 480kHz and 960kHz SCS. Down-select for 120kHz, once we know more about the maximum of RBs. |
| ZTE, Sanechips | We agree with Proposal 2. There is no need to define 2 kinds of sequence types for above 52.6GHz which requires larger spec efforts. Among the 2 alternatives, we support Alt1 considering the better coverage in most cases. |
| Huawei/HiSilicon | We see merits with both proposals but prefer that just one of them is selected. |
| Lenovo, Motoroloa Mobility | We prefer Alt1, as it has been shown in our contribution that simple frequency domain repetition shows significant increase of PAPR and CM comparing to long sequence-based approach which results in different link budget. However, we are also fine with Alt 2, if a combination of repeitition and long sequence is supported. For example, the long sequence is used for multiple RBs (but not total RBs) and then repetiting the long sequence to occupy total RB allocation. |
| Apple | We also think that there should be a down-selection. We prefer Alt 1 |
| Intel | We support Alt-1, and we share the same view as Nokia regarding the need of multiplexing, which has been already agreed should be considered with lower priority compared to MIL when down-selecting among options: Agreement:User-multiplexing can be considered but as lower priority compared to maximum isotropic loss for PUCCH as a design criterion. |
| CATT | We still support alt1. No need for optimization of multiplexing user. |
| Sony | As pointed out in the moderator summary, both Alt-1 and Alt-2 are already part of Rel-15 or Rel-16; hence, there is no added complexity if both alternatives are kept. Given that it has proven difficult to reach a consensus on this issue, we are open to keeping both sequence constructions in Rel-17, if this would facilitate an agreement. On the other hand, if the majority of companies prefers to downselect to only one alternative, then we prefer Alt-2. As discussed in our contribution, both Alt-1 and Alt-2 offer similar performance in terms of coverage (i.e., MIL), but only Alt-2 can multiplex UEs with misaligned RB allocations. |

# 5 RE Mapping for Enhanced PF0/1/4 for 120 kHz SCS

Agreement:

* For 120 kHz SCS:
	+ Support at least Alt-1 for enhanced PF0/1 for both PUCCH resources before and after dedicated PUCCH resource configuration
	+ FFS: Whether or not Alt-2 is additionally supported for PF0/1 for either or both of the following:
		- PUCCH resources before dedicated PUCCH resource configuration
		- PUCCH resources after dedicated PUCCH resource configuration
	+ FFS: Supported RE mapping scheme(s) amongst {Alt-1, Alt-2} for enhanced PF4 including design details
* Notes:
	+ Alt-1 = all REs within each RB are mapped
	+ Alt-2 = a subset of REs within each RB are mapped (sub-PRB interlaced mapping)
	+ Which RE mapping scheme(s) to support for PF0/1/4 to be concluded in RAN1#106
* Note: No further enhancements on RB shortage issue and frequecy hopping distance issue should be considered for PUCCH resource sets prior to RRC configuration.

The open issues are:

* Decide whether or not to additionally support Alt-2 for PF0/1 before/after dedicated PUCCH resource configuration
* Decide which amongst Alt-1, Alt-2 are supported for DMRS of PF4

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel | **Proposal 4: For the enhanced (multi-RB) PUCCH formats 0/1 for 120 kHz SCS only mapping over all REs within each RB is supported.** **Proposal 5: For the enhanced (multi-RB) PUCCH formats 4 for 120 kHz SCS all REs within each RB are mapped.** |
| Futurewei | ***Proposal 2. For PF0/1, consider support Alt-2 additionally for 120kHz SCS only if it provides notable MIL gain over Alt-1; for PF4, support one alternative that has better MIL for more cases, and we are inclined to Alt-1 based on the simulation results******Proposal 3. Alt-2 can be considered for before and after dedicated PUCCH resource configurations only if notable MIL gain is observed. If there is only marginal MIL gain or no MIL gain over Alt-1, Alt-2 should not be supported for either before or after PUCCH resource allocation.******Proposal 4. For PF0, sub-PRB resource mapping can provide marginal MIL gains for 120kHz SCS, thus can be considered for both before and after dedicated PUCCH resource configurations******Proposal 5. Support only the full-RE resource mapping for PF1. Sub-PRB resource mapping for PF1 is not considered due to inferior MIL performance.*** ***Proposal 6. Support only the full-RE resource mapping for PF4. Sub-PRB resource mapping for PF4 should not be supported ~~for~~ due to its inferior MIL performance.***  |
| vivo | **Proposal 8: For enhanced PUCCH format 0/1, for 120 kHz SCS, we additionally support alt 2 for RE mapping for PUCCH resource after dedicated PUCCH resource configuration.** **Proposal 10: For DMRS of PUCCH format 4, the sub-PRB interlaced mapping should be supported.** |
| ZTE | **Proposal 3: Sub-PRB mapping is not supported for PF0/1.****Proposal 4: Sub-PRB mapping is not supported for DMRS of PF4.** |
| NTT DOCOMO | ***Proposal 4:*** *Alt-1 should be supported for enhanced PF0/1/4 for both PUCCH resources before and after dedicated PUCCH resource configuration.* |
| Nokia | ***Proposal 3:*** *For 120 kHz SCS, all REs within each RB are mapped also for enhanced PUCCH format 4 (i.e. Alt-1).****Proposal 4:*** *Multiple RE mapping schemes are not supported for enhanced PUCCH format 0/1/4 .* |
| Apple | ***Proposal 3:*** *To ensure consistent design across all SCSs, for 120 kHz SCS, all REs within each RB are mapped.* |
| LGE | **Proposal #1: Considering the inter-modulation distortion (IMD) issue for the sub-PRB interlaced mapping and the implementation complexity to support two different RE mapping methods, support only Alt-1 (i.e., all REs within each RB are mapped) as the unified RE mapping for all PUCCH format 0/1/4 and for both PUCCH resources before and after dedicated PUCCH resource configuration.** |
| Samsung | **Proposal 3: Support Alt-1 (full-PRB mapping) for PUCCH format 0/1/4.** |
| Huawei | ***Proposal 3: Sub-PRB interlaced mapping is not introduced for 120 kHz SCS.*** |
| Interdigital | ***Proposal 4:*** *It is preferred to support all RE mapping for DMRS of PUCCH format 4 with 120 kHz SCS as well as other enhanced PUCCH formats.* |
| WILUS | * *Proposal 1: The interlaced or sub-PRB interlaced design even for enhanced PF4 seems not necessary to apply to 60GHz unlicensed spectrum from the perspective of power boosting in the new numerologies, i.e., 480kHz, 960kHz, and 120kHz SCS.*
* *We support Alt-1 even for enhanced PF4 in addition to support of Alt-1 for PF0/1 which was already agreed at the RAN1#105-e meeting.*
	+ *Alt-1: All REs within each RB are mapped.*
		- *Note: PRB and sub-PRB interlaced mapping is not considered further.*
 |
| MediaTek | Proposal 2: Support only Alt-1 as the RE mapping scheme for enhanced PUCCH format 4. |
| Spreadtrum | ***Proposal 2: For enhanced (multi-RB) PUCCH Formats 0/1/4 for 120 kHz SCS, support allocation of N\_RB contiguous RBs in which all Res within each RB are mapped. Sub-PRB interlaced mapping is not considered further.*** |
| Ericsson | **Proposal 4 Do not support sub-PRB interlace mapping (Alt-2) for PUCCH Formats 0/1 either before or after RRC configuration.****Proposal 5 Do not support sub-PRB interlace mapping (Alt-2) for DMRS of PUCCH Format 4.** |

The following is a high level summary of company evaluations:

|  |  |
| --- | --- |
| **Company** | **Evaluation summary** |
| Intel | * PF0
	+ MIL evaluated assuming US, Europe, and SK regulations
	+ Compared Alt-1 vs. Alt-2 (Comb-2 pattern) for two different sequence constructions (single long sequence, repeated sequence + CSC)
	+ N\_RB ranges from 1 .. 40
	+ Delay spread 5 ns and 40 ns
	+ **MIL loss for Alt-2**
 |
| Futurewei | * MIL evaluated assuming US and SK regulations
* Compared Alt-1 vs. Alt-2 (Comb-2, 4, and 6)
* N\_RB = 1, 2, 4, 8, 16, 22
* 10 ns Delay spread
* PF0
	+ **MIL gain for Alt-2 ranging from -1.5 .. 2 dB depdending on # of RBs and Comb 2, 4, or 6**
	+ Gain increases as comb becomes more sparse
* PF1
	+ Comparable MIL between Alt-1 and Alt-2 for N\_RB = 22
	+ **MIL loss for Alt-2 ranging from 0.5 .. 3 dB depending on # of RBs and Comb 2, 4, or 6**
	+ Loss increases as the comb becomes more sparse
* DMRS of PF4
	+ **MIL loss for Alt-2 ranging from 0.5 .. 7 dB depending on # of RBs and Comb 2, 4, or 6**
	+ Loss increases as the comb becomes more sparse
 |
| vivo | * PF0
	+ Compared Alt-1 (called Alt 1-2) vs. Alt-2 (called Alt 2-1)
	+ N\_RB = 2
	+ Multiplexing of 2 users
		- Alt-1: CDM mux (2 users use different cyclic shifts)
		- Alt-2: FDM mux (Comb-2 with 1 user on each comb)
	+ Comparable MIL for Alt-1 and Alt-2 if UE powers are balanced
	+ **Alt-2 has ~3 dB MIL gain in US/SK if UE receive powers are imbalanced by 3 (?) dB**
* DMRS of PF4
* Compared Alt-1 vs. Alt-2 for 3 combinations of (UE\_EIRP, UE\_P) considering up to 18 RBs
	+ (25, 21) dBm
	+ (40, 21) dBm
	+ (43, 23) dBm
* 4, 11, 22 bit payload
* 14 OFDM symbols
* Delay spread 10 ns
* **MIL gain for Alt-2 of 0.5 – 2 dB (dependent on payload, delay spread)**
 |
| ZTE | * PF0
	+ MIL evaluated assuming SK regulations
	+ Compared Alt-1 vs. Alt-2 (Comb 2 or 12)
	+ 5, 10, 20 ns delay spread
	+ **MIL loss for Alt-2 of ~ 1dB**
* DMRS of PF4
	+ MIL evaluated assuming US, EU, SK regulations
	+ Compared Alt-1 vs. Alt-2 (Comb 2)
	+ Considered 0 and 3 dB power boosting for DMRS for Alt-2
	+ 4, 11, 22 bit payload
	+ 5, 10, 20 ns delay spread
	+ **Comparable performance for Alt-1 vs. Alt-2 when 3 dB power boosting is used for DMRS in Alt-2**
 |
| Ericsson | * PF0
	+ MIL evaluated assuming US and EU regulations
	+ Compared Alt-1 vs. Alt-2 (Comb-2)
	+ 2,4,6,8,10,12 RBs
	+ 5 ns and 40 ns delay spread
	+ **Comparable performance between Alt-1 and Alt-2**
* PF0 when multiplexing 2 users
	+ MIL evaluated assuming US and EU regulations
	+ Multiplexing of 2 users
		- Alt-1: CDM mux (2 users use different cyclic shifts)
		- Alt-2: FDM mux (Comb-2 with 1 user on each comb)
	+ Considered balanced and imbalanced (3 dB) Rx powers between UE1 and UE2
	+ 10 RBs
	+ 5 and 20 ns delay spread
	+ **Comparable performance between Alt-1 and Alt-2 for both balanced and imbalanced Rx powers**
* DMRS of PF4
	+ MIL evaluated assuming US and EU regulations
	+ Compared Alt-1 vs. Alt-2
	+ Multiplexing of 2 or 4 users
		- Comb-2 for DMRS used when OCC2 for UCI is configured
			* 2 users multiplexed
		- Comb-4 for DMRS used when OCC4 for UCI configured
			* 4 users multiplexed
	+ 3 dB power boosting for DMRS for Alt-2
	+ 10 RBs
	+ 4, 11, 22 bit payload
	+ 5 and 20 ns delay spread
	+ **Comparable performance between Alt-1 vs. Alt-2**
 |

In summary:

* For PF0
	+ Two companies (vivo, Futurewei) found a MIL gain for Alt-2
		- One company (vivo) found that the gain occurs when the received powers for 2 users are imblanced (no gain for balanced received powers)
	+ Two companies (Intel, ZTE) found a MIL loss for Alt-2
	+ One company (Ericsson) found comparable MIL for Alt-1 and Alt-2 for both balanced and imbalnced receive powers for 2 users
* For PF1
	+ One company (Futurewei) found a MIL loss for Alt-2
* For DMRS of PF4
	+ One company (vivo) found a MIL gain for Alt-2
	+ Two companies (ZTE, Ericsson) found comparable MIL for Alt-1 and Alt-2 when 3 dB power boosting is used for DMRS

The following is a summary of support for Alt-1 and Alt-2 based on company contributions:

For PF0/1 for PUCCH resources after RRC configuration:

* Alt-1 only:
	+ Intel, ZTE, NTT DOCOMO, Nokia, Apple, LGE, Samsung, Huawei, Interdigital, WILUS, Spreadtrum, Ericsson
* Alt-1 + Alt-2:
	+ vivo, Futurewei (PF0 only)

For PF0/1 for PUCCH resource sets prior to RRC configuration:

* Alt-1 only:
	+ Intel, ZTE, NTT DOCOMO, Nokia, Apple, LGE, Samsung, Huawei, Interdigital, WILUS, Spreadtrum, Ericsson
* Alt-1 + Alt-2:
	+ Futurewei (PF0 only)

For DMRS of PF4:

* Alt-1:
	+ Intel, ZTE, NTT DOCOMO, Nokia, Apple, LGE, Samsung, Huawei, Interdigital, WILUS, MediaTek, Spreadtrum, Ericsson
* Alt-2:
	+ vivo

**Proposal 3 For PF0/1 for PUCCH resources after RRC configuration, further discuss and decide by end of RAN1#106-e whether or not Alt-2 is supported in addition to Alt-1.**

**Proposal 4 Agree to the following:**

* For PF0/1 for PUCCH resource sets prior to RRC configuration, Alt-2 (sub-PRB interlaced mapping) is not supported.

**Proposal 5 For DMRS of PF4, further discuss and down-select by end of RAN1#106-e one of Alt-1 and Alt-2.**

## 5.1 <1st Round Comments>

Please provide your company view on Proposasl 3, 4, 5:

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | We are ok with the proposals. Ideally we should decide already before the end of the meeting. |
| vivo | We are okay with proposal 3, 4, and 5.As we discussed, Alt 2 has the benefit when UE multiplexing is considered. We propose to support it along with Alt 1 to cover all possible senarios.Espeacially for DMRS for PF4, as summaried by the FL, no evaluation results showed any MIL performance loss of Alt 2.  |
| ZTE, Sanechips | We agree with Proposal 3, 4, and 5. Alt2 should be excluded for PF0/1/4 for PUCCH resources prior to/after RRC configuration. |
| Huawei/HiSilicon | We are fine with Proposal 4. Regarding Proposal 3 and 5, while this is a good intention of what RAN1 should do, explicitly making such intermediate proposals has limited value, in our view. |
| Lenovo, Motoroloa Mobility | We agree with Proposal 3,4, and 5. |
| Apple | We are fine with the proposals |
| Intel | We are OK with the FL’s proposals.  |
| CATT | Support the proposals |
| Sony | We are ok with P3, P4, P5. |

# 6 Payload Limitation and Rate Matching for PF4

## 6.1 Maximum UCI Payload for PF4

In 38.214, it is specified that the UE is not expected to report CSI when the total number of UCI + CRC bits larger than 115 when configured with PF4.

A UE is not expected to report CSI with a total number of UCI bits and CRC bits larger than 115 bits when configured with PUCCH format 4. For CSI reports transmitted on a PUCCH, if all CSI reports consist of one part, the UE may omit a portion of CSI reports. Omission of CSI is according to the priority order determined from the Prii,CSI(*y,k,c,s*) value as defined in Clause 5.2.5. CSI report is omitted beginning with the lowest priority level until the CSI report code rate is less or equal to the one configured by the higher layer parameter *maxCodeRate*.

In the last meeting it was discussed whether or not this limitation should be lifted for enhanced (multi-RB) PF4.

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel | **Proposal 7: For enhanced PUCCH format 4, rate matching to N PRBs without changing UCI limitation is supported (Alt-1).** |
| Futurewei | ***Proposal 7: From the standard effort perspective, it is recommended to keep the same restriction (upper limit) on the UCI payload for PF4, and use PF3 for a larger UCI payload, similar to Rel-16.***  |
| ZTE | **Proposal 7: Rate matching can be performed over N PRBs, and the UCI payload limitation can be relaxed.** |
| NTT DOCOMO | ***Proposal 6:*** *The same CSI payloads upper limit as in Rel-15/16 should be supported for PUCCH format 4with multi-PRB allocation.*  |
| Apple | ***Proposal 6:*** *For rate matching in enhanced PF4** *Support same restriction (upper limit) on the UCI payload as in Rel-15/16 PF4*
* *Rate matching to the configured number of RBs N\_RB (similar to Rel-16 rate matching to the fixed number of RBs N = 10/11 of an interlace for PF3)*
 |
| Qualcomm | We iterate our views that for UCI payload, we support Alt-a, as PUCCH enhancement in this WI is to increase coverage rather than capacity. Moderator's note: Alt-a corresponds to "Suppport same restriction for PF4 as in Rel-15/16" |
| OPPO | **Proposal 8: for enhanced PF4, maintain the same UCI payload limitation.** |
| Samsung | **Proposal 4: Support rate matching over all configure RBs with existing UCI upper limit for PUCCH format 4.**  |
| Huawei | ***Proposal 5: Increase the UCI payload upper limit and do rate matching across the whole configured PRBs for enhanced PUCCH format 4.*** |
| MediaTek | **Proposal 3: Support same restriction (upper limit) on the UCI payload as in Rel-15/16 for PF4** |
| Ericsson | **Observation 3 It is not necessary to remove the PUCCH payload limitation of 115 bits for enhanced (multi-RB) PF4 since the objective of the WI is to increase coverage for existing payloads.** |

The following two alternatives are identified, and the company support is as follows:

* Alt-1: Maintain same maximum UCI payload for PF4 as in Rel-15/16 (115 bits)
	+ Intel, Futurewei, NTT DOCOMO, Apple, Qualcomm, OPPO, Samsung, MediaTek, Ericsson
* Alt-2: Increase the maximum UCI payload for PF4
	+ ZTE, Huawei

For those companies preferring Alt-1, the rationale is that the objective is to increase coverage for PF4, and that PF3 can be used for larger payloads. For those companies preferring Alt-2, the rationale is that if multiple RBs are supported, then those RBs can be used to carry larger payload.

**Conclusion 1 Conclude on the following:**

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

### 6.1.1 <1st Round Comments>

Please provide your company view on the Conclusion 1. If your have concerns with the conclusion, please indicate what is your proposal for the increased payload size for PF4.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | We support the Conclusion 1, for maximized commonality with the existing specs. |
| vivo | We support conclusion 1. |
| ZTE, Sanechips | We are fine with Conclusion 1 considering the majority’s view. |
| Huawe/HiSilicon | The advantage of increasing the maximum UCI payload is more, or better, CSI reports. It appears to be a trivial specification change to achieve that. Increasing the UCI limit may not be compromising coverage since ultimately the gNB will configure the number of PRBs and the CSI reporting mode.  |
| Apple | We are fine with the conclusion |
| Intel | We support the FL’s conclusion, and we do not see any technical merit in lifting the Rel.16 restriction for the UCI payload limit for PF4. In case a larger payload would need to be used PF3 could be used, which was engineered for this purpouse. |
| CATT | Support the conclusion. |

## 6.2 Rate Matching for PF4

The following agreement was made in RAN1#104-e

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: $N=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ where $α\_{2},α\_{3},α\_{5}$ 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

According to this agreement, when the UE is configured with NRB > 1 for PF4, the actual number of RBs is always equal to the configured number, i.e., NRB does not vary dynamically based on PUCCH payload as it does for PF3 in Rel-15. This is the same situation as for PF2/3 in Rel-16 for the case when interlacing is configured. For example, when a single interlace is configured for interlaced PF2/3, the number of RBs is fixed at 10 or 11 (see 38.211 Section 6.3.2.6.3). This means that as the PUCCH payload varies, the code rate varies, thus rate matching is performed according to the fixed number of RBs. This is captured in 38.212 Section 6.3.1.4 as follows:

6.3.1.4 Rate matching

For PUCCH formats 2/3/4, the total rate matching output sequence length  is given by Table 6.3.1.4-1, where  , , and  are the number of symbols carrying UCI for PUCCH formats 2/3/4 respectively;  and  are the number of PRBs that are determined by the UE for PUCCH formats 2/3 transmission respectively according to Clause 9.2 of [5, TS38.213]; and $N\_{SF}^{PUCCH,2}$, $N\_{SF}^{PUCCH,3}$, and  are the spreading factors for PUCCH format 2, PUCCH format 3, and PUCCH format 4, respectively.

* **Table 6.3.1.4-1: Total rate matching output sequence length **

|  |  |
| --- | --- |
| ***PUCCH format*** | ***Modulation order*** |
| QPSK | π/2-BPSK |
| PUCCH format 2 | $$16∙N\_{symb,UCI}^{PUCCH,2}∙N\_{PRB}^{PUCCH,2}/N\_{SF}^{PUCCH,2}$$ | N/A |
| PUCCH format 3 | $$24∙N\_{symb,UCI}^{PUCCH,3}∙N\_{PRB}^{PUCCH,3}/N\_{SF}^{PUCCH,3}$$ | $$12∙N\_{symb,UCI}^{PUCCH,3}∙N\_{PRB}^{PUCCH,3}/N\_{SF}^{PUCCH,3}$$ |
| PUCCH format 4 | $$24∙N\_{symb,UCI}^{PUCCH,4}/N\_{SF}^{PUCCH,4}$$ | $$12∙N\_{symb,UCI}^{PUCCH,4}/N\_{SF}^{PUCCH,4}$$ |

In the last meeting, primarily two alternatives were discussed for rate matching for multi-RB PF4

* Alt-1: Rate matching to *N*RB RBs, similar as for PF2/3 in Rel-16 when interlacing is configured
* Alt-2: Rate matching to 1 RB as in Rel-15/16, followed by repetition of the coded bits in each of the configured RBs

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel | **Proposal 7: For enhanced PUCCH format 4, rate matching to N PRBs without changing UCI limitation is supported (Alt-1).** |
| Futuruewei | ***Proposal 8: Consider repetition as a new rate matching mechanism for the small payload case only if the final agreed value of maximum NRB is larger than 16.*** ***Proposal 9: For standard effort consideration, not to further investigate other rate matching mechanisms except for repetition despite the potentially agreed value of maximum NRB*** |
| vivo  | **Proposal 11:** **The rate matching to the configured number of RBs should be supported for enhanced PF4.** |
| ZTE | **Proposal 7: Rate matching can be performed over N PRBs, and the UCI payload limitation can be relaxed.** |
| NTT DOCOMO | ***Proposal 7:*** *Similar rate matching mechanism to NR-U PF3 interlaced mapping with 10/11 RBs, i.e., rate matching to the configured number of RBs, should be supported.* |
| Apple | ***Proposal 6:*** *For rate matching in enhanced PF4** *Support same restriction (upper limit) on the UCI payload as in Rel-15/16 PF4*
* *Rate matching to the configured number of RBs N\_RB (similar to Rel-16 rate matching to the fixed number of RBs N = 10/11 of an interlace for PF3)*
 |
| Qualcomm | For rate matching mechanism for enhanced PF4, we support Alt-a, as it is beneficial to leverage the same rate matching mechanism as interlaced PF3, which is already supported in Rel-16Moderator's note: Alt-a corresponds to Alt-1 above (rate matching to N\_RB RBs) |
| OPPO | **Proposal 9: for enhanced PF4, add bit level diversity and rate-match over N\_PRB.**  |
| Samsung | **Proposal 4: Support rate matching over all configure RBs with existing UCI upper limit for PUCCH format 4.**  |
| Huawei | ***Proposal 5: Increase the UCI payload upper limit and do rate matching across the whole configured PRBs for enhanced PUCCH format 4.*** |
| MediaTek | **Proposal 4: Support rate matching to the number of allocated RBs using existing rate matching mechanism for PF4.**Moderator Note: The moderator assumes that MediaTek's proposal is Alt-1 due to the following statement prior to Proposal 4: "Rate matching should be done via the existing rate matching mechanisms that rate matches to the number of allocated RBs. It is worth noting that repetition based rate matching schemes should be avoid since they do not provide coding gain in general." |
| Ericsson | **Proposal 6 For enhanced (multi-RB) PF4, support rate matching to the configured number of RBs NRB.** |
|  |  |

The following is a summary of support for the two alternatives for rate matching for PF4:

* Alt-1: Rate matching to *N*RB RBs, similar as for PF2/3 in Rel-16 when interlacing is configured
	+ Intel, Futurewei (if max(N\_RB) <= 16), vivo, ZTE, NTT DOCOMO, Apple, Qualcomm, OPPO (?), Samsung, Huawei, MediaTek, Ericsson
* Alt-2: Rate matching to 1 RB as in Rel-15/16, followed by repetition of the coded bits in each of the configured RBs
	+ Futurewei (if max(N\_RB) > 16), OPPO(?)

**Proposal 8 Agree to the following:**

* For enhanced (multi-RB) PF4, the UCI payload is rate matched to the configured number of RBs, N\_RB
* Note: This is analogous to Rel-16 for PF2/3 when interlacing is configured when there is a fixed number of RBs for the configured interlace(s).

### 6.2.1 <1st Round Comments>

Please provide your company view on Proposal 8.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | We support Proposal 8. |
| vivo | We support proposal 8. |
| ZTE, Sanechips | We are fine with Proposal 8. |
| Huawei/HiSilicon | We are fine with Proposal 8. |
| Lenovo, Motorola Mobility | We are okay with proposal 8. |
| Apple | We are fine with the proposal |
| Intel | We are OK with proposal 8 |

# 7 PUCCH Resource Set Prior to RRC Configuration

## 7.1 Indication of Number of RBs

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: $N=2^{α\_{2}}∙3^{α\_{3}}∙5^{α\_{5}}$ where $α\_{2},α\_{3},α\_{5}$ 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

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Futurewei | ***Proposal 10: Support the Alt-1 to configure N\_RB through SIB1 prior to RRC configuration.***  |
| vivo | **Proposal 3: The indication of NRB for common PUCCH format 0/1 can be predefined in the table of PUCCH resource sets before dedicated PUCCH resource configuration.** |
| CATT | **Proposal 5 The number of RBs for PUCCH format0/1/4 can be cell specific or UE specific configured.****Proposal 7 The gNB needs to indicate the UE with the configured number of RBs for PUCCH format0/1/4 during the initial access process.** |
| NTT DOCOMO | ***Proposal 8:*** *For the PUCCH resource table for initial PUCCH resource,* *at least cell-specific and UE-specific PRB offsets should be revisited for multi-PRB allocation.****Proposal 9:*** *The maximum number of RBs for PUCCH resource sets before dedicated PUCCH configuration should be specified considering minimum. CBW, transmission power gain for each number of RBs under the regulations and FDM capacity.****Proposal 11:*** *For the PUCCH resource sets before dedicated PUCCH resource configuration,* the *cell-specific number of RBs for PUCCH format 0/1 before dedicated PUCCH configuration should be indicated by SIB1* |
| Nokia | ***Proposal 6:*** *In case of common PUCCH resource set, Alt-2 is supported for the configuration of the number of RBs.*Moderator's note: Alt-2 refers to the agreement from RAN1#104bis-e on configuration granularity***Proposal 7:*** *Common PUCCH resource sets prior to dedicated configuration are modified to indicate different number of RBs depending on the BWP SCS value* |
| Apple | ***Proposal 7:*** *For PUCCH Resource Sets prior to RRC configuration the UE should use the value of NRB configured through SIB1.* |
| LGE | **Proposal #7: To determine the value of NRB for the initial PUCCH resource, the following options can be considered:*** **Opt.1: Directly use the predefined maximum value of NRB for PF 0/1 in the specification.**
* **Opt.2: Use the value of NRB configured through RRC signalling (e.g., SIB1) by gNB.**
* **Opt.3: Calculate the value of NRB based on the size of the initial BWP and the required number of FDM resources for each PUCCH resource set.**
 |
| Qualcomm | **Proposal 2: RAN1 support different number of RBs for common PUCCH resource by configuring multiple N\_RBs through RRC.****Proposal 3: RAN1 should study how to indicate UE's capability of supporting wide-band PUCCH during initial access.** |
| Samsung | **Proposal 5: Support contiguous multi-PRB PUCCH format 0/1 before RRC connection setup*** **support different number of multiple PRBs for different scenarios.**
* **support different number of multiple PRBs for different UEs.**
 |
| Ericsson | **Proposal 2 For PUCCH resource sets prior to RRC configuration, support indication via SIB1 of the number of RBs, NRB, for PUCCH format 0/1. If the number of RBs is not indicated, the UE assumes single RB. FFS: supported value(s) of NRB.** |

The following broad alternatives have been identified for indication of the number of RBs, N\_RB:

* Alt-1: N\_RB is signaled via SIB1
	+ Futurewei, CATT(?), NTT DOCOMO, Apple, Qualcomm, Ericsson
* Alt-2: N\_RB is predefined by specification for each SCS, and is possibly different for each row of the PUCCH configuration table
	+ vivo, Nokia
* Alt-3: Indicated by DCI that schedules Msg4
	+ Samsung

Two companies (see [9] and [16]) also raised the possibility to support a mechanism to indicate a different number of RBs for different UEs during initial access.

**Proposal 9 Further discuss how to indicated the number of RBs for PUCCH resources prior to RRC configuration**

### 7.1.1 <1st Round Comments>

Please provide your company view on Proposal 9, including addressing the following questions:

**Question 1**: Which alternative for indication of number of RBs do you support (see Alt-1,2,3 above)?

**Question 2**: Is it needed to support a mechanism to indicate a different number of RBs for different UEs during initial access (e.g., as discussed in [9] and [16])? If so, what are the benefits, and how should the mechanism work?

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | Question 1: We support Alt-2, as it avoids additionals signaling and follows the same principle as Rel-15 and Rel-16. Since the time domain resource allocation for PUCCH is also predefined, it makes little sense to choose a different solution for the frequency domain. Question 2: The need for UE specific resource allocation has not been identified in earlier releases, and we do not see that it is needed in this WI either. Such signaling mechanism would unnecessarily complicate the operation without clear benefits.  |
| vivo | Q1: support Alt 2 for the same reason as Nokia.Q2: we’re not clear about the benefits of UE-specific indication during initial access.  |
| ZTE, Sanechips | We are fine with Proposal 9.A1: Al1 is preferred due to the better flexibility.A2: There is no need to do so. |
| Huawei/HiSilicon | Alt. 1 appears to be the most flexible and simple one. |
| Lenovo, Motoroloa Mobility | Question 1: We support Alt1 and Alt2.Question 2: Similar view as Nokia |
| Apple | We are fine with proposal 9Alt-1. Simple way of signaling N\_RB to accommodate different UE types |
| Intel | Q1: We support Alt.1, which allows to achieve an higher level of flexibility.Q2: We believe that for initial access, mechanism to indicate different number of RBs may not be technically needed. However, since UE’s capability signalling has not been discussed in the summary, we would like to highlight this point here. We believe that a framework to allow a UE to indicate capability signalling (i.e., beamforming gain) may need to be introduced. As pointed out in our tdoc [19], UE power class and beamfoming gain have high impact in MIL, and if gNB makes wrong assumption the related loss may be quite substantial. We believe that this point is worth discussion within RAN1. |
| CATT | Q1: We support alt1 and ok with alt3 .Q2: We think it is beneficial to support a mechanism to indicate a different number of RBs for different UEs during initial access vs after initial access. |

## 7.2 PUCCH Resource Set Construction

The following table provides a summary of company proposals on details of the construction of the PUCCH resource set prior to RRC configuration.

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel | **Proposal 8: RAN1 should further discuss possible enhancements to PUCCH resource sets before dedicated PUCCH resource configuration to support at least same number of orthogonal resources as the legacy design.**  |
| vivo | **Proposal 4: The PUCCH frequency resource and the first PRB index are dependent on the NRB.** |
| ZTE | **Proposal 8: The similar solution in NR-U in rel-16 can be reused for Rel-17 PUCCH enhancement before RRC connected.** |
| NTT DOCOMO | ***Proposal 10:*** *For the PUCCH resource sets before dedicated PUCCH configuration, the following enhancement can be considered to transmit with larger band width.** *The cell-specific resources can be overlapped.*
* *Frequency hopping can be not supported for 60 GHz unlicensed band operation.*
 |
| LGE | **Proposal #6: A number of RBs greater than 1 should be supported even for the initial PUCCH resource and the PRB offset value also needs to be scaled by NRB.** |
| LGE | **Proposal #8: 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 #9: 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.** |
| OPPO | **Proposal 4: The potential RB shortage issue prior to RRC configuration can be handled by gNB implementation.** |
| Ericsson | **Proposal 3 Assuming that the number of RBs is configurable in SIB1, RAN1 should use the Rel-15 PUCCH configuration table 9.2.1-1 as a starting point for discussion on configuration of PUCCH resource sets prior to RRC configuration in combination with an updated procedure on the starting RB indices of the multi-RB PUCCH resources in a set.** |

As pointed out by several companies, the following note is contained in the RAN1#105-e agreement shown in Section 4:

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

It is the moderator's understanding that this means that the following enhancements are out-of-scope for construction of the PUCCH resource set prior to RRC configuration:

* Introduction of additional time domain starting positions and/or additional OCCs
* Support of a different RE mapping scheme (e.g., sub-PRB interlaced mapping)
* Equalization of hopping distance for the PUCCH resources within a set

With that in mind, the construction of PUCCH resource sets prior to RRC configuration becomes simpler; however, there is still a dependence on how the number of RBs should be indicated (see the alternatives Alt-1,2,3 in the previous Section 6.1), and whether or not the number of RBs should be different for each row of the PUCCH configuration Table 9.2.1-1 from 38.213:

**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} |

**Example Construction 1 (same N\_RB for each row)**:

Assuming that N\_RB is indicated to the UE somehow (see Alt-1, 2, or 3 in prior Section 6.1), the UE assumes that the indicated number of RBs is the same for whatever row of the PUCCH configuration table is indicated in SIB1. In this case, Table 9.2.1-1 could be used "as is." It is also assumed that by implementation, the gNB ensures that whatever row of the table is indicated, that the indicated N\_RB and initial UL BWP size are compatible to ensure that 16 PUCCH resources can be constructed as per Rel-15/16.

Once N\_RB is known (either signaled or hardwired by specification), the UE could then determine the PRB indices and the initial cyclic shift indices for the PUCCH resources in the set based on the following simple modification of the text in 38.213 Section 9.2.1 where N\_RB is provided according to Alt-1, 2, or 3. This would preserve the frequency hopping pattern used in Rel-15/16, and further ensure that the multi-RB PUCCH resources in the set do not overlap each other (see illustration in [12]):

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 $\left(RB\_{BWP}^{offset}+\left⌊{r\_{PUCCH}}/{N\_{CS}}\right⌋\right)∙N\_{RB}$ and the lowest PRB index of the PUCCH transmission in the second hop as $N\_{BWP}^{size}-\left(1+RB\_{BWP}^{offset}+\left⌊{r\_{PUCCH}}/{N\_{CS}}\right⌋\right)∙N\_{RB}$, where $N\_{CS}$ is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes

- 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 $N\_{BWP}^{size}-\left(1+RB\_{BWP}^{offset}+\left⌊{\left(r\_{PUCCH}-8\right)}/{N\_{CS}}\right⌋\right)∙N\_{RB}$ and the lowest PRB index of the PUCCH transmission in the second hop as $\left(RB\_{BWP}^{offset}+\left⌊{\left(r\_{PUCCH}-8\right)}/{N\_{CS}}\right⌋\right)∙N\_{RB}$

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

**Example Construction 2 (different N\_RB for each row)**:

In this example, N\_RB is indicated to the UE according to Alt-2 and is different for each row of the PUCCH configuration table. In one example (see [14]) N\_RB could be hardwired as shown in the highlighted column below. Clearly, further discussion would be required on what value of N\_RB to support for each row.

Like for Example 1, once N\_RB is known for whatever row is indicated by SIB1, the same modification of the text in 38.213 Section 9.2.1 as shown for Example 1 could be used by the UE for determining the PRB indices and initial cyclic shift indices for the PUCCH resources in the set.

 Table 1. Proposed modifications to the common PUCCH resource sets

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Index | PUCCH format | First symbol | Number of symbols | PRB offset | Set of initial CS indexes | **PRBs for 120/ 480/960 kHz SCS** |
| 0 | 0 | 12 | 2 | 0 | {0, 3} | **1/1/1** |
| 1 | 0 | 12 | 2 | 0 | {0, 4, 8} | **12 / 3 / 2** |
| 2 | 0 | 12 | 2 | 3  | {0, 4, 8} | **4 / 1 / 1** |
| 3 | 1 | 10 | 4 | 0 | {0, 6} | **1/1/1** |
| 4 | 1 | 10 | 4 | 0 | {0, 3, 6, 9} | **1/1/1** |
| 5 | 1 | 10 | 4 | 2  | {0, 3, 6, 9} | **1/1/1** |
| 6 | 1 | 10  | 4 | 4 | {0, 3, 6, 9} | **1/1/1** |
| 7 | 1 | 4 | 10 | 0 | {0, 6} | **1/1/1** |
| 8 | 1 | 4 | 10 | 0 | {0, 3, 6, 9} | **12 / 3 / 2** |
| 9 | 1 | 4 | 10 | 2 | {0, 3, 6, 9} | **4 / 1 / 1** |
| 10 | 1 | 4 | 10 | 4  | {0, 3, 6, 9} | **1/1/1** |
| 11 | 1 | 0 | 14 | 0 | {0, 6} | **1/1/1** |
| 12 | 1 | 0 | 14 | 0 | {0, 3, 6, 9} | **1/1/1** |
| 13 | 1 | 0 | 14 | 2  | {0, 3, 6, 9} | **12 / 3 / 2** |
| 14 | 1 | 0 | 14 | 4  | {0, 3, 6, 9} | **4 / 1 / 1** |
| 15 | 1 | 0 | 14 |  | {0, 3, 6, 9} | **1/1/1** |

**Proposal 10 Further discuss the construction of the PUCCH resource set prior to RRC configuration**

### 7.2.1 <1st Round Comments>

Please provide your company view on Proposal 10 including addressing the following questions.

**Question 1**: Which of the following two alternatives do you support:

* Alt-1: Indicated value of N\_RB (either by signaling or hardwired by specification) is the same, regardless of which row of Table 9.2.1-1 is used, **e.g.,** **Example Construction 1**
* Alt-2: Value of N\_RB is hardwired by specification and is different for each row of Table 9.2.1-1, **e.g., Example Construction 2**

**Question 2**: Do you have a different view on how the PUCCH resource set should be constructed? Please elaborate.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | Question 1: We support Alt-2. Simularly as the other parameters, the number of PRBs may also vary depending on the row of the table, and the SCS applied. We are open to discuss the exact values further. |
| vivo | We prefer alt-2. We think this issue should be discussed together with indication of RB number in 7.1. |
| ZTE, Sanechips | We are fine with Proposal 10.A1: Alt1 is preferred due to the better flexibility.A2: We share similar view with Moderator. |
| Huawei/HiSilicon | We are fine with Proposal 10. |
| Lenovo, Motoroloa Mobility | We support Alt 2. |
| Apple | We are fine with the proposalAs Vivo has said, this should be jointly discussed with the issue in 7.1.  |
| Intel | Q1: we support Alt-1, since we should prefer to configure the number of PRBs through RRC signalling, which may offer more flexibility than hardcoding some values in the spec.Q2: Regarding the RB shortage issue our view is a bit different: Our understanding is that the note and conclusion made last time on this topic was under the assumption made so far and based on the max PRB values agreed, and the intention was to not enhance multiplexing capability behind what is supported in Rel.16. However, if the maximum number of PRBs are increased, this topic should be discussed further since for many combination of numerologies, initial BW part and PUCCH resources configurations, frequency partitioning would not be possible as the available number of PRBs would not be sufficient, and multiplexing capability would be extremely constrained compared to legacy. |
| CATT | We support Alt 2. |
| Sony | We are okay with the proposal. As pointed out by others, 7.1 and 7.2 can better be discussed together. |

# References

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5. R1-2106693 Discussion on enhancements for PUCCH formats 0/1/4 for above 52.6GHz Spreadtrum Communications
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11. R1-2107002 Discussion on the PUCCH enhancements for 52.6 to 71GHz ZTE, Sanechips
12. R1-2107052 PUCCH enhancements Ericsson
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14. R1-2107106 Enhanced PUCCH formats 0/1/4 Nokia, Nokia Shanghai Bell
15. R1-2107239 Discussion on enhancements for PUCCH format 0/1/4 OPPO
16. R1-2107332 Enhancements for PUCCH for NR in 52.6 to 71GHz band Qualcomm Incorporated
17. R1-2107437 Enhancements for PUCCH formats 0/1/4 to support NR above 52.6 GHz LG Electronics
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20. R1-2107728 Discussion on Enhancements for PUCCH formats 0/1/4 above 52.6 GHz Apple
21. R1-2107847 PUCCH format 0/1/4 enhancements for NR from 52.6 to 71 GHz NTT DOCOMO, INC.
22. R1-2108149 Discussion on PUCCH enhancement for PUCCH format 0/1/4 WILUS Inc.