3GPP TSG RAN WG1 #112bis-e R1-230xxxx

e-Meeting, April 17 – 26, 2023

**Agenda item: 9.12.2**

**Source: Moderator (Nokia)**

**Title: FL summary #2 of power domain enhancements (AI 9.12.2)**

**Document for: Discussion and Decision**

# Introduction

Power domain enhancements was included as one of the enhancements to be studied and specified in the NR coverage enhancement work item approved (revised) in RAN1#96 [1]:

* *Study and if necessary specify following power domain enhancements*
	+ *Enhancements to realize increasing UE power high limit for CA and DC based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, in compliance with relevant regulations (RAN4, RAN1)*
	+ *Enhancements to reduce MPR/PAR, including frequency domain spectrum shaping with and without spectrum extension for DFT-S-OFDM and tone reservation (RAN4, RAN1)*

Section 2 summarizes the key aspects of enhancements for increasing UE power high limit for CA and DC, while Section 3 summarizes the key aspects of enhancements for reducing MPR/PAR. The summaries in these two sections are based on companies’ contributions submitted under AI 9.12.2 to RAN1 #112bis-e [2]-[27].

All related proposals from different contributions, organized per aspect, are listed in Appendix A, for reference.

Previous Rel-18 agreements are summarized in Appendix B.

# Summary of contributions on enhancements for increasing UE power high limit for CA and DC

Contributions submitted under AI 9.12.2 discussed several aspects of enhancements for increasing UE power high limit for CA and DC. A systematic categorization will be used in this document to summarize the content of all contributions. This is done according to both the number of submitted proposals on the different aspects and on the relevance the latter have for designing the feature, from FL’s perspective. Concerning the second criterion, its rationale is given by the natural relationship of consequentiality which exists between different aspects. In the remainder of the document, aspects are thus categorized as follows:

* **High priority aspects**
	+ Implications of the reply LS from RAN4
	+ Enhanced signaling aspects
* **Mid priority aspects**
	+ NA
* **Other aspects**
	+ NA

The categorization above will determine the initial priority order for the discussions to be held for AI 9.12.2. In this context, sections 2.1 and 2.2 will focus on discussions which will (2.1) and may (2.2) be discussed during RAN1 #112bis-e. Section 2.3 will collect all other aspects.

Tags [OPEN], [AVAILABLE], [CLOSED] and [PAUSED] will be used to identify the status of the discussion at any moment of the meeting. New sections for specific aspects will be open during the meeting, should discussions for the higher priority aspects progress fast.

## [OPEN] High priority aspects

Two high priority aspect is identified at the beginning of the meeting:

1. Implications of the reply LS from RAN4
2. Enhanced signaling aspects

Several companies have discussed about such aspects in the submitted contributions. Summary, discussion, and proposals on these aspects are provided in the following sub-sections. Sub-section numbers follow the list above, for simplicity.

### [PAUSED] Implications of the reply LS from RAN4

In this meeting, RAN1 receives an LS from RAN4 (R1-2302270) replying to RAN1 LS (R1-2210739) on enhancements to realize increasing UE power high limit for CA and DC. The following can be noted from the LS from RAN4:

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| RAN4 would like to note that the delivery of high-power UL across all bands is dependent on SAR/MPE considerations at the UE during CA/DC operation. Regarding information exchange needed between the UE and gNB to improve scheduling and network performance when using higher power CA/DC, RAN4 has discussed UL power associated with possible solutions (Issue 4 and 5 in Topic#2 in [1]).RAN4 has discussed several proposed schemes, however, there is no consensus on them yet. |

It can be observed that, although the possible solutions are still being discussed in RAN4 and no consensus has been reached yet, the possible solutions (Issue 4 and 5 in Topic#2) mentioned in reference [1] of the LS may provide some inputs for RAN1:

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| **Issue 4: Whether PHR reporting should be considered for a carrier that is configured for DL but not for UL (no active UL BWP)****<Recommended WF>*** Further clarification would be required to justify the necessity to introduce PHR reporting for the carrier that is configured for DL but no UL (no active UL BWP) for coverage enhancement purpose.
	+ The difference between SRS carrier switching and the proposed scheme should be clarified.
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| **Issue 5: Whether and how PHR reporting enhancement should be considered for FR1 carriers****<Recommended WF>*** RAN4 discussion will focus on the following solutions that have been proposed in this meeting:
	+ 1. Power class fallback ΔPPowerClass with aperiodic PHR.
			- Report power-class fallback ΔPPowerClass in the PHR per serving cell, any power-class change, fallback or return to declared power class, should trigger an aperiodic PHR. This also includes FDD PC2.
			- Report power-class fallback ΔPPowerClass,CA in the multi-entry PHR for the BC; any BC power-class change, fallback or return to advertised BC power class, should also trigger an aperiodic PHR.
			- For EN-DC report power-class fallback ΔPPowerClass,EN-DC in the multi-entry PHR for the BC.
		2. Power class being used by the UE. Because reporting ΔPPowerClass must be a huge burden for both UE and network.
			- For single band HPUE operation, PC being used by a UE must be able to be reported per serving cell.
			- For UL inter band CA HPUE operation, PC being used by a UE must be able to be reported per serving cell per band within a band combination as well as CA PC being used CA for the band combination itself.
		3. The sustainable duty cycle over a certain duration that would prevent triggering a power class fallback at the UE, as well as period of applicability of the ∆PPowerClass report.
		4. Introduce a scheme for a UE to report uplink symbol evaluation period and starting timing.
		5. Enhance the current power headroom reporting framework to enable P-MPR reporting (via MPE field) for FR1 carriers.
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Furthermore, the following agreement was made in RAN1#112:

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| **Agreement**Further discussions in RAN1 concerning means to facilitate higher power transmissions in CA and DC, if applicable, can target increasing gNB awareness of UE’s Tx power, e.g., PHR reporting enhancement such as current power class, power class change, or application of P-MPR by UE (subject to RAN4’s input). * + FFS: details.
 |

From FL’s perspective, RAN1 can move one step forward compared to the above agreement made in RAN1 #112 by focusing the discussion only on the potential solutions identified in the above RAN4 way-forward.

All the considered enhancements seem to target the PHR report, whose design is up to RAN2. However, the information carried by a possibly enhanced PHR report may or may not have RAN1 specification impact. At present this is unclear. Thus, assessing whether RAN1 specification impact would be needed to support any of the above enhancements seems the natural next step. I propose to carry out this discussion in the next section

From FL’s perspective, no further implications can be identified, and no further LS out (from RAN’s perspective) is needed for the time being.

***2.1.1-Q1***

***Do you agree that no action is needed in response to RAN4’s LS, other than taking it into account for RAN1 work?***

***Please provide additional views if your answer is NO.***

#### Discussion

FL’s recommendation is for companies to input their answer to question **2.1.1-Q1**, in the table below.

If your answer is NO, you cand add additional views in the second table below.

**2.1.1-Q1 [1/2]**

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| Answer | Company |
| **Yes** | Sharp, CMCC, CTC, Nokia/NSB, Intel, LGE, OPPO |
| **No** | Ericsson (prefer to defer the question) |

**2.1.1-Q1 [2/2]**

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| Company | Additional views in case your answer is NO |
| NTT DOCOMO | For RAN4 LS, yes it is generally for information – in that sense, no reply from RAN1 to RAN4 seems ok (and yes, ***taking it into account for RAN1 work*** should definitely be considered). Meanwhile, we think it may be possible to have a bit of information to *assist* RAN4 discussion a bit more. As Moderator kindly captured in 2.1.2, a number of companies showed their own opinions in the Tdocs (which we really appreciate, since we know much less companies were interested in that topic itself). Actually the relevant discussion was triggered by RAN1 LS (while some companies argued this topic should be led by RAN4 per WID), so we believe it would be quite straightforward to have some informative outputs from RAN4 to RAN1.  |
| Fujitsu | RAN1 can expect RAN4 will discuss about possible solutions[1]. RAN1 should make a baseline about these solutions, so that it can respond flexibly to the results of RAN4’s discussions. |
| QC | Yes, there do not appear to be any questions directed at RAN1 and a response may not be necessary.We would however like RAN1 to have some more detailed discussions on the topics that RAN4 is looking at. One feedback we received was that it was not clear to RAN4 what enhancements will be useful from a RAN1 perspective. Some guidance to them on this aspect will be greatly helpful. |
| Ericsson | We don’t see that a response is needed immediately, but it’s a bit hard to answer 2.1.1-Q1 without having the discussion. So our preference would be to decide if an LS is needed after some discussion. This could be still in this meeting or, say, the next meeting. |
| ZTE | It’s no need to reply the RAN4 LS. But, depending on the discussion, it is possible that RAN1 could inform RAN4 about the related progress made in RAN1 if any.  |
| Panasonic | We share same view as ZTE. |
| vivo  | Regarding the LS from RAN4, we also agree that no reply is requested from RAN4.Regarding whether an LS to be sent to RAN4 is needed, it can be up to RAN1 and RAN4 discussions in parallel this and next week. Probably RAN4 would send us another LS this or next week. |
| Spreadtrum | No reply to RAN4 LS seems OK. But it may be helpful to RAN4’s discussion if the behavior of gNB schedulers under different solutions could be notified to RAN4. For example, the behavior of gNB schedulers under PC fallback approach and the P-MPR approach may be need to be clarified. |

FL’s comments on April 19

Thanks for providing your comments in the summary and during the offline session. Given the situation I suggest pausing the discussion and adjourn the matter later (in this or in a future meeting, if needed.

### [OPEN] Enhanced signaling aspects

Several companies discussed and proposed directions for studying enhanced signaling mechanisms to improve information exchange between UE and gNB to facilitate higher power transmissions in CA and DC.

The following proposals have been made:

**Overall**

* Four companies (OPPO [6], Xiaomi [21], China Telecom [17], NTT Docomo [18]) propose further discussing/studying the signalling impact and solutions on increasing UE power high limit for CA and DC.
* One company (Fujitsu [8]) proposes that increasing gNB awareness of UE’s Tx power should be standardized in Rel-18 to enjoy the benefit of increasing UE power high limit for CA and DC.
* One company (Xiaomi [21]) proposes studying the mechanism to enable efficient use of the increased full power for CA/DC.
* One company (CMCC [11]) proposes studying new signaling and new trigger event to let UE report its energy headroom.
* One company (Qualcomm [19]) proposes repurposing the existing PHR framework to report any new parameters that are agreed to be shared by the UE to the gNB. Enhancements could include the addition of new octets to accommodate new fields, new trigger conditions, new procedures for computing certain fields, finer granularity for reporting existing fields, etc.

**Signaling of evaluation period and starting time**

* One company (Spreadtrum [4]) proposes studying a scheme for a UE to report uplink symbol evaluation period and starting timing.
* One company (Nokia/NSB [20]) proposes that PHR can be configured to contain the duty cycle evaluation period and starting time.
* One company (CMCC [11]) proposes that **t**he exact evaluation period could be limited to one system frame or multiple system frames. The starting timing could be limited to the starting of the system frame.

**Signaling of current PC/CA PC**

* Two companies (Spreadtrum [4], LGE [27]) propose studying/discussing enhancements for UE to report current CA power class to gNB in PHR.
* One company (Nokia/NSB [20]) proposes that PHR can be configured to contain the current PC that is used by the UE per serving cell.
* One company (Nokia/NSB [20]) proposes that PHR can be configured to contain the currently used CA PC.
* One company (Qualcomm [19]) proposes introducing a power class indicator along with additional signaling to
	+ indicate the estimated duration of power class fallback (for a UE operating at a lower power class), or to
	+ indicate the maximum duty cycle over a certain duration that a UE is able to support without triggering a power class fallback (for a UE operating at a higher power class)

**Signaling of PC change**

* Two companies (Spreadtrum [4], LGE [27]) propose further discussing the necessity of power class change indication discussed.
* One company (InterDigital [14]) proposes supporting UE indication of power class change in power headroom report.
* One company (Ericsson [15]) proposes using 2 bits (‘R’ bits for FR1) of PHR to convey ΔPPowerClass and power class fallback, i.e. ‘DPC’ = 00: 0dB; 01: 3dB; 10: 6dB.

**Signaling of P-MPR**

* One company (Spreadtrum [4]) proposes not supporting P-MPR reporting in FR1.
* Once company (CMCC [11]) proposes that the difference for PC and P-MPR could be jointly report by UE.
* One company (Qualcomm [19], Google [26]) proposes enhancing the current power headroom reporting framework to allow a user to also report P-MPR (via MPE field) for FR1 carriers.
* One company (Qualcomm [19]) proposes that, when computing PHR based on a reference PUSCH, allow a UE to set P-MPR to a non-zero value and allow the UE to report the resulting Pcmax.
* One company (Ericsson [15]) proposes that, if P-MPR is used (‘P’ bit is set), use 2 bits (‘R’ bits for FR1) of PHR to convey power capability according to P-MPR method: 01: 0<𝑃−𝑀𝑃𝑅≤3, 10: 3<𝑃−𝑀𝑃𝑅≤6, 11: 6<𝑃−𝑀𝑃𝑅.
* One company (LGE [27]) proposes discussing whether to indicate P-MPR relevant information explicitly in PHR report could help gNB schedule uplink transmission while not triggering UE power class fallback.

**Other proposals of signaling solutions**

* One company (ZTE [3]) proposes supporting one of the following alternatives.
	+ Alt 1. PHR reporting enhancement with a certain duration for the applicability of one among {the fallback power class ∆PPowerClass (potentially with a finer granularity), the default power class, or Pc,max}.
	+ Alt 2. Introduce a scheme for a UE to report uplink symbol evaluation period and starting timing.
* One company (Fujitsu [8]) proposes choosing one option from the following three options to increase gNB awareness of UE’s Tx power, which are currently discussed in RAN4.
	+ Option 1: Introduce sustainable duty cycle report for both PC fallback and P-MPR
	+ Option 2: Introduce PC change report for PC fallback and sustainable duty cycle for P-MPR
	+ Option 3: Introduce PC change report for PC fallback and P-MPR report for P-MPR
* One company (Xiaomi [21]) proposes considering the following approaches to help UE get a better chance to maintain the high power class:
	+ P-MPR reporting in FR1 due to SAR requirements
	+ Number of symbols or proportion of symbols in the current SAR window that UE assumes to sustain the high power class without having to fallback to make a power class change;
	+ UE recommended maxUplinkDutyCycle value that would prevent triggering a power class fallback;
* One company (Xiaomi [21]) proposes that the enhancement to solve the SAR compliance issue for a better awareness of UE energy/power availability can be applied to both non-CA and CA/DC cases.
* One company (Xiaomi [21]) proposes supporting the report of informative PHR at least to improve the accuracy of the acknowledgement of UE power/energy change due to SAR requirements.
* One company (Qualcomm [19]) proposes enhancing the current power headroom reporting framework to allow a user to report power headroom for a carrier that is configured for downlink but not for uplink (i.e., no active uplink BWP), and to allow a user to report the duration over which the reported Pcmax can be sustained.

**Triggering of the enhanced signaling.**

* One company (Apple [13]) proposes that any event that results a change in power class will trigger an aperiodic PHR. Examples of such events are SAR (specific absorption rate) regulatory requirements (which is transparent to NW)
* One company (Xiaomi [21]) proposes considering at least P/AP triggering and reporting of the enhanced PHR;
* One company (InterDigital [14]) proposes studying events that can trigger UE to report power class change.
* One company (Google [26]) proposes indicating the exact evaluation period of maximum duty cycle to the base station via UE capability.
* One company (Ericsson [15]) proposes that changes in ΔPPowerClass (and power class) can trigger a PHR. Additionally, changes in P-MPR driven by network scheduling can trigger a PHR.
* One company (LGE [27]) proposes discussing on triggering events for PHR reports to help gNB anticipate when power reduction could potentially occur such as not to schedule uplink transmission within remaining uplink duty cycle at UE.

From FL’s perspective, and as discussed in Section 2.2.1, the natural next step at this stage is to progress in the direction of the RAN1 specification impact analysis of the enhancements that RAN4 is currently discussing, according to the LS. Indeed, a rather neat overlap exists between such enhancements and what is proposed by companies in the contributions submitted to AI 9.12.2 for RAN1 #112bis-e. The rationale is rather straightforward:

* Evident impact of this enhancement is in RAN4, which is the main reason why RAN1 previously agreed not to carry out any normative work prior to RAN4 reaching a conclusion on this enhancement.
* All the considered enhancements so far would impact the PHR report, whose content is described in RAN2 specification.
* As discussed in several contributions, the RAN1 impact of this enhancement could be at least related to the events which may trigger an enhanced PHR report and/or the periodicity of such enhanced reports.
* Uncertainty exists w.r.t. other potential RAN1 specification impacts.
* If no evident RAN1 impact is identified for a given enhancement, then no RAN1 agreement is needed for the enhancement to take place and corresponding RAN1 discussion can stop (while discussion would continue at least in RAN4).

My suggestion is thus to proceed according to existing agreements and open a constructive discussion on the RAN1 potential specification impact, if any, that each of the enhancements included in the RAN4 LS could have, namely:

1. Power class fallback ΔPPowerClass with aperiodic PHR.
2. Power class being used by the UE. Because reporting ΔPPowerClass must be a huge burden for both UE and network.
3. The sustainable duty cycle over a certain duration that would prevent triggering a power class fallback at the UE, as well as period of applicability of the ∆PPowerClass report.
4. Introduce a scheme for a UE to report uplink symbol evaluation period and starting timing.
5. Enhance the current power headroom reporting framework to enable P-MPR reporting (via MPE field) for FR1 carriers.

The following questions are thus asked.

***2.1.2-Q1***

***Please identify expected RAN1 specification impact of the following potential enhancements:***

***1. Power class fallback ΔPPowerClass with aperiodic PHR.***

***2. Power class being used by the UE. Because reporting ΔPPowerClass must be a huge burden for both UE and network.***

***3. The sustainable duty cycle over a certain duration that would prevent triggering a power class fallback at the UE, as well as period of applicability of the ∆PPowerClass report.***

***4. Introduce a scheme for a UE to report uplink symbol evaluation period and starting timing.***

***5. Enhance the current power headroom reporting framework to enable P-MPR reporting (via MPE field) for FR1 carriers.***

***2.1.2-Q2***

***Should any enhancements as per 2.2.2-Q1 RAN1 be supported in Rel-18, which periodicity should be envisioned for the enhanced PHR report?***

1. ***Periodic enhanced reports***
2. ***Event-based aperiodic enhanced reports***
3. ***Both periodic and event-based aperiodic enhanced reports***

***Please elaborate on your answer and provide additional details, should the latter be B or C.***

#### Discussion

FL’s recommendation is for companies to input their answers to questions **2.1.2-Q1** and **2.1.2-Q2**, in the tables below.

**We do not have much time left thus constructive attitude is greatly appreciated.** Please do not hesitate to add further views/explanations to substantiate your choices. This would be very helpful.

Concerning **2.1.2-Q2**,companies are encouraged to add an “X” in the column(s) corresponding to the chosen answer.

**2.1.2-Q1 [1/5]**

**[*Power class fallback ΔPPowerClass with aperiodic PHR*]**

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| Company | Answer |
| NTT DOCOMO | Assuming PHR enhancement is the main target (on which we are still open to discuss), section 7.7 of 38.213 should be considered carefully. We may or may not have impacts due to this enhancement.  |
| CTC | If a selection needs to be made for PHR enhancement, P-MPR reporting can be prioritized just for simplicity. With the aspect of power class,ΔPPowerClass is more appropriate than PowerClass since PowerClass needs more bits to be represented and more network overhead is needed compared withΔPPowerClass. |
| Nokia/NSB | Reporting strictly ΔPPowerClass value only does not have any impact on RAN1 specifications, as ΔPPowerClass value is defined in RAN4 specifications and PHR triggering events are defined in RAN2 specifications. However, the potential value from ΔPPowerClass reporting is improved if additional assistance information is reported together with ΔPPowerClass value. The assistance information can be e.g. UE’s estimate of the time when ΔPPowerClass would return to lower ΔPPowerClass value (i.e. higher power class). We see that RAN1 should discuss whether such assistance information should be transmitted together with ΔPPowerClass value, what information it could be, and whether the assistance information would have impact on RAN1 specifications e.g. how to determine the assistance information. |
| Fujitsu | If RAN1 enhance of PHR, at least, RAN1 should consider the impact of section 7.7 of TS38.213. In addition, RAN1 should discuss whether to enhance of PHR or not. Note that there may be other impacts for RAN1 specs if reporting in ways other than PHR enhancements. |
| QC | Only PHR framework (38.213/38.321) needs to be updated. Need to either repurpose existing fields or introduce a new octet. New trigger conditions can also be introduced, but this may go into MAC spec (38.321).Unrelated comment: We have noticed that the set of enhancements that the companies are looking at can be broadly classified into “reactive” reporting and “proactive” reporting. The former refers to reporting a quantity after a change has occurred --- for example, reporting that a power class fallback has occurred or P-MPR has changed. The latter refers to UE providing some future guidance on what tx powers to expect to help the gNB with carrier selection/activation, scheduling, etc. Duration of fallback, sustainable duty cycling, energy headroom, etc would fall in this category. While today’s schedulers may not be able to take full advantage of “proactive” reporting, we think that as uplink CA deployments get more traction, this information could be taken into account by the schedulers.We can try to see if companies can come to some agreement on the set of “reactive” reporting enhancements that are worth considering and a set of “proactive” reporting enhancements that we think might be useful in the future. |
| Ericsson | Agree with DOCOMO that PHR reporting related aspects in 38.213 should be checked. Regarding P-MPR, our understanding is that gNB should be able to use the additional information in the new PHR to improve scheduling. gNB may not know if the P-MPR is due to proximity or scheduling on another RAT, whereas if there is PC fallback due to exceeding a duty cycle, the gNB knows it should schedule the UE less. If P-MPR based mechanisms are defined, this should be clarified. |
| ZTE | It may or may not have RAN1 impacts depending on further discussion on the details, e.g., the starting time and how long the reported PHR applies. It may end up with no RAN1 impacts while RAN1 can first proceed the discussion.  |
| Panasonic | We share same view as DOCOMO. |
| LGE | Current power Headroom Report (PHR) procedure is designed to provide gNB with power headroom and maximum transmit power values. ΔPPowerClass and ΔPPowerClass,CA by power class change could be implicitly suggested by the configured maximum output power PCMAX changes based on its equations in both upper and lower bound already. If we are interested in reactive information, gNB may observe the configured maximum output power changes by monitoring existing regular or event-triggered PHR reports (aperiodic PHR). Considering ΔPPowerClass in a new/modified PHR reporting with explicit signal, RAN1 spec impact seems to be marginal.  |
| vivo  | In our understanding, it is possible to support this without any RAN1 impacts considering that the PHR specified in section 7.7 of 38.213 is transparent to RAN1 with respect to $P\_{CMAX,f,c}$ which is the only parameter that would be impacted by introducing $ΔP\_{PowerClass}$. See following text in section 7.1.1of 38.213 when $P\_{CMAX,f,c} $is referred to in RAN1.

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| - $P\_{CMAX,f,c}(i)$is the UE configured maximum output power defined in [8-1, TS 38.101-1], [8-2, TS 38.101-2] and [8-3, TS 38.101-3] for carrier $f$ of serving cell $c$ in PUSCH transmission occasion $i$. |

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| Spreadtrum | Potential enhancements is mainly related to PHR specified in 38.213 and 38.321. Potential enhancements can impact on gNB scheduling and thus uplink resource allocation and feature configuration may also be affected. But is not clear whether there will be impact on RAN1's specification or not. Above potential enhancements is mainly related to RAN4 specifications and RAN2 specifications. |

**2.1.2-Q1 [2/5]**

[***Power class being used by the UE. Because reporting ΔPPowerClass must be a huge burden for both UE and network***]

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| --- | --- |
| Company | Answer |
| NTT DOCOMO | Basically the same comment as in above.  |
| CTC | The same comment as above. |
| Nokia/NSB | Similarly, reporting strictly UE’s current power class only does not have any impact on RAN1 specifications, as UE’s current power class is defined in RAN4 specifications and PHR triggering events are defined in RAN2 specifications. However, the potential value from UE’s power class reporting is improved if additional assistance information is reported together with it. There is dependency between the suitable assistance information content and PHR triggering event. For example, if the current power class is reported at the change of the PC, the assistance information can be e.g., UE’s estimate of the time when UE would return to higher power class. However, there can be also other events that could trigger the corresponding PHR, e.g. if the transmitted UL symbol ratio exceeds a predefined percentage of the max. duty cycle, the assistance information can be the duty cycle evaluation period and starting time, allowing gNB to determine sustainable duty cycle and its applicability time. We see that RAN1 should discuss what event(s) should trigger the power class reporting, whether assistance information should be transmitted together with the UE’s current power class, what information it could be, and whether the assistance information would have impact on RAN1 specifications e.g. how to determine the assistance information. |
| Fujitsu | Our comments is same as 2.1.2-Q1[1/5] |
| QC | Same as above. Only PHR framework (38.213/38.321) needs to be updated. Need to either repurpose existing fields or introduce a new octet. New trigger conditions can also be introduced, but this may go into MAC spec (38.321).Not sure why ΔPPowerClass is considered a huge burden to report. |
| Ericsson | Also the same comment as above. |
| ZTE | The same comment as above.  |
| Panasonic | Same comment as above. |
| LGE | ΔPPowerClass and ΔPPowerClass,CA change occurs based on power class change conducted by UE based on its capability (e.g. maxUplinkDutyCycle-PC2-FR1, maxUplinkDutyCycle-interBandCA-PC2-r17 ) with (average) percentage of symbols during a certain evaluation period that can be scheduled for uplink transmission as to ensure compliance with applicable electromagnetic energy absorption requirements provided by regulatory bodies.If we are interested in reactive information, gNB may observe the configured maximum output power changes by monitoring existing regular or event-triggered PHR reports (aperiodic PHR). Considering power class change in a new/modified PHR reporting with explicit signal, RAN1 spec impact seems to be marginal.  |
| Vivo  | See our comments in response to Q1 1/5. |
| Spreadtrum | The same comment as Q1 1/5. |

**2.1.2-Q1 [3/5]**

**[*The sustainable duty cycle over a certain duration that would prevent triggering a power class fallback at the UE, as well as period of applicability of the ∆PPowerClass report.*]**

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| --- | --- |
| Company | Answer |
| NTT DOCOMO | In addition to the comments added above, for 3 and 4, it requires some more consideration in time-domain, which could be something in a unit of slots/frames/etc. If 7.7 is impacted, such an aspect may need to be considered. |
| CTC | Question 3 and 4 revolves around reporting or configuring the duty cycle to prevent power class from falling back, it needs SAR estimation for a higher transmission in some symbols/slots and is more complicated than PHR enhancement. Considering limited TU, PHR enhancement should be prioritized if high power CA/DC transmission is supported from RAN4 decision. |
| Nokia/NSB | We see that RAN1 should discuss that whether reporting of sustainable duty cycle and/or period of applicability is supported and how these values would be determined (e.g. what duty cycle UE assumes for the period of applicability). However, we see that this kind of information should be reported only together with the current ΔPPowerClass, power class or P-MPR value as assistant information. |
| Fujitsu | It is necessary to consider whether 3 and 4 can be reported by enhancement of PHR. If possible, RAN1 should consider the impact of section 7.7 of TS38.213 at least, the impact on the specification regarding the time domain should also be considered. |
| QC | Any forward-looking parameters/estimates can be reported as part of PHR. New octets may be necessary. New trigger conditions can also be considered. Sections on PHR framework in 38.213 and 38.321 will need to be updated. RAN4 spec may need some revisions in case new parameters related to tx power are introduced. |
| Ericsson | This is a bit hard to answer. If the time frames are very long (100s of ms, seconds, or more), then it can be questioned why the time duration would be defined, since knowing an exact duration seems less valuable, and simply knowing the current power capability of the UE could be enough. On the other hand, if the time duration is very short, the PHR overhead could be high, and how reporting works for these short durations should be clarified. From a gNB scheduling viewpoint, budgeting available power for future transmissions, and strictly limiting the scheduler to follow that power, complicates the scheduling quite a bit. This can be rather more challenging in the CA case where schedulers are not well coordinated across cells. So for us, an aperiodic PHR trigger seems more straightforward: the scheduler can assume that a given power is available under current conditions, and the UE can indicate when conditions change.But if time duration does need to be defined, agree with DOCOMO that PHR related aspects in 38.213 may need consideration.  |
| ZTE | Regarding potential RAN1 impacts, the same comment as above. We see it is beneficial for gNB scheduling by reporting a sustainable duty cycle to address the ambiguity of the evaluation period for UE PC fallback. But, we should avoid any scheduling restrictions. For instance, if strictly following the proposal, gNB should prevent triggering a power class fallback during a certain duration, meaning the percentage of UL symbols scheduled for UL transmissions should be no larger than UE capability *maxUplinkDutyCycle-PC2-FR1* if present, or no larger than 50% otherwise. Therefore, we think only the later part of the proposal is sufficient, i.e., reporting a sustainable duty cycle over a certain duration for the applicability of ∆PPowerClass/the fallback power class. The reported duration could also apply to *Pc,max* or P-MPR (if any) that isreported in the same PHR.  |
| Panasonic | For solution 3 or solution 4, as shown in 2.1.2-Q1, we think that it is beneficial to provide such information to gNB in PHR in order to enable more suitable feature configurations and resource scheduling because gNB can know when UE fallbacks to the default power class. Both solutions requires to consider time duration aspect.  Among these 2 solutions, solution 4 might be more friendly to a UE as it is a proactive solution from UE perspective, while solution 3 might look like a work around solution that would prevent triggering a power class fallback at the UE. Therefore, we would slightly prefer solution 4. |
| LGE | Especially for FR1, current PHRs are triggered in certain conditions pertaining to *phr-ProhibitTimer*, *phr-PeriodicTimer*, *phr-Tx-PowerFactorChange*, etc which are not directly involved in MPE compliance. gNB is not still aware of how much available power left, and/or how many symbols left within uplink duty cycle before UE conducts power class fallback. Introducing sustainable duty cycle on top of power class fallback would help gNB expect when power reduction could potentially occur. In this case, we may need to check potential impacts on 38.213.  |
| Vivo  | It’s not clear and hard to decide on how or how long or how accurate a UE can estimate the application time of a reported ∆PPowerClass. Therefore, for simplicity, it might be enough to report the ∆PPowerClass under current condition. |
| Spreadtrum | The same comment as Q1 1/5. It may impact on PHR related aspects in 38.213 if time duration does need to be defined. |

**2.1.2-Q1 [4/5]**

[***Introduce a scheme for a UE to report uplink symbol evaluation period and starting timing***]

|  |  |
| --- | --- |
| Company | Answer |
| NTT DOCOMO | Same comment as in 3/5.  |
| CTC | Same comment as in 3/5 |
| Nokia/NSB | We see that RAN1 should discuss the triggering event(s) for reporting this information (e.g. when the transmitted UL symbol ratio exceeds a predefined percentage of the max. duty cycle). |
| Fujitsu | Our comments is same as 2.1.2-Q1[3/5] |
| QC | We prefer to report estimated duration of fallback. Again, this can be introduced as part of PHR framework. 38.213 and 38.321 may need to be revised. RAN4 spec may need some revisions in case new parameters related to tx power are introduced. |
| Ericsson | Same comment as 3/5. |
| ZTE | Regarding potential RAN1 impacts, the same comment as above. This can also address the ambiguity of the evaluation period for UE PC fallback. |
| Panasonic | Same comment as in 2.1.2-Q1 [3/5]. |
| LGE | Same comment as in 3/5 |
| Vivo  | See our comments in response to Q1 3/5. |
| Spreadtrum | Same comment as 3/5. |

**2.1.2-Q1 [5/5]**

[***Enhance the current power headroom reporting framework to enable P-MPR reporting (via MPE field) for FR1 carriers.***]

|  |  |
| --- | --- |
| Company | Answer |
| NTT DOCOMO | Same comment as in 1/5, 2/5.  |
| CTC | Same comment as in 1/5. |
| Nokia/NSB | The existing mechanism, including triggering events, as defined in RAN2 for FR2 could be reused if reporting strictly P-MPR value only, without any impact on RAN1 specifications. The potential value from P-MPR reporting is improved if additional assistance information is reported together with it. The assistance information can be e.g. sustainable duty cycle to maintain low P-MPR value or applicability period for the reported P-MPR value. However, the rules for P-MPR setting are part of RAN4 specifications and, hence, we do not see any impact on RAN1 specifications from that part either. |
| Fujitsu | Our comments is same as 2.1.2-Q1[1/5], [2/5] |
| QC | Same comment as above. |
| Ericsson | The same comment as in 1/5. |
| Panasonic | Same comment as in 2.1.2-Q1 [1/5]. |
| LGE | UE reports P-MPR value in the PHR procedure in FR2 when measured power reduction is equal to or higher than a threshold (e.g. P-MPR\_00) for MPE reporting. MPE field in PHR MAC CE indicates an index to Table 6.1.3.8-3 (Effective power reduction for MPE P-MPR) in 38.321, and the corresponding measured values of P-MPR levels in dB are specified in Table 10.1.26.1-1 (Mapping of FR2 P-MPR) in 38.133 as effective power reduction. Similar to 1/5 and 2/5, PHR could carry reports P-MPR value for both FR1 and FR2 explicitly which is reactive information. Considering P-MPR value of MPE field in a new/modified PHR reporting, RAN1 spec impact seems to be marginal |
| Vivo  | P-MPR reporting in FR1 can be similar to P-MPR reporting in FR2, MPE field can be reused by RAN2 and no RAN1 impacts are expected. |
| Spreadtrum | Same comment as in 1/5. |

**2.1.2-Q2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Company | A | B | C | Additional details |
| NTT DOCOMO | X | X | X | We are open to any direction. Basically the reporting metric is important, and depending on which, reporting behavior can be enhanced in a way suitable to it.  |
| Sharp | X | X | X | In any case, we expect that RAN1 spec impact is marginal (e.g. just adding the references to new RRC parameters, etc.) |
| CMCC | X | X | X | RAN1 spec impact should be carefully avoided, considering the give and the take. |
| Nokia/NSB |  | X |  | Event-based aperiodic reporting can mitigate the PHR reporting overhead while still improving gNB awareness. The exact suitable events for report triggering depend on the content of the enhanced PHRs and we have outlined some examples of the triggering events on the responses to 2.1.2-Q1 together with corresponding PHR content. |
| Fujitsu | X | X | X | RAN1 should make a baseline so that it can respond flexibly to the results of RAN4’s discussions. |
| QC | X | X | X | Open to all three. We can decide on the reporting frequency based on the new parameters we agree to report.  |
| Ericsson |  | 1st prio | 2nd prio | Our assumption is that the enhancements here target relatively slow changes in power capability in the UE. In order to minimize the PHR overhead, we are primarily interested in event based reporting, and so it has first priority to us, if prioritization is needed. However, periodic reports can also convey information to help scheduling, and can be second priority in our view. |
| Intel | X | X | X | We are open to consider periodic or event-triggering based PHR reporting mechanism.  |
| LGE | X | X | X | Open to all options to discuss. Those options could come up with the discussion of five potential solutions together. Triggering events and relevant RRC parameters seems to be RAN2 impact. However, RAN1 may need to discuss the triggering events based on the potential solutions provided by RAN4 LS to get alignment with RAN1’s |
| ZTE |  |  |  | Both legacy periodic or event-triggering based PHR reporting mechanism can be considered. The question is whether to introduce new reporting mechanisms like new timers or new events. Open to discuss at this point.  |
| Panasonic | X | X | X | We are open to discuss any direction.  |
| Vivo  |  |  |  | According to our comments provided for Q1, this discussion can be up to RAN2 and RAN4 as no RAN1 impacts are expected. |
| OPPO | X | X | X | Open to all three. |
| Spreadtrum |  |  |  | We are open to discuss it.  |

FL’s comments on April 19

Thank you all for the good comments. After the offline session we had earlier today, it seems that not only **consensus does not exist in RAN4 on which direction to pursue** (according to the content of the LS) but also consensus does not exist in RAN1 about the technical understanding of different approaches and their implications.

For this reason, it seems that discussion requires a larger technical depth to be able to identify a possible way forward for this objective. Furthermore, it became evident that my initial categorization (as per offline session) on reactive and proactive enhancements was incomplete and improvements are needed. I would then like to restructure that discussion and open it again, also inviting companies to go to deeper levels in their comments. If we cannot discuss about all the implications that each direction has, there will always be confusion and doubts. Progress would be very hard in this case.

Two enhancement types have been discussed so far:

* Reactive enhancement type, which is in response to events, a.k.a. higher layer triggers
* Proactive enhancement type, which is not in response to an event.

Additionally, two periodicities can be considered for a possible enhanced PHR report:

* Periodic reports.
* Aperiodic reports.

It is my understanding that companies think that several combinations between enhancement types and periodicity framework are possible.

FL’s suggestion is to further work on this aspect and identity what should be prioritized and why. The rationale would be to ensure RAN1 is able to advance on this topic while waiting for RAN4 further input.

In this context, I would invite companies to engage in a constructive discussion about the aspects above, where special focus should be given at least to:

* Performance benefits/degradation and implementation impact of the considered enhancement type and periodicity
	+ Actionability of the information included in the enhanced PHR report seems to be a relevant aspect for gNB, hence please comment on this as well.
* Time considerations, that is the validity over time that a certain information would have if it was included in an enhanced PHR report.
	+ This seems to apply to proactive enhancements only, however, please comment on this specifically if you think this also applies to reactive enhancements.
	+ Note: One company commented during the offline stating that the validity of a sustainable duty cycle report could be ranging between 100 and 500 ms. Companies are invited to start the discussion using these values as a reference.
* Specification impact details, e.g., to Clause 7.7 in TS 38.213
	+ While this may seem premature, it is obvious that large potential specification impact may be a criterion used to deprioritize a certain enhancement.

Finally, I would like to remark that **scheduler design is an implementation aspect which is not expected to be discussed here**. If knowing how the scheduler operates is needed to advance in the discussion on a specific enhancement, this should suggest that such enhancement should not be pursued.

With reference to the list of enhancements referred to in the LS reply sent by RAN4, companies are invited to provide further detailed technical views in the following tables. **Please follow the structure of the table if you add new rows**. **If you have views for more than one enhancement, please use different rows so that pros and cons are for each enhancement.**

**2.1.2-Q3 (1/2): Reactive Enhancements**

|  |  |  |
| --- | --- | --- |
| #Index: Company name | Additional content in the PHR report, e.g., *ΔPPowerClass* | Views |
| #3-1: QC | Parameter: Power class/ΔPPowerClass Type of report: Reported via PHR. Trigger based and/or periodic reporting as configured by gNB. | **PROS** | Helps gNB know of any change to UE capabilities due to power class change, for e.g. MPR table that applies. Note that transmit power is already reported via Pcmax. |
| **CONS** | Doesn’t convey how long this change will apply. It is merely a snapshot.Some additional clarity on this mechanism will be helpful.Its not clear if RAN4 intended new MPR table, and other capabilities come into effect. Its not clear if UE is expected to fall back even if tx powers are low. |
| #3-2: QC | Parameter: P-MPR for FR1 Type of report: Reported via PHR. Trigger based and/or periodic reporting as configured by gNB. | **PROS** | Indirectly lets gNB know that UE is having issues with RF exposure. Can be taken as a weak signal to the gNB to not schedule too aggressively on that carrier in the near term. |
| **CONS** | Doesn’t convey how long this state will persist. It is merely a snapshot and doesn’t convey longer term power availability.It can be argued that in certain cases P-MPR doesn’t vary much or varies rather slowly. This has been the case for single CC uplink without heavy WiFi usage. Things are likely to change for PC2/PC1.5 operation across multiple bands. |
| #3-3: DOCOMO | Parameter: Indication of the state of ΔPPowerClass , e.g., codepoint 0 when indicateΔPPowerClass=0, codepoint 1 otherwiseType of report: Reporting via PHR | **PROS** | Similar to #3-1 |
| **CONS** | If ΔPPowerClass value could be diverged in the future, this reporting is not very compatible to such cases |
|  |  | **PROS** |  |
| **CONS** |  |
|  |  | **PROS** |  |
| **CONS** |  |
|  |  | **PROS** |  |
| **CONS** |  |
|  |  | **PROS** |  |
| **CONS** |  |
|  |  | **PROS** |  |
| **CONS** |  |

**2.1.2-Q3 (2/2): Comments from companies**

|  |  |  |
| --- | --- | --- |
| Company | Target of comments | Comments  |
| NTT DOCOMO | #3-1, #3-2 | We share QC’s observation |
| NTT DOCOMO | #3-3 | Intend to minimize the granularity of reported value, compared with #3-1 for ΔPPowerClass. While it seems there is a clear cons of future compatibility.  |
| LGE | #3-1, #3-2, #3-3 | Technical point of view, we share QC/DCM’s observation. With no enhanced triggering event configured (e.g. aperiodic PHR report right after its power class change), even though current power class (or Power Class change) and ΔP\_PowerClass in PHR reports is explicitly signaling and occupying the resources, it remains as reactive. Since there seems to be no clear evidence how much improve gNB awareness for UE power high limit comparing to current behaviors, if those options are preferred, consider the aperiodic triggering events for gNB to be reactive as soon as possible. |

**2.1.2-Q4 (1/2): Proactive Enhancements**

|  |  |  |
| --- | --- | --- |
| #Index: Company name | Additional content in the PHR report, e.g., *sustainable duty cycle* | Views |
| #4-1QC (multiple options with slight variations are listed here for completeness. Intent is to select one) | Parameter: Start and length of evaluation period for power class fallback. Type of report: Reported via PHR. Trigger based and/or periodic reporting as configured by gNB. Reported whenever ΔPPowerClass is reported. | **PROS** | Provides additional clarity to gNB on duration of power class fallback. |
| **CONS** | Evaluation period may vary dynamically and is up to UE implementation. UE may not track duty cycle requirements if there is no need to do so. Sliding window approach may make it difficult to identify start. **Not preferred from a UE viewpoint**. |
| #4-2: QC  | Parameter: Estimated duration of fallback (suggested unit of time: frame). UE reports how long it is likely to operate in default power class mode.Type of report: Reported via PHR. Trigger based and/or periodic reporting as configured by gNB. Reported whenever ΔPPowerClass is reported. | **PROS** | Provides additional clarity to gNB on duration of power class fallback. Is decoupled from underlying UE implementation. |
| **CONS** | Only meaningful to report after a fallback has occurred. Doesn’t provide gNB with any means to prevent a fallback. |
| #4-3: QC (preferred) | Parameter: Estimated duration over which UE can sustain Pcmax before additional RF exposure constraints kick in, i.e., additional P-MPR is required. (suggested unit of time: frame)Type of report: Reported via PHR. Trigger based and/or periodic reporting as configured by gNB. Assumptions: duty cycle assumed to be same as the value reported as part of UE capability or default value if not reported as part of UE capability  | **PROS** | Provides guidance to gNB on whether gNB can continue to sustain high power transmissions.  |
| **CONS** |  |
| #4-4: QC | Parameter: Sustainable duty cycle to prevent a fallback (units: dimension less quantity). UE reports the maximum duty cycle it can sustain before a power class fallback is triggered. Reported only when UE is in higher power class state.Note: This is not a scheduling restriction on the gNB. Type of report: Reported via PHR. Trigger based and/or periodic reporting as configured by gNB.  | **PROS** | Provides additional guidance to gNB on how higher power class can be sustained. |
| **CONS** | Not useful for a UE that is already in default power class state. Need to assess how P-MPR is taken into account within this framework.  |
| #4-5: QC (preferred) | Parameter: Energy/power availability --- for a given duration T, UE reports max power P that it can sustain assuming a duty cycle D. (suggested units: dBm)Type of report: Reported via PHR. Trigger based and/or periodic reporting as configured by gNB. Assumptions: T and D configured by gNB; takes UE capability into account.  | **PROS** | Likely to be most useful for a gNB to plan. Aids gNB decisions on carrier switching, BWP activation, SUL-NUL operation, CA scheduling, L1-L2 mobility (fast cell switching), etc. |
| **CONS** |  |
| #4-6: DCM | Parameter: Length of evaluation period for power class fallback, in unit of framesType of report: UE capability signaling, or PHR | **PROS** | Provides some clarity (while smaller than Q#4-1) to gNB on duration of power class fallback. Potentially smaller burden for UE to report?  |
| **CONS** | As start timing is unclear, it may not be very informative even if reported.  |
|  |  | **PROS** |  |
| **CONS** |  |
|  |  | **PROS** |  |
| **CONS** |  |

**2.1.2-Q4 (2/2): Comments from companies**

|  |  |  |
| --- | --- | --- |
| Company | Target of comments | Comments  |
| NTT DOCOMO | #4-1 to #4-5 | We basically share QC’s observation. We are open for any direction. For a particular one #4-5, we wonder if RAN4 is ready to condier such power limitation in unit of energy. Clarification on whether RAN4 consider D or not is appreciated.  |
| NTT DOCOMO | #4-6 | Intend to minimize UE reporting effort compared to #4-1 a bit |
| LGE | #4-1 to #4-6 | Open to all options. Slightly prefer #4-4. As for cons aspect by QC, when a UE is already in default power class state, legacy PHR information such as tracking/analyzing maximum transmit power and power headroom value changes could be helpful for gNB. If my understanding is correct, legacy PHR information and enhanced #4-4 method seem to complement each other. However, more study is required, and see other options from companies. |

## [CLOSED] Mid priority aspects

No mid priority aspects are identified at the beginning of the meeting.

## [CLOSED] Others

No other aspects are identified at the beginning of the meeting.

# Summary of contributions on enhancements for reducing MPR/PAR

Contributions submitted under AI 9.12.2 discussed several aspects of enhancements for reducing MPR/PAR. A systematic categorization will be used in this document to summarize the content of all contributions. This is done according to both the number of submitted proposals on the different aspects and on the relevance the latter have for designing the feature or having a good progress for the discussion, from FL’s perspective. Concerning the second criterion, its rationale is given by the natural relationship of consequentiality which exists between different aspects. In the remainder of the document, aspects are thus categorized as follows:

* **High priority aspects**
	+ Design aspects of FDSS-SE – DMRS
* **Mid priority aspects**
	+ MPR/PAR reduction techniques – solutions
	+ MPR/PAR reduction techniques – modulation order
	+ Design aspects of FDSS w/ SE – FDRA
	+ Design aspects of FDSS w/ SE – extensions factors
	+ Design aspects of FDSS w/ SE – MCS
	+ Design aspects of FDSS w/ SE – power control
	+ Design aspects of FDSS w/ SE – others
	+ Design aspects of TR – FDRA
	+ Design aspects of TR – overall
* **Other aspects**
	+ Evaluation methodology
	+ Complementary enhancements

The categorization above will determine the initial priority order for the discussions to be held for AI 9.12.2. In this context, sections 3.1 and 3.2 will focus on discussions which will (3.1) and may (3.2) be discussed during RAN1 #112bis-e. Section 3.3 will collect all other aspects.

Tags [OPEN], [CLOSED] and [PAUSED] will be used to identify the status of the discussion at any moment of the meeting. New sections for specific aspects will be open during the meeting, should discussions for the higher priority aspects progress fast.

## [CLOSED] High priority aspects

One high priority aspect is identified at the beginning of the meeting:

1. Design aspects of FDSS w/ SE – DMRS

Most companies have discussed at large about such aspect in the submitted contributions. Summary, discussion, and proposals on it are provided in the following sub-section.

### [OPEN] Design aspects of FDSS w/ SE – DMRS

Several contributions acknowledged the fundamental nature of this aspect and discussed it in detail. Most companies provided an explicit proposal for a specific technical direction to be pursued.

In this context, one company proposed a new scheme for the case of DMRS sequence length small than 30, based on ZC sequences (Qualcomm [19]). More precisely, it is proposed in [19] to construct a set of Type 1 DMRS sequences for a given RB allocation by using ZC sequences of two or more prime lengths, e.g., both the nearest smaller and larger prime number to the target sequence length. This would yield a total number of candidate sequences larger than 30 sequences, in general. Pruning mechanisms to obtain 30 sequences could be based on cross-correlation properties between the sequences, but details would be left FFS for now. Given the presence of Approaches A and B in the agreements made in RAN1 #112, I suggest labeling this alternative as Approach C, where the word Approach is used instead of Option, to avoid ambiguity with the outdated Option C (as per discussions RAN1 had until RAN1 #112bis-e excluded).

Remaining companies confirmed interest and relevance of the study but did not put forward any explicit proposal.

A high-level summary of companies’ preferences based on the contributions is as follows, where preferences are to be understood as subject to supporting FDSS-SE in Rel-18.

Long sequences

|  |  |  |
| --- | --- | --- |
|  | **# of preferences** | **Companies** |
| **Approach A.1** | 7 | Huawei/HiSi [2], vivo [5], Spreadtrum [4], CATT [7], Nokia/NSB [20], Qualcomm [19], Panasonic [22] |
| **Approach A.2** | 6 | ZTE [3], Nokia/NSB [20], China Telecom [17], Qualcomm [19], IITH [23], Panasonic [22] |
| **Approach B** | 4 | Lenovo [10] |
| Type 1 only: Ericsson [15] |
| Type 2 only: Nokia/NSB [20], Panasonic [22]  |

Short sequences

|  |  |  |
| --- | --- | --- |
|  | **# of preferences** | **Companies** |
| **Approach A.1** | 1 | Huawei/HiSi [2] |
| **Approach A.2** | 5 | China Telecom [17] |
| Type 1 only: vivo [5] |
| Type 2 only: ZTE [3], Nokia/NSB [20], IITH [23] |
| **Approach B** | 2 | Lenovo [10] |
| Type 1 only: Ericsson [15] |
| **Approach C** | 1 | Qualcomm [19] |

Concerning how to extend the DMRS sequence in case of Approach A.1, A.2 and Approach C, the following preferences have been expressed:

|  |  |  |
| --- | --- | --- |
|  | **# of preferences** | **Companies** |
| **Cyclically (per-RE logic)** | 5 | Huawei/HiSi [2], Spreadtrum [4], CATT [7], Nokia/NSB [20] |
| Type 1 only: Qualcomm [19]  |
| **Like data (per-PRB logic)** | 2 | vivo [5] |
| Type 2 only: Qualcomm [19] |

From FL’s perspective some facts are worth highlighting to promote a pragmatic approach to this complex discussion:

* Different companies’ preferences and proposals are heterogeneous. At the same time, some candidate directions are supported by at least 5 companies each.
* All other candidate directions are supported by at most 3 companies.
* Approach B shows sub-par link performance in all contributions who measured its performance against other approaches, unless low-PAPR Type 2 DMRS sequences are used.
* One company studied the OBO of Approach B and deemed it sufficient.

Concerning the approach for extending the DMRS sequence, when and if applicable, most companies argue that this should occur cyclically, at least when Type 1 DMRS are considered.

Many contributions show that channel estimation quality is impacted by choosing low-PAPR Type 1 or low-PAPR Type 2 sequence. However, the extent of such performance difference is unclear. A large variance exists between the results contributed by different companies, for the configurations as per working assumption made during RAN1 #112. From FL’s perspective it is very unlikely that the same scheme can be observed as yields so good or poor performance. The most reasonable explanation is that different receiver implementations may lead to different link performance. Since RAN1 did not agree on decoding/equalization/detection algorithms to be used, the above seems a plausible explanation at the very least. Consequently, such results cannot be used to conclude what is concluded in some contributions, that is:

* Low-PAPR Type 2 DMRS are not a good option for FDSS-SE,

**OR**

* Low-PAPR Type 2 DMRS are a good option for FDSS-SE.

Given the above, and from FL’s perspective, the following conclusions seem reasonable:

* Preferences stemming from very different simulation results are often not the best candidates for middle ground solutions, when such heterogeneity is observed.
* It is unclear why RAN1 should agree on only one solution when more than one could be supported and the actual configuration could be left to network’s decision based on UE capabilities and receiver implementation, if and when applicable.
* It is unclear why an enhancement targeting PUSCH should preclude the use of legacy DMRS sequences that have been specified in the earliest stages of NR.

I propose to engage in a constructive effort where the group works together to identify a common ground which could be sufficiently inclusive and yet allow optimizations to take place (up to configuration). To facilitate this effort, I would like to re-illustrate the situation outlined above using more explicit references to the schemes behind the different approaches. Companies’ preferences for long sequences can be re-illustrated as follows:

Long sequences

|  |  |  |  |
| --- | --- | --- | --- |
| **Scheme** |  | **# of preferences** | **Companies’ names** |
| *Type 1 generated for inband and cyclic extension to excess band* |  | 5 | Nokia/NSB, Huawei/HiSi, Qualcomm, Spreadtrum, CATT, Panasonic |
| *Type 1 generated for inband with symmetric extension to excess band* |  | 1 | VIVO |
| *Type 2 generated for inband with symmetric extension to excess band* |  | 6 | Nokia/NSB, ZTE, China Telecom, IITH, Qualcomm, Panasonic |
| *Type 1 or Type 2 generated for total allocation* |  | 1 | Lenovo |
| *Type 1 generated for total allocation* |  | 1 | Ericsson |

Companies’ preferences for short sequences can be re-illustrated as follows:

Short sequences

|  |  |  |  |
| --- | --- | --- | --- |
| **Scheme** |  | **# of preferences** | **Companies’ names** |
| *DFT transformed Type 1 generated for inband and cyclic extension to excess band* |  | 1 | Huawei/HiSi |
| *Type 1 generated for inband with symmetric extension to excess band* |  | 2 | VIVO, China Telecom |
| *Type 2 generated for inband with symmetric extension to excess band* |  | 4 | Nokia/NSB, ZTE, China Telecom, IITH,  |
| *Type 1 or Type 2 generated for total allocation* |  | 1 | Lenovo |
| *Type 1 generated for total allocation* |  | 1 | Ericsson |
| *ZC sequences (like Type 1) of two or more prime lengths generated for inband and cyclic extension to excess band* |  | 1 | Qualcomm |

Clear majorities exist for at least 2 solutions for long sequences and 1 solution for short sequences. However, as stated before, I would suggest working towards a more inclusive approach which could provide implementation flexibility at both UE and gNB. This may ease the concerns of some companies and hopefully lead to an acceptable middle ground.

The following two questions are asked to start the discussion.

**3.1.1-Q1**

|  |
| --- |
| ***Assumptions******If a given DMRS sequence as per one of the alternatives is supported, NW can configure it subject to:**** ***NW decision***
* ***UE capability***

***Discussion on the corresponding UE capabilities would occur in the appropriate session.*** |

***If FDSS-SE is supported in Rel-18, which of the following three alternatives should be preferred for the DMRS when FDSS-SE is configured and the DMRS sequence length before extension of the sequence, if any, is larger than or equal to 30?***

***Alt-1:***

* ***Rel-15 Type 1 low-PAPR DMRS generated for inband and cyclic extension to excess band***
* ***Rel-16 Type 2 low-PAPR DMRS generated for inband with symmetric extension to excess band***

***Alt-2:***

* ***Rel-15 Type 1 low-PAPR DMRS generated for inband and cyclic extension to excess band***
* ***Rel-16 Type 2 low-PAPR DMRS generated for inband with symmetric extension to excess band***
* ***Rel-15 Type 1 low-PAPR DMRS*** ***generated for total allocation***
* ***Rel-16 Type 2 low-PAPR DMRS*** ***generated for total allocation***

***Alt-3***

* ***More than one DMRS sequence, but different from the Alternatives above. If you choose this Alternative, please propose which DMRS sequences you would include and why. Moreover, please do not propose a single DMRS sequence or the same list you proposed in your contribution, if any.***

**3.1.1-Q2**

|  |
| --- |
| ***Assumptions******If a given DMRS sequence as per one of the alternatives is supported, NW can configure it subject to:**** ***NW decision***
* ***UE capability***

***Discussion on the corresponding UE capabilities would occur in the appropriate session.*** |

***If FDSS-SE is supported in Rel-18, which of the following three alternatives should be preferred for the DMRS when FDSS-SE is configured and the DMRS sequence length before extension of the sequence, if any, is shorter than 30?***

***Alt-1:***

* ***Rel-15 Type 1 low-PAPR DMRS generated for inband and cyclic extension to excess band***
* ***Rel-16 Type 2 low-PAPR DMRS generated for inband with symmetric extension to excess band***

***Alt-2:***

* ***Rel-15 Type 1 low-PAPR DMRS generated for inband and cyclic extension to excess band***
* ***Rel-16 Type 2 low-PAPR DMRS generated for inband with symmetric extension to excess band***
* ***Rel-15 Type 1 low-PAPR DMRS*** ***generated for total allocation***
* ***Rel-16 Type 2 low-PAPR DMRS*** ***generated for total allocation***
* ***DFT transformed Type 1 generated for inband and cyclic extension to excess band***
* ***FFS: ZC sequences (like Type 1) of two or more prime lengths generated for inband and cyclic extension to excess band***

***Alt-3***

* ***More than one DMRS sequence, but different from the Alternatives above. If you choose this Alternative:***
	+ ***please propose which DMRS sequences you would include and why.***
	+ ***please do not propose a single DMRS sequence or the same list you proposed in your contribution, if any.***

#### Discussion

FL’s recommendation is for companies to add views about **3.1.1-Q1** and **3.1.1-Q2**.

**We do not have much time left and we need to work together constructively. I would appreciate if you could act accordingly.**

Please also consider that a large variance exists between different companies’ results, which should all be considered equally valid. This makes them hard to use for justifying strong objections/proposals and further motivates the FL effort to promote a constructive and inclusive discussion which may address most if not all companies’ concerns.

In this context, Alt-3 has been added to the list for completeness and allow companies to offer other possible solutions. At the same time, I count on everyone not to use it to repeat what has already been proposed in the Tdocs. This would not lead us anywhere. Indeed, and as explained above, **if you choose Alt-3, please respect the “constraints” in the corresponding sub-bullets**. **If you do so, please elaborate on your answer, and provide a precise and constructive proposal to allow the discussion to progress.**

**3.1.1-Q1**

|  |  |  |
| --- | --- | --- |
| Company | Answer | Further comments/explanations |
| CTC | Al2 | Demodulation performance is the most important metric for DMRS, while the PAPR/CM value similar to data is enough. As observed in most simulation results, at most 1dB gain can be observed for both demodulation performance and the data PAPR/CM value. Considering it is up to NW to configure the target DMRS sequence, more sequence type is beneficial for NW configuration flexibility. |
| Nokia/NSB |  Alt. 1 (also fine with Alt. 2) | Our first preference is Alt. 1 for simplicity. But we are also fine with Alt. 2 if that’s majority view, with an understanding that there is no harm for NW to configure more than one way of DMRS sequence generation. |
| IITH | Alt 2 |  |
| QC | Alt 1 | I suppose there will be a separate discussion on whether the extension is similar to data or not. |
| Ericsson | Prefer to inform RAN4 of feasible alternatives from RAN1 perspective.  | RAN1 has not been able to determine the net performance of different DMRS designs, since most companies in RAN1 do not work with RF+baseband simulations. From our simulations of OBO for data+DMRS, we do not see that the DMRS design impacts OBO. Our understanding is that OBO is calculated for the full PUSCH (data+DMRS) in RAN4. One more nuanced aspect is that EVM depends on the channel estimate and so data and dmrs are inter-dependent even for EVM. Overall, the net performance of different DMRS design alternatives should be verified in RAN4, since RAN4 is where net MPR/PAR reduction is to be evaluated.Whether there is UE complexity impact from having different spectrum extension between data and DMRS is also not established in RAN1 in our understanding. RAN4 often has better insights into implementation complexity as well, and so they would weigh in on this aspect for DMRS.My suggestion would be to inform RAN4 of the design alternatives that are feasible from a RAN1 perspective, and to have RAN4 identify the performance differences and assess relative UE complexity. If FDSS-SE is pursued in RAN4, then downselection among DMRS design alternatives can be done in RAN1 based on RAN4’s performance and complexity feedback. |
| Intel |  | A clarification question: is the intention to support Alt. 1 or Alt. 2 if FDSS-SE is supported? Our understanding is that there are some details which need to be further discussed, e.g., for cyclic extension, whether it is based on per-RE or per-PRB. We do not think we can agree with either Alt. 1 or Alt. 2 without such details. Another question: for symmetric extension, why this cannot be applied for low PAPR type 1 sequence? Our view is that we need to first decide whether FDSS-SE scheme can be applied for pi/2 BPSK or QPSK. This decision has impact on whether we need to support Type 1 or Type 2 DMRS.  |
| ZTE |  | We should minimize the number of DMRS sequences to be considered. Supporting more DMRS sequences without clear benefits/performance gain can only introduce more specification efforts and complicate NW management of different kinds of UEs with different UE capabilities.We feel it’s better to first align the understanding of the terms like cyclic extension (per RE or per RB?), and if it is per RB, is there any difference compared to symmetric extension. Otherwise, it may cause ambiguity on what we are trying to agree.  |
| Panasonic | Alt.1 | Based on our PAPR/CM evaluation, Alt.1 provides best PAPR/CM performance. |
| Vivo  |  | One comment is that does it mean that some combinations, e.g. DMRS type 2 with QPSK, which are not supported in current spec. would be supported if FDSS with SE is supported in NR Rel-18?It seems that the intention of alt-2 is to support all possible DMRS extension and generation methods, will these different DMRS extension and generation methods be treated as independent UE capabilities. Note that one of the options below is not captured:*• Rel-15 Type 1 low-PAPR DMRS generated for inband with symmetric extension to excess band*In our view, the conclusion on which DMRS extension/generation methods should be supported can be up to RAN4 discussions via checking the real net gain from both observations from RAN1 and RAN4. It would be enough to capture what are observed in RAN1 evaluations. |
| OPPO | Alt.1 | Prefer Alt. 1 for simplicity, OK with Alt.2 |
| Spreadtrum |  | Considering that a large variance exists between different companies’ results，RAN1 can inform RAN4 some feasible alternatives from RAN1 perspective and request RAN4 to evaluate the performance of each feasible solution. RAN1 can make a decision based on feedback from RAN4. If multiple DMRS sequences can be supported, it may impact the specification and increase the complexity of UE implementation. |
| Huawei, Hisilicon | Alt.2 | Prefer Alt.2. PAPR/CM & demodulation performance is enough for down selecting DMRS options, and the extension method of type 1 DMRS needs to be specified (per RE or per RB) |

**3.1.1-Q2**

|  |  |  |
| --- | --- | --- |
| Company | Answer | Further comments/explanations |
| Nokia/NSB |  Alt. 1 (also fine with Alt. 2) | Our first preference is Alt. 1 for simplicity. But we are also fine with Alt. 2 if that’s majority view, with an understanding that there is no harm for NW to configure more than one way of DMRS sequence generation. |
| IITH | Alt 3 | The following sequence generation methods can be considered for DMRS generation* Rel-15 Type 1 low-PAPR DMRS generated for inband and cyclic extension to excess band
* Rel-16 Type 2 low-PAPR DMRS generated for inband with symmetric extension to excess band
* Rel-15 Type 1 low-PAPR DMRS generated for total allocation
* Rel-16 Type 2 low-PAPR DMRS generated for total allocation

With this, there will be uniformity between DMRS generation for lengths >=30, and for length < 30.Additionally, the current FDSS-SE has been studied primarily for QPSK data, and it has been shown that the proposed method improves different metrics of coverage enhancement. Since, Type-1 CGS is also a QPSK sequence, the FDSS-SE method used for QPSK data will be sufficient for type-1 CGS coverage.  |
| QC |  | I think we can discuss this after there is more clarity on Q1. We can settle the design direction for > 4 RB allocations and then comeback to this. |
| Ericsson |  | Similar comment to QC: need to handle the larger allocations first. Also would like some discussion on the need for a separate design for sequence length less than 30. |
| Intel |  | Similar comment as above. In addition, for short sequence, careful study is needed to consider “DFT transformed Type 1 generated for inband and cyclic extension to excess band”. This has large specification and implementation impact while the benefit is not clear.  |
| ZTE |  | Same comment as above.  |
| vivo  |  | Same comments as above. |
| OPPO |  | Same comment as above. |
| Spreadtrum |  | Same comment as above.  |
| Huawei, Hisilicon | Alt 3(also fine with Alt. 2) | The following sequence generation methods can be considered for DMRS generation* DFT transformed Type 1 generated for inband and cyclic extension to excess band
* Rel-16 Type 2 low-PAPR DMRS generated for inband with symmetric extension to excess band

It should be noted that PAPR/CM of Rel-15 Type 1 low-PAPR DMRS generated for inband and cyclic extension to excess band is higher than data, which makes it unusable. And DFT transformed Type 1 could resolve this issue. And the demodulation performance of the above two options are quite similar, so the proposed Alt 3 is preferred. |

FL’s comments on April 19

Thank you for the comments and for the good discussion we had during the offline sessions. As explained during the offline session, it may be good to continue the discussion from the long sequences, given that similar approach can then be used for short sequences as well.

First some definitions are given, for completeness, in case of 8 PRBs total allocation with extension factor 25%, i.e., 6+2.

**Definitions (examples for 6+2 PRB case)**

**Sequence generated for the total allocation**

* A DMRS sequence is generated considering the number of PRBs in the inband + extension.
* The sequence length depends on the number of PRBs in the inband + extension and spans 8 PRBs.
* The sequence is mapped from the PRB with lowest index to the PRB with the highest index
* The sequence is 48 symbols long. From the PRB with the lowest index to the PRB with the highest index, it reads: [0,1,…47]

|  |  |
| --- | --- |
| **RE index in PRB** | **RB index** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **0** | 0 | 6 | 12 | 18 | 24 | 30 | 36 | 42 |
| **2** | 1 | 7 | 13 | 19 | 25 | 31 | 37 | 43 |
| **4** | 2 | 8 | 14 | 20 | 26 | 32 | 38 | 44 |
| **6** | 3 | 9 | 15 | 21 | 27 | 33 | 39 | 45 |
| **8** | 4 | 10 | 16 | 22 | 28 | 34 | 40 | 46 |
| **10** | 5 | 11 | 17 | 23 | 29 | 35 | 41 | 0 |

**Cyclic extension of the sequence, a.k.a., per-RE extension**

* A DMRS sequence is generated considering the number of PRBs in the inband (no extension).
* The sequence length depends on the number of PRBs in the inband and spans 6 PRBs.
* The sequence is then cyclically extended according to a per-RE logic to span the PRBs in the extension.
* The sequence is 48 symbols long. Depending on how the sequence is mapped to PRBs, two possibilities exist:
	+ Mapping from PRB with the lowest index of the inband to the PRB with the highest index of the inband and then extension towards the PRBs with lower and higher indices in the extension. This reads as follows, as is represented in the first figure below:
		- [25,26,…, 30, 0, 1,…, 30, 0, 1,…, 10]
		- Note: given that this method uses the PRBs inband to generate the sequence, it is the approach used by most companies in their contribution and can be considered a baseline.
	+ Mapping from PRB with the lowest index of the total allocation to the PRB with the highest index of the total allocation.This reads as follows, as is represented in the second figure below:
		- [0, 1,…, 30, 0, 1,…, 16]

|  |  |
| --- | --- |
| **RE index in PRB** | **RB index** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **0** | 25 | 0 | 6 | 12 | 18 | 24 | 30 | 5 |
| **2** | 26 | 1 | 7 | 13 | 19 | 25 | 0 | 6 |
| **4** | 27 | 2 | 8 | 14 | 20 | 26 | 1 | 7 |
| **6** | 28 | 3 | 9 | 15 | 21 | 27 | 2 | 8 |
| **8** | 29 | 4 | 10 | 16 | 22 | 28 | 3 | 9 |
| **10** | 30 | 5 | 11 | 17 | 23 | 29 | 4 | 10 |

|  |  |
| --- | --- |
| **RE index in PRB** | **RB index** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **0** | 0 | 6 | 12 | 18 | 24 | 30 | 5 | 11 |
| **2** | 1 | 7 | 13 | 19 | 25 | 0 | 6 | 12 |
| **4** | 2 | 8 | 14 | 20 | 26 | 1 | 7 | 13 |
| **6** | 3 | 9 | 15 | 21 | 27 | 2 | 8 | 14 |
| **8** | 4 | 10 | 16 | 22 | 28 | 3 | 9 | 15 |
| **10** | 5 | 11 | 17 | 23 | 29 | 4 | 10 | 16 |

**Symmetric extension of the sequence, a.k.a., per-PRB extension**

* A DMRS sequence is generated considering the number of PRBs in the inband (no extension).
* The sequence length depends on the number of PRBs in the inband and spans 6 PRBs.
* The sequence is then extended according to a per-PRB logic to span the PRBs in the extension.
* The sequence is 48 symbols long. From the PRB with the lowest index to the PRB with the highest index, it reads: [30,0,…, 4, 0, 1, …, 30, 0, 1,…4, 0, 1, …, 5]

|  |  |
| --- | --- |
| **RE index in PRB** | **RB index** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **0** | 30 | 0 | 6 | 12 | 18 | 24 | 30 | 0 |
| **2** | 0 | 1 | 7 | 13 | 19 | 25 | 0 | 1 |
| **4** | 1 | 2 | 8 | 14 | 20 | 26 | 1 | 2 |
| **6** | 2 | 3 | 9 | 15 | 21 | 27 | 2 | 3 |
| **8** | 3 | 4 | 10 | 16 | 22 | 28 | 3 | 4 |
| **10** | 4 | 5 | 11 | 17 | 23 | 29 | 4 | 5 |

Similar examples can be made for the short sequences case.

Now, coming to the received comments:

* At least two companies do not see the need for enhancing DMRS at this stage, given that net gain results do not highlight strict need to enhance DMRS conclusively.
* At least one company observes the opposite.
* DMRS have already been enhanced in the past after the introduction of FDSS in NR, e.g., Rel-16 Type 2 low-PAPR DMRS have only been introduced in Rel-16. Thus, similar process may occur in this case, if needed.
* According to what has been proposed by companies, Type 2 DMRS could be configured with QPSK. This would be a new configuration in general, however it does not seem problematic formally speaking given that the whole FDSS-SE would be a new configuration.
* Discussion in the UE features session could ensure all capabilities are worked out properly and concerns from different companies can be addressed, e.g., interplay between Type 2 DMRS and QPSK data and so on.

Alt. 3 and Alt. 4 were added during the offline session. The results new version of 3.1.1-Q1 is thus proposed for completeness. It is noted that discussions on which per-RE extension approach (as per description above) would be adopted in case of Alt-1 and Alt-2 will occur at a later stage, if any of these two alternatives is retained.

**3.1.1-Q1-v2**

|  |
| --- |
| ***Assumptions******If a given DMRS sequence as per one of the alternatives is supported, NW can configure it subject to:**** ***NW decision***
* ***UE capability***

***Discussion on the corresponding UE capabilities would occur in the appropriate session.*** |

***If FDSS-SE is supported in Rel-18, which of the following three alternatives should be preferred for the DMRS when FDSS-SE is configured with QPSK and the DMRS sequence length before extension of the sequence, if any, is larger than or equal to 30?***

***Alt-1:***

* ***Rel-15 Type 1 low-PAPR DMRS generated for inband and cyclic extension (per-RE) to excess band***
* ***Rel-16 Type 2 low-PAPR DMRS generated for inband with symmetric extension (per-PRB, like data) to excess band***

***Alt-2:***

* ***Rel-15 Type 1 low-PAPR DMRS generated for inband and cyclic extension (per-RE) to excess band***
* ***Rel-16 Type 2 low-PAPR DMRS generated for inband with symmetric extension (per-PRB, like data) to excess band***
* ***Rel-15 Type 1 low-PAPR DMRS*** ***generated for total allocation***
* ***Rel-16 Type 2 low-PAPR DMRS*** ***generated for total allocation***

***Alt-3***

* ***Rel-15 Type 1 low-PAPR DMRS*** ***generated for total allocation***
* ***Rel-16 Type 2 low-PAPR DMRS*** ***generated for total allocation***

***If DMRS enhancement is later found necessary, that could be added if time allows in Rel-18 or later***

***Alt-4***

* ***Rel-15 Type 1 low-PAPR DMRS*** ***generated for inband with symmetric extension (per-PRB, like data) to excess band***
* ***Rel-16 Type 2 low-PAPR DMRS generated for inband with symmetric extension (per-PRB, like data) to excess band***

Companies’ preferences expressed so far would be as follows:

|  |  |
| --- | --- |
| **Alternative** | **Companies** |
| *Alt. 1* | Panasonic, OPPO, Nokia (2nd), QC |
| *Alt. 2* | Huawei, Nokia, Panasonic (2nd), IITH, CTC |
| *Alt. 3* | Ericsson, Apple |
| *Alt.4* | ZTE |

A majority exists for Alt. 2 but this alternative is not acceptable for at least 3 other companies, for the time being. I would thus propose to keep collecting companies’ views in the table above to have a more complete picture of the situation. Companies are invited to add their names (and 2nd preference, if applicable) in the table above.

Further views can be added in the table below.

**3.1.1-Q1-v2**

|  |  |  |
| --- | --- | --- |
| Company | Answer | Further comments/explanations |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

Additionally, I would like to propose a further approach to advance in this discussion to ensure that progress continues, and we make the best use of the limited available time. The idea here would be to completely abstract from the sequence type and simply talk about where DMRS are placed in the frequency domain.

RAN1 made the following agreement in Rel-18.

|  |
| --- |
| **Agreement**The following design aspects of frequency domain spectrum shaping with spectrum extension (FDSS-SE), are considered for studying MPR/PAR reduction enhancements in Rel-18:* Spectrum extension size is expressed in integer units of RBs.
* Both DMRS and data symbols undergo spectrum shaping
* FFS:
	+ Which extensions factor(s) to consider, where extension factor (α) is given by spectrum extension size / Total allocation size.
	+ Impact of shaping filter on FDSS-SE performance
	+ How to extend DMRS sequence to spectrum extensions, based on either the existing ZC-sequence DMRS or low-PAPR DMRS for PUSCH (FG 16-6c)
	+ How extension size is determined
 |

Stemming from this agreement and from what all companies considered in the respective contributions, the following proposal is formulated (the usual note is added before it for completeness).

|  |
| --- |
| **FL’s NOTE**It should be noted that the following proposal includes a condition on whether FDSS-SE is supported in Rel-18 or not, to prevent ambiguous readings and understandings. While not ideal, this seems a reasonable approach at this stage, given the limited available time for this discussion and the fact that RAN1 should be ready if and when RAN4’s conclusion is shared with RAN1. It is FL’s understanding that all agreements subject to the support or not of FDSS-SE in Rel-18 will not have any RAN1 normative power if RAN4 concludes that FDSS-SE is not supported in Rel-18. |

**FL’s proposal 4**

**If FDSS-SE is supported in Rel-18, DMRS are mapped on PRBs of both inband and extension and gNB can assume that they are filtered using the same Tx shaping filter as data.**

**FFS: whether and which optimizations to Rel-15 and/or Rel-16 DMRS, including sequence extension and/or mapping, to be used with FDSS-SE, are needed.**

**Note: whether this will have RAN1 specification impact (if any) is a separate discussion and subject to RAN4’s conclusion to support FDSS-SE as one MPR/PAR reduction solution for Rel-18 (if any).**

Companies are invited to input their views about **FL’s proposal 4**, only **if strong concerns exist**. I would be surprised if this was the case, though, since this is what both RAN1 and RAN4 have been considering so far in practice. Having said this, if you express a concern, please also **propose constructive alternative proposals that could achieve consensus**. We need to advance on all these discussions for the sake of an efficient use of the very limited available time. **I would appreciate if all could be constructive and not block progress on this aspect**. Thank you.

**FL’s proposal 4**

|  |  |
| --- | --- |
| Company | Answer/Views |
| NTT DOCOMO | We are fine with the FL’s proposal 4.  |
| Intel | We still think Rel-15 and 16 DMRS design should be considered as a starting point for FDSS-SE. We do not think it is reasonable to consider a completely new design of DMRS sequence, which would involve substantial efforts. We still prefer to add “Rel-15 and 16 DMRS as starting point” in one of the notes.  |
|  |  |
|  |  |

## [CLOSED] Mid priority aspects

Nine mid priority aspects are identified at the beginning of the meeting:

1. MPR/PAR reduction techniques – solutions
2. MPR/PAR reduction techniques – modulation order
3. Design aspects of FDSS w/ SE – FDRA
4. Design aspects of FDSS w/ SE – extensions factors
5. Design aspects of FDSS w/ SE – MCS
6. Design aspects of FDSS w/ SE – power control
7. Design aspects of FDSS w/ SE – others
8. Design aspects of TR – FDRA
9. Design aspects of TR – others

Discussion on most of these aspects is closed for the time being. FL’s comments are provided for all such aspects to explains why this is the case. Discussion about these aspects may start when need arises, regardless of how many high priority aspects are still being discussed. Discussion on the few other aspects is open.

### [CLOSED] MPR/PAR reduction techniques – solutions

Several contributions discussed this aspect.

* One company (Huawei/HiSi [2]) proposes to deprioritize TR.
* One company (vivo [5]) proposes prioritizing FDSS evaluations for MPR/PAR reduction study.
* One company (China Telecom [17], OPPO [6]) proposes that TR can also be considered as a candidate MPR/PAR reduction solution.
* One company (InterDigital [14]) proposes supporting FDSS and TR with spectrum extension.
* One company (Qualcomm [19]) argues that inner RB allocations with small RB allocations, for e.g., 1-32 RBs, should be prioritized.
* One company (Qualcomm [19]) argues that priority should be given to mechanisms that allow a 0-Db MPR waveform to be transmitted at a transmit power exceeding the maximum power associated with the UE power class.
* One company (Qualcomm [19]) proposes that, for RB allocations that are of interest to coverage enhancements with DFT-S-OFDM waveforms and QPSK modulation, transparent techniques such as peak cancellation should be prioritized over non-transparent techniques such as TR and FDSS-SE.

Additionally,

* One company (Samsung [16]) proposes to discuss the gains of MPR/PAR reduction techniques, and potential impact on Gnb implementation.
* One company (Apple [13]) proposes not supporting non-transparent scheme if no clear gain over transparent scheme is observed.

From FL’s perspective, the situation is identical to what was observed at the beginning of RAN1 #112.

FL’s comments made at the beginning of RAN1 #112 are thus still valid. Some of them are reproposed here for completeness. Further comments are added.

The last proposals/observations about the gains are already covered by the existing agreed RAN1/RAN4 work split, and current RAN4 agreements. Indeed, the following two agreements were made during RAN1 #104b-e:

|  |
| --- |
| **<Way forward/Agreement>:**FDSS enhancement (i.e., FDSS with spectrum extension) in Rel-18 should be carefully studied and should not be specified unless the gain of the power boost is justifiedConclusion: The decision is postponed. In any case, we are going to study the schemes in the objective.**<Way forward/Agreement>:**Actual conclusion of the MPR/PAR reduction methods should be based on net coverage gain results combining transmitter and receiver performance |

As I explained during RAN1 #111 and RAN1 #112, it is safe to state that RAN1 should not be concerned by this any longer.

Concerning the schemes that RAN1 should focus on in Rel-18, the situation doesn’t seem to be different from RAN1 #112. RAN1’s work on candidate solution identification is over until RAN4 takes a decision on which MPR/PAR reduction solutions, if any, are supported in Rel-18. Until then, RAN1 can discuss and agree on potential specification impact and feature design aspect that would be needed should RAN4 conclude to support, e.g., FDSS-SE. However, according to agreed RAN1/RAN4 work split principles, further solutions prioritization/de-prioritization it is not within RAN1’s current responsibilities, but within RAN4’s.

Given all the above, priority in RAN1 should be given to other aspects of the discussion at least until a decision is taken by RAN4 on which MPR/PAR reduction techniques, if any, is supported and specified in Rel-18.

### [CLOSED] MPR/PAR reduction techniques – modulation order

Two contributions discussed and expressed preference on the target modulation schemes to be considered for the MPR/PAR reduction techniques. A high-level summary of companies’ preferences based on the contributions is as follows:

* One company (Intel [9]) proposes that FDSS-SE is not supported for pi/2-BPSK and QPSK modulation.
* Two companies (Huawei/HiSi [2], Intel [9])) proposes that FDSS-SE is not supported for pi/2-BPSK modulation.

From FL’s perspective, further discussions on the modulation order may not be strictly needed at this stage. Indeed, the RAN1 link level performance study has been completed and its results shared with RAN4 for the latter to be able to conclude which MPR/PAR reduction solution, if any, is supported and specified in Rel-18.

Furthermore, the following agreements made in RAN4 #104-b and RAN4 #106 should also be noted.

|  |
| --- |
| **<Way forward/Agreement>:**Actual conclusion of the MPR/PAR reduction methods should be based on net coverage gain results combining transmitter and receiver performanceAgreement:  QPSK is the targeted modulation for further coverage enhancements At least for simulation study |

In other words, RAN4:

* Will base the decision on the net gain results and not on combination of 10% BLER SINR and PAPR/CM reduction results.
* Has already decided to focus the remaining part of the study on QPSK, i.e., pi/2 BPSK is not further studied.

Thus, given that RAN1 is still waiting for input from RAN4 (which may also include the modulation order), thus priority should be given to other relevant RAN1 aspects of the discussion, e.g., DMRS, FDRA, etc.

### [OPEN] Design aspects of FDSS w/ SE – FDRA

Several contributions discussed the FDRA design aspect of FDSS-SE. A high-level summary of companies’ preferences based on the contributions is as follows:

* Three companies (Huawei/HiSi [2], Spreadtrum [4], Sharp [25]) propose that FDRA field indicates the number of PRBs in the inband.
* One company (Intel [9]) proposes further studying the potential specification impact on ignaling mechanism for frequency resource for FDSS-SE scheme.
* One company (Spreadtrum [4]) proposes that the scheme of generating integer PRBs numbers for the extension band should be studied.

FL’s assessment is that DMRS and FDRA design aspects are the most relevant RAN1 aspects attention should be focused on during RAN1 #112-bis-e, with the former having higher priority than the latter. Other topics will still be discussed during this meeting, however attention to FDRA may be higher.

Therefore, while waiting for further inputs from RAN4, RAN1 can start discussing on these aspects to facilitate later normative work, if any.

From a purely technical perspective, FL’s understanding is that if the resource block allocation signaled by FDRA for FDSS-SE indicates the inband resource, then several legacy operations would be unchanged and implementation impact at the UE would be greatly reduced, if any. Indeed, this would allow to preserve existing mechanisms and implementations at the UE to at least determine:

* The DFT size for the transform precoder for the data and DMRS, the latter being the case when the DMRS sequence is defined over the inband resource and extended to span the inband+extension (please refer to Section 3.1.2).
* TBS determination (assuming no change occurs in the way MCS index is indicated to UE, which is a very reasonable assumption since no technical merit seems to exist to do otherwise).

For what concerns power control aspects, decision on FDRA does not seem so relevant to identify whether further optimizations are desirable in case FDSS-SE is supported in Rel-18. Indeed, the presence of the SE is sufficient for discussing whether optimizations are needed or not, irrespective of what the FDRA indicates. Discussions on this aspect may occur in Section 3.2.5.

Given the above, the following FL’s proposal is formulated.

|  |
| --- |
| **FL’s NOTE**It should be noted that the following proposal includes a condition on whether FDSS-SE is supported in Rel-18 or not, to prevent ambiguous readings and understandings. While not ideal, this seems a reasonable approach at this stage, given the limited available time for this discussion and the fact that RAN1 should be ready if and when RAN4’s conclusion is shared with RAN1. It is FL’s understanding that all agreements subject to the support or not of FDSS-SE in Rel-18 will not have any RAN1 normative power if RAN4 concludes that FDSS-SE is not supported in Rel-18. |

**FL’s proposal 1**

**If FDSS-SE is supported in Rel-18, the FDRA field indicates the number of PRBs in the inband.**

**Note1: whether power control optimizations are desirable is a separate discussion**

**Note2: whether this has specification impact or not is a separate discussion and subject to RAN4’s conclusion to support FDSS-SE as one MPR/PAR reduction solution for Rel-18 (if any).**

#### Discussion

FL’s recommendation is for companies to add views about **FL’s proposal 1**, if applicable. Companies are invited to input their views in the corresponding table below. **Please consider the FL’s note above**. The goal is to make an efficient use of available time without reverting the agreed RAN1/RAN4 work split principles.

**FL’s proposal 1**

|  |  |
| --- | --- |
| Company | Answer/Views |
| NTT DOCOMO | If FL’s note is the common understanding, and given a number of companies kindly put their effort on this issue, we are fine with FL’s proposal 1.  |
| Sharp | Support the proposal.  |
| CTC | We are fine with FL’s proposal 1, and open if the FDRA field indicates the number of PRBs in the inband + extension band |
| Nokia/NSB | Support. |
| Intel | We support the proposal as this would minimize the spec impact, e.g., TBS calculation. For the first Note 1, we suggest to remove as this may not be relevant to the FDRA indication.  |
| LGE | Support |
| ZTE | For the main bullet, we suggest to add ‘as legacy’ at the end of the sentence. Basically, how FDRA indicates the inband allocation is the same as legacy, though it may or may not have other spec impacts on other aspects, e.g., TBS, as reflected in Note 2. For Note 1, we have similar comment as Intel. |
| Ericsson | There seem to be pros and cons with indicating the number of inband vs. the total extension. We can see that TBS calculation might weigh in favor of indicating the inband, however, power control or other functions relying on the total number of RBs would then need to operate on a different quantity than what is indicated in FDRA. We observe that other WG’s specifications also rely on the allocated resources, so we hesitate to redefine what resources are provided by the FDRA field without more discussion. |
| Panasonic | If FDSS-SE is supported, we slightly prefer indication of inband + extension, so that UE can determine extension size based on an extensions factor α, where it is given by extension size / (inband + extension) size. When αis specified such as 25%, there is no need a signalling of α. |
| CATT | For FDSS-SE if supported, FDRA can either indicate the number of RBs before extension or after extension. We think it may be simpler to indicate the number of RBs before extension due to the limitation of DFT size. So we are generally fine with the proposal. For Note 1, we would like to understand what the baseline is for “power control optimizations” in case of FDSS-SE. |
| Vivo  | Fine. |
| QC | Okay with the general direction. Need to be clear on how the RAN4 constraints apply and how inner vs outer vs edge classification is established.  |
| OPPO | Support. |
| Spreadtrum | Support. |
| Huawei, Hisilicon | We have a concern that the transmission power is computed by indicated RB number according to current spec and **it would reduce the achievable net gain** when the computed power is below the maximum transmission power. In this case, the transmission power, e.g. , is proportional to the indicated number of PRB. Since the extension RBs are not reflected in power control formula but occupy some power, which reduces the power density of RE and degrades net gain. For example, when SE ratio is 1/4, the power loss can be up to 1.25 dB, when SE ratio is 1/9, the power loss can be up to 0.51 dB. The power loss really reduces the performance gain of FDSS-SE, and should be considered carefully. If the indicated number of PRBs was the sum of inband and extension, then the gain reduction can be mostly fixed. But with this proposal, the gain reduction cannot be fixed because the power control discussion is closed now. Therefore, we think whether the FDRA field indicates the number of PRBs in the inband should be discussed jointly with power control formula. **A note is added that the total number of PRB of indicated in-band PRB and extension PRB is applied as the bandwidth of resource assignment** **in the uplink power control calculation.** The detailed analysis is given as follows.The formula for PUSCH power control is given. If a UE transmits a PUSCH on active UL BWP  of carrier  of serving cell  using parameter set configuration with index  and PUSCH power control adjustment state with index , the UE determines the PUSCH transmission power in PUSCH transmission occasion  as

|  |
| --- |
|  [dBm] (8)where,- is the UE configured maximum output power defined in [8-1, TS 38.101-1], [8-2, TS38.101-2] and [8-3, TS38.101-3] for carrier *f* of serving cell *c* in PUSCH transmission occasion *i*.- is a parameter composed of the sum of a component and a component  where .- is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks for PUSCH transmission occasion *i* on active UL BWP *b* of carrier *f* of serving cell *c* and $μ$ is a SCS configuration defined in [4, TS 38.211]- is a parameter to control the pathloss compensation ratio, is a downlink pathloss estimate in dB calculated by the UE using reference signal (RS) index $q\_{d}$ for the active DL BWP, as described in clause 12, of carrier $f$ of serving cell $c$- is a power offset value of different modulation and coding scheme (MCS) format relative to a reference MCS format. , *C* is the number of code blocks transmitted, is the size of code block, andis the number of resource elements,, is the symbol number of the PUSCH transmission occasion *i* on the active BWP *b* of the carrier *f* of the serving cell *c*, is subcarrier number of the PUSCH symbol excluding demodulation reference signal (demodulation reference signal, DMRS) subcarrier and phase tracking reference signal,. The parameter  is indicated by the delta MCS signaling.-  is the power control adjustment for active UL BWP *b* of carrier *f* of serving cell *c* in PUSCH transmission occasion *i*. |

 According to above formula, the density of the transmission power over RE would reduce due to the extension RBs, this reduction is closely related with SE ratio, i.e., large SE ratio and flat filter would result in large power reduction. This reduction would degrade the coverage performance if the maximum transmission power is not achieved.  |

FL’s comments on April 19

Thanks for all the comments made so far.

A large majority of companies support the proposal. It has been argued by some companies that if this proposal is agreed first, then discussions on FL’s proposal in Section 3.2.5 would be easier. This is a fair point.

Two companies commented on the possible impact that this decision may have on other WGs. I fail to see why this should be an issue. Indeed, this would be business as usual in RAN1, or any other WG. Agreements are made in RAN1 about RAN1 aspects. If adjustments are needed in other WGs to accommodate for the impact of RAN1’s agreements, such adjustments are made in the concerned WG. If further interactions are needed to clarify doubts, then the concerned WG can liaise with RAN1. Clearly, RAN1 should not ask permission or authorization to take the best decision from RAN1 perspective.

I am honestly very surprised to see all this references to RAN4 in this discussion, for any item. Reality is that this work item has both RAN1 and RAN4 involved, where normative power exists in both. Business as usual, as I said. If the principle of asking to other WGs every time possible adjustments may be needed, then we would need tens of TUs for each item, which is of course impossible.

Another company elaborated in detail about implications for power control, which were also hinted at by two other companies. This is a very good contribution to this discussion and shows why the first note was included in FL’s proposal 1. I think that deleting completely the note, as asked by 2 companies, would not yield any clarity or benefit in this regard, since the discussion on the power control may still be needed. In this context, I prefer not adding the Note as requested by the company who elaborated on the issue but actually an FFS point. The reason being that RAN1 has not agreed yet on how the extension factor is to be signaled/applied. Thus, it seems reasonable to be precise in the FFS formulation, but also to leave that discussion open.

The proposal is thus re-formulated as follows.

**FL’s proposal 1-v2**

**If FDSS-SE is supported in Rel-18, the FDRA field indicates the number of PRBs in the inband.**

**FFS: the bandwidth of resource assignment**  **in the uplink power control calculation.**

**Note1: whether this has specification impact or not is a separate discussion and subject to RAN4’s conclusion to support FDSS-SE as one MPR/PAR reduction solution for Rel-18 (if any).**

Companies are invited to input their views about **FL’s proposal 1-v2**, only **if strong concerns exist**. If you do so, please **do not suggest taking the matter to other WGs**, but rather propose constructive alternative proposals that could achieve consensus. We need to advance on all these discussions for the sake of an efficient use of the very limited available time. Reality is that most companies were already ok with the original version of this proposal. **I would appreciate if all could be constructive and not block progress on this aspect**, which is arguably one of the least controversial to work out (together with the MCS discussion). Thank you.

**FL’s proposal 1-v2**

|  |  |
| --- | --- |
| Company | Answer/Views |
| Intel | We are fine with the proposal in principle. Suggest to update the FFS as **FFS: determination of bandwidth of resource assignment** **in the uplink power control calculation** |
|  |  |
|  |  |
|  |  |

### [OPEN] Design aspects of FDSS w/ SE – extension factors

This aspect is discussed in detail by one company (Huawei/HiSi [2]) which proposes supporting two extension factors, i.e., 1/4 and 1/9. The rationale of this proposal is that optimal spectrum extension selection depends on the spectral efficiency of the transmission, where the larger the MCS the smaller the optimal spectrum extension (according to results in [2]).

From FL’s perspective, the 1/9 proposal may also serve the purpose of being able to configure a spectrum extension factor whose denominator is a multiple or 3 and not 2. This would allow to configure, for instance practically relevant values such as 16, 32, 48 and 64 PRBs. In other words, NW’s scheduler flexibility would be larger in this case, since a larger number of FDRA + spectrum extension values which would result in an integer number of PRBs in the extension (as per existing agreements) could be indicated. To better understand the impact of supporting multiple SE factors on the scheduler flexibility, the list of possible valid configurations (all yielding valid DFT sizes for the applying the transform precoder over the inband) are given in the table below. Please note that no value is given for 1/8 (one of the values included in the working assumption made during RAN1 #111), since this does not yield valid DFT sizes for applying the transform precoder.

In this context, it could be argued that all numbers that can be obtained by means of setting the SE factor to 1/9 could be obtained by setting it to 1/3. However, this would be an unfair comparison since the two values would yield two very different SE configurations, suitable for different optimal link adaptation strategies, i.e., different optimal MCS ranges, and “optimal” filter selection.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SE factor** | 1/3 | 1/4 | 1/3 | 3/8 | 1/4 | 1/3 | 1/9 | 1/3 | 1/4 | 1/3 |
| **#PRBs inband** | 4 | 6 | 8 | 10 | 12 | 12 | 16 | 16 | 18 | 20 |
| **#PRBs inband+extensions** | 6 | 8 | 12 | 16 | 16 | 18 | 18 | 24 | 24 | 30 |
|  |  |  |  |  |  |  |  |  |  |  |
| **SE factor** | 3/8 | 1/3 | 3/8 | 1/9 | 1/3 | 1/4 | 1/3 | 1/3 | 3/8 | 1/9 |
| **#PRBs inband** | 20 | 24 | 30 | 32 | 32 | 36 | 36 | 40 | 40 | 48 |
| **#PRBs inband+extensions** | 32 | 36 | 48 | 36 | 48 | 48 | 54 | 60 | 64 | 54 |
|  |  |  |  |  |  |  |  |  |  |  |
| **SE factor** | 1/4 | 1/3 | 3/8 | 1/4 | 1/4 | 1/3 | 3/8 | 1/9 | 1/3 |  |
| **#PRBs inband** | 48 | 48 | 50 | 54 | 60 | 60 | 60 | 64 | 64 |  |
| **#PRBs inband+extensions** | 64 | 72 | 80 | 72 | 80 | 90 | 96 | 72 | 96 |  |

In this context, it could be argued that all numbers that can be obtained by means of setting the SE factor to 1/9 could be obtained by setting it to 1/3. However, this would be an unfair comparison since the two values would yield two very different SE configurations, suitable for different optimal link adaptation strategies, i.e., different optimal MCS ranges, and “optimal” filter selection. At the same time, it is worth observing that 1/3 would be the only value for which PRB allocations smaller than 6 inband PRBs would be configurable.

Given the above observations, it seems reasonable to start discussing about potential SE factor candidate values for FDSS-SE, should the latter be supported in Rel-18.

The following question is thus asked, and it would be great if all companies could express their view on this, irrespective of their current position on FDSS-SE, to ensure the answers stem from the comprehensive technical understanding of the group. It is also worth observing that, according to FL’s understanding it would always be up to NW to configure the SE factor. Supporting multiple values (if applicable) from which NW may pick would not only allow resource allocation flexibility but also implementation flexibility.

**3.2.4-Q1**

***If FDSS-SE is supported in Rel-18, which of the following SE factors could be supported (and thus configurable by NW)? Multiple choices are possible.***

* **1/9**
* **1/4**
* **1/3**
* **3/8**

***Companies are invited to explain their choice(s) for others to understand why certain preferences are expressed and for facilitating a good technical discussion.***

#### Discussion

FL’s recommendation is for companies to add views about **3.2.4-Q1**. Companies are encouraged to add an “X” in the column(s) corresponding to the chosen SE factor(s).

**We do not have much time left thus constructive attitude is greatly appreciated.** Please do not hesitate to add further views/explanations to substantiate your choices. This would be very helpful.

**3.2.4-Q1**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Company | 1/9 | 1/4 | 1/3 | 3/8 | Further comments/explanations |
| Nokia/NSB |  | x |  |  | We think that supporting only ¼ should be sufficient. However, we are open for other factors. This may also depend on input from RAN4. |
| Intel |  |  |  |  | Suggest to wait for the progress in RAN4. Many factors needs to be considered to determine the extension factor.  |
| ZTE |  |  |  |  | Similar comment as Intel. Depending on the evaluation results from RAN4, we can then have a better decision.  |
| Ericsson |  | x |  |  | ¼ can be a starting point. Open to more discussion; agree that RAN4 needs more progress here as well. |
| Panasonic |  |  |  |  | Similar comment as Intel. |
| CATT |  |  |  |  | Following FL’s proposal 1, if the inband size is indicated, we think it is more natural to define the SE ratio as excess band/inband so that the number of RBs after extension=inband size\*(1+SE ratio). In terms of detailed SE ratios, we think a single value may not be sufficient for different numbers of RBs. |
| Vivo  |  |  |  |  | We’re open for discussing the repetition factors. On the other hand, we also share similar view as majority that this can be determined based on the input from both RAN4 and RAN1. |
| QC |  |  |  |  | We might need more than one value. Will depend on what values RAN4 thinks are useful to consider depending on the net coverage gains observed. Its also not clear why this parameter needs to be provided via RRC. If there are gains using FDSS, then this will have be to used in conjunction with legacy PUSCH and efficient link adaptation will need to be considered when determining the factors indicated via DCI and RRC.  |
| OPPO |  |  |  |  | Open for the repetition factors and OK to wait for the progress in RAN4. |
| Huawei, Hisilicon | x | x |  |  | Based on our simulation results, 1/9 shows a larger net gain than 1/4 when MCS is high and 1/4 outperforms 1/9 for low MCS. Additionally, the highest spectrum efficiency in a given spectrum bandwidth for FDSS-SE is provided only by small extension ratio 1/9 because it has the largest available TBS in the given bandwidth. For example, in a 5Mhz bandwidth with 25 PRBs, the maximum number of scheduled PRBs is 20 PRBs for ¼ SE and around 22 PRBs for 1/9 SE. Therefore, assuming that the TBS calculation is based on in-band PRBs only, the maximum TBS within 5MHz bandwidth is only achieved by 1/9 SE +MCS#9.  |

FL’s comments on April 19

Thank you for the comments. It would appear that:

* Most companies prefer waiting for RAN4 input before deciding which spectrum extension values could be supported in Rel-18, if FDSS-SE is supported to begin with.
	+ FL’s comment: my understanding is that RAN4 may simply conclude that FDSS-SE should be supported or not in Rel-18. A detailed analysis on which extension factor to support may not be carried out in time, given the limited available TUs. Furthermore, by looking at the net gain results provided by companies in RAN4, it would seem that ¼ is by far the most studied extension factor due to its good performance overall.
* The ones that expressed a preference agree on the fact that at least ¼ should be configurable
	+ FL’s comment: this could be an idea for a first value, with further values FFS
* One comment highlights the fact that we should also decide how extension factors are configured, e.g., via RRC, DCI, both.
	+ FL’s comment: point taken; I will add an FFS.
* Only one company proposes to support 1/9, with a solid technical argument (from FL’s perspective at least) which other companies have not mentioned or commented on. I think this is worth considering, especially given that other companies mentioned the fact that one extension factor may not be sufficient.
* One company commented that if the inband size is indicated, we think it is more natural to define the SE ratio as excess band/inband so that the number of RBs after extension=inband size\*(1+SE ratio).
	+ FL’s comment: one may also argue that it is natural to calculate the number of RB’s after extension as inband size/(1-SE ratio). This shows that there may not be a natural way to calculate the quantity, since we are talking about simple products/divisions that be inverted straightforwardly. From FL’s perspective, if FDSS-SE is supported in Rel-18, any agreement about FDRA and extension factor can be captured easily by the Editor and how to do it will be natural.

For all these reasons, I would propose to start with a conditional working assumption on ¼ and 1/9, with a couple of FFS points to consider observations and preferences of some companies. The pint of having a working assumption is to have something to begin with, while giving companies time to further check any details they may want to check, and possibly to RAN4 to express some opinions, if any.

This working assumption could then be confirmed/changed/enhanced, depending on RAN4’s conclusion.

|  |
| --- |
| **FL’s NOTE**It should be noted that the following proposal includes a condition on whether FDSS-SE is supported in Rel-18 or not, to prevent ambiguous readings and understandings. While not ideal, this seems a reasonable approach at this stage, given the limited available time for this discussion and the fact that RAN1 should be ready if and when RAN4’s conclusion is shared with RAN1. It is FL’s understanding that all agreements subject to the support or not of FDSS-SE in Rel-18 will not have any RAN1 normative power if RAN4 concludes that FDSS-SE is not supported in Rel-18. |

**FL’s proposal for Working Assumption 1**

**If FDSS-SE is supported in Rel-18, at least spectrum extension factors ¼ and 1/9 are supported.**

**FFS: other spectrum extension factors**

**Note1: whether this has impact on DCI or not or has further specification impact or not is a separate discussion and is also subject to RAN4’s conclusion to support FDSS-SE as one MPR/PAR reduction solution for Rel-18 (if any).**

Companies are invited to input their views about **FL’s proposal for Working Assumption 1**, only **if strong concerns exist**. If you do so, please propose constructive alternative proposals that could achieve consensus. We need to advance on all these discussions for the sake of an efficient use of the very limited available time. **I would appreciate if all could be constructive**. Thank you.

**FL’s proposal for Working Assumption 1**

|  |  |
| --- | --- |
| Company | Answer/Views |
| Intel | It is a bit surprising that extension factor of 1/9 is included in the proposal. In the agreed simulation assumptions, extension factor of 1/9 was never considered. We can consider ¼ to move forward, but we would like to point out that overall performance depends on not only the extension factor, but also the selection of shaping filters.  |
|  |  |
|  |  |
|  |  |

### [PAUSED] Design aspects of FDSS w/ SE – MCS

This aspect is discussed in detail by one company (Huawei/HiSi [2]) which proposes to indicate MCS index to UE in case FDSS-SE is configured, to allow UE to carry out a legacy TBS calculation.

From FL’s perspective, what is proposed in [2] corresponds to legacy operations. In other words, the proposal in [2] can be rephrased as “no specification impact on MCS indication and TBS calculation”.

As a matter of fact, no alternative proposals have been brought forward on this subject throughout Rel-18. Indeed, all simulations have been carried out using this assumption and no evident technical reason seems to exist which could justify a different course of action.

I would then take this opportunity to formulate a proposal and possibly close this discussion for this release. Before doing so I will copy paste the FL’s note I added in Section 3.2.3 here, for the sake of clarity.

|  |
| --- |
| **FL’s NOTE**It should be noted that the following proposal includes a condition on whether FDSS-SE is supported in Rel-18 or not, to prevent ambiguous readings and understandings. While not ideal, this seems a reasonable approach at this stage, given the limited available time for this discussion and the fact that RAN1 should be ready if and when RAN4’s conclusion is shared with RAN1. It is FL’s understanding that all agreements subject to the support or not of FDSS-SE in Rel-18 will not have any RAN1 normative power if RAN4 concludes that FDSS-SE is not supported in Rel-18. |

**FL’s proposal 2**

**If FDSS-SE is supported in Rel-18, MCS indication and TBS calculation are performed as per existing procedures.**

#### Discussion

FL’s recommendation is for companies to add views about **FL’s proposal 2**, if applicable. Companies are invited to input their views in the corresponding table below. **Please consider the FL’s note above**. The goal is to make an efficient use of available time without reverting the agreed RAN1/RAN4 work split principles.

**FL’s proposal 2**

|  |  |
| --- | --- |
| Company | Answer/Views |
| NTT DOCOMO | Given there is only one company discussing this issue in the Tdoc, we wonder if it is good to continue further discussions? While the direction of FL proposal 2 seems quite reasonable, we wonder if it could be a bit too premature to conclude so. If majority is ok with it, then we are fine.  |
| Sharp | Taking this as a conclusion and having no discussion at all on this issue would lead to the same consequence. Either is fine to us. |
| CTC | Discussing this topic before a conclusion is approved for **proposal 1** is a bit early. In our opinion, MCS or TBs calculation based on whether FDRA indication is only for inband PRBs or for both inband and extension band. |
| Nokia/NSB | Support. |
| Intel | Support.  |
| Ericsson | Also need more discussion here. As others companies comment, this depends on proposal 1. |
| CATT | Support.  |
| Vivo  | Fine. |
| QC  | We may need to spell it out that TBS determination is based on inband allocation. |
| OPPO | Support. |

FL’s comments on April 19

Thank you for the comments. FL’s understanding is that all companies find it reasonable but prefer waiting for the outcome of the discussion on FL’s proposal 1 before agreeing on FL’s proposal 2. This is a fair point and I will pause the discussion for the time being, until further progress is achieved for FL’s proposal 1.

### [CLOSED] Design aspects of FDSS w/ SE – power control

Three companies (Huawei/HiSi [2], Intel [9], Nokia/NSB [20]) propose studying power control (including potential specification impact and whether/how to enhance the power control mechanism) to consider the difference of power spectral density of the REs due to the FDSS.

From FL’s understanding, optimizations to the power control framework in case of adoption of FDSS-SE in Rel-18 are desirable but not strictly needed. For this reason, I see no urge to open this discussion prior to the RAN4’s decision on which MPR/PAR reduction solution(s) to support in Rel-18, if any. This is different from, for instance, what can be said about FDRA indication, for instance, given that agreements would surely be needed for that aspect, in case.

For these reasons, discussions on power control seem to be premature/unnecessary at this stage. I suggest discussing about this aspect on a need basis.

I am still labeling this as mid-priority to highlight its importance, but the section is closed, and no discussion is planned, for the time being.

### [CLOSED] Design aspects of FDSS w/ SE – others

Three companies proposed to discuss the following aspects related to the support of specific parameters or approaches to specify FDSS-SE, other than modulation order/FDRA/DMRS.

**Others - how to extend the spectrum**

One company (Huawei/HiSi [2]) proposes supporting cyclic shift plus symmetric extension for spectrum extension.

**Others – further details on extension factors:**

One company (Panasonic [22]) proposes that, if FDSS with SE is supported, determine SE size based on an extensions factor α, where it is given by spectrum extension size / total allocation size. SE size is expressed in integer units of RBs

**Others - DFT size:**

One company (Nokia/NSB [20]) proposes that no new additional DFT size options to be introduced by RAN1 to support Rel-18 power domain enhancements.

From FL’s understanding, and similar to what I wrote for Section 3.2.6, further refinements and more advanced agreements on FDSS-SE, other than the ones proposed in some previous sections, seem to be premature/unnecessary at this stage. I suggest discussing about these on a need basis. This could happen either when RAN4’s decision related to which MPR/PAR reduction solution, if any, is supported in Rel-18 is taken or when discussion on more relevant RAN1 aspects is at a more advanced stage, e.g., DMRS/FDRA.

I am still labeling these aspects as mid-priority to highlight their importance, but the section is closed, and no discussion is planned, for the time being.

### [OPEN] Design aspects of TR – FDRA

One contribution discussed the FDRA design aspect of TR as follows:

* One company (Lenovo [10]) proposes studying whether the FDRA indicator provides the indication for PRTs or not.

FL’s assessment is that FDRA is among the RAN1 design aspects which are relevant enough to require the attention of the group even prior to the conclusion that RAN4 will make. Therefore, similar to what is done for FDSS-SE, I would propose to start discussing on FDRA for TR to facilitate later normative work, if any, while waiting for further inputs from RAN4.

I understand that some companies wish to de-prioritize discussions on TR, however according to the agreed RAN1/RAN4 work split principles, and after the end of the link level performance study in RAN1 (which is the current situation), a decision on whether to consider TR or not in Rel-18 is RAN4’s prerogative.

The following question is thus asked.

**3.2.8-Q1**

**If TR is supported in Rel-18, would the FDRA indicator provide the indication of the inband only or inband + extension (where the PRT are placed)?**

#### Discussion

FL’s recommendation is for companies to add views about **3.2.8-Q1**, if applicable, in the corresponding table below. Given the limited available time, constructive attitude is appreciated.

**3.2.8-Q1**

|  |  |
| --- | --- |
| Company | Answer/Views |
| NTT DOCOMO | Given there is only one company discussing this issue in the Tdoc, we wonder if it is good to continue further discussions? While the direction of FL proposal 2 seems quite reasonable, we wonder if it could be a bit too premature to conclude so. If majority is ok with it, then we are fine.  |
| Sharp | OK. |
| CTC | Either is fine, and inband only is slightly preferred for a possible alignment with FDSS FDRA indication. |
| Nokia/NSB | If TR is supported, we prefer FDRA indicator provides the indication of the inband only, given that this solution would minimize the specification impact, e.g., on TBS determination etc. |
| Intel | We prefer the inband indication only.  |
| LGE | It seems there isn’t enough discussion on TR. But if TR is supported as in RAN1/RAN4 work split principles, inband only is fine to have same approach with FDSS-SE |
| ZTE | If TR is supported, we prefer inband indication. But considering TR is of less interests among companies, we could down-prioritize any discussion related to TR.  |
| Ericsson | Similar comments as for proposal 1: there are pros and cons to inband vs. inband+extension, and RAN1 specs may not be the only ones impacted by this. |
| Panasonic | If tone reservation is supported, we think both approaches can work. We slightly prefer indication of inband + extension, so that UE can determine sideband extension size based on an extensions factor α, where it is given by extension size / (inband + extension) size. When αis specified such as 25%, there is no need a signalling of α. |
| Vivo  | Inband only is preferred. |
| QC | FDRA can provide inband allocation. But whether the extension factor is provided via DCI or via DCI needs more discussion. We will need to take link adaptation into account.  |
| OPPO | Prefer inband allocation, OK with (inband + extension). |
| Huawei, Hisilicon | If TR is supported, FDRA indicator provides the indication of the inband only |

FL’s comments on April 19

Thank you for the comments. It would appear that similar situation as the one for FDSS-SE applies in this case. The comments I made for that discussion apply here as well, hence I would suggest companies to have a look at those instead of replicating them here. This applies also to the comments related to interacting with other WGs.

@QC: this seems a separate discussion to me, but point taken. I think this type of detail can be discussed after preliminary agreements are made (as usual), similar to what I suggested doing for FDSS-SE.

The following proposal is thus formulated (the usual note is added before it for completeness).

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| --- |
| **FL’s NOTE**It should be noted that the following proposal includes a condition on whether FDSS-SE is supported in Rel-18 or not, to prevent ambiguous readings and understandings. While not ideal, this seems a reasonable approach at this stage, given the limited available time for this discussion and the fact that RAN1 should be ready if and when RAN4’s conclusion is shared with RAN1. It is FL’s understanding that all agreements subject to the support or not of FDSS-SE in Rel-18 will not have any RAN1 normative power if RAN4 concludes that FDSS-SE is not supported in Rel-18. |

**FL’s proposal 3**

**If TR is supported in Rel-18, the FDRA field indicates the number of PRBs in the inband.**

**Note1: whether this has specification impact or not is a separate discussion and subject to RAN4’s conclusion to support FDSS-SE as one MPR/PAR reduction solution for Rel-18 (if any).**

Companies are invited to input their views about **FL’s proposal 3**, only **if strong concerns exist**. If you do so, please propose constructive alternative proposals that could achieve consensus. Reality is that mostr companies provided positive comments on the direction suggested in 3.2.8-Q1, hence I invite other companies to operate constructively, if possible. We need to advance on all these discussions for the sake of an efficient use of the very limited available time. **I would appreciate if all could be constructive**. Thank you.

**FL’s proposal 3**

|  |  |
| --- | --- |
| Company | Answer/Views |
|  |  |
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### [CLOSED] Design aspects of TR – others

Four companies proposed to discuss the following aspects related to the support of specific parameters or approaches to specify TR, other than modulation order/FDRA/DMRS.

**PRT design**

Two contributions discussed the design aspect of TR related to PRT design. A high-level summary of companies’ preferences based on the contributions is as follows:

* One company (Oppo [6]) proposes that the signal of PRT should be determined for TR.
* One company (Sony [24]) proposes considering configuration of known tone puncturing patterns for transparent tone reservation PAPR reduction.

**Tone reservation size**

Two contributions discussed the design aspect of TR related to extension factors.

* One company (Panasonic [22]) proposes that, if TR is supported, tone reservation size is determined based on extension factor, which is given by spectrum extension size / total allocation size and sideband tone reservation size is expressed in integer units of RBs.
* One company (Lenovo [10]) proposes to determine candidate values for tone reservation size and tone reservation size could be determined explicitly or implicitly according to the indication from gNB.

FL’s assessment is that,

* For PRT design, this is an advanced aspect of TR which may become relevant only after a possible decision, made by RAN4, to specify support for this scheme in Rel-18. Additionally, it can safely be argued that this would be an implementation detail (at least for a transparent instance of TR). Priority should be given to other aspects of the discussion at least until a decision is taken by RAN4 on which MPR/PAR reduction solution, if any, is supported in Rel-18.
* For tone reservation size, it was agreed that sideband tone reservation size is expressed in integer units of RBs for the study. However, extension factor definition was only agreed for FDSS-SE but not TR.

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| **Agreement**The following design aspects of tone reservation (TR), are considered for studying MPR/PAR reduction enhancements in Rel-18:* Sideband tone reservation size is expressed in integer units of RBs.
* FFS:
	+ Sideband tone reservation size
	+ Sideband tone reservation size determination
	+ Whether PRTs are added only to data or also DMRS symbols
 |
| **Agreement**The following design aspects of frequency domain spectrum shaping with spectrum extension (FDSS-SE), are considered for studying MPR/PAR reduction enhancements in Rel-18:* Spectrum extension size is expressed in integer units of RBs.
* Both DMRS and data symbols undergo spectrum shaping
* FFS:
	+ Which extensions factor(s) to consider, where extension factor (α) is given by spectrum extension size / Total allocation size.
	+ Impact of shaping filter on FDSS-SE performance
	+ How to extend DMRS sequence to spectrum extensions, based on either the existing ZC-sequence DMRS or low-PAPR DMRS for PUSCH (FG 16-6c)
	+ How extension size is determined
 |
| **Agreement**The following baseline parameterization is used for link-level performance evaluation of MPR-PAR reduction solutions in RAN1 for Rel-18.

|  |  |
| --- | --- |
| Channel  | PUSCH, 14 symbols  |
| Carrier frequency and scenario | 4GHz (Urban), 28GHz (Urban)700MHz (Rural), |
| Channel BW | 100MHz for Urban20MHz for Rural, |
| SCS | 30 kHz (4GHz), 120 kHz (28GHz)15 kHz (700 MHz),  |
| Channel model | TDL-C 300ns for FR1 Urban (4GHz), TDL-A 30ns for FR2 Urban (28GHz), TDL-D 30ns for Rural |
| UE speed | 3km/h |
| Waveform | According to agreements |
| Modulation | According to agreements |
| Number of Tx antennas | 1, Optional: 2  |
| Number of Rx antennas | 4 for FR1 Urban, 2 for FR2,2 or 4 for FR1 Rural,  |
| Number of DMRS symbols | 2 |
| Number of PUSCH data symbols | 12 |
| HARQ configuration | No retransmissions |
| Frequency hopping | Disabled |
| Number of PRBs | Reported by companies |
| MCS | Chosen as a function of the number of PRBs to guarantee same spectral efficiency between MPR/PAR reduction solutions and baseline/benchmarks as per agreements |
| Extension factor [FDSS-SE] / sideband size [TR] (α) | [1/8, 1/4, 3/8] is encouraged.  |
| BLER | 10% |

For any parameter that is not listed in the table, companies are encouraged to consider corresponding value from TR 38.830 (or TR 38.868, if the parameter is absent in TR 38.830) and report the parameter with the results.Notes: * Other configurations and scenarios can be studied, and corresponding results can be reported.
* RAN1 to inform RAN4 about the content of the table.
* This table can be updated in future meetings, especially if alignment with assumptions and parameterization in RAN4 is needed
 |

In addition, given the agreement above on LLS parameters (row for Extension factor [FDSS-SE] / sideband size [TR] (α)), it seems that the natural common understanding is that the definition of the tone reservation size for tone reservation is aligned with the definition of extension factor for FDSS-SE. For this reason, I see no ambiguity or lack of clarity in this case, nor I see the need for a discussion on this at present. I suggest waiting until RAN’4 conclusion is reached before deciding whether a formal alignment of the two definitions is needed.

Therefore, no need for discussion is identified by FL at the beginning of the meeting. The topic won’t be discussed during RAN1 #112bis-e.

## [CLOSED] Others

As discussed at the beginning of Section 3, discussions on different aspects of enhancements for MPR/PAR reduction have been prioritized to ensure that constructive discussions and effective progress can be achieved during RAN1 #112bis-e. Priority has been given to the aspects and topics discussed in section 3.1. All other aspects are listed in section 3.2 and 3.3, where proposals made by companies in their contributions are reported and described in detail.

Aspects in this section may not be handled during RAN1 #112bis-e unless urgent technical need arises during the discussion on other aspects. For this reason, no specific FL’s proposal or recommendation is formulated at this stage. Should other discussions progress fast and converge to agreements, sections for specific aspects, currently in 3.3, may be open for discussions and corresponding FL’s proposals and recommendations may be made.

### [CLOSED] Evaluation methodology

Several contributions discussed this aspect. A high-level summary of companies’ preferences based on the contributions is as follows:

**Receiver for evaluation**

* One company (Huawei/HiSi [2]) proposes that MRC receiver should be supported when FDSS-SE is performed.

**Performance comparison**

* One company (Ericsson [15]) proposes that, if RAN1 draws conclusions with respect to the performance of MPR/PAR reduction schemes, the conclusions consider both where boosting can and cannot be used.
* One company (MediaTek [12]) proposes that:
	+ for FDSS with spectrum extension, coding performance losses and PAR reduction figures are separately analyzed/compared for different spectral filtering and extension factor configurations.
	+ for tone reservation, coding performance losses and PAR reduction figures are separately analyzed/compared for different number of PRT size.

**RF simulation**

* One company (Ericsson [15]) proposes that companies are encouraged to provide RF simulations in RAN1 to better understand the behaviour of MPR reduction schemes.

FL’s assessment on the above proposals is that RAN1’s part of the performance evaluation has been completed in RAN1 #112. All assumptions that companies considered for obtaining the results that RAN1 reported to RAN4 via LS have been included, with no restriction (this includes receiver assumptions, which in many cases were identical across companies). Indeed, no further simulation results collection is planned in RAN1 due to time limitation and natural order of decisions between RAN1 and RAN4. Surely companies can still provide simulations results in their contributions submitted to RAN1, however no further discussion about them will happen, unless an urgent need arises, given that RAN1 will not conclude anything related to the support or not of a given MPR/PAR reduction solution in Rel-18. Please note that this understanding is fully aligned with the following conclusion made in RAN1 #111 (in turn aligned with the agreed RAN1/RAN4 work split principles) and the RAN4’s WF on how actual conclusion will be drawn by RAN4 in Rel-18.

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| **Conclusion** It is RAN1 understanding that:* Performance comparison based on net gain results combining transmitter and receiver performance is performed by RAN4.
* No final decision would be taken by RAN1 on which MPR/PAR reduction solution, will be specified in Rel-18, if any, since this is RAN4’s responsibility.
	+ - It does not preclude RAN1 specification impact
 |

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| **<Way forward/Agreement>:**Actual conclusion of the MPR/PAR reduction methods should be based on net coverage gain results combining transmitter and receiver performance |

For this reason, no need for discussion is identified by FL at the beginning of the meeting. The topic won’t be discussed during RAN1 #112bis-e.

### [CLOSED] Complementary enhancements

One company (Sony [24]) proposes studying means of signaling UE chosen TR patterns to the gNB, how the UE would efficiently decide which N tones in its FDRA should fall in its TR pattern, and paradigms of tone reservation pattern choice that are amenable to efficient signaling to the gNB.

# [CLOSED] Proposals for GTW

# 5 [CLOSED] Agreements during RAN1 #112bis-e

# References

1. RP-221858 Revised WID on Further NR coverage enhancements, China Telecom, Jun. 2022.
2. R1-2302351 Discussion on coverage enhancement in power domain Huawei, HiSilicon
3. R1-2302760 Discussion on power domain enhancements ZTE
4. R1-2302624 Discussion on power domain enhancements Spreadtrum
5. R1-2302510 Discussions on issues of power domain enhancements vivo
6. R1-2302574 The study of power domain enhancements OPPO
7. R1-2302691 Discussion on power domain enhancements CATT
8. R1-2302916 Discussion on power domain enhancements for CA/DC Fujitsu
9. R1-2302787 Discussions on power domain enhancement Intel Corporation
10. R1-2303091 Power domain enhancements Lenovo
11. R1-2303257 Discussion on power domain enhancements CMCC
12. R1-2303354 Discussion on power-domain enhancements MediaTek Inc.
13. R1-2303509 Discussion on power domain coverage enhancement Apple
14. R1-2303454 Discussion on power domain enhancements InterDigital, Inc.
15. R1-2303662 Power Domain Enhancement Evaluation Methodology and Schemes Ericsson
16. R1-2303154 Power domain enhancements Samsung
17. R1-2303035 Discussion on power domain enhancements China Telecom
18. R1-2303732 Discussion on power domain enhancements NTT DOCOMO, INC.
19. R1-2303616 Power-domain enhancements Qualcomm Incorporated
20. R1-2302881 RAN1 impacts for power domain enhancements Nokia, Nokia Shanghai Bell
21. R1-2302971 Discussion on power domain enhancements Xiaomi
22. R1-2302886 Discussion on power domain enhancements Panasonic
23. R1-2303777 DMRS design for power domain enhancements Indian Institute of Tech (H)
24. R1-2302864 Considerations on tone reservation for PAPR reduction Sony
25. R1-2303767 Power domain enhancements for Rel-18 CovEnh Sharp
26. R1-2303658 Discussion on power domain enhancements Google
27. R1-2303751 Discussion on power domain enhancements LG Electronics

# Appendix A: Proposals from contributions aggregated by topic

## A.1 Enhancements for increasing UE power high limit for CA and DC

### A.1.1 Increasing UE power high limit for CA and DC

**Scope and RAN1/RAN4 interaction**

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| **R1-2302510 vivo*****Proposal 1:*** *The potential enhancements proposed by RAN4 could be further studied in RAN1 and whether any enhancements would be needed depends on RAN4’s further discussions.***R1-2303154 Samsung*****Proposal 1****: Further discuss enhancements to realize increasing UE power high limit for CA and DC taking into account RAN4 work.* **R1-2303616 Qualcomm*****Proposal 6****: RAN1 to identify specific aspects of power-class fallback and P-MPR allowance that are useful to report from UE to gNB. RAN1 can send an LS to RAN4 indicating usefulness of these specific aspects and request RAN4 to investigate the feasibility of reporting these via the PHR framework.***R1-2303732 NTT Docomo*****Proposal 1:*** *Clarify the objective more to have a well-focused target for RAN1 work****Proposal 3:*** *RAN1#112bis-e to discuss some details of reporting mechanism, assuming the captured metrics in issue 5 in the summary referred to in RAN4 LS, improve mutual understanding on this issue, including:**- When to report the metic(s)**- How to report the metric(s)****Proposal 4:*** *RAN1#112bis-e to discuss what gain is expected by the metrics captured in RAN4 summary [5], and to inform RAN4 of the discussion result* |

**New signaling aspects**

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| **R1-2302574 OPPO*****Proposal 2:*** *RAN1 further discuss the signaling impact for the proposed solutions* *on increasing UE power high limit for CA and DC.***R1-2302624 Spreadtrum*****Proposal 6.*** *Study a scheme for a UE to report uplink symbol evaluation period and starting timing.****Proposal 7.*** *Study enhancements for UE to report current CA power class to gNB in PHR.****Proposal 8.*** *The necessity of power class change indication can be further discussed.****Proposal 9.*** *Do not support P-MPR reporting in FR1.***R1-2302760 ZTE*****Proposal 1:*** *To address the ambiguity of evaluation period for UE power class fallback, support one of the following alternatives.* * *Alt 1. PHR reporting enhancement with a certain duration for the applicability of one among {the fallback power class ∆PPowerClass (potentially with a finer granularity), the default power class, or Pc,max}.*
* *Alt 2. Introduce a scheme for a UE to report uplink symbol evaluation period and starting timing.*

**R1-2302881 Nokia/NSB*****Proposal 1:*** *PHR can be configured to contain the current PC that is used by the UE per serving cell as well as the currently used CA PC together with the duty cycle evaluation period and starting time.* * *FFS reporting of further information such as sustainable duty cycle, estimated time to return to the higher power class, or triggering PHR before PC fallback at lower duty cycle threshold.*

**R1-2302916 Fujitsu*****Proposal 1:*** *Increasing gNB awareness of UE’s Tx power should be standardized in Rel-18 to enjoy the benefit of increasing UE power high limit for CA and DC****Proposal 2:*** *Choose one option from the following three options to increase gNB awareness of UE’s Tx power, which are currently discussed in RAN4.** *Option 1: Introduce sustainable duty cycle report for both PC fallback and P-MPR*
* *Option 2: Introduce PC change report for PC fallback and sustainable duty cycle for P-MPR*
* *Option 3: Introduce PC change report for PC fallback and P-MPR report for P-MPR*

**R1-2302970 Xiaomi*****Proposal 1:*** *Support to study the enhancements to information exchange between UE and gNB to improve scheduling and network performance when using higher power CA/DC.****Proposal 2:*** *RAN1 study on the mechanism to enable efficient use of the increased full power for CA/DC should be carried out.****Proposal 3:*** *Consider the following approaches to help UE get a better chance to maintain the high Power class,** *P-MPR reporting in FR1 due to SAR requirements*
* *Number of symbols or proportion of symbols in the current SAR window that UE assumes to sustain the high power class without having to fallback to make a power class change;*
* *UE recommended maxUplinkDutyCycle value that would prevent triggering a power class fallback;*

***Proposal 4:*** *The enhancement to solve the SAR compliance issue for a better awareness of UE energy/power availability can be applied to both non-CA and CA/DC cases.****Proposal 5.*** *Support reporting of informative PHR at least to improve the accuracy of the acknowledgement of UE power/energy change due to SAR requirements.* ***Proposal 6:*** *Further considering at least P/AP triggering and reporting of the enhanced PHR;***R1-2303035 China Telecom*****Proposal 1:*** *Enhancement of higher transmission power in CA and DC should be carefully studied.***R1-2303257 CMCC*****Proposal 1:*** *Energy headroom is helpful for gNB determination of high power UE schedule.****Proposal 2:*** *Study new signalling and new trigger event to let UE report its energy headroom.****Proposal 3:*** *The difference for PC and P-MPR could be jointly report by UE.****Proposal 4:*** *The exact evaluation period could be limited to one system frame or multiple system frames.****Proposal 5:*** *The starting timing could be limited to the starting of the system frame.***R1-2303454 InterDigital*****Proposal 1:*** *Support UE indicating the power class change to the gNB.* ***Proposal 2:*** *Support UE indication of power class change in power headroom report.****Proposal 3:*** *Study events that can trigger UE to report power class change.* **R1-2303509 Apple*****Proposal 2****: Any event that results a change in power class will trigger an aperiodic PHR. Examples of such events are SAR (specific absorption rate) regulatory requirements (which is transparent to NW)* **R1-2303616 Qualcomm*****Proposal 1:*** *For enhancements to reduce MPR/PAPR, prioritize inner RB allocations with small RB allocations, for e.g., 1-32 RBs.****Proposal 7****: For R18 CA/DC enhancements, repurpose the existing PHR framework to report any new parameters that are agreed to be shared by the UE to the gNB. Enhancements could include the addition of new octets to accommodate new fields, new trigger conditions, new procedures for computing certain fields, finer granularity for reporting existing fields, etc.****Proposal 8:*** *To facilitate better understanding at the gNB of UE’s operations in relation to power class fallback, consider introducing a power class indicator along with additional signaling to* * *indicate the estimated duration of power class fallback (for a UE operating at a lower power class), or to*
* *indicate the maximum duty cycle over a certain duration that a UE is able to support without triggering a power class fallback (for a UE operating at a higher power class)*

***Proposal 9:*** *Enhance the current power headroom reporting framework to allow a user to also report P-MPR (via MPE field) for FR1 carriers.****Proposal 10:*** *When computing PHR based on a reference PUSCH, allow a UE to set P-MPR to a non-zero value and allow the UE to report the resulting Pcmax.****Proposal 11:*** *Enhance the current power headroom reporting framework to allow a user to report power headroom for a carrier that is configured for downlink but not for uplink (i.e., no active uplink BWP).****Proposal 12****: Enhance the current power headroom reporting framework to allow a user to report the duration over which the reported Pcmax can be sustained.* **R1-2303658 Google*****Proposal 1:*** *To support high power transmission in CA and DC, following enhancements can be considered* *• Option 1: Introduce MPE/P-MPR triggering mechanism in FR1 for PHR reporting**• Option 2: UE indicates the exact evaluation period of maximum duty cycle to the base station via UE capability* **R1-2303662 Ericsson*****Proposal 4:*** *Changes in ΔPPowerClass (and power class) can trigger a PHR. Use 2 bits (‘R’ bits for FR1) of PHR to convey ΔPPowerClass and power class fallback, i.e. ‘DPC’ = 00: 0dB; 01: 3dB; 10: 6dB****Proposal 5:*** *Additionally, changes in P-MPR driven by network scheduling can trigger a PHR. If P-MPR is used (‘P’ bit is set), use 2 bits (‘R’ bits for FR1) of PHR to convey power capability according to P-MPR method: 01: 0<𝑃−𝑀𝑃𝑅≤3, 10: 3<𝑃−𝑀𝑃𝑅≤6, 11: 6<𝑃−𝑀𝑃𝑅***R1-2303732 NTT Docomo*****Proposal 2:*** *RAN1 to study a method for UE to report the exact availability of higher transmit power for inter-band CA/EN-DC UL transmission***R1-2303751 LGE*****Proposal 1****. RAN1 to discuss whether to indicate current power class and/or power class change explicitly in PHR report could help gNB increase awareness of UE’s Tx power for UE power higher limit for CA/DC.****Proposal 2.*** *RAN1 to discuss whether to indicate P-MPR relevant information explicitly in PHR report could help gNB schedule uplink transmission while not triggering UE power class fallback.****Proposal 3.*** *RAN1 to discuss on triggering events for PHR reports to help gNB anticipate when power reduction could potentially occur such as not to schedule uplink transmission within remaining uplink duty cycle at UE.* |

**Others**

|  |
| --- |
| **R1-2303767 Sharp*****Proposal 1:*** *Extend P-MPR to be applicable to FR1.* |

## A.2 Enhancements for reducing MPR/PAR

### A.2.1 Scope and RAN1/RAN4 interaction

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| **R1-2303035 China Telecom*****Proposal 2:*** *Non-transparent FDSS performance and spec impact should be studied, and normative work can be done in Rel-19.***R1-2303354 MediaTek*****Proposal 1:*** *Although FDSS without spectrum extension can be promising from RAN1 perspective due to zero link performance loss (i.e., no impact on coding rate), its details should be discussed in RAN4.* |

### A.2.2 Evaluation methodology

**Performance comparison**

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| **R1-2303354 MediaTek*****Proposal 2:*** *For FDSS with spectrum extension, coding performance losses and PAR reduction figures are separately analyzed/compared for different spectral filtering and extension factor configurations.****Proposal 3:*** *For tone reservation, coding performance losses and PAR reduction figures are separately analyzed/compared for different number of PRT size.***R1-2303662 Ericsson*****Proposal 1:*** *If RAN1 draws conclusions with respect to the performance of MPR/PAR reduction schemes, the conclusions take into account both where boosting can and cannot be used.* |

**Receiver**

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| **R1-2302351 Huawei/HiSi*****Proposal 2:*** *MRC receiver should be supported when FDSS and SE is performed.* |

**RF simulation**

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| --- |
| **R1-2303662 Ericsson*****Proposal 3:*** *Companies are encouraged to provide RF simulations in RAN1 to better understand the behavior of MPR reduction schemes* |

### A.2.3 MPR/PAR reduction techniques

**Candidate solutions**

|  |
| --- |
| **R1-2302351 Huawei/HiSi*****Proposal 9:*** *Tone reservation should be deprioritized.***R1-2302510 vivo*****Proposal 2:*** *Prioritize FDSS evaluations for MPR/PAR reduction study.***R1-2302574 OPPO*****Proposal 1:*** *Tone reservation can be considered as a candidate MPR/PAR solution to be further studied, including the signal design of PRT.* **R1-2303035 China Telecom*****Proposal 5:*** *TR can be also considered as a candidate MPR/PAR solution to be further studied.***R1-2303154 Samsung*****Proposal 2****: Further discuss the gains of MPR/PAR reduction techniques, and potential impact on gNB implementation.***R1-2303454 InterDigital*****Proposal 4:*** *Support FDSS and tone reservation with spectrum extension.***R1-2303509 Apple*****Proposal 1****: Do not support non-transparent scheme if no clear gain over transparent scheme is observed.***R1-2303616 Qualcomm*****Proposal 2:*** *For enhancements to reduce MPR/PAPR, prioritize mechanisms that allow a 0-dB MPR waveform to be transmitted at a transmit power exceeding the maximum power associated with the UE power class.****Proposal 5:*** *For RB allocations that are of interest to coverage enhancements with DFT-S-OFDM waveforms and QPSK modulation, it is suggested that transparent techniques such as peak cancelation be prioritized over non-transparent techniques such as tone reservation and FDSS with BW expansion. In particular, study mechanisms required to enable a UE to transmit at a power exceeding its power class.* |

**Modulation schemes**

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| --- |
| **R1-2302351 Huawei/HiSi*****Proposal 1:*** *The*π*/2-BPSK using FDSS with SE is not supported.***R1-2302787 Intel*****Proposal 1:*** *FDSS with SE is not supported for PUSCH with π/2 BPSK and QPSK modulation.*  |

### A.2.4 Design aspects of FDSS-SE

**Spectrum extension options**

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| **R1-2302351 Huawei/HiSi*****Proposal 4:*** *Cyclic shift plus symmetric extension should be supported.*  |

**Extension factors**

|  |
| --- |
| **R1-2302351 Huawei/HiSi*****Proposal 3:*** *Two spectrum extension ratios should be supported which are 1/4 and 1/9.* **R1-2302624 Spreadtrum*****Proposal 5.*** *The scheme of generating integer PRB numbers for the extension band should be studied.***R1-2302886 Panasonic*****Proposal 1:*** *If FDSS with SE is supported, determine SE size based on an extensions factor α, where it is given by spectrum extension size / total allocation size.* * *SE size is expressed in integer units of RBs*
 |

**DMRS**

|  |
| --- |
| **R1-2302351 Huawei/HiSi*****Proposal 5:*** *When inband length is larger than or equal to 30, adopt approach A1 with option b, where A DMRS sequence is generated considering the number of PRBs in the inband (no extension). The sequence length depends on the number of PRBs in the inband. The sequence is then cyclically extended to span the PRBs in the extension.****Proposal 6:*** *When inband length is less than 30, adopt approach A1.***R1-2302510 vivo*****Proposal 3:*** *If FDSS-SE is supported for QPSK modulated PUSCH, only Type 1 DMRS sequence generation is supported.****Proposal 4:*** *If FDSS-SE is supported for QPSK modulated PUSCH, no matter whether the DMRS sequence length before extension is larger than or equal to 30 or less than 30, apply Per-RB solution to the Type 1 DMRS sequence.***R1-2302624 Spreadtrum*****Proposal 1.*** *Type 1 DMRS sequences with Approach A.1-b can be considered when the DMRS sequence length before extension of the sequence is larger than or equal to 30.****Proposal 2.*** *The applicability of type 2 sequences with spectrum extension can be further studied.****Proposal 3.*** *The applicable DMRS sequence require further study for short DMRS sequence.***R1-2302691 CATT*****Proposal 1:*** *For Type 1 DMRS sequence, if supported, Approach A with RE extension should be adopted.****Proposal 2:*** *For DMRS sequence length before extension larger than or equal to 30 for FDSS-SE if supported, DMRS sequence is generated according to Approach A.1 with RE extension.***R1-2302760 ZTE*****Proposal 2:*** *If non-transparent FDSS with spectrum extension is supported, adopt Type 2 DMRS sequence with Approach A.* **R1-2302787 Intel*****Proposal 2:*** *Further study the following potential specification impact if FDSS with SE scheme is supported** + *Signalling mechanism for frequency resource.*
	+ *DMRS design*
	+ *Transmit power control mechanism*

***Proposal 3:*** *Further study DMRS designs for FDSS-SE scheme with the consideration of both low PAPR Type 1 and Type 2 DMRS sequences.***R1-2302881 Nokia/NSB*****Proposal 4:*** *For sequences longer than 24, for DMRS transmission when FDSS-SE is configured, do not consider type 1 DMRS sequences without spectrum extension or using symmetric extension of inband legacy sequence (i.e., processed similarly as data) due to clearly worse PAPR/CM compared to data****Proposal 5:*** *For sequences longer than 24, For DMRS transmission when FDSS-SE is configured consider supporting type 2 sequences either with symmetric spectrum extension or without extension.* ***Proposal 6:*** *For sequences longer than 24, for DMRS transmission when FDSS-SE is configured, if optimized DMRS is desired, consider supporting type 1 sequences using per-RE extension logic.****Proposal 7:*** *For sequences shorter than 30, for DMRS transmission when FDSS-SE is configured consider supporting at least type 2 sequences either with symmetric spectrum extension or without extension.***R1-2303035 China Telecom*****Proposal 3:*** *For long DMRS sequence, generation based on inband PRBs and then extended with the usage of DMRS sequence type 2 is prioritized.****Proposal 4:*** *For short DMRS sequence, generation based on inband PRBs and then extended with the usage of DMRS sequence type 1 or type 2 is prioritized.***R1-2303091 Lenovo*****Proposal 1:*** *If FDSS-SE is supported in Rel-18, Approach B should be supported for DMRS sequence determination.***R1-2303154 Samsung*****Proposal 3****: Further discuss the design of the DM-RS sequence generation for FDSS-SE.* **R1-2303616 Qualcomm*****Proposal 3:*** *If FDSS with BWE is specified and it is agreed to be supported using low-PAPR Type 1 DMRS, at least for RB allocations > 4 RB, generate the DMRS sequence using a ZC sequence that is cyclically extended to span the excess RBs before being mapped to tones.* * *Note: This method of cyclic extension for DMRS symbol differs from that of data symbols.*

***Proposal 4****: If FDSS with BWE is specified, existing 5G NR Type 2 (pi/2 BPSK) DMRS can be reused with similar bandwidth expansion and FDSS as data symbols.* * *For* $\geq 5$ *RB allocations, another alternative is to reuse Type 1 (ZC-based) DMRS with cyclic extension of the ZC sequence prior to tone mapping, followed by FDSS.*

***Proposal 5:*** *For FDSS with BWE and RB allocations of less than 5 RBs, consider constructing a set of Type 1 DMRS sequences for a given RB allocation by using Zadoff-Chu sequences of two or more prime lengths.* * *FFS: How to prune the combined set to obtain a final set of 30 sequences.*

**R1-2303662 Ericsson*****Proposal 2:*** *Rel-15 DMRS is used with FDSS-SE if FDSS-SE is specified, unless there are significant net gains established by RF simulations from enhanced DMRS designs.***R1-2303777 IITH*****Proposal 1:***  *Low PAPR type 2 DMRS sequences may be processed similar to data sequences for spectrum extension and shaping and used as RS sequences with approprately chosen filter.****Proposal 2:*** *Approach-A.2 can be considered for RS generation for lengths less than or equal to 30 and greater than 30.* |

**FDRA**

|  |
| --- |
| **R1-2302351 Huawei/HiSi*****Proposal 7:*** *The**gNB should indicate the RB allocation of non-extension spectrum, spectrum extension ratio, MCS index to UEs, based on which the UEs calculate the size of transport block.* **R1-2302624 Spreadtrum*****Proposal 4.*** *The FDRA field only indicates the number of PRBs in the inband.* **R1-2302787 Intel*****Proposal 2:*** *Further study the following potential specification impact if FDSS with SE scheme is supported** + *Signalling mechanism for frequency resource.*
	+ *DMRS design*
	+ *Transmit power control mechanism*

**R1-2303767 Sharp*****Proposal 2:*** *The spectrum extension is defined outside of the frequency resources allocated by FDRA.* |

**DFT size**

|  |
| --- |
| **R1-2302881 Nokia/NSB*****Proposal 2:*** *No new additional DFT size options to be introduced by RAN1 to support Rel-18 power domain enhancements.* |

### A.2.5 Design aspects of tone reservation

**Extension factors**

|  |
| --- |
| **R1-2302886 Panasonic*****Proposal 2:*** *If tone reservation is supported, to determine sideband tone reservation size based on an extensions factor α, where it is given by spectrum extension size / total allocation size, is necessary.* * *Sideband tone reservation size is expressed in integer units of RBs.*

**R1-2303091 Lenovo*****Proposal 2:*** *RAN1 should determine the candidate sideband tone reservation size* * *The candidates could be determined based on RAN1 evaluation.*
* *The candidates could be related to the scheduled size of the allocated resource.*

***Proposal 3:*** *Sideband tone reservation size determination could be determined explicitly or implicitly according to the indication from gNB.* |

**PRT**

|  |
| --- |
| **R1-2302864 Sony*****Proposal 1:*** *RAN1 should consider configuration of known tone puncturing patterns for transparent tone reservation PAPR reduction.***R1-2302574 OPPO*****Proposal 1:*** *Tone reservation can be considered as a candidate MPR/PAR solution to be further studied, including the signal design of PRT.* |

**DMRS**

|  |
| --- |
|  |

**FDRA**

|  |
| --- |
| **R1-2303091 Lenovo*****Proposal 4:*** *RAN1 should determine whether the FDRA indicator provides the indication for PRTs or not.* |

### A.2.6 Other enhancements on top of MPR/PAR reduction techniques

**Power control**

|  |
| --- |
| **R1-2302351 Huawei/HiSi*****Proposal 8:*** *Study whether/how to enhance the power control to take into account the difference of power spectral density of the REs due to the FDSS-SE.* **R1-2302787 Intel*****Proposal 2:*** *Further study the following potential specification impact if FDSS with SE scheme is supported** + *Signalling mechanism for frequency resource.*
	+ *DMRS design*
	+ *Transmit power control mechanism*

**R1-2302881 Nokia/NSB*****Proposal 3:*** *In case FDSS-SE is supported in Rel-18, RAN1 to discuss whether and how to enhance the power control framework to account for the power density peculiarities of FDSS-SE and further improve its performance, if time allows it.* |

**Selection and signaling of TR patterns**

|  |
| --- |
| **R1-2302864 Sony*****Proposal 2:*** *RAN1 should study means of signaling UE chosen TR patterns to the gNB.****Proposal 3:*** *RAN1 should study the question of how the UE would efficiently decide which N tones in its FDRA should fall in its TR pattern.****Proposal 4:*** *RAN1 should study paradigms of tone reservation pattern choice that are amenable to efficient signaling to the gNB.* |

**Other**

|  |
| --- |
|  |

# Appendix B: Previous agreements on power domain enhancements

**Agreement**

The following work split principles will be adopted in RAN1 for power domain enhancement throughout Rel-18 from RAN1 perspective and send LS to RAN4 in this meeting:

* RAN1 performs link level simulations of candidate solutions for power domain enhancements to study at least the SNR variation, PAPR/CM, and EVM, brought by each solution.
	+ Transparent MPR/PAR reduction solutions can be considered as a benchmark for studying the performance of non-transparent solutions.
* RAN1 is not expected to perform RF simulations of candidate solutions for power domain enhancements
	+ Results of RF simulations can be included in RAN1 contributions
* RAN1 will assess RAN1 specification impact of candidate MPR/PAR reduction solutions
	+ A list of candidate solutions, including necessary parameters, from RAN1 perspective should be ready before the end of RAN1 #111, and should be included in an LS to RAN4.
* RAN1 understands that RAN4 is responsible for selecting the Rel-18 MPR/PAR reduction solution, if any.

**Conclusion**

Sub-PRB transmission is de-prioritized for the study of MPR/PAR reduction solutions in Rel-18.

**Agreement**

The following spectrum extension options for frequency domain spectrum shaping with spectrum extension (FDSS-SE), are considered for studying MPR/PAR reduction enhancements in Rel-18:

* Option 1: Symmetric extension
* Option 2: Cyclic extension
* Option 3: Cyclic shift plus symmetric extension.

**Agreement**

The following design aspects of tone reservation (TR), are considered for studying MPR/PAR reduction enhancements in Rel-18:

* Sideband tone reservation size is expressed in integer units of RBs.
* FFS:
	+ Sideband tone reservation size
	+ Sideband tone reservation size determination
	+ Whether PRTs are added only to data or also DMRS symbols

**Agreement**

For enhancements to realize increasing UE power high limit for CA and DC, RAN1 can study based on RAN4’s input

* Whether RAN1 enhancements to information exchange between UE and gNB are needed to improve scheduling and network performance when using higher power CA/DC.
	+ FFS how to realize such information exchange, e.g., signalling enhancement, and what is the spec impact.

**Agreement**

DFT-s-OFDM is the target waveform for the study and, if applicable, the design of MPR/PAR reduction solutions in Rel-18.

Note: No doubt from RAN1 about the offline consensus “Results concerning the application of solutions for DFT-s-OFDM to CP-OFDM can be presented by companies in their contributions”.

**Agreement**

For power-domain enhancements targeting MPR/PAR reduction, study the following configurations for DFT-S-OFDM:

       At least pi/2-BPSK and QPSK modulation are considered

o   FFS: other modulations, e.g., 16-QAM

       Any number of RB can be considered

       The starting RB of the allocation can be any RB in the BWP

o   FFS:

  Whether restrictions on the number of allocated RB or on the starting RB of the allocation are considered.

**Agreement**

At least the following candidate solutions for MPR/PAR reduction will be studied in RAN1.

* Frequency domain spectrum shaping w/ spectrum extension
* Frequency domain spectrum shaping w/o spectrum extension
* Tone reservation (which can only be w/ spectrum extension)

**Agreement**

The following design aspects of frequency domain spectrum shaping with spectrum extension (FDSS-SE), are considered for studying MPR/PAR reduction enhancements in Rel-18:

* Spectrum extension size is expressed in integer units of RBs.
* Both DMRS and data symbols undergo spectrum shaping
* FFS:
	+ Which extensions factor(s) to consider, where extension factor (α) is given by spectrum extension size / Total allocation size.
	+ Impact of shaping filter on FDSS-SE performance
	+ How to extend DMRS sequence to spectrum extensions, based on either the existing ZC-sequence DMRS or low-PAPR DMRS for PUSCH (FG 16-6c)
	+ How extension size is determined

**Agreement**

For link-level performance evaluation:

* R17 PUSCH DFT-s-OFDM waveform is the baseline for performance comparison
* Transparent schemes (to be reported by companies) can be used as benchmark for the performance assessment

All considered solutions should be configured to operate with same amount of time-frequency resource and a same spectral efficiency, that is:

* Same number of DFT-s-OFDM symbols
* Same TBS
* Same RB allocation

Note: it is understood that minor TBS variations across different waveform configurations can occur and are acceptable.

**Agreement**

For link-level performance evaluation, the performance of the considered MPR/PAR reduction solutions is studied using at least the metrics included in the work split principles for power domain enhancement agreed by RAN1 for Rel-18, for instance, but no limited to, $ΔSNR$, defined as the SNR variation w.r.t. baseline under the requirement BLER=10-1.

* FFS whether further definition or refinement of the metrics is needed

Note: metrics other than the ones included in the work split principles for power domain enhancement agreed by RAN1 for Rel-18 can be reported by companies.

**Agreement**

For link-level performance evaluation, companies are encouraged to report configuration details of the following aspects, when applicable:

* Shaping filter used for evaluating frequency domain spectrum shaping w/ and w/o spectrum extension (both the filter used at the transmitter and at the receiver should be reported, if the two filters are assumed to be mismatched).
* PRT generation algorithm used for evaluation tone reservation w/ spectrum extension.
* Design details and configuration of any transparent scheme used as benchmark

**Agreement**

For link-level performance evaluation of MPR/PAR reduction solutions involving the use of Tx filter, companies are encouraged to assume a Tx filter which fulfills a set of spectrum flatness requirements, e.g., existing RAN4 spectrum flatness requirements

* FFS whether the set of spectrum flatness requirements shall be the same set of constraints as in the current RAN4 spec or not.

For link-level performance evaluation of MPR/PAR reduction solutions involving the use of spectrum extensions or sideband, companies are encouraged to report whether/how the extended portion of the spectrum is handled by the receiver in the simulations.

Agreement

* At least the following enhancements to information exchange between UE and gNB to facilitate higher power transmissions in CA and DC can be considered for study. Enhanced signaling, if necessary and subject to RAN4’s input, to allow:
* Determination at gNB of power class change at the UE
* Increased awareness at gNB of energy/power availability at the UE, e.g., a budget.
	+ More informative PHR to be sent from UE to gNB, which may include, e.g., P-MPR related information, power headroom for carrier configured for DL but not UL, power class change indication.
* More effective scheduling decisions in the context of UL CA, e.g., best band combination, preferred carrier for servicing uplink, adaptive load sharing across sharing,
* Other options are not precluded.

**Agreement**

For RAN1 link-level performance evaluation of MPR/PAR reduction solutions involving the use of ~~Tx~~ spectrum shaping filter, companies are encouraged to use at least the following spectrum shaping filter configuration for calibration purpose:

* 2-tap, e.g., (1 0.28), 3-tap, e.g., (0.335 1 0.335), ~~and~~ (0.28 1 0.28)
* Truncated RRC (0.5, 0.1667)

There is no restriction to use other spectrum shaping filter coefficients in simulations~~, e.g., [1 0.28]~~.

Note: the above does not have spec impact.

**Agreement**

The following non-transparent solutions for MPR/PAR reduction are currently under discussion in RAN1.

* Frequency domain spectrum shaping w/ spectrum extension
* Tone reservation w/ spectrum extension

In addition, transparent schemes, for instance but not limited to frequency domain spectrum shaping w/o spectrum extension or schemes based on clipping and filtering, are also being evaluated to serve as a benchmark to assess the benefits of non-transparent solutions. Companies are allowed to use any transparent transmission scheme of their choice.

Agreement

At least the symmetric spectrum extension option for frequency domain spectrum shaping with spectrum extension (FDSS-SE), are considered for studying MPR/PAR reduction enhancements in Rel-18.

**Conclusion**

It is RAN1 understanding that:

* Performance comparison based on net gain results combining transmitter and receiver performance is performed by RAN4.
* No final decision would be taken by RAN1 on which MPR/PAR reduction solution, will be specified in Rel-18, if any, since this is RAN4’s responsibility.
	+ - It does not preclude RAN1 specification impact

**Agreement**

For the study of the PAPR/CM of DMRS when considering tone reservation as candidate enhancement for MPR/PAR reduction in Rel-18, RAN1 to consider at least the case that PRTs are added to the DMRS symbols (in the sideband). The case of PRTs not added to DMRS symbols can be used as a benchmark.

**Agreement**

The LS out RAN1 aims at drafting before the end of RAN1 #111 should include at least the following three parts:

1. List of candidate non-transparent and an initial list of transparent (if any) schemes considered for study by RAN1
2. Schemes-specific parameterization used by RAN1 for evaluation, e.g., spectrum extension factor and cyclic shift (if applicable), sideband size, filter assumptions (if any), channel model and so on.
3. Further parameterizations ~~for~~ used in RAN1 evaluations, e.g., carrier frequency, channel model and so on.

Agreement

The following baseline parameterization is used for link-level performance evaluation of MPR-PAR reduction solutions in RAN1 for Rel-18.

|  |  |
| --- | --- |
| Channel  | PUSCH, 14 symbols  |
| Carrier frequency and scenario | 4GHz (Urban), 28GHz (Urban)700MHz (Rural), |
| Channel BW | 100MHz for Urban20MHz for Rural, |
| SCS | 30 kHz (4GHz), 120 kHz (28GHz)15 kHz (700 MHz),  |
| Channel model | TDL-C 300ns for FR1 Urban (4GHz), TDL-A 30ns for FR2 Urban (28GHz), TDL-D 30ns for Rural |
| UE speed | 3km/h |
| Waveform | According to agreements |
| Modulation | According to agreements |
| Number of Tx antennas | 1, Optional: 2  |
| Number of Rx antennas | 4 for FR1 Urban, 2 for FR2,2 or 4 for FR1 Rural,  |
| Number of DMRS symbols | 2 |
| Number of PUSCH data symbols | 12 |
| HARQ configuration | No retransmissions |
| Frequency hopping | Disabled |
| Number of PRBs | Reported by companies |
| MCS | Chosen as a function of the number of PRBs to guarantee same spectral efficiency between MPR/PAR reduction solutions and baseline/benchmarks as per agreements |
| Extension factor [FDSS-SE] / sideband size [TR] (α) | [1/8, 1/4, 3/8] is encouraged.  |
| BLER | 10% |

For any parameter that is not listed in the table, companies are encouraged to consider corresponding value from TR 38.830 (or TR 38.868, if the parameter is absent in TR 38.830) and report the parameter with the results.

Notes:

* Other configurations and scenarios can be studied, and corresponding results can be reported.
* RAN1 to inform RAN4 about the content of the table.
* This table can be updated in future meetings, especially if alignment with assumptions and parameterization in RAN4 is needed

**Agreement**

Study the PAPR/CM[/OBO] of DMRS with FDSS-SE, e.g., the following solutions:

* + Option 1 - Based on low PAPR Type 1 DMRS sequence:
		- 1-a: A DMRS sequence is generated considering the number of PRBs in the inband + extension. The sequence length depends on the number of PRBs in the inband + extension.
		- 1-b A DMRS sequence is generated considering the number of PRBs in the inband (no extension). The sequence length depends on the number of PRBs in the inband. The sequence is then cyclically extended to span the PRBs in the extension.
		- 1-c A DMRS sequence is generated considering the number of PRBs in the inband (no extension). The sequence length depends on the number of PRBs in the inband. DMRS extension is applied similar to data to span the PRBs in the extension.
* Option 2 - Based on low PAPR type 2 DMRS sequence
	+ - Variances like those of Option 1 can be referred
	+ Option 3 – For in-band DMRS lengths 6/12/18/24 symbols, DMRS sequence is obtained by DFT transformation of low PAPR sequence type 1. Then the sequence is extended to span the PRBs in the extension in the same way as data extension.

Note: Other solutions can be studied. Comparison with the three solutions above is encouraged. Sequence with different density between in-band and extension can be studied

**Working Assumption**

* **The following set of configurations is for companies’ consideration for the calibration of the link performance of MPR/PAR reduction techniques.**

|  |  |  |
| --- | --- | --- |
|   | No spectrum extension | With spectrum extension |
| TBS value | Tput estimation for DDDSU @4GHz | #PRBs | MCS | #PRBs before extension | #PRBs after extension | MCS | Spectrum extension factor |
| 2408 | 963.2 kbps | 16 | 7 | 14 | 16 | 8 | 1/8  |
| 5376 | ~2.15 Mbps | 32 | 8 | 28 | 32 | 9 | 1/8  |
| 272 | 108.8 kbps | 8 | 0 | 6 | 8 | 1 | ¼ |
| 1032 | 412.8 kbps | 8 | 6 | 6 | 8 | 8 | ¼ |
| 2152 | ~0.9 Mbps | 40 | 2 | 30 | 40 | 3 | ¼ |
| 4992 | ~2.0 Mbps | 40 | 6 | 30 | 40 | 8 | ¼ |
| 552 | 220.8 kbps | 16 | 0 | 10 | 16 | 2 | 3/8 |
| 1736 | 694.6 kbps | 32 | 2 | 20 | 32 | 4 | 3/8 |
| [432 | 172.8 kbps | 8 | 2 | 6 | 8 | 3 | ¼] |
| [808 | 323.2 kbps | 24 | 0 | 18 | 24 | 1 | ¼] |

* **The values above serve as a common basis, but any other configuration and result reported by companies will be considered for any input related to LLS that RAN1 may provide to RAN4.**
* **Results of the simulations of MPR/PAR reduction solutions which companies may report in contributions to RAN1 #112 should be reported using the template in R1-2212918.**
* **Note: At least 10% BLER SNR is reported**

**Agreement**

Further discussions in RAN1 concerning means to facilitate higher power transmissions in CA and DC, if applicable, can target increasing gNB awareness of UE’s Tx power, e.g., PHR reporting enhancement such as current power class, power class change, or application of P-MPR by UE (subject to RAN4’s input).

* + FFS: details.

**Agreement**

If FDSS-SE is supported in Rel-18, RAN1 to further study the following approaches for DMRS, when the DMRS sequence length before extension of the sequence, if any, is larger than or equal to 30:

* Approach A – the DMRS sequence is extended: A DMRS sequence is generated considering the number of PRBs in the inband (no extension). The sequence length depends on the number of PRBs in the inband. Two sequence types can be considered:
	+ A.1: The sequence is a Type 1 DMRS sequence.
	+ A.2: The sequence is a Type 2 DMRS sequence.

FFS: how the sequence is extended.

* Approach B – the DMRS sequence is not extended: A DMRS sequence based on type 1 or type 2 DMRS sequence is generated considering the number of PRBs in the inband + extension. The sequence length depends on the number of PRBs in the inband + extension.

Note: if type 2 is used then both the number of PRBs in the inband and the number of PRBs in the inband+extension must be valid DFT sizes as per NR specification

Performance metrics considered for the study are PAPR, CM[, and OBO] for DMRS and 10% BLER SNR for data (to measure channel estimation accuracy).

**Agreement**

If FDSS-SE is supported in Rel-18, and RB allocations resulting in DMRS sequence length smaller than 30 before extension of the sequence, if any, are supported, RAN1 to study at least the following approaches:

* Approach A – the DMRS sequence is extended: A DMRS sequence is generated considering the number of PRBs in the inband (no extension). The sequence length depends on the number of PRBs in the inband. Two sequence types can be considered:
	+ A.1: The sequence is obtained by DFT transformation of an existing DMRS sequence, e.g., Type 1 DMRS sequence.
	+ A.2: The sequence is a Type 1 or Type 2 DMRS sequence.

 FFS: how the sequence is extended.

* Approach B – the DMRS sequence is not extended: A DMRS sequence based on type 1 or type 2 DMRS sequence is generated considering the number of PRBs in the inband + extension. The sequence length depends on the number of PRBs in the inband + extension.

Note: if type 2 is used then both the number of PRBs in the inband and the number of PRBs in the inband+extension must be valid DFT sizes as per NR specification

Note: Other sequences are not precluded for Approach A and Approach B.

Performance metrics considered for the study are PAPR, CM [, and OBO] for DMRS and 10% BLER SNR for data (to measure channel estimation accuracy).

**Agreement**

Include in the LS to RAN4 for reporting LLS results

Note: The excel file is used to collect the results.

**Working Assumption**

The following set of configurations is for companies’ consideration for the comparison of the performance of DMRS with FDSS-SE.

|  |  |
| --- | --- |
| **No spectrum extension** | **With spectrum extension** |
| **#PRBs** | **MCS** | **#PRBs before extension** | **#PRBs after extension** | **MCS** | **Spectrum extension factor** |
| 8 | 0 [only QPSK] | 6 | 8 | 1 [only QPSK] | ¼ |
| 8 | 6 | 6 | 8 | 8 | ¼ |
| 40 | 2 | 30 | 40 | 3 | ¼ |
| 40 | 6 | 30 | 40 | 8 | ¼ |
|  |  |  |  |  |  |
| [6 | 3 | 4 | 6 | 5 | 1/3] |
| [36 | 7 | 32 | 36 | 8 | 1/9] |

* FR1 4GHz Urban scenario is prioritized.
* The following filters are for companies’ consideration for the calibration of the performance of DMRS with FDSS-SE
* 3-tap (0.28 1 0.28)
* [Truncated RRC (0.5, 0.1667) or 2-tap (1 0.28)]
* Note1: Considered metrics are PAPR/CM, 10% BLER SNR of data for the considered DMRS configuration (for measuring impact of channel estimation accuracy)[, and OBO]
* Note2: companies are encouraged to consider a receiver which at least makes use of the extension for the decoding (e.g., MRC)
* Note3: The values above serve as a common basis, but any other configuration can be studied by companies.

Agreement

The Draft LS R1-2302080 is endorsed in principle.

Agreement

The Final LS R1-2302081 is endorsed.