3GPP TSG RAN WG1 #110bis-e R1-2210324

e-Meeting, October 10th – 19th, 2022

**Agenda item: 9.14.2**

**Source: Moderator (Nokia, Nokia Shanghai Bell)**

**Title: FL summary #3 of power domain enhancements (AI 9.14.2)**

**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 9.14.2 to RAN1 #110b-e [2]-[20].

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

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

Contributions submitted under AI 9.14.2 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**
	+ De-prioritization of HPUE related power domain enhancement
	+ Coordination with RAN4
* **Mid priority aspects**
	+ RAN1 scope clarification
	+ New signaling aspects
* **Other aspects**
	+ NA

The categorization above will determine the initial priority order for the discussions to be held for AI 9.14.2. 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 #110b-e. Section 2.3 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.

## High priority aspects

Two high priority aspects are identified at the beginning of the meeting:

1. De-prioritization of high-power UE related power domain enhancement
2. Coordination with RAN4

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

### [CLOSED] De-prioritization of high-power UE related power domain enhancement

This aspect was discussed explicitly in one contribution. Specifically,

* One company (vivo [5]) proposes that high-power UE (HPUE) related power domain enhancement should be deprioritized in Rel-18 coverage enhancement topic.

This topic is highly relevant in the context of a discussion on this item at the beginning of the release. Therefore, the following question is formulated for collecting companies’ views.

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| **2.1.1-Q1 Do you agree that high-power UE related power domain enhancements should be deprioritized in Rel-18 coverage enhancement discussions?** |

#### First round of discussions

FL’s recommendation is to have a first round of discussion about **2.1.1-Q1**. Companies are invited to input their views in the corresponding table below.

**2.1.1-Q1**

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| Company | Answer/Views |
| QC | HPUE typically refers to a UE that can transmit at 26 dBm or higher in a band. Its not clear what exactly Vivo is proposing here, or what their understanding is. This effort is not about introducing HPUEs in new bands. The WID expects us to take R17 enhancements in RAN4 related to high power transmissions across multiple bands in uplink and study any RAN1 enhancement that can facilitate such operation.Note that UEs are already designed with multiple RF chains across different bands. The goal here is to see if we can use this hardware to better use. It would be a shame if UE vendors and OEMs put in the effort to build UEs capable of supporting multiple bands, only for RAN1 to not support these UEs adequately. To date DL-CA has received widespread adoption while ULCA has not seen the same level of traction. A lot of UE capability is going unused throughout a UE’s entire lifecycle.UEs have grown in sophistication on how they handle transmissions across different bands and how they handle RF exposure. It is worth using this opportunity to see if we can make sure the gNB has better awareness of a UE’s ability to support high power transmissions across different bands. How to better support scheduling in UL-CA, how to support band selection for uplink tx switching could be other aspects worth considering.@FL: not sure if this is the most constructive approach to open discussions on a new topic in a new WID. It might be more helpful for us to figure out what would be worth investigating closely. At least a handful of companies including an operator have identified potential issues that RAN1 can try to address. For future rounds, please seek input on these aspects as well. |
| DOCOMO | It is a bit unclear to us what the exact intention of “high-power UE related”. So not sure what is to be exactly deprioritized? Due to above, not sure whether here is a place to recode below; however, as an operator, we really sympathize with QC’s comment above, especially:*Note that UEs are already designed with multiple RF chains across different bands. The goal here is to see if we can use this hardware to better use. It would be a shame if UE vendors and OEMs put in the effort to build UEs capable of supporting multiple bands, only for RAN1 to not support these UEs adequately. To date DL-CA has received widespread adoption while ULCA has not seen the same level of traction. A lot of UE capability is going unused throughout a UE’s entire lifecycle.*There are some contributions which try to point out the issue which may be resolved per RAN1 effort. We do not quite understand why we start with de-prioritization without seeing them.  |
| Ericsson | It should be studied in RAN4 and RAN1 according to the WID:* 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)

Therefore, we should start the study, and priority can be addressed as we learn more. |
| Intel | We tend to agree FL’s assessment. However, we would like to mention that this can be deprioritized in RAN1, but not in RAN4. |
| vivo | Agree. Since HPUE related discussions are happening in parallel in RAN4 in both Rel-18 coverage enhancement topic and HP basket WI, any necessary enhancement related to RAN1 can be triggered by RAN4 LS. RAN4 should decide whether to remove this bullet from Rel-18 coverage enhancement scope and handle it in RAN4 high power basket WI. |
| Panasonic  | We do not agree. We prefer to coordinate with RAN4 to discuss this aspect. |
| Samsung | Based on the WID, we may need to coordinate with RAN4. |
| Fujitsu | We agree with Qualcomm and DOCOMO. We don’t understand the reason why we can deprioritize this topic without any discussion. RAN1 can discuss based on RAN1 contribution, then make the decision. |
| Huawei, HiSilicon | OK |
| CMCC | Since this is a RAN4 leaded WI, we prefer not to deprioitize this topic without any discussion. We also agree that if the UE’s hardware can support this feature, then RAN1 should try to make it workable |
| Nokia/NSB | From our perspective, the release is starting, and most companies argue that the scope is unclear and that RAN1 should not do anything until new cases and/or enhancements are introduced. Given the above, plus the limited time available (only 6 meetings) and the fact that relevant challenges seem to exist for the other objective of the power domain enhancement (targeting MPR/PAR reduction), we are sympathetic with vivo’s proposal and think RAN1 should consider the possibility of de-prioritizing UE related power domain enhancements in Rel-18 coverage enhancement discussions very seriously. Of course, this de-prioritization, if any, is in RAN1 perspective. |
| ZTE | Without knowing what exactly would be studied and enhanced, it is premature to de-prioritize at the first place, especially the leading WG is RAN4. There may be two aspects under this objective.* One is to extend HPUE into more band combinations/new cases. This is purely RAN4 expertise, and should leave to RAN4 discussion.
* Another aspect is to utilize the RAN4 Rel-17 HPUE enhancements to study whether any RAN1 enhancements can be considered. For this aspect, it is more RAN1 work and could be decided in RAN1. We are not keen on enhancements in this aspect, but ok to further study at this point.
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| MediaTek | We expect RAN4 to lead the discussions and coordinate with RAN1 if they need support from us. However, we are not sure what deprioritization would mean here. According to WID, the topic should be studied, and we would prefer RAN1 to study for a better understanding before reaching such a conclusion. |
| Sharp | We do not think any deprioritization is necessary before starting the study. |
| CATT | We agree that the scope from RAN1 perspective is unclear. But on the other hand, to directly agree to de-prioritize without discussion seems premature.  |
| Lenovo | We think given the limited TU, maybe anyway deprioritization will be needed. But we are open to have a study at this stage. |
| InterDigital | We do not agree with deprioritizing this topic. Agree with DOCOMO. |

**FL’s comment on October 12**

Thank you everyone for commenting about this aspect. It is evident that most companies do not wish to de-prioritize this objective, although the general take is that scope is not clear.

No de-prioritization will occur, and I would like to invite all companies who have different views to consider the possibility of not proposing it further, given the opposite opinion of several other companies (the majority, actually).

The discussion on this aspect will not continue.

Now, I feel I need to add few comments, following what has been written by Qualcomm and DOCOMO. A question from the FL is not a proposal, but an invitation to provide views on a topic (which often stems from a company’s proposal). In this context, what was suggested by one company about de-prioritization was clearly a fit subject for a question given that:

1. It was evident that more than one company could have shared the same opinion (and it is the case)
2. It was important for all companies to be able to express a view on this (and avoid continuous discussions on this in the future, should a majority be clear already, as is the case, for instance)

No proposal of this kind should be ignored by the FL, ever. In this context, it would have been weird to discuss about de-prioritization after other discussions had started already. It would have been very unfair and odd.

Conversely, what happened gave the group the opportunity to have a fair and transparent exchange on a possibly problematic topic, to get it out of the system “as soon as possible”. The result has been very constructive. That’s something I consider as the *bare minimum* for any discussion which could have an impact on work plans. I intend to apply the same approach to any other discussion on the power domain enhancements in Rel-18.

I hope this clarifies the situation and sets some understanding which may be used to avoid future similar discussions. As far as I am concerned, I will not engage in any further exchange which goes beyond the topic at hand.

### [PAUSED] Coordination with RAN4

Two contributions discussed this aspect. High-level summary of companies’ opinions based on the contributions follows.

* One company (ZTE [3]), argues that RAN4 should lead the discussion on whether/how to introduce additional cases for increasing UE power high limit for CA and DC.
* One company (Samsung [16]), propose to send an LS to RAN4 asking which potential enhancements RAN4 is planning to consider for this objective.

From FL’s perspective, the two proposals share similar spirit and highlight a possible lack of clarity of the WID for what concerns the enhancements for increasing UE power high limit for CA and DC. The following question is thus asked.

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| **2.1.2-Q1** **Do you agree that RAN1 should send an LS to RAN4 to (at least):*** **ask which potential enhancements RAN4 is planning to consider for this objective**
* **inform RAN4 that RAN1 will not discuss whether/how to introduce additional cases for increasing UE power high limit for CA and DC**

**Note: If you think that an LS should be written and sent, but also think that different elements should be included, please add them to your reply.** |

#### First round of discussions

FL’s recommendation is to have a first round of discussion among companies about **2.1.2-Q1**. The goal is to identify the preferred direction RAN1 should pursue for handling this complex issue. Feel free to elaborate on your answer in the suitable box.

**2.1.2-Q1**

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| Company | Views |
| QC | We don’t think an LS is necessary. RAN4 has already concluded its R17 work. We need to take RAN4’s work into account and figure out if we can further facilitate high power transmissions across different bands. |
| DOCOMO | The first bullet could be ok. But why the second bullet can be put here without RAN1 discussion is not very clear. We believe RAN1 should discuss whether the issue exists or not.  |
| Ericsson | The LS could bring some clarity to what RAN1 might study. RAN1 is not the right place to define power classes or high power limit behaviors, and RAN4 should provide information needed on these to RAN1 if we are to evaluate them and design mechanisms around them. |
| Intel | RAN4 is currently discussing the power domain enhancement starting from this meeting. Our view is that we can wait for some progress in RAN4 first and if they identify some issues that need to be considered/addressed in RAN1 by sending an LS, RAN1 can continue the study on this aspect.  |
| vivo | In our understanding, the LS should be triggered from RAN4 when their HPUE related discussions are stable. Therefore, LS from RAN1 seems not necessary at this stage. |
| Panasonic | We support to send an LS to RAN4. In addition, in LS, we would like to ask * Whether to apply the increasing UE power high limit by RAN4 to single carrier operation (instead of only multi-carrier operation in CA/DC)?

This is because we think that the single carrier operation with the increasing UE power high limit can provide better coverage performance than that of the operation in CA/DC. |
| Samsung | We think a coordination with RAN4 is needed at this early stage in order to have an understanding of what RAN4 is planning to enhance. Sending an LS would save some time rather than waiting for RAN4 to inform RAN1. |
| Fujitsu | We agree Qualcomm that RAN4 has already concluded its R17 work. We need to take RAN4’s work into account and figure out if we can further facilitate high power transmissions across different bands. An LS can be sent if we identify the necessity through the discussion in this meeting.  |
| Huawei, HiSilicon | Agree. |
| CMCC | Sending a LS to RAN4 can be helpful for RAN1 to figure out how to facilitate this topic. The power control procedure with power headroom and MPR seems highly related to the RAN4 spec. |
| Nokia/NSB | We think that such an LS would be useful, especially if the objective is de-prioritized. Indeed, RAN1 can afford waiting for RAN4 before taking further decisions on this objective, if any. |
| ZTE | In our view, RAN4 as the leading WG may anyway send an LS to RAN1 about their decision. Sending an LS from RAN1 to RAN4 may not be that necessary for the HPUE issue only. On the other hand, considering tight coordination with RAN4 is needed also for MPR/PAR reduction, it could be ok to send an LS to inform RAN4 about RAN1 decisions on both aspects. With above, if LS to be sent, we suggest the following changes just in case RAN4 may task RAN1 to do some study. * **ask which potential enhancements RAN4 is planning to consider for this objective**
* **inform RAN4 that RAN1 will not discuss whether/how to introduce additional cases for increasing UE power high limit for CA and DC, unless triggered by RAN4.**
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| MediaTek | We prefer to wait before sending an LS without concrete outcome. RAN4 has just started discussions on this topic in Rel-18 and they may trigger an LS to RAN1 if needed. |
| Sharp | Some more information from RAN4 (e.g., how they expected the network to use the R17 UE capability report associated with the high power limit) would be helpful for RAN1 to study whether/what enhancements are necessary. |
| CATT | RAN4 is the leading group of this objective and it is reasonable to let RAN4 start first. We can wait for the progress in RAN4 and we do not think sending LS from RAN1 at this point is needed. |
| InterDigital | We don’t think LS is necessary for this. |
| Apple | LS to RAN4 is preferred, otherwise we need to wait for RAN4 progress. |

**FL’s comment on October 12**

Thank you for adding your views. Most companies prefer to wait before sending the LS. I will pause the discussion in this section and open Section 2.2.1 and Section 2.2.2, for companies to further discuss about the RAN1 scope for this enhancement and highlight issues to solve.

## Mid priority aspects

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

1. RAN1 scope clarification
2. New signaling aspects

Summary, discussion, and FL’s comments/proposals on these aspects are provided in the following different sub-sections, whose numbers are given in the list above. Note that “RAN1 scope clarification” is only temporarily labelled as Mid priority aspect, given the two current high priority aspects for enhancements for increasing UE power high limit for CA and DC. This labelling will change as discussion on the two high priority item progresses.

### [CLOSED] RAN1 scope clarification

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

* One company (ZTE [3]) argues that RAN1 needs to clarify whether any RAN1 enhancement is needed, and any enhancement requiring large RAN1 specification impact without clear performance gain is not pursued.
* One company (NTT DOCOMO [18]) proposes to clarify the objective to have a well-focused target for RAN1 work.
* One company (CATT [5]) argues that the impact for RAN1 spec needs more discussion.

**FL’s comment on October 12**

Given that the discussions on prioritization and coordination with RAN4 are paused following companies’ inputs, the discussion on the RAN1 scope and objectives is open. The following 2 questions are formulated.

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| **2.2.1-Q1** ***Could you please elaborate on what should be RAN1 scope for the enhancements to realize increasing UE power high limit for CA and DC?*** |

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| **2.2.1-Q2** ***Should RAN1 introduce additional cases for increasing UE power high limit for CA and DC?*** |

#### First round of discussions

FL’s recommendation is to have a first round of discussion about **2.2.1-Q1** and **2.2.1-Q2**. Companies are invited to input their views in the corresponding table below.

**2.2.1-Q1**

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| Company | Answer/Views |
| DOCOMO | In our understanding, in Rel-17 RAN4 WI *“Increasing UE power high limit for CA and DC”*, RAN4 defined the required conditions for UE where the UE is able to perform transmissions over multiple carriers (more accurately, inter-band CA and inter-band EN-DC) with “higher total transmit power”. This “higher total transmit power” simply means a summation of maximum transmit power at each carrier (band). The following is the corresponding specification for inter-band CA in Rel-17 version of 38.101-1:

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| 6.2A.4.1.3 Configured transmitted power for Inter-band CA[…]For uplink inter-band carrier aggregation with one serving cell c per operating band when same slot symbol pattern is used in all aggregated serving cells, PCMAX\_L = MIN {10log10∑ MIN [ pEMAX,c/(tC,c), pPowerClass.c/(MAX(mprc·∆mprc, a-mprc)·tC,c ·tIB,c·tRxSRS,c), pPowerClass,c/pmprc], PEMAX,CA, PPowerClass,CA-ΔPPowerClass, CA} PCMAX\_H = MIN{10 log10 ∑ pEMAX,c , PEMAX,CA, PPowerClass,CA-ΔPPowerClass, CA}where- pEMAX,c is the linear value of PEMAX, *c* which is given by IE *P-Max* for serving cell *c* in [7];- PPowerClass,CA is the maximum UE power specified in Table 6.2A.1.3-1 without taking into account the tolerance specified in the Table 6.2A.1.3-1; If the UE indicates [HigherPowerLimitCADC] for an eligible CA configuration as specified in Table 6.2A.1.3-1 and ΔPPowerClass, CA = 0, PPowerClass,CA is replaced by 10 log10 ∑ pPowerClass,c.- pPowerClass,c is the linear value of the maximum UE power for serving cell *c* specified in Table 6.2.1-1 according to [powerClassPerBand] if indicated or ue-PowerClass otherwise without taking into account the tolerance; - ΔPPowerClass,CA = 3 dB for a power class 2 capable UE when the requirements of default power class are applied as specified in sub-clause 6.2.A.1.3; otherwise ΔPPowerClass, CA = 0 dB; […] |

As described in the yellow-part, a UE could perform inter-band CA transmission with the maximum power of 10 log10 ∑ pPowerClass,c., if and only if UE supports [HigherPowerLimitCADC] capability and ΔPPowerClass, CA = 0. The value of ΔPPowerClass, CA is, as described in the cyan-part, “3 dB for a power class 2 capable UE when the requirements of default power class are applied as specified in sub-clause 6.2.A.1.3; otherwise 0 dB”. Thus, to achieve the summation of maximum transmit power for each band, the condition “for a power class 2 capable UE when the requirements of default power class are applied as specified in sub-clause 6.2.A.1.3” shall be avoided, which is described as follows:

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| If a UE supports a different power class than the default UE power class for the band combination listed in Table 6.2A.1.3-1 and the supported power class enables the higher maximum output power than that of the default power class:– if the field of UE capability maxUplinkDutyCycle-interBandCA-PC2 is not absent and the average percentage of uplink symbols transmitted in a certain evaluation period is larger than maxUplinkDutyCycle-interBandCA-PC2 as defined in TS 38.331 (The exact evaluation period is no less than one radio frame); or– if the IE P-Max as defined in TS 38.331 [7] is provided and set to the maximum output power of the default power class or lower;– shall apply all requirements for the default power class to the supported power class and set the configured transmitted power as specified in clause 6.2A.4;– else;– shall apply all requirements for the supported power class and set the configured transmitted power as specified in clause 6.2A.4 (regardless of the average percentage of uplink symbols if the field of UE capability *maxUplinkDutyCycle-interBandCA-PC2* is absent).The average percentage of uplink symbols is defined as 50% × ( DutyNR, x /maxDutyNR,x + DutyNR, y /maxDutyNR,y, ). DutyNR, x, DutyNR, y represent the actual percentage of uplink symbols transmitted in the same evaluation period (The exact evaluation period is no less than one radio frame) for NR Band x, NR Band y respectively; maxDutyNR,x,maxDutyNR,y represent the field of UE capability *maxUplinkDutyCycle-PC2-FR1* per band as defined in TS 38.331. For NR Band x or NR Band y, – if power class of one or both of the bands within the band combination is power class 2 and the corresponding UE capability maxUplinkDutyCycle-PC2-FR1 is absent;– the corresponding maxDutyNR,x or maxDutyNR,y is equal to 50%;– else if the band is configured with power class 3;– the corresponding maxDutyNR,x or maxDutyNR,y is equal to 100%. |

Here the key point is which requirement (i.e., either the one for the default power class or the one for the supported power class) the UE shall apply is dependent on the average percentage of uplink symbols on each band. And the percentage is calculated based on “a certain evaluation period”, of which the exact duration is actually up to UE implementation. gNB doesn’t have anything on it. Therefore, gNB may not able to understand whether the UE could actually perform inter-band CA with higher transmit power as supported in RAN4 in Rel-17. To resolve the issue above, what we think is necessary is to define the exchange of information between UE and gNB in a timely manner, which requires the work outside RAN4 in our view. One possible solution is for RAN1 (or RAN2) to define a framework with which a UE can give the information on applicability of high-power UL CA/DC. Note that we assume the possible solution might eventually be RAN2 matter, e.g., extending PHR reporting. Having said that, we believe studying the issue itself can be done in RAN1. Note also that we see another company raising similar but different issue in their contribution. For example, reporting MPE and/or MPR is also proposed. We agree they are also something unclear from gNB perspective, while they also have an influence on the actual maximum transmit power determination based on the equation above. We here understand a common key point is the lack of information at scheduler side. In summary, we think RAN1 scope should generally be:* Study what kind of information exchange between UE and gNB is missing in order to achieve higher power CA/DC
* Study how to achieve such information exchange
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| vivo | This is RAN4 led item, any RAN1 enhancement if needed should be triggered by RAN4 according the work plan being discussed. It is also possible that RAN4 may move this item to other work items.Therefore, from RAN1 point of view, we should wait for RAN4 or RAN decision on whether and how to study this item. The RAN1 enhancements or whether they’re needed are not clear at this stage. This is also why we propose to deprioritize this discussion **in RAN1**, it doesn’t mean this item will not be discussed, it’s happening in RAN4. |
| Intel | We share similar view as vivo that as RAN4 is leading WG on the UE power high limit for CA and DC, the RAN1 discussion should be triggered by RAN4 LS. At least from our understanding, there is no clear guidance on the exact RAN1 scope.  |
| QC | RAN1 can focus on whether any additional signalling mechanisms or scheduler assistance can facilitate UL-CA/DC operations. I see very strong parallels between this discussion and the discussion on the topic of dynamic waveform switching where pretty much all gNB vendors have requested enhancements to PHR framework to enable more informed waveform switching.We are asking the same question here. Can we enhance existing PHR framework to facilitate (a) activation of UL-CA and (b) scheduling transmissions across multiple bands once UL-CA is enabled and (c) increasing awareness of power/energy budget available at the UE for each carrier/band?This can also benefit other enhancements currently under discussion, namely:* Uplink tx switching across 4 bands --- does gNB need any assistance to determine which carrier it prefers to use for uplink and,
* RAN4 work on enabling 4 tx UEs in uplink.

Here is a simple question to ponder over: if UE indicates via PHR1 on CC1 that it can deliver 23 dBm on CC1 and then say it indicates via PHR2 on CC2 that it can deliver 23 dBm, what does the gNB assume the UE can deliver if concurrent transmissions are scheduled?Uplink enhancements at the UE are moving at a fast clip. UE power management is getting more sophisticated. Yet UL-CA deployments are lagging. This may be a good opportunity for companies to identify the pain points so that we can try to address them. @vivo, the entire power-domain enhancement topic is lead by RAN4, do you prefer that RAN1 not do anything until we receive an LS from RAN4? |
| Apple | This objective in WID is vague, and RAN4 is the leading group. We need some guidance from RAN4 to proceed. |
| OPPO | Share similar view as other companies. RAN1 discussion could be triggered by RAN4 LS. |
| ZTE | We are fine with moderator’s approach to first collect the potential RAN1 enhancements from proponents, and then to see whether anything should be done in RAN1. But it seems there are lots of different proposals here as summarized by moderator below. Even RAN1 is to start some discussion, it’s better to have some focus here.  |
| InterDigital | Agree with DOCOMO and QC |
| Ericsson | The scope is indeed unclear from a RAN1 perspective. However, we are fine to consider at least the ideas brought forth by proponents so far in RAN1. If Tx power behavior other than what is supported in the Rel-17 RAN4 “Increasing UE power high limit for CA and DC” is to be considered, that should be provided to us by RAN4. The simulations do not look particularly straightforward, so we expect the time for study will be pretty tight.  |
| Fujitsu | We think realizing increased UE power caps for CA and DC will introduce new problems for gNB, which is mentioned in our contribution. According to the current specifications, the SAR issue for CA case will be avoided by UE implementation. On the other hand, it is not required for a UE to inform a gNB of its cumulative transmit power information, which may cause UE autonomous Tx suspension due to SAR limit. This will result in an inconvenience at the gNB scheduler. Therefore, gNB cannot fully utilize the benefit of increasing UE power high limit for CA and DC. This issue is from the gNB's point of view, not from the UE's point of view. We think this is the reason for the opinion of vivo and other companies. However, if new signaling/report is introduced, not only gNB can know the timing about UE autonomous Tx suspension due to SAR limit but also gNB can perform more flexible scheduling, which enables gNB to avoid unexpected UE autonomous Tx suspension/power reduction. We suppose this is the rationale of the argument by vivo and others.Which mean gNB and UE can fully utilize the benefit of increasing UE power high limit for CA and DC. We believe this is definitely a RAN1 topic and RAN4 cannot be aware of this issue. Hence, waiting for RAN4 wouldn't be a good idea.In summary, Realizing increased UE power caps for CA and DC will introduce new problems from the gNB's point of view especialy scheduler. This issue should be discussed RAN1.Of course, LS can be sent if RAN4 guidance is needed for discussion in RAN1. |

**2.2.1-Q2**

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| Company | Answer/Views |
| DOCOMO | Here we might not get FL’s question well; does “***additional cases for increasing UE power high limit for CA and DC***” mean extending the applicable case of increasing UE power high limit for CA and DC to e.g., another type of CA/DC? If so, we believe this is indeed RAN4 matter.  |
|  |  |
| Vivo | No. The WID doesn’t tell any detailed enhancements, it just tells RAN4 should lead the discussions to see if anything more is needed on top of what they’ve done for increasing UE power high limit for CA/DC in Rel-17. RAN1 may be impacted if RAN4 finds any detailed enhancements necessary.If any new RAN1 specific enhancement items are expected to be triggered by RAN1, it should be discussed in RAN plenary first to update the WID and extend the scope, which is not preferred from our side given limited TU we have.

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| * 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)
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| Intel | No. We do not foresee additional cases for increasing UE power high limit for CA and DC |
| QC | This is up to RAN4. They may wish to pursue extending the R17 framework to, say, the PC2+PC2 case. We don’t see RAN1 being involved here. |
| Apple  | It’s not clear the meaning of additional case. If there are some new cases, it should be disucsed in RAN4 first. |
| OPPO | NO. It should be discussed in RAN4 first.  |
| Sharp | No. That is up to RAN4. |
| ZTE | It’s RAN4 work. RAN1 doesn’t need to make any conclusion on this aspect now.  |
| InterDigital | Seems to be RAN4-related. |
| Ericsson | Agree this is up to RAN4, as we comment above. |
| CMCC | No. RAN4 may discuss. |
| Fujitsu | We think it should be discussed in RAN4. |
| Samsung | If any, it would be RAN4 to add more cases in addition to what already specified in Rel-17.  |

**FL’s comment on October 14**

Thank you for adding your views. I guess that the reason why I had organized the discussion as I did is clear to everyone now. We obviously have two separate camps, and the majority is willing to receive an input from RAN4 before taking any action in RAN1. At the same time, we have at least 4 companies suggesting interesting directions for RAN1 study and willing to open the discussion to understand whether signalling enhancements exist for giving gNB more tools to enable/activate or support UL-CA operations.

Now, given:

* what was observed during the first round of discussion,
* the fact that this objective will not be deprioritized, as per previous discussion,
* the proposal made by at the least 4 companies,

I think it is fair to put forward an open proposal related to what RAN1 should do for this objective. This will be done in Section 2.2.2 for consistency with the topic at hand.

This section is closed.

### [OPEN] New signaling aspects

Four companies (Fujitsu [8], InterDigital [14], NTT DOCOMO [18], Qualcomm [19]) discussed and proposes directions for studying new signaling mechanisms between UE and Gnb. Specifically,

* One company (Fujitsu [8]) proposes introducing a new signaling/report from UE to Gnb to let Gnb know the timing about UE autonomous Tx suspension due to SAR limit. FFS: Details of signaling/report.
* One company (InterDigital [14]) proposes supporting indication of aggregated power class in power headroom report.
* One company (NTT DOCOMO [18]) proposes studying a method for UE to report the exact availability of higher transmit power for inter-band CA/EN-DC UL transmission.
* One company (Qualcomm [19]) proposes introducing signaling mechanisms between UE and Gnb focused on:
	+ increasing awareness of power or energy budget available at the UE for each carrier/band,
	+ aiding the selection of the best band combination for UL CA, and
	+ aiding scheduling policy when UE is configured with multiple bands in UL CA, for e.g., selecting preferred carrier for servicing uplink, or adaptive load sharing across carriers.

In addition, the following are also proposed in [19]:

* Introduce signaling to allow UE to report aspects related to power management and RF exposure.
* Enhance the current power headroom reporting framework to allow a user to also report P-MPR (via MPE field) for FR1 carriers.
* 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).
* Introduce MAC-CE signaling to allow UE to report energy headroom for each of the bands in a CA/DC configuration given to the UE.
	+ FFS: signaling details, including, periodicity, reporting triggers, relation to PHR, how to handle multiple bands, reference power, etc.

**FL’s comment on October 12**

It has been observed by few companies that one of the possible goals for this item is to study enhancements to further facilitate high power transmissions across different bands. This provides a more informative context to the proposal listed above.

The following question is then asked to start the discussion.

|  |
| --- |
| **2.2.2-Q1** ***Given R17 RAN4’s work, are there any enhancements needed in RAN1 to further facilitate high power transmissions across different bands?******Please elaborate on which enhancements should be (at least) studied in Rel-18, if your answer is YES. Details are welcome, if possible.*** |

#### First round of discussions

FL’s recommendation is to have a first round of discussion about **2.2.2-Q1**. Companies are invited to input their views in the corresponding table below.

**2.2.2-Q1**

|  |  |
| --- | --- |
| Company | Answer/Views |
| DOCOMO | As we described for 2.2.2-Q1:In summary, we think RAN1 scope should generally be:* Study what kind of information exchange between UE and Gnb is missing in order to achieve higher power CA/DC
* Study how to achieve such information exchange

One potential solution is, as raised by some companies, extending PHR reporting. UCI-based solution may also be considered, but we are open. Note that, similar to other companies, we are not very supportive to have more and more work here either considering TU, other sub-agendas, etc. So we believe the simpler solution would be better.  |
| Vivo | Not necessary at this stage as we commented earlier. |
| Intel | Share similar view as vivo |
| QC | Mostly echoing Docomo’s comment.Is any scheduler assistance needed to enable/activate or support UL-CA operations? Does PHR framework need any updates? Would Gnb like to have more information on UE’s energy budget per carrier?We understand this is the first meeting. We want companies to be given a chance to consult with their scheduler/implementation teams to figure out what may be useful here. Lets then take this feedback into consideration and try to figure out how to proceed.  |
| Apple | We share the views with vivo and Intel. |
| OPPO | Not necessary. |
| Sharp | For RAN1’s scope, we agree with Docomo. On the other hand, we prefer to discuss what the issue with the existing ignalling is from the RAN1 point of view, before discussing the possible enhancements. |
| ZTE | Facilitate NW for better scheduling is attractive but it needs to discuss 1) how much benefit/gain the proposed enhancements can provide compared with leaving this to implementation based on current signalling, 2) how much spec impact the enhancements may have. |
| InterDigital | Agree with DOCOMO and QC. It seems difficult to achieve significant benefit with this feature without providing appropriate information to the scheduler. |
| Ericsson | Ok to consider enhancements according to what RAN4 has defined in R17, as commented above. |
| Fujitsu | We support DOCOMO’s opinion shown below:* Study what kind of information exchange between UE and gNB is missing in order to achieve higher power CA/DC
* Study how to achieve such information exchange

UE to inform a gNB of regarding RF exposure information (ex; cumulative transmit power and energy budget) is not required about the existing specification. Which may cause UE autonomous Tx suspension due to SAR limit. This will result in an inconvenience at the gNB scheduler. From the gNB's point of view, the lack of information needed for scheduling is a problem and should be discussed in RAN1. |
| Samsung | The answer to this question depends on several aspects, including network implementation and scheduling, and performance benefits. Specification impact is also an additional aspect. It needs careful consideration of all these aspects before considering solutions. |

#### Second round of discussions

Thank you for adding your views. As commented in Section 2.2.1, which is partially repeated here for simplicity, that is

Given:

* what was observed during the first round of discussion,
* the fact that this objective will not be deprioritized, as per previous discussion,
* the proposal made by at the least 4 companies,

I think it is fair to put forward an open proposal related to what RAN1 should do for this objective.

The proposal follows.

**FL’s proposal 13**

For enhancements to realize increasing UE power high limit for CA and DC, RAN1 will study

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

I think the above proposal gives the possibility to all interested companies to study the problem at hand with a clear scope and propose results of this study in their contributions.

This seems fair to FL and may ensure that RAN1 makes a good use of allocated time for this objective while waiting for future input from RAN4, if any.

In this context, it should be noted that most companies who commented in Section 2.1.2 are not agreeing that an LS out from RAN1 to RAN4 is needed as present. For this reason, I will not pursue this direction for the time being (in this meeting, of course) for the sake of an efficient use of our time, unless a change of majority view is observed in comments to FL’s proposal 13. If this is the case, Section 2.1.2 will be reopened in the next round.

Companies are invited to input their views on **FL’s proposal 13** in the table below. **Constructive attitude and comments are greatly appreciated**. If you cannot agree with the current formulation of the proposal, please provide an alternative formulation.

**FL’s proposal 13**

|  |  |
| --- | --- |
| Company | Answer/Views |
| QC | Support. This serves as a good starting point to see if RAN1 can pursue any useful enhancements in this context.  |
| Fujitsu | We support FL’s proposal. |
| DOCOMO | We support FL’s proposal.  |
| Ericsson | Support in principle but we might clarify. If I understand correctly, the idea is to improve the knowledge of available UE power in the network, allowing better scheduling and more efficient operation / better network performance. As written, the enhancements could be possibly be misread to be needed at gNB only, rather than enhancements to messaging affecting both the UE and gNB. Also, the idea is not to increase the power already defined for UE power high limit feature, so higher power is not achieved, just when it is available is better known. Suggest:For enhancements to realize increasing UE power high limit for CA and DC, RAN1 will study* Whether RAN1 enhancements to information exchange between UE and gNB are needed ~~at gNB to achieve~~ 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.
 |
| ZTE | We are ok to further study this aspect. However, ‘higher power CA/DC’ in the proposal seems ambiguous. On top of the updates from Ericsson, we suggest to change ‘when using higher power CA/DC’ to ‘when increasing UE power high limit for CA and DC’, or we can simply delete it as this has been mentioned in the main bullet.  |
| Nokia/NSB | Support. |
| Samsung | Fine to further discuss. The wording proposed by Ericsson is also fine. As mentioned in the previous round, potential enhancements can impact gNB implementation, and such aspect needs to be taken into consideration in the study. |
| vivo2 | As far as we know, RAN4 is discussing the scenarios to be considered for this objective. Before the scenarios and potential RAN1 impacts are confirmed by RAN4, we do not think RAN1 should prioritize RAN1 impacts study. It would be weird to see RAN1 is discussing some RAN1 enhancements while RAN4 concludes to do nothing in a RAN4 lead objective which is possible.Without this proposal, companies who are interested and would like to start the study earlier than RAN4, are still allowed to propose any RAN1 enhancements in RAN1 though we think this is too early as the scenarios are not clear yet from RAN4. |

## Others

No additional aspects have been identified by FL.

# Summary of contributions on enhancements for reducing MPR/PAR

Contributions submitted under AI 9.14.2 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, 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**
	+ Way of working (RAN1 and RAN4 work split)
	+ Candidate MPR/PAR reduction techniques
	+ Design aspects of FDSS-SE
	+ Design aspects of TR
* **Mid priority aspects**
	+ Parameterization for evaluations
	+ MPR/PAR reduction techniques
* **Other aspects**
	+ Complementary enhancements

The categorization above will determine the initial priority order for the discussions to be held for AI 9.14.2. 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 #110b-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.

## High priority aspects

Four high priority aspects are identified at the beginning of the meeting:

1. Way of working (RAN1 and RAN4 work split)
2. Candidate MPR/PAR reduction techniques
3. Design aspects of FDSS-SE
4. Design aspects of TR

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

### [CLOSED] Way of working (RAN1 and RAN4 work split)

Several contributions acknowledged the fundamental nature of this aspect and discussed it in detail. High-level summary of companies’ preferences and opinions based on the contributions follows.

Six companies (ZTE [3], CATT [7], CMCC [11], MediaTek [12], Apple [13], Nokia/NSB [20]) propose to introduce a specific work split and/or actual order of work between RAN1 and RAN4:

* Two companies propose to wait until RAN4 progress is achieved and inputs are provided to RAN1 before starting corresponding RAN1 discussion.
* Three companies propose that the performance evaluation of candidate solutions to yield MPR/PAR reduction should be carried out in RAN4.
* One company (CMCC [11]) explicitly mentions the need for assessing specification impact of FDSS and TR based solutions.

From FL’s perspective, there seems to be a common understanding among companies who discussed RAN1 and RAN4 work split that RAN4 should have a paramount role for the power domain enhancements, at least for the part related to performance evaluation.

At the same time, assessing RAN1 specification impact of candidate solutions does not seem to depend on the performance evaluation carried out in RAN4. Carrying out this part of the RAN1 work seems feasible, irrespective of whether performance evaluation results are available or not.

Further selection of the solution if any, could be then carried out by RAN1 based on performance evaluation results (provided by RAN4) and specification impact analysis (made by RAN1).

In this context, freezing the number of candidate solutions (and their description) in RAN1 before #110b-e is over, and informing RAN4 accordingly (via LS, for instance) would seem a reasonable approach from my perspective. This would allow RAN4 to study the solutions and possibly take the first decisions during RAN4 #105, i.e., the latency in RAN1 would be acceptable.

Two questions are asked to collect companies’ opinions on FL’s understanding and assessments.

|  |
| --- |
| **3.1.1-Q1 Provide your view on the following proposed RAN1/RAN4 work split:*** *RAN4 is responsible for performance evaluation of candidate solutions to reduce MPR/PAR in Rel-18. No selection of the MPR/PAR reduction solution, if any, is performed by RAN1 before performance evaluation results are shared by RAN4.*
* *RAN1 is responsible for assessing RAN1 specification impact of candidate MPR/PAR reduction solutions*
	+ *Final list of candidate solutions should be ready before the end of RAN1 #110b-e, to be included in an LS to RAN4.*
* *RAN1 is responsible for selecting the Rel-18 MPR/PAR solution, if any, based on performance evaluation (provided by RAN4) and specification impact analysis (made by RAN1)*

*Note*: *discussion on specification impact of candidate MPR/PAR reduction solutions will start after the candidate solutions have been shortlisted.* |

|  |
| --- |
| **3.1.1-Q2 *Is there any performance evaluation/analysis that can and should be carried out by RAN1, irrespective of the study carried out by RAN4?**** ***Note: this question is asked for the sake of completeness, to ensure that RAN1 does not overlook important study directions.***
 |

#### First round of discussions

FL’s recommendation is to have a first round of discussion among companies about **3.1.1-Q1** and **3.1.1-Q2**.The goal is to identify the preferred direction RAN1 should pursue for handling the next steps. Feel free to elaborate on your answer in the suitable box, if applicable. **If you do not agree with what is being proposed, please provide a precise alternative approach/proposal to allow the discussion to progress.**

Constructive attitude is greatly appreciated, for the sake of an efficient use of the limited time RAN1 has.

**3.1.1-Q1**

|  |  |
| --- | --- |
| Company | Answer/Views |
| QC | The decision making will need to be based on net coverage gain and not just performance evaluation carried out by RAN4. RAN4 will not have the expertise to run link-level simulations to assess impact of different Gnb receivers. Also, we can’t tell RAN4 that they don’t have the power to make decisions. They can make agreements if they feel sufficiently comfortable. Also, if RAN4 prefers to agree to certain transparent techniques that do not involve RAN1, that should be allowed.  |
| DOCOMO | Generally fine. If companies are willing to perform LLS, it would also be ok.  |
| Ericsson | We agree completely that RAN4 should be the final arbiter of implementation feasibility and achievable output power. However, we think it is difficult to separate design decisions from performance evaluation, so RAN1 needs to be able to perform accurate simulations of power domain enhancements. MPR evaluation methods are well established in RAN4, and we can use those in RAN1 to compare design alternatives. (Please see R1-2209673 for what we have in mind) RAN1 can then provide the spec impacts and our understanding of the performance/complexity tradeoffs to RAN4 based on these evaluations. RAN4 can then use this to select the schemes to specify, if any.RAN1 should naturally assess the RAN1 spec impact of schemes, and this work can be in parallel to RAN4 evaluations. Regarding the timeline, we think that targeting February (two meetings from now) for a go/no go decision on specifying power domain enhancements drives some urgency to identify schemes. However, identifying the final schemes already in this meeting is too early. Identifying schemes for investigation could be by next meeting, and an LS could be sent to RAN4 then on potential spec impacts, which RAN4 would have time to take into account. We actually don’t think it is super critical to have an early list of schemes to RAN4, since schemes are already being proposed in both RAN1 and RAN4, and determining simulations setups and doing the evaluations can proceed already. What could happen is that some RAN1 spec related issue is not taken properly into account in RAN4, but if RAN1 is doing a reasonable job of evaluations, we at least can reflect the issue in our conclusions.Another issue is that ‘transparent’ techniques that do not have RAN1 specification impact need to be considered along with those that do have RAN1 spec impact. In RAN1, transparent techniques should be considered as a baseline on which non-transparent techniques can build. While RAN1 would not specify them, RAN4 can develop performance requirements based on them, and indeed RAN4 are discussing transparent techniques in this meeting. Because RAN4 does not need RAN1 input, the timeline for transparent techniques can be later then non-transparent. However, the RAN4 efforts for scheme evaluation and potential MPR reduction will take considerable time. Therefore, it can be beneficial to have a separate timeline for transparent and non-transparent schemes.Given the tight timelines, we think rather than concluding on MPR/PAR reduction schemes in February, RAN4 should have a checkpoint on whether to specify, to continue study of, or to not pursue enhancements requiring RAN1 spec impact to reduce MPR/PAR. That way, if it is clear that non-transparent enhancements are beneficial, there can be time to specify them in Rel-18, or if they are clearly not beneficial, the WI time can be used for other work, and if more time is needed for study, the study can continue. If continued study is chosen, then the outcome of the work could be a TR, rather than simply a choice not to specify.After the February checkpoint, RAN4 work continues on transparent schemes, and based on the checkpoint, may continue on non-transparent schemes. We think a deadline for pursuing power domain enhancements schemes or not from a RAN4 perspective can then be in May or perhaps later, and this of course should be concluded by RAN4.**In summary, we propose*** RAN1 does performance evaluations of power domain enhancements using RAN4 methodologies, i.e. RAN1 should (see R1-2209673):
	+ Quantify relative link performance of a given transmission configuration as $SNR\_{0}+OBO$, where $SNR\_{0}$ is the SNR (in Db) needed to reach a target BLER, and $OBO$ is the output power backoff for the configuration (in Db).
	+ Determine PA output backoff using RF simulations and according to RAN4 requirements for error vector magnitude, in band emissions, spectrum flatness, spectrum emission mask, and adjacent channel leakage, spurious and accounting for counter-IM3.
* RAN4 makes the final decision on power domain enhancement schemes, as they have the expertise on implementation feasibility and achievable output power.
	+ RAN1 can inform RAN4 of their findings on specification impact and our view of performance/complexity tradeoffs.
* RAN1 can provide a list of schemes to RAN4 by RAN1#111, but this meeting (RAN1#110bis) is too early.
	+ RAN4 is already discussing a list of schemes, so it is better to give more thought than to rush an input to RAN4.
* In February (RAN1#112/RAN4#106), there is a checkpoint where RAN4 decides on whether to specify, to continue study of, or to not pursue enhancements requiring RAN1 spec impact to reduce MPR/PAR.
	+ After the checkpoint, RAN4 work continues on transparent schemes, and based on the checkpoint, may continue on non-transparent schemes.
* In May (RAN4#107), RAN4 decides if/what to specify on requirements for power domain enhancements (including transparent and, according to the checkpoint outcome, possibly non-transparent)
 |
| Intel | We tend to agree with FL that RAN1 can first identify potential candidate MPR/PAR reduction solutions and RAN4 can start with performance evaluation. However, given that RAN4 is leading WG for this topic, our understanding is that final decision on whether solutions to reduce MPR and PAR will be considered for Rel-18, should be made by RAN4, not RAN1. Note that RAN4 may also identify a set of solutions that can be considered for MPR/PAR reductions, e.g., transparent solutions. RAN1 can also consider this for further study. In addition, regarding “*Final list of candidate solutions should be ready before the end of RAN1 #110b-e, to be included in an LS to RAN4*”, given this is the first meeting for this topic, it is not clear to us whether RAN1 has sufficient time to assess all the specification impact within this meeting. We think some additional time is necessary to conclude the study in RAN1 in term of specification impact.  |
| Vivo | Given this is RAN4 led item and RAN1 can provide some candidate solutions from RAN1 point of view so that RAN4 can determine final candidate solutions for evaluation in order to determine the necessity of MPR/PAR reduction enhancement. RAN4 also needs to consider their work load and feasibility of evaluating RAN1 proposed solutions from RAN4 point of view to determine final candidate solutions to be evaluated.Therefore, we propose to have following work split:* *RAN4 is responsible for performance evaluation of candidate solutions to reduce MPR/PAR in Rel-18 and determine whether the enhancement is needed. Selection of the MPR/PAR reduction solution, if any, is performed by both RAN1 and RAN4 before performance evaluation results are shared by RAN4. RAN1 sends the candidate solutions from RAN1 point of view to RAN4 to help RAN4 to decide final candidate solutions to be evaluated.*
 |
| Panasonic  | We think that RAN1 would discuss the list of candidate solutions and include them in the LS to RAN4. The list can be formulated based on below section 3.1.2. |
| Samsung | Regarding *Final list of candidate solutions should be ready before the end of RAN1 #110b-e* – this schedule seems a bit too aggressive, especially considering that the intention is to ask RAN4 to do evaluation of such schemes. Perhaps the list can be finalized in next RAN1#111 to allow time to discuss the solutions in RAN1. In any case we would assume that both RAN1 and RAN4 would propose candidate solutions.On the other hand, we see the value in starting an early coordination with RAN4, so we would be fine with sending an LS in this meeting.  |
| Huawei, HiSilicon | There is SNR degradation caused by FDSS-SE. Therefore, the effective gain is MPR gain minus SNR degradation. It should be reflected in the last bullet for selecting Rel-18 MPR solution.It is good to send a list of candidate solution to RAN4, with necessary parameters. But it is hard to conclude that RAN1 can provide a final list at the first meeting, since some important parameters may not be stable, e.g. SE ratio, FDSS filter.Therefore, we suggest changes in red below* *RAN4 is responsible for performance evaluation of candidate solutions to reduce MPR/PAR in Rel-18. No selection of the MPR/PAR reduction solution, if any, is performed by RAN1 before performance evaluation results are shared by RAN4.*
* *RAN1 is responsible for assessing RAN1 specification impact of candidate MPR/PAR reduction solutions*
	+ *~~Final~~ A list of candidate solutions should be ready before the end of RAN1 #110b-e, to be included in an LS to RAN4.*
* *RAN1 is responsible for selecting the Rel-18 MPR/PAR solution, if any, based on performance evaluation (provided by RAN4), SNR degradation (if any, provided by RAN1) and specification impact analysis (made by RAN1)*

*Note*: *discussion on specification impact of candidate MPR/PAR reduction solutions will start after the candidate solutions have been shortlisted.* |
| CMCC | Generally fine. For the sub-sub-bullet about the time budget for *Final list of candidate solutions ,* ending before this meeting seems a little bit tight.  |
| Nokia, NSB | Agree with the proposed work split.Additionally, we propose that RAN1 prioritizes the study of non-transparent schemes having RAN1 impact (i.e. FDSS w/ SE and tone reservation) |
| ZTE | We agree with companies that RAN4 as the leading WG should have the responsibility to make final decisions. Without knowing the performance evaluation results, we are not sure how to determine the list of candidate solutions. What should be the metric/criterion, e.g., should we include all proposed candidates considering the evaluation results are not available now? We noticed RAN4 is discussing the evaluation methodology/assumptions now. RAN1 can start discussion on additional evaluation methodology/assumptions after receiving RAN4 input. With above said, we suggest the following revisions: * *RAN4 is responsible for performance evaluation of candidate solutions to reduce MPR/PAR in Rel-18. ~~No selection of the MPR/PAR reduction solution, if any, is performed by RAN1 before performance evaluation results are shared by RAN4.~~*
* *RAN1 can start discussion on additional evaluation methodology/assumptions if needed after receiving RAN4 input on evaluation methodology/assumptions.*
* *RAN1 is responsible for assessing RAN1 specification impact of candidate MPR/PAR reduction solutions*
	+ *~~Final list of candidate solutions should be ready before the end of RAN1 #110b-e, to be included in an LS to RAN4.~~*
* *RAN~~1~~4 is responsible for selecting the Rel-18 MPR/PAR solution, if any, based on performance evaluation (provided by RAN4) and specification impact analysis (made by RAN1)*

*Note*: *discussion on specification impact of candidate MPR/PAR reduction solutions will start after the candidate solutions have been shortlisted.* |
| MediaTek | Selecting the MPR/PAR solution should be based on not just RAN4 performance evaluation and RAN1 spec impact, but also based on potential coverage gain analysis/simulations. We think that companies in RAN1 should be free to perform evaluation and analysis for study purpose irrespectively of RAN4’s progress on the topic. However, agreements or any down-selection (among potential methods) should not be made in RAN1 until RAN4 reaches a decision. We expect RAN4 to act as the lead WG on this. As the leading WG, RAN4 should be responsible for selecting the MPR/PAR solution, instead of RAN1. Also, we are not so sure about the feasibility of the intended deadline “*before the end of RAN1 #110b-e*” for the final list of candidate solutions. Some discussions are needed to understand different solutions. For RAN4 perspective, they can make agreements irrespectively of RAN1 progress. If RAN4 requires RAN1 expertise, they can also coordinate via LS with RAN1. If RAN4 decides to support an enhancement that doesn’t require any RAN1 spec impact, further study in RAN1 will no longer be needed. If RAN4’s decision requires RAN1 spec change, we expect RAN1 to be informed via LS, upon which RAN1 can try to reach an agreement. |
| Sharp | Fine with the proposal. |
| CATT | We agree with Huawei that in addition to MPR/PAR reduction, SNR degradation should be evaluated and considered.In addition, we agree with the comments that RAN4 should not be prevented to make selection/conclusion. |
| Lenovo | We have similar view with ZTE. |
| InterDigital | Ericsson’s proposal seems a good way forward to ensure timely completion of the work. However, conclusions should be validated by RAN4. |
| Apple | We agree with FL’s assessment and the proposed work split between RAN1 and RAN4. As for the deadline of candidate techniques to provide to RAN4, it seems not necessary, studying the PAPR is falling into RAN4 expertise. |

**3.1.1-Q2**

|  |  |
| --- | --- |
| Company | Answer/Views |
| QC | Link-level evaluations will need to be carried out by RAN1. Baseline comparisons, spectral efficiencies to target, are all in RAN1 domain. |
| DOCOMO | LLS, if the need is identified, could be performed. What QC has listed above would be ok for us.  |
| Ericsson | Please see 3.3.1-Q1 for what we think RAN1 should study. |
| Vivo | RAN1 can perform some link level simulations, spec. impact and complexity analysis to down-select some candidate solutions for RAN4 to consider. |
| Panasonic  | We support the question 3.1.1-Q2. |
| Samsung | Link-level simulations as needed. |
| Huawei, HiSilicon | The most urgent tasks is to provide necessary information for RAN4 MPR evaluations. In this sense, the following should be evaluated in RAN1* Receiver performance evaluation, i.e., SNR degradation due to coding rate increase
* Proper SE ratio to provide better trade-off between power gain and SNR degradation, with the same TBS, different MCS, the same total number of scheduled PRBs, etc.
* DMRS performance impact, ZC sequence-based DMRS v.s. low-PAPR DMRS used for Pi/2 BPSK.
 |
| CMCC | RAN1 could make some performance evaluation using e.g. LLS. |
| Nokia, NSB | We don’t see a need for parallel performance evaluation/analysis.  |
| ZTE | For solutions having RAN1 impacts, RAN1 can work out some evaluation methods to compare different schemes. It should be business as usual. For now, without knowing what RAN4 would agree on the evaluation, we may start this discussion later to avoid potential duplication.  |
| MediaTek | Evaluations via LLS should be studied in RAN1. We agree with QC’s comment. |
| CATT | We agree that link-level performance should be evaluated in RAN1. |
| InterDigital | Agree with Qualcomm. |
| Appel | Agree with Nokia |
|  |  |

**FL’s comment on October 12**

Thank you all for adding your views.

Most companies agree that final decision on which MPR/PAR reduction solution(s) should be selected in Rel-18 should up to RAN4.

Most companies believe that at least LLS could be performed by RAN1 to assess receiver performance with focus on SNR degradation brought by the adoption of MPR/PAR reduction techniques. This is due to the fact that RAN1 has the expertise to assess the impact of different receivers at Gnb.

Most companies believe that asking RAN1 to provide a list of candidate solutions to consider by the end of RAN1 #110b-e is not desirable and such list should be ready for RAN1 #111.

One company (Ericsson) propose to include elements of the Workplan in the description of the work split. This information seems more suitable for inclusion in the workplan currently being worked on by the Moderator. I would not include it in the discussion on the work split for the time being.

One company (Ericsson) argues that RAN1 should also perform RF simulations, and account for OBO in the performance assessment. While the technical merit of this proposal is rather obvious, this would seem a study RAN4 should do. No other company proposed this, while others openly proposed to defer the RF part of the study to RAN4. For this reason, this suggestion is not retained for the time being, hoping to facilitate the identification of a middle ground.

A FL proposal is thus formulated.

**FL’s proposal 6**

**The following work split principles will be adopted in RAN1 for power domain enhancement throughout Rel-18:**

* *RAN1 performs link level simulations of candidate solutions for power domain enhancements to study at least the SNR degradation and PAPR/CM reduction, if any, brought by each solution.*
	+ *Transparent MPR/PAR solutions can be considered as a benchmark for studying the performance of non-transparent solutions.*
* *RAN1 will not perform RF simulations of candidate solutions for power domain enhancements*
* *RAN1 will assess RAN1 specification impact of candidate MPR/PAR reduction solutions*
	+ *Final 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.*
* *RAN4 is responsible for selecting the Rel-18 MPR/PAR solution, if any.*

*Notes*: *Discussion on specification impact of candidate MPR/PAR reduction solutions will start after the candidate solutions have been shortlisted by RAN1.*

Companies are invited to input their views on **FL’s proposal 6** in the table below. It is understood that the proposal may not be fully aligned with any of the alternative proposal brought by companies during the initial round of comment. It has indeed been crafted to be a middle ground solution which is hopefully agreeable to all.

**FL’s proposal 6**

|  |  |
| --- | --- |
| Company | Views |
| DOCOMO | Agree  |
| vivo | Fine. |
| Intel | We are generally fine with the proposal. However, the deadline to finalize the final list of candidate solutions is too tight based on our understanding. We suggest to delay this to Feb or April meeting. In the last bullet, suggest to change “• RAN4 is responsible for selecting the Rel-18 MPR/PAR reduction solution, if any”It is not clear to us the meaning of the note. In any case, RAN1 will investigate the potential spec impact for the candidate solutions.  |
| Apple | Not exactly the clear the purpose of the simulation, as RAN1 will not make the final decision. Will we provide the simulation results or observation to RAN4 for reference? It could be better to coordinate with RAN4 to make it clear what exactly work is needed from RAN1. |
| OPPO | Fine with the proposal. |
| Spreadtrum | Support the first three bullets. But for the last bullet, RAN1 can do decision on the solutions if it is sufficient from RAN1’s perspective. So it is too restrict |

**FL’s comment on October 13**

Thank you for the very constructive GTW session. The following proposal was agreed, and the first LS draft will be shared tomorrow at the latest. This discussion is closed.

**Agreements**

The following work split principles will be adopted in RAN1 for power domain enhancement throughout Rel-18 from RAN1 perspective and send an 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.

### [OPEN] MPR/PAR reduction techniques

Several contributions acknowledged the fundamental nature of this aspect and discussed it in detail. Some companies proposed to focus the study on a specific candidate, or set of candidate solutions, whereas other companies provided suggestions on which specific waveform instances and configurations should be configured for the candidate studies. Some of these last proposals may have implications on the evaluation methodology (if any, in RAN1).

* 7 companies (Huawei/HiSi [2], ZTE [3], Lenovo [10], Apple [13], Sharp [17], Qualcomm [19], Nokia/NSB [20]) propose to consider FDSS w/ spectrum extension as a candidate solution to study.
	+ Observations made by other companies imply that a larger support for inclusion of this solution in the list exists.
* 4 companies (Intel [9], Spreadtrum [4], Lenovo [10], Apple [13]) propose to consider FDSS w/o spectrum extension as a candidate solution to study.
	+ Observations made by other companies imply that a larger support for inclusion of this solution in the list exists.
* 4 companies (OPPO [6], Lenovo [10], InterDigital [14], Qualcomm [19]) propose to consider TR as a candidate solution to study.
* 1 company (Lenovo [10]) proposes sub-PRB transmission as a candidate solution to study.
* 1 company (Ericsson [15]) proposes transparent MPR reduction schemes such as clipping and filtering, companding, and digital predistortion as candidate solutions to study.
* 1 company (Samsung 16)) proposes to further study advanced receivers to support reduced MPR.
* 1 company (Qualcomm [19]) argues that priority should be given to non-transparent techniques that allow a 0-Db MPR waveform to be transmitted at a transmit power exceeding the maximum power associated with the UE power class as candidate solution to study.

Additionally,

* One company (OPPO [5]) proposes to study performance of TR for both DFT-s-OFDM and CP-OFDM
* One company (ZTE [3]) proposes to study performance of FDSS w/ SE for pi/2-BPSK.
* Three companies (ZTE [3], Qualcomm [19], Nokia/NSB [20]) propose to study performance of FDSS w/ SE for QPSK.
* One company (ZTE [3]) proposes to study performance of FDSS w/o SE for QPSK.
* One company (Qualcomm ([19]) proposes to study the performance of TR for QPSK.
* One company (Qualcomm ([19]) proposes to study the performance of both TR and FDSS w/ SE for both inner and outer small RB allocation (1-16 RBs), where excess bandwidth is given in unit of RBs for both schemes.
* Two companies (Qualcomm [19], Nokia/NSB [20]) propose to focus only on DFT-s-OFDM and that DMRS undergo spectrum shaping as much as data symbols.

It is also worth noting that all companies who commented on the waveform to consider, but one (OPPO [6]), exclusively focus on DFT-s-OFDM. From FL’s this is consistent with the WID and:

* Considers the typical waveform configured by NW in case of coverage shortage, i.e., DFT-s-OFDM
* Considers the waveform which already naturally offers lower MPR and PAR, to further provide LB gain over the current best candidate in NR.
* Provides a more consistent way to compare different MPR/PAR reduction solutions

A proposal is thus formulated.

**FL’s proposal 1**

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

In this context, the proposal to consider both inner and outer RB allocations formulated by one company (Qualcomm [19]) seems a reasonable starting point which, given the content of other companies’ contributions, seem aggregable from my perspective. This is the case also for the proposal of focusing on QPSK waveform configurations. Conversely, a discussion on the allocation sizes to consider and on possible other modulation orders may be in order (differences seem to exist across companies).

The following proposal is formulated

**FL’s proposal 2**

**For power-domain enhancements targeting MPR/PAR optimization focus on the following configurations for DFT-S-OFDM:**

* **QPSK modulation**
* **RB allocation can be anywhere in the BWP (i.e., both inner and outer RBs are considered)**
* **FFS:**
	+ **Whether only small RB allocations, e.g., 1🡪16 PRB, are considered.**
	+ **Whether other modulations are considered.**

Now, discussions on which scenarios to focus on heavily depend on the discussion on RAN1/RAN4 work split. At the same time, and following the spirit of the discussion in Section 3.1.1, there are obvious majority views in the group which could be used to down-select a number of agreeable candidate solutions to study, both in terms of performance (RAN4?) and specification impact (RAN1). These seem to be:

* FDSS w/ SE
* FDSS w/o SE
* TR (which can only be w/ SE)

Given the limited time we have for this WI, and the challenge of working in parallel with another WG, I would suggest not including single company’s proposal in the list of supported candidates, since this would hardly be justifiable. Furthermore, I think that Rx only solutions may not be fully aligned with the scope of the WI given that they would not provide a constructive means to reduce both MPR and PAR, but rather target the compensation of the effect of non-linearities arising from operating the PA at the UE according to relaxed MPR requirements (whereas the PAR target of the WID would not be met). Albeit interesting, this would require a study on advanced Rx which does not target PAR reduction and is not included in the WID.

At the same time, it does not seem to prevent interested companies from studying alternative if they so wish. RAN1 may also suggest RAN4 to consider them as benchmarks, if RAN4 so wish.

With this spirit in mind, I would propose the following.

**FL’s proposal 3**

**At least the following candidate solutions for MPR/PAR reduction will be studied in Rel-18.**

* **FDSS w/ spectrum extension**
* **FDSS w/o spectrum extension**
* **TR (which can only be w/ spectrum extension)**

**Whether other solutions will be studied as well will be decided before the end of RAN1 #110b-e.**

To avoid any misunderstanding, the goal of FL’s proposal 3 is to make sure RAN1 can provide a complete list of candidate solutions to RAN4 by the end of this meeting, as discussed in Section 3.1.1.

A question is also asked.

|  |
| --- |
| **3.1.2-Q1 Please provide your comment/preference on the following “other solutions” to study in Rel-18**1. sub-PRB transmission.
2. transparent MPR reduction schemes such as clipping and filtering, companding, and digital predistortion.
3. advanced receivers to support reduced MPR.
 |

#### First round of discussions

FL’s recommendation is to have a first round of discussion among companies about **FL’s proposal 1**, **FL’s proposal 2**, **FL’s proposal 3** and **3.1.2-Q1**.The goal is to identify the preferred direction RAN1 should pursue for handling the next steps. Feel free to elaborate on your answer in the suitable box, if applicable. Constructive attitude is greatly appreciated, for the sake of an efficient use of the limited time RAN1 has.

**FL’s proposal 1**

|  |  |
| --- | --- |
| Company | Views |
| QC | Agree |
| Ericsson | DFT-S-OFDM is a logical starting point to target the studies toward. However, if a scheme can improve CP-OFDM without modification, we think it should not be precluded. So we prefer to either leave this proposal open for now, or have the following refinement:**FL’s proposal 1****DFT-s-OFDM is the target waveform for the study and design of MPR/PAR reduction solutions in Rel-18.** * **Solutions that can be directly used for CP-OFDM can also be used in studies and designs.**
 |
| Intel | We support FL’s proposal 1. |
| Vivo | Agree. DFT-S-OFDM has lower power back-off value than CP-OFDM and should be the target waveform. |
| Panasonic | We support the FL’s proposal 1. |
| Samsung | Fine with this proposal |
| Huawei, HiSilicon | We agree that DFT-s-OFDM is the target waveform for the study and design of MPR/PAR reduction solutions in Rel-18 |
| CMCC | Fine. |
| Nokia, NSB | Agree.DFT-s-OFDM is more suitable for the cell-edge Ues, and it has considerably smaller MPR (compared to CP-OFDM). It’s only natural that DFT-s-OFDM is used as the starting point for further MPR/PAR reduction, to ensure the enhancement provides absolute performance that can never be achieved by Rel-15/16/17 available tools and solutions. |
| ZTE | Support. |
| MediaTek | We agree that DFT-S-OFDM should be targeted. Since the WID states “*Study and if necessary specify*”, we see following change as necessary:**FL’s proposal 1****DFT-s-OFDM is the target waveform for the study ~~and design~~ of MPR/PAR reduction solutions in Rel-18.** |
| Sharp | Support the proposal. |
| CATT | Agree |
| Lenovo | Fine with the proposal |
| InterDigital | Support the proposal. |
| Apple | Fine |

**FL’s proposal 2**

|  |  |
| --- | --- |
| Company | Views |
| QC | Will be good to keep pi/2 BPSK. Pi/2 BPSK applied to higher MCS values could be a viable alternative.Okay to consider inner and outer allocations. Leave out edge RB allocations as the issues impacting them are quite different.  |
| Ericsson | It is too early in the study to restrict configurations without assessing their benefit. We would be OK with the middle bullet: * **RB allocation can be anywhere in the BWP (i.e., both inner and outer RBs are considered)**

We are open to considering restrictions after some short study, when there would be some quantitative measure of potential benefit. |
| Intel | We are generally fine with the proposal. It is not very clear the meaning of inner and outer RB allocation. Our understanding is that this means the RB allocation can be inside or on the edge of BWP. If this is correct understanding, we suggest the following update:* **~~RB allocation can be anywhere in the BWP~~ RB allocation inside and on the edge of BWP is considered. ~~(i.e., both inner and outer RBs are considered)~~**
 |
| vivo | Both pi/2 BPSK and QPSK should be studied in our view. So we propose to not exclude pi/2 BPSK which is mainly for low PAPR operation. |
| Panasonic  | We support the FL’s proposal 2 in general. Particularly, we think the sub-bullet “FDSS w/o spectrum extension” is not necessary because it is supported by Rel. 16 FDSS framework without spectrum extension (SE). Then the candidate solutions in this proposal could be * Option 1: FDSS with SE
* Option 2: Tone reservation

If Option 1 is supported, it can be considered as an extension of Rel. 16 FDSS without SE framework. If Option 2 is supported, there could be two available methods that can be configured to a UE, i.e., a Rel. 16 FDSS without SE and Rel. 18 tone reservation. If both methods are independently configured to work at the same time, where each component works separately on its own. It may give rise to potential issues in the following. Therefore, we would like to ask RAN1/RAN4 to take them into account when the study is carried out. * Potential issue 1: Radio resource in frequency-domain are not utilized which results in low spectral efficiency.
* For example, in Fig. 1, only a few tones from legacy resource allocations in frequency-domain in Rel. 16 FDSS are used for data

Fig. 1. An example of radio resource allocations in frequency-domain creates issue 1* Potential issue 2: If the resource allocations in frequency-domain are not properly configured, the achievable reduction of MPR/PAR may be decreased.
* For example, in Fig. 2, Rel. 16 FDSS and tone reservation do not work well because a part of the reserved tones for UE#1 is overlapped with a part of data tones for UE#2 in a not proper configuration of the resource allocations.

Fig. 2. An example of radio resource allocations in frequency-domain creates issue 2 |
| Samsung | Generally fine with the proposal. Regarding the FFS for modulation, both pi/2 BPSK and QPSK can be considered.  |
| Huawei, HiSilicon | We agree that power-domain enhancements targeting MPR/PAR optimization focus on QPSK modulation and RB allocation can be anywhere in the BWP (i.e., both inner and outer RBs are considered). Besides, different RB allocations like 8PRB/16PRB/32PRB/64PRB should be studied. Other modulation like 16QAM is an optional study point.  |
| CMCC | We can wait until more information about whether any other modulations should be studied is provided. |
| Nokia, NSB | Agree. For FFS points, * our results show that FDSS w/ SE can provide link budget gain for a wide range of allocation sizes. Hence, we don’t see why any RB allocation should be excluded in RAN1 (surely RAN4 can study configurations that RAN4 deems interesting). This would have an unnecessary specification and implementation impact.

W.r.t. other modulation schemes, we think that focusing on QPSK is sufficient in Rel-18. As a matter of fact, Pi/2 BPSK without spectrum extension has been studied extensively already (Rel-15 – Rel-17). Furthermore, based on our results and results in at least [3] and [4], FDSS with spectrum extension does not provide meaningful improvement to the pi/2 BPSK performance (compared to the case without spectrum extension). |
| ZTE | At this stage, we also suggest keeping both pi/2 BPSK and QPSK on the table.  |
| MediaTek | On our view, it’s too early to introduce these restrictions in the configuration at study phase. |
| Sharp | Fine with the proposal. We are also OK not to limit the MCS for now. |
| CATT | Fine in principle. |
| Lenovo | we think pi/2 BPSK should also be included. |
| InterDigital | OK with the proposal, but also fine to keep pi/2 BPSK |
| Apple | Fine with the proposal. |

**FL’s proposal 3**

|  |  |
| --- | --- |
| Company | Views |
| QC | Agree |
| Ericsson | The list only covers schemes with RAN1 spec impact. Transparent schemes such as clipping, companding, and digital predistortion are perhaps even more important, since they can bring benefit without upgrading entire service areas of network. As such they should be the baseline on which the non-transparent schemes improve. Also, RAN4 is discussing transparent schemes, and we should not be misaligned with their part of the work. As commented above, we do not think this first meeting for Rel-18 Cov Enh power domain enhancements should be a deadline for scheme identification. Suggest:**At least the following candidate solutions for MPR/PAR reduction will be studied in Rel-18.** **Non-transparent schemes, e.g. :*** **FDSS w/ spectrum extension**
* **FDSS w/o spectrum extension**
* **TR (which can only be w/ spectrum extension)**

**Non-transparent schemes, e.g. :*** **Clipping and Filtering**
* **Companding**
* **Digital predistortion**

**~~Whether other solutions will be studied as well will be decided before the end of RAN1 #110b-e.~~** |
| Intel | We are fine with the proposal. It would be good to list the full name of the solutions, e.g., frequency domain spectrum shaping, or tone reservation in the proposal. Suggest to change the main bullet as **At least the following candidate solutions for MPR/PAR reduction ~~will~~ can be studied in Rel-18.**  |
| Vivo | To narrow down the scope of the solutions, we prefer to focus on the first 2 solutions and TR can be optionally studied. |
| Panasonic  | We support the FL’s proposal 3. |
| Samsung | Considering this is the first meeting, before doing any down-selection, the first step would be to list all considered/proposed schemes so companies can further check and study. There is no strong reason to exclude the proposed schemes in the “other solutions”. RAN4 is also discussing scheme like transparent or non-transparent. Thus, we suggest to list all the schemes and defer down selection.  |
| Huawei, HiSilicon | FDSS w/o spectrum extension could only provide marginal net gain for QPSK. So we think that only FDSS w/ spectrum extension should be studied for QPSK. FDSS w/o spectrum extension is not necessary. The analysis in our contribution shows that TR does not have gains over FDSS in terms of performance or implementation complexity. Hence, we prefer to down-prioritize TR. |
| Nokia, NSB | As shown by many companies already, FDSS w/o spectrum extension provides only limited gain for QPSK. We would prefer removing it from the list to focus on the most promising candidate solutions.We can live with having it in for the time being, if no other company shares our view. |
| ZTE | Ok with the proposal. The three candidate solutions are the ones mentioned in the WID and therefore have high priority than other solutions.  |
| MediaTek | We don’t think that RAN1 can provide a complete list of candidate solutions to RAN4 and expect RAN4 not to consider a different solution. We can accept the following revised version:**FL’s proposal 3****At least the following candidate solutions for MPR/PAR reduction can be ~~will be~~ studied in RAN1 ~~in Rel-18~~.** * **FDSS w/ spectrum extension**
* **FDSS w/o spectrum extension**
* **TR (which can only be w/ spectrum extension)**

**~~Whether other solutions will be studied as well will be decided before the end of RAN1 #110b-e.~~** |
| Sharp | Support the proposal. |
| CATT | Fine with the proposal. |
| Lenovo | Support a tend to support the proposal and we also think the “will” should be changed to “can”. |
| InterDigital | Support the proposal. |
| Apple | Ok with the proposal. |

**3.1.2-Q1**

**Please use a), b) and c) as per question formulation to express your views, if any.**

|  |  |
| --- | --- |
| Company | Views |
| QC | On b: Transparent techniques will need to be used as a baseline (assuming they don’t require any spec change). We should not preclude any transparent technique. |
| Ericsson | Regarding a), this seems out of scope of the item, as it targets low data rate services which are not considered for Rel-18 Cov Enh. Regarding b) As commented for FL Proposal 3, it is essential to study transparent schemes together with non-transparent schemes.Regarding c) We are open to discuss this, but wonder if it should first be proposed in RAN4, and how much extra effort would be needed. |
| Intel | 1. Our understanding is that sub-PRB based transmission is mainly targeted for further coverage enhancement, but not specifically targeted for power domain enhancement. This can be deprioritised in the study.
2. For transparent MPR reduction schemes, we are open to discuss this.
3. it is not clear to us how to reduce MPR/PAR based on advanced receiver. It would be good to clarify.
 |
| Vivo | These items should be deprioritized given the high work load. |
| Panasonic | We would like to deprioritize the other solutions due to limited timing unit. |
| Samsung  | As commented above, we suggest to list all schemes for further consideration. |
| Huawei, HiSilicon | 1. Don’t support to study sub-PRB transmission.
2. Don’t support to study transparent MPR reduction schemes such as clipping and filtering, companding, and digital predistortion.
3. Not clear definition for advanced receiver yet. Clarification is suggested on whether it is an receiver dedicated to FDSS-SE or a standalone advanced receiver to reduce MPR.

The reasons are given as follows. * Clipping and filtering, companding and digital predistortion could only provide marginal MPR gain and clipping and filtering and digital predistortion may cause high processing complexity. Besides, these methods may cause signal distortion.
* Rx only solutions and sub-PRB transmission seem not to be fully aligned with the scope of the WI.
 |
| Nokia, NSB | 1. Similar to Rel-17, we propose to deprioritize this. Implementation implications and specification impact may not be justified.
2. Such techniques may not provide adequate MPR (link budget) improvement, and could be harder for the UE to implement in their most powerful instance. Hence, we propose to deprioritize them. We propose to focus on non-transparent schemes (FDSS w/ SE, TR).
3. We are fine deprioritizing this.

On the other hand, we could consider the possibility of using spectrum extension for both PRTs and data/DMRS according to a ratio. This may be interesting to consider finding a trade-off between PAPR reduction, net gain and receiver complexity. Indeed, according to results we saw through simulations, most of the gain coming from FDSS-SE is provided by data transmitted in the “inner” portion of the excess band (the first half, for instance). Further studies would be needed, of course. |
| ZTE | Ok to deprioritize sub-PRB transmission.Regarding other transparent MPR reduction schemes and advanced receivers, it seems more RAN4 related, and could be better to ask/let RAN4 to decide.  |
| MediaTek | We prefer not to have down-selection of schemes at this early stage. Companies should be welcome to study any solution.  |
| Lenovo | We can accept this item to be deprioritized considering the word load. |
| InterDigital | Agree with Ericsson |

**FL’s comment on October 12**

Thank you for adding your views.

**Concerning FL’s proposal 1**

@Ericsson: no other company expressed interest in considering CP-OFDM in this study. I understand that from your perspective this is suboptimal, however it is fair to say that the available time is rather scarce and we should focus on the directions, i.e., waveform, which is unanimously considered the waveform to configure for extending the coverage and that already offers the lowest MPR/PAR values (obviously insufficient, otherwise we wouldn’t be having this discussion). I hope you can accept the restriction to DFT-s-OFDM only for the sake of progress.

@MediaTek: point taken. At the same time, RAN1 may eventually design the solutions and it would be better not to have to agree again on which target waveform should be considered. I will modify the proposal to account for your observation, while still having the word “design” in it. I hope you can be ok with it.

**Concerning FL’s proposal 2**

Study of higher order modulation cases as well is not proposed by many companies. At the same time, I am not sure that excluding completely the possibility of studying them is necessary. Conversely, I think that it is fair to say most company would like to prioritize QPSK and would be ok with including pi/2-BPSK as well.

Switching the focus to the RB allocation, I understand the original phrasing is unclear for some companies. Suggestions were made to make it clearer. I will simplify that sub-bullet in the revised proposal.

**Concerning FL’s proposal 3**

@MediaTek: The use of “*At least*” implies that other solutions can be studied as well. Thus, is fair to use “will” instead of “can” given that most companies wish to focus the study only on those and may accept the compromise of having other solutions included in the study. We must be serious, if only one company studies or proposes a solution, we cannot expect RAN1 to propose that solution to RAN4, regardless of the reported performance, due to lack of other results from other companies. Furthermore, and moving to your second suggested modification, if we add “in RAN1” as you suggest, there is no implication for RAN4. Indeed, RAN4 can study other solutions as well if deemed interesting, irrespective of what is agreed in RAN1 in this regard.

@Ericsson, Samsung: As you say, we should not prevent other techniques to be studied at such an early stage. However, it is just fair to highlight the ones most companies proposed to focus the study on, while not preventing any other solution to be studied.

**Concerning 3.1.2-Q1**

All companies agree that sub-PRB transmission can be de-prioritized, including the proponent (Thank you @Lenovo, for understanding the situation). A corresponding proposal is formulated.

FL’s proposals 1, 2 and 3 are modified as follows (and FL’s proposal 7 is added).

**FL’s proposal 1-v1**

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

**FL’s proposal 2-v1**

**For power-domain enhancements targeting MPR/PAR reduction, ~~optimization~~ focus on the following configurations for DFT-S-OFDM:**

* **At least pi/2-BPSK and QPSK modulation are considered**
	+ **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**
	+ **FFS:**
		- **Whether restrictions on the number of allocated RB or on the starting RB of the allocation are considered.**
	+ **~~Whether other modulations are considered.~~**

**FL’s proposal 3-v1**

**At least the following non-transparent candidate solutions for MPR/PAR reduction will be studied in RAN1 ~~Rel-18~~.**

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

**Companies can study and present results for any other transparent scheme which could be used as benchmark for assessing the performance of non-transparent solutions.**

**~~Whether other solutions will be studied as well will be decided before the end of RAN1 #110b-e.~~**

**FL’s proposal 1-v1**

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

Companies are invited to input their views on **FL’s proposal 1-v1** , **FL’s proposal 2-v1**, **FL’s proposal 3-v1** and **FL’s proposal 7** in the table below. It is understood that the proposal may not be fully aligned with any of the alternative proposal brought by companies during the initial round of comment. It has indeed been crafted to be a middle ground solution which is hopefully agreeable to all.

**FL’s proposal 1-v1**

|  |  |
| --- | --- |
| Company | Views |
| DOCOMO | Support |
| vivo | Fine. |
| Intel | Support |
| Apple | “If applicable” is confusing. If not applicable, we will consider CP-OMDM? |
| OPPO | Support |
| Spreadtrum | Support  |
| FL | @Apple: If applicable here means that there may or may not be a design of a solution given that it depends on the outcome of the decision that RAN4 will take after the study is completed. Hence there is no implication for CP-OFDM.Another formulation of the proposal could be using the expression “**if any”**:**DFT-s-OFDM is the target waveform for the study and the design, if any, of MPR/PAR reduction solutions in Rel-18.** I hope this clarifies the intention and that we can agree to any of the two formulations (which are equivalent to me). |
| MediaTek | Thank you for the update. We are OK with “if applicable”. If this is not agreeable, we can also consider “if justified” or “if agreed to specify” as some suggestions. |
| QC | Okay |
| ZTE | Support  |
| InterDigital | Support |
| Ericsson | DFT-S-OFDM is of course a natural choice for MPR/PAR reduction. But why should we exclude algorithms such as tone reservation or transparent methods that can be directly used for CP-OFDM, if they come essentially for free? Then our proposal is (again):**DFT-s-OFDM is the target waveform for the study and the design, if any, of MPR/PAR reduction solutions in Rel-18.** * **Solutions that can be directly used for CP-OFDM can also be used in studies and designs.**
 |
| CMCC | Fine. |

**FL’s proposal 2-v1**

|  |  |
| --- | --- |
| Company | Views |
| DOCOMO | Support |
| vivo | “For power-domain enhancements targeting MPR/PAR reduction” can be updated to “For studying power-domain enhancements targeting MPR/PAR reduction” given the assumptions are only for studying the solutions. |
| Intel | Suggest to update the main bullet as “For power-domain enhancements targeting MPR/PAR reduction, ~~optimization~~ ~~focus on~~ study the following configurations for DFT-S-OFDM:” It is also not clear to us whether FFS is needed or not. It is not aligned with the second and third bullet, which basically means that no restriction on the number of RBs and RB allocation.  |
| OPPO | Support |
| Spreadtrum | Support  |
| FL | @Intel: There is indeed some redundancy, but it does not seem harmful to me. In fact, the idea of the FFS is to allow further discussions on RB allocations if RAN1 assess that some restrictions may be needed after all. I hope this clarifies the intention ( Please consider the following updated proposal after vivo’s and Intel’s comments:**FL’s proposal 2-v3**For power-domain enhancements targeting MPR/PAR reduction, ~~optimization~~ ~~focus on~~ study the following configurations for DFT-S-OFDM: * At least pi/2-BPSK and QPSK modulation are considered
	+ 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
	+ FFS:
		- Whether restrictions on the number of allocated RB or on the starting RB of the allocation are considered.
	+ ~~Whether other modulations are considered.~~
 |
| Sharp | Fine with the updated proposal |
| MediaTek | We are OK with proposal 2-v3. |
| QC | I see that the number of RBs is left fully open ended. Is there a reason to study large RB allocations? Can proponents clarify the motivation? |
| ZTE | Ok with the updated proposal.  |
| InterDigital | Ok with updated proposal |
| Ericsson | Following from 1-v1, propose:For power-domain enhancements targeting MPR/PAR reduction, ~~optimization~~ ~~focus on~~ study the following configurations ~~for DFT-S-OFDM~~:  |
| CMCC | Proposal 2-v3 is OK. |

**FL’s proposal 3-v1**

|  |  |
| --- | --- |
| Company | Views |
| DOCOMO | Maybe we are mistaken, but is FDSS w/o spectrum extension non-transparent? What kind of RAN1 impact is assumed by that? Or the intention of “transparent” is not only for RAN1?  |
| Vivo | The term “non-transparent” should be clarified.For example, sometimes transparent means DMRS would be also considered for FDSS so that filter would be treated as part of the channel and transparent on the receiver side.Or does “non-transparent” mean zero spec. impact? |
| Intel | We share similar view as DOCOMO that FDSS w/o SE is transparent solution for MPR/PAR reduction, which was studied in Rel-15 with pi/2 BPSK. Suggest to change “will be” to “can be” |
| Spreadtrum | From RAN1’s perspective, FDSS w/o SE is transparent, but RAN4 may have some specification change. So clarification is needed for FDSS w/o SE. |
| FL | Thank you all, you are correct.The proposal is updated as follows:**FL’s proposal 3-v2**At least the following non-transparent candidate solutions for MPR/PAR reduction will be studied in RAN1 ~~Rel-18~~. * ~~FDSS~~ Frequency domain spectrum shaping w/ spectrum extension
* ~~FDSS Frequency domain spectrum shaping w/o spectrum extension~~
* ~~TR~~ Tone reservation (which can only be w/ spectrum extension)

Companies can study and present results for any other transparent scheme which could be used as benchmark for assessing the performance of non-transparent solutions.~~Whether other solutions will be studied as well will be decided before the end of RAN1 #110b-e.~~ |
| Sharp | Support the updated proposal |
| MediaTek | We would still prefer to use “can” instead of “will” in the main sentence. We agree that the wording “at least” keeps the possibility to study some other solutions. However, in our understanding, using the wording “can” instead of “will” serves a different meaning. It allows a company to study only a subset of the listed solutions. For example, if a company studies and presents results comparing FDSS with extension vs. FDSS without extension, are their results going to be neglected because they have not studied tone reservation? This is our concern and that’s why we would suggest using the wording “can” instead of “will”. |
| QC | Instead of striking off that second bullet entirely, why don’t we include it in the last sentence so that it brings a bit more awareness: Companies can study and present results for any other transparent scheme which could be used as benchmark for assessing the performance of non-transparent solutions, for e.g., FDSS Frequency domain spectrum shaping w/o spectrum extension. |
| ZTE | OK with the proposal with the updates from QC.  |
| InterDigital | Fine with proposal and updates from QC |
| Ericsson | Somewhat prefer ‘can’ given Mediatek’s thinking here. Hopefully, we would not be too legalistic, but …Minor comment: not clear what ‘other’ refers to here; expect it is a remnant of earlier edits “present results for any ~~other~~ transparent scheme” |
| CMCC | Ok with proposal 3-v2. |

**FL’s proposal 7**

|  |  |
| --- | --- |
| Company | Views |
| DOCOMO | Support |
| vivo | Fine assuming the proposal 7 (there seems a typo for this proposal number) is:**FL’s proposal 1-v1****Sub-PRB transmission is de-prioritized for the study of MPR/PAR reduction solutions in Rel-18.**  |
| Intel | Support |
| OPPO | Support |
| Spreadtrum | Support  |
| FL | I confirm it is FL’s proposal 7 and there is a typo above. Thank you! |
| Sharp | Support |
| MediaTek | Support |
| QC | Support |
| ZTE | Support |
| InterDigital | Support |
| Ericsson | Support to deprioritize sub-prb. |
| CMCC | Support |
| Samsung | Ok |

#### Second round of discussions

**FL’s comment on October 14**

Thank you for adding your views.

FL’s proposal 7 looks stable and will be shared in the reflector for email approval

The other 3 proposals are practically stable but for two suggestions made by Ericsson (and the comment made by MediaTek on the “will vs. can” interpretation).

A couple of suggestions have been made by Qualcomm as well. They will be included in the updated proposals.

Concerning Qualcomm’s comment on the number of RBs. My understanding is that some companies observed that MPR/PAR reduction techniques can provide non-negligible gains across a wide range of RB allocations. Conversely, only Qualcomm proposed to have some restrictions. Given that, as of today, no decision has been taken on configuration restrictions for these solutions (we haven’t even agreed to have them in the spec in the first place, yet), it seems rather normal to allow the study of the performance of such solutions in more general settings. This may eventually lead to normative restrictions, if necessary (and applicable) After all, also results obtained during Rel-17, especially for the PUSCH for Msg3, showed that larger FDRA allocations can make sense for short coverage scenarios depending on the TBS. So that would seem technically founded. Having said this, my understanding is that some specific configurations any still be agreed on for the parameterization for evaluations (to simplify comparisons). I will propose this in Section 3.2.2 for simplicity. I hope you can be fine with this approach.

Moving to the “will vs. can” discussion, I start by saying that I like to think that we are all sufficiently open minded not to get stuck on this. I explained earlier why it is fair to use the “will” instead of “can”.

I can add that the sentence with “will” does not force anyone to study anything, but simply puts the accent on the three solutions which were supported by 4 or more companies already in Ran1 #110b-e. This is fair and correctly represent the status in RAN1.

However, and I wish to state this clearly to avoid misunderstandings, **results presented for one or two solutions out of three will obviously be considered exactly as if results for 3 solutions were presented**. In other words, if a company does not wish to simulate TR or FDSS, this can be done, and results presented by this company will be included in the list of contributed results with no “penalty”. We have been doing this since the beginning of the Rel-17 SI and I see no reason to change this good habit.

I hope this can provide sufficient clarity to MediaTek.

Moving to FL’s proposal 1-v1, Ericsson’s suggestion has not been supported by any other company. Hence, I think it is fair to ask Ericsson to reconsider their position and invite to consider an alternative middle ground proposal from the FL, which does not alter the nature of the proposal but is written in more inclusive flavour. I would also invite other companies who do not have strong concerns to refrain from asking to revert the proposal to its previous version (of course, this can be done if a company has strong concerns!).

The FL’s proposal 1-v1, 2-v3 and 3-v2 are then **updated** as follows.

**FL’s proposal 1-v2**

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

* **Results concerning the application of solutions for DFT-s-OFDM to CP-OFDM can be presented by companies in their contributions.**

**FL’s proposal 2-v4**

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

* **At least pi/2-BPSK and QPSK modulation are considered**
	+ **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**
	+ **FFS:**
		- **Whether restrictions on the number of allocated RB or on the starting RB of the allocation are considered.**
	+ **~~Whether other modulations are considered.~~**

**FL’s proposal 3-v3**

**At least the following non-transparent candidate solutions for MPR/PAR reduction will be studied in RAN1 ~~Rel-18~~.**

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

**Companies can study and present results for any other transparent scheme, e.g., FDSS Frequency domain spectrum shaping w/o spectrum extension, which could be used as benchmark for assessing the performance of non-transparent solutions.**

**~~Whether other solutions will be studied as well will be decided before the end of RAN1 #110b-e.~~**

Companies are invited to input **only strong concerns**, if any, on these updated proposals in the table below. Please do not comment if you can live with them.

**FL’s proposal 1-v2**

|  |  |
| --- | --- |
| Company | Concerns |
| Ericsson | We can accept proposal 1-v2. In this way, we at least quantify the potential to reuse algorithms that apply to DFT-S-OFDM to CP-OFDM. Such reuse may broaden the benefit of MPR reduction algorithms without increasing the RAN1 spec impact. |
| Spreadtrum | We fail to see any benefit of applying MPR reduction to CP-OFDM.  |
| ZTE | Fine with the proposal.  |
| Samsung | Fine, although the content of the sub-bullet is superfluous – companies can always present the results they want to present.  |
| vivo2 | Fine. Note that this is also being discussed in RAN4 and we should be aligned with RAN4. |

**FL’s proposal 2-v4**

|  |  |
| --- | --- |
| Company | Concerns |
| Ericsson | Support |
| Spreadtrum | One clarification questions: For the second sub-bullet, number of RB is the allocated RB for actual transmission or DFT-size RB? |
| ZTE | Support |
| Samsung | Fine |
| vivo2 | Fine with proposal. Note that this is being discussed in RAN4 as well, we may need to align with RAN4. |

**FL’s proposal 3-v3**

|  |  |
| --- | --- |
| Company | Concerns |
| Ericsson | Proposal 2-v3 looks good overall. Regarding transparent schemes, I understand that “e.g., FDSS Frequency domain spectrum shaping w/o spectrum extension,” is meant to clarify that this can be a transparent scheme. However, it may serve to emphasize this scheme over others, which I don’t think is intended (especially for QPSK). Listing the transparent schemes may be too detailed at this stage, so I’d suggest to use a note as follows. A minor comment: ‘other’ does not seem correct, since the bullets above are for non-transparent schemes.**Companies can study and present results for any ~~other~~ transparent scheme (i.e. a scheme without RAN1 spec impact)~~, e.g., FDSS Frequency domain spectrum shaping w/o spectrum extension,~~ which could be used as a benchmark for assessing the performance of non-transparent solutions.*** **Note: FDSS Frequency domain spectrum shaping w/o spectrum extension can be a transparent scheme**
 |
| Spreadtrum | Support |
| ZTE | Agree with Ericsson’s comment and OK with Ericsson’s update.  |
| Samsung | OK with Ericsson’s edits on transparent schemes. |
| vivo2 | Do not support this proposal.Frequency domain spectrum shaping w/o spectrum extension is not supported for modulation types other than pi/2 BPSK in legacy, it should be studied for QPSK as well. And it has RAN4 impacts so it will not be transparent in our understanding. TR should be deprioritized compared the other 2 methods though we’re open to have it studied with lower priority given limited TU we have. |

### [CLOSED] Design aspects of FDSS

The goal of this session is to identify the design aspects of FDSS (w/ and w/o spectrum extension) which would be used to identify specification impact and describe waveform assumptions (either used by RAN1 or RAN4 depending on the outcome of the discussion in Section 3.1.1) for performance evaluations.

**FDSS**

No company proposed specific design aspects of FDSS w/o spectrum extension. From FL’s understanding the only possible design aspect in this case could be the design of the filter. However, the design would likely be the same as the one used for FDSS-SE. A corresponding proposal is made below.

**FDSS-SE**

Three companies (Huawei/HiSi [2], Qualcomm [19] and Nokia/NSB [20]) discussed the design aspects of frequency domain spectrum shaping with spectrum extension (FDSS-SE) that should be considered in RAN1. Specifically,

* One company (Huawei/HiSi [2]) proposes studying the handling of DMRS symbol of a PUSCH with FDSS-SE including the following:
	+ DMRS symbol should be filtered by FDSS.
	+ Whether the DMRS sequence is extended to the resource elements that are used for spectrum extension.
* One company (Huawei/HiSi [2]) proposes that different filters, such as, RRC, Kaiser, 3- tap filter, should be studied to find the optimal or several suitable filters for maximizing the coverage enhancement gain.
* One company (Qualcomm [19]) proposes studying FDSS-SE as a non-transparent waveform shaping technique to transmit DFT-S-OFM waveforms at a higher transmit power, including the following:
	+ Excess bandwidth is given in units of RBs
	+ DMRS and data symbols undergo spectrum shaping
* One company (Nokia/NSB [20]) proposes the following design aspects for FDSS-SE:
	+ Define Extension factor (α) as Excess band size / Total allocation size.
		- Support α = 0.25.
	+ Support FDSS-SE without limitations to supported PRB allocations.

In addition, the following are proposes for further study:

* Solutions to yield only integer numbers of PRB allocations for the excess band, i.e., spectrum extension.
* How to use the existing FDRA indicator in the context of FDSS-SE.
* Solutions for FDSS-SE to guarantee low CM of DMRS.

From FL’s perspective, although candidate solutions for MPR/PAR reduction should be further discussed in Section 3.1.2, RAN1 can discuss design aspects of each candidate solution in parallel for the sake of efficiency. Therefore, the following proposal is formulated.

**FL’s proposal 4**

**The following design aspects of frequency domain spectrum shaping with spectrum extension (FDSS-SE), are considered for 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.**
	+ **How to extend DMRS sequence to spectrum extensions**
	+ **How extension size is indicated**

It is also noted that at least three approaches to extension have been described in companies’ contributions. Let *M* be the output of the M-point DFT and *K* the total number of tones after extensions have been added:

1. Symmetric extension [3, 4, 5, 15, 20]: the first $\frac{K-M}{2}$ samples of the sequence of *M* samples are appended at the end of the sequence itself, whereas the last $\frac{K-M}{2}$ samples of the sequence of *M* samples are prepended to the sequence itself.
2. Cyclic extension [19]: the sequence of *M* samples is cyclically extended to obtain *K* samples.
3. Cyclic shift plus symmetric extension [2]: the sequence of *M* samples is cyclically shifted by a factor L, and then extended by symmetric spectrum extension to obtain *K* samples.

A first question is thus asked.

|  |
| --- |
| **3.1.3-Q1 Please provide your view on which approach to extension should be considered in Rel-18, and why?**1. **Symmetric extension**
2. **Cyclic extension**
3. **Cyclic shift plus symmetric extension**
4. **Other (please describe)**
 |

Finally, and concerning the filter to consider for the study of FDSS, only one company provided an explicit proposal. Namely, it has been proposed to study different filters, such as, RRC, Kaiser, 3-tap filter. From FL’s perspective, it would be first important to decide whether a specific filter should be assumed in the RAN1 study, or whether such decision should be taken only by the WG (RAN4 and/or RAN1) who will perform the performance evaluation of FDSS w/ and w/o extensions.

A second question is asked.

|  |
| --- |
| **3.1.3-Q2 Should a specific filter be assumed in the RAN1 study, or should such decision be taken only by the WG (RAN4 and/or RAN1) who will perform the performance evaluation of FDSS w/ and w/o extensions?****Please provide possible options, should you think that a specific filter should be assumed in the RAN1 study.** |

#### First round of discussions

FL’s recommendation is to have a first round of discussion about **FL’s proposal 4**, **3.1.3-Q1** and **3.1.3-Q2.** Companies are invited to input their views in the corresponding table below. Constructive attitude in this regard is greatly appreciated. In this sense, if you cannot support the proposal, please propose an alternative formulation which considers the current spirit.

**FL’s proposal 4**

|  |  |
| --- | --- |
| Company | Views |
|  QC | Agree |
| Ericsson | We’d like to clarify that these aspects are studied and can be considered against alternatives. Also, we prefer not to define extension factor just yet, and think we can focus on how much extension is needed. Lastly, for performance evaluations, how extension size is determined is more important than what signaling is used to indicate it.**The following design aspects of frequency domain spectrum shaping with spectrum extension (FDSS-SE), are considered for Rel-18:*** **If spectrum extension size is expressed in integer units of RBs.**
* **If both DMRS and data symbols undergo spectrum shaping**
* **FFS:**
	+ **Amount of extension ~~Which extensions factor(s)~~ to consider~~, where extension factor (α) is given by spectrum extension size / Total allocation size.~~**
	+ **If/how to extend DMRS sequence to spectrum extensions**

**How extension size is ~~indicated~~ determined** |
| Intel | As this is for study and not intended to make decision, we suggest to change the main bullet as “study”We think spectrum shaping filter should be an important aspect to study for FDSS-SE, e.g., impact on the performance when shaping filter is not matched between Tx and Rx, how this is related to extension factor, etc., In addition, it is not very clear to us whether power domain enhancement needs to be considered for DMRS. In Rel-16, low PAPR DMRS sequence was specified, and our understanding is that FDSS-SE may not be applied for DMRS sequence. However, we understand that if DMRS and data do not undergo the same channel, the channel estimation performance may be degraded. We suggest to at least put this FFS. Based on the above, we suggest the following update:**Study the following design aspects of frequency domain spectrum shaping with spectrum extension (FDSS-SE)~~, are considered for Rel-18:~~*** **Spectrum extension size is expressed in integer units of RBs.**
* **~~Both DMRS and data symbols undergo spectrum shaping~~**
* **FFS:**
	+ **Both DMRS and data symbols undergo spectrum shaping**
	+ **Which extensions factor(s) to consider, where extension factor (α) is given by spectrum extension size / Total allocation size.**
	+ **Impact of shaping filter**
	+ **How to extend DMRS sequence to spectrum extensions**

**How extension size is indicated** |
| vivo | Agree with FL proposal in principle.Just one minor comment, given this is a study phase of this MPR reduction enhancement, we propose to have following updates:**FL’s proposal 4****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.**
	+ **How to extend DMRS sequence to spectrum extensions**
	+ **How extension size is indicated**
 |
| Panasonic  | We are open to discuss the FL’s proposal 4 as this is the extension of Rel. 16 FDSS framework. |
| Samsung | No need for this proposal. RAN4 can decide these design aspects. |
| Huawei, HiSilicon | * Spectrum extension could be expressed in integer units of RBs to facilitate resource scheduling.
* Extension factor can be defined by spectrum extension size / Total allocation size or spectrum extension size / DFT size.

RAN1 should further agree that for comparison between schemes using different SE factors, the same spectral efficiency should be assumed. For example the same TBS and the same total number of RBs used for transmission.We emphasize that the optimal extension factor should be carefully studied. The optimal expansion ratio is closely related to the FDSS filters and code rates. In our results [2], one can see that the optimal extension factor is 37.5% with 3-tap filter when the code rate is 1/6 and the optimal extension factor becomes 25% with TRRC filter when the code rate is 1/3.Besides, the design of filter coefficients is also important. According to the two figures below, 3-tap filter [-0.28,1, -0.28] can achieve same CM performance with 3-tap filter [-0.335,1, -0.335], but the waveform orthogonality of 3-tap filter [-0.28,1, -0.28] is better than 3-tap filter [-0.335,1, -0.335], which result in a 0.3dB BLER performance gain. C:\Users\z00649747\AppData\Roaming\eSpace_Desktop\UserData\z00649747\imagefiles\DF0F4EAA-6B52-45F3-BAAD-3978BB281532.png* We agree that both DMRS and data symbols undergo spectrum shaping. For given total frequency resource, the $\frac{π}{2}-BPSK$ sequence with FDSS can provide better CM performance than ZC sequence with FDSS-SE and transmitted data signal with FDSS-SE. Thus, whether the DMRS sequence should be extended requires study.
 |
| Nokia, NSB | Agree with the FL proposal. Concerning the extension factor, our understanding is that 0.25 provides a good trade-off between 10%-BLER SINR and MPR reduction.  |
| MediaTek | RAN4 can discuss these aspects. |
| Sharp | For spectrum extension size, we are option to consider another alternative as well. Ericsson’s update looks fine. FL proposal 2 has the sub-bullet point saying that FFS whether only small RB allocations. If only a small number of RBs is assumed, we should study how much transmission power loss the extension leads to. |
| CATT | We agree that it can be discussed in RAN4. |
| Lenovo | We have similar view with Intel.  |
| InterDigital | Support in principle, but maybe better to leave two first sub-bullets open. |
| Apple | We have similar view with Intel. |

**3.1.3-Q1**

|  |  |
| --- | --- |
| Company | Views |
| QC | Aren’t all three equivalent in a theoretical sense?That aside, what is the assumption on gNB receiver? Will a gNB receiver discard any tones? If so, should the scheme be designed for such a receiver? |
| Ericsson | We are open to studying any of these, and downselecting as a result of the study. |
| Intel | We are generally fine with the proposals.  |
| Vivo | We think symmetric extension should be prioritized. |
| Panasonic  | We prefer the symmetric extension because it can potentially provide achievable MPR/PAR reduction.  |
| Samsung | RAN4 can decide these design aspects. |
| Huawei, HiSilicon | Alternative a) and b) are special cases of c). We prefer the method of Cyclic shift plus symmetric extension since our results show that cyclic shift can provide further reduction of CM/PAPR.  |
| Nokia, NSB | We propose to focus on symmetric extension. The key benefit of symmetric extension (compared to cyclic extension) is that inband part of the transmission is the same with and without extension. This makes the design simpler and allow smooth coexistence with legacy receivers. Additionally, it can provide the largest PAPR reduction.Our understanding of cyclic shift plus symmetric extension is that the latter converges to symmetric extension (w.r.t. inband RBs) when maximum PAR reduction is observed, |
| Sharp | Open to study any of the options. |
| Lenovo | We are open to study the options. |
| InterDigital | Open to study all options. |
| Apple | Open to study the options. |

**3.1.3-Q2**

|  |  |
| --- | --- |
| Company | Views |
| QC | We are okay to assume a specific filter to drive RAN1 evaluations. It might help align the results.When it comes to specification, if we decide to specify this, we prefer to leave the choice of the actual filter to the UE. We can agree to boundary conditions on spectrum flatness as it is currently done for pi/2 BPSK. |
| Ericsson | It may be helpful to agree on filter(s) to help with alignment on simulation results. The most important aspect is that filters meet RAN4 requirements, e.g. spectrum flatness, and provide good performance taking into account a range of allocation bandwidths. We don’t expect that filter type is a crucial aspect, but are open to comparing alterative designs. |
| Intel | The choice of shaping filter and filter parameters can impact the PAPR reduction performance and link level performance significantly. Our understanding is that typically shaping filter is not specified in the specification. It is up to company to report the filter used in the simulations. Further, we also need to study the impact on the link level performance when the shaping filter is not matched between Tx and Rx.  |
| Vivo | Either way is fine. If a common filter is needed, we propose to use 3-tap filter which was also used in earlier FDSS study. |
| Panasonic | In Rel. 15/16, the FDSS without SE does not specify an exact shaping function, however, certain requirements are defined which yield boundary conditions for shaping filter implementations, i.e., gNB does not have knowledge of the exact FDSS filter or shaping function used in a UE. This approach allows UE vendors to pursue their own implementation and performance optimizations, while the system performance is guaranteed through the minimum RF requirements specified in the specifications, such as transmit signal spectral flatness, in-band / output back-off (OOB) emissions, and EVM. We think this approach can be reused for Rel. 18 CovEnh. |
| Samsung | RAN4 can decide these design aspects. |
| Huawei, HiSilicon | Specific filter should not be assumed in the RAN1 study. This is the implementation behavior on the UE side. However, it should be noted that the results will be dependent on the filter. |
| CMCC | If a common filter can not be agreed with companies quickly, it is fine to let the companies have option to choose and report what filter they used in the simulation. |
| Nokia, NBS | We think that the exact FDSS function does not need to be defined or specified, but the performance requirements need to be specified by RAN4 to define the boundary conditions to the implementation. This would be in line with the approach defined for pi/2 BPSK with FDSS (in Rel-15) and would seem a wise course of action.At the same time, we think it would be best if companies reported the FDSS function(s) used in their evaluations. This would simplify comparisons between different results. |
| InterDigital | If possible, it would be good to align filters. If this cannot be achieved without delaying the work then having companies report their filter is preferable. |
| Apple | For study purpose, it’s ok to assume a specific filter. If specify it in spec, we prefer to leave it to vendor implementation.  |

**FL’s comment on October 12**

In the initial round of discussion, 5 companies agree with FL’s proposal 4 while 4 companies agree in principle and suggest modifications on the wording. On the other hand, 3 companies state that the design aspects should be decided by RAN4. In addition, one company elaborates on the aspects mentioned in FL’s proposal 4 without stating whether to support it or not. From FL’s perspective, given that the majority supports performing link-level simulation (LLS) in RAN1 (according to companies’ inputs for question 3.1.1-Q2), the design aspects of FDSS should be agreed in RAN1, at least for the LLS. If RAN1 could make progress on agreeing the design aspects for studying, this could help RAN4 as well.

Concerning the spectrum extension size, it seems reasonable to keep the bullet as is, given all the comments companies made on sub-PRB transmission.

Concerning the extension factor, I think that providing a simple definition may provide a unified way to express a concept and talk about it without ambiguity and misunderstandings among companies. I do not see why this could constrain the study in any way.

Concerning comments made about spectral efficiency (for instance, Huawei/HiSi) are taken into account for the discussion in Section 3.2.1. about evaluation methodology.

Some companies, for instance Samsung and MediaTek, argue that all these aspects (and the following) should be decided by RAN4. This would be possible if RAN1 did not perform any performance evaluation. However, it is quite evident that most companies think that at least LLS simulations should be performed by RAN1. Hence, I hope you can reconsider your position and provide constructive feedback on the proposals in Section 3.1.3 and 3.1.4.

FL’s proposal 4 is reformulated considering the concerns from Ericsson, Intel, vivo and Lenovo as follows.

**FL’s proposal 4-v1**

**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:**
	+ **Both DMRS and data symbols undergo spectrum shaping**
	+ **Which extensions factor(s) to consider, where extension factor (α) is given by spectrum extension size / Total allocation size.**
	+ **Impact of shaping filter**
	+ **How to extend DMRS sequence to spectrum extensions**
	+ **How extension size is ~~indicated~~ determined**

Concerning 3.1.3-Q1, 5 companies are open to consider all options of spectrum extension for further study, 3 companies prefer prioritizing symmetric extension, one company prefers considering cyclic shift plus symmetric extension, one company thinks that the listed extension options are equivalent theoretically, and one company prefers waiting for RAN4 input. Finally, one company suggests clarifying the assumption on gNB receiver. From FL’s perspective and given that the majority supports performing link-level simulation (LLS) in RAN1 (according to companies’ inputs for question 3.1.1-Q2), the design aspects of FDSS should be agreed in RAN1 for the study via LLS, to ensure comparability of the results. In this context, details on spectrum extension should be agreed regardless of whether the receiver uses the extended part or not, given that they impact the way SNR degradation and CM changes would occur. Companies can report evaluation results for both cases, depending on the assumed receiver architecture at gNB.

The following proposal is formulated for at least listing down the candidate options for studying.

**FL’s proposal 8**

**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.**

Concerning 3.1.3-Q2, 4 companies are open to align on the shaping filter for evaluation, 2 companies do not agree to align on the shaping filter for evaluation, 1 company is fine with either aligning the shaping filter or not, 4 companies prefer letting companies reporting the shaping filter, and one company prefers waiting for RAN4 input. From FL’s perspective, it is worth clarifying that the intention of aligning shaping filter is to facilitate the evaluation results comparison. This does not necessarily mean that the gNB should know the filter used by the UE. Given the current situation, a proposal is formulated in Section 3.2.1 stating that the shaping filter used for evaluating FDSS w/ and w/o spectrum extension is reported by companies (for both transmitter and receiver).

FL’s recommendation is to further discuss about **FL’s proposal 4-v1** and **FL’s proposal 8.** Companies are invited to input their views in the corresponding table below. Constructive attitude in this regard is greatly appreciated. In this sense, if you cannot support the proposal, please propose an alternative formulation which considers the current spirit.

**FL’s proposal 4-v1**

|  |  |
| --- | --- |
| Company | Views |
| DOCOMO | Fine with the proposal |
| vivo | Whether both DMRS and data symbols undergo spectrum shaping has already been studied in earlier release when normal FDSS was introduced in release 15, we do not think this study needs to be repeated in Rel-18. We do not think we should specify a filter for FDSS in this study and we should leave this up to implementation similar to legacy FDSS. |
| Intel | We are fine with the proposal. |
| Apple | Ok with this proposal |
| OPPO | OK with the proposal. |
| Spreadtrum | Support  |
| FL | The proposal is updated to account for vivo’s comment, which is fair and technically correct.I also added that in the FDSS-SE a clarification that the impact of the shaping filter which is FFS is about the performance of FDSS-SE (and not the spec). I hope this clarifies.**FL’s proposal 4-v2**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:
	+ ~~Both DMRS and data symbols undergo spectrum shaping~~
	+ 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
	+ How extension size is ~~indicated~~ determined
 |
| QC | I see that the bullet on DMRS and data symbols undergoing spectrum shaping has been struck off entirely. What is the assumption in this case? Companies free to do what they want? How will we align results?Bring it back as it aligns with how FDSS is handled for pi/2 BPSK. |
| ZTE | Does deleting of the bullet on DMRS and data implies both DMRS and data should undergo spectrum shaping? Based on the discussion, it’s better to keep it as FFS now. |
| InterDigital | Fine with proposal. Maybe the second sub-bullet on “both DMRS and data symbols etc.” should be restored to ensure alignment. |
| Ericsson | OK |
| CMCC | Fine with FL’s proposal. |

**FL’s proposal 8**

|  |  |
| --- | --- |
| Company | Views |
| DOCOMO | Fine with the proposal |
| vivo | Option1 is enough to minimize the spec. impact and evaluation effort. |
| Intel | We are fine with the proposal. |
| Apple | Ok with this proposal |
| OPPO | OK with the proposal. |
| Spreadtrum | Support  |
| FL | Thank you. No modification to FL’s Proposal 8 is proposed. |
| QC | Okay |
| ZTE | Fine with the proposal.  |
| InterDigital | Support |
| Ericsson | OK |
| CMCC | Fine. |
| Samsung | Fine  |
|  |  |

**FL’s comment on October 14**

Thank you for adding your views.

In previous round of discussion, most companies were Ok with FL’s proposal 4 or FL’s proposal 4-v1, except the bullet point on “both DMRS and data symbols undergo spectrum shaping”, wherein at least one company (Intel) preferred to put the bullet as FFS. This was done although it is quite clear that the technical understanding companies are following is that data and DMRS undergo the same spectrum shaping to ensure that no channel estimation degradation occurs.

Subsequently, one company (vivo) highlighted what I have just written that stated that this topic had been discussed in Rel-15 and the outcome should be applied for Rel-18, i.e., both DMRS and data symbols undergo spectrum shaping. I tried capturing this comment by removing the bullet in FL’s proposal 4-v1. However, three companies (Qualcomm, ZTE, InterDigital) prefer keeping the bullet for clarifying the work in Rel-18.

From FL’s perspective, this would be a wise way forward, given has already been discussed in previous releases and the understanding that already exists in RAN1.

@vivo: I hope that this is fine with you. You may find that the updated proposal states the obvious for you, but I think it is better to ensure 100% alignment exists between assumptions made by companies.

@Intel: I hope you can revise your previous statement and decide that you can live with this proposal. All other companies who commented are aligned on the same understanding, which is the understanding RAN1 has been using in previous Releases as well. Your comment on performance degradation seems to imply that you share the same technical understanding. Please note that this would also be very helpful for identifying the candidate solutions to include in the LS to RAN4 at the end of RAN1 #111.

The following FL’s proposal 4-v3 will then be shared in the reflector for email approval. I hope all companies who commented so far can live with it. In addition, FL’s proposal 8 looks stable and will also be shared in the reflector for email approval.

**FL’s proposal 4-v3**

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
	+ How extension size is ~~indicated~~ determined

### [CLOSED] Design aspects of TR

Two companies (OPPO [6] and Qualcomm [19]) discussed the design aspects of tone reservation (TR) would be used to identify specification impact and describe waveform assumptions (either used by RAN1 or RAN4 depending on the outcome of the discussion in Section 3.1.1) for performance evaluations. Specifically,

* One company (OPPO [6]) proposes studying allocation mechanism of peak reduction tone (PRTs) to a UE, including location of PRTs, the number of subcarriers of PRTs, etc.
* One company (Qualcomm [19]) proposes studying sideband tone reservation as a non-transparent waveform shaping technique to transmit DFT-S-OFM waveforms at a higher transmit power.
	+ Sideband tone reservation is given in units of RBs

From FL’s perspective, although solution to be adopted for MPR/PAR reduction should be further discussed in Section 3.1.2, RAN1 can discuss design aspects of each candidate solution in parallel for the best use of meeting time. Therefore, the following proposal is formulated.

**FL’s proposal 5**

**The following design aspects of tone reservation (TR), are considered for Rel-18:**

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

Concerning the reserved tones generation, some options have been mentioned in different companies Tdocs, however no proposal was explicitly made. It would seem appropriate from FL perspective to have for this aspect a similar discussion as the one I am proposing to have for the shaping filter of FDSS (w/ or w/o SE).

The following question is asked.

|  |
| --- |
| **3.1.4-Q1 Should a reserved tones generation algorithm/approach be assumed in the RAN1 study, or should such decision be taken only by the WG (RAN4 and/or RAN1) who will perform the performance evaluation of FDSS w/ and w/o extensions?****Please provide possible options, should you think that a specific filter should be assumed in the RAN1 study.** |

#### First round of discussions

FL’s recommendation is to have a first round of discussion about **FL’s proposal 5** and **3.1.4-Q1**.Companies are invited to input their views in the corresponding tables below. Please remember that the goal is to advance as much as we can, without hindering possible further refinements. Therefore, constructive attitude in this regard is greatly appreciated. In this sense, if you cannot support the proposal, please propose an alternative formulation which considers the current spirit.

**FL’s proposal 5**

|  |  |
| --- | --- |
| Company | Views |
| QC | Looks okay. |
| Ericsson | Similar to proposal 4, we’d like to clarify that these aspects are studied and can be considered against alternatives. Aslo, for performance evaluations, how sideband size is determined is more important than what ignalling is used to indicate it.**FL’s proposal 5****The following design aspects of tone reservation (TR), are considered for Rel-18:*** **If sideband tone reservation size is expressed in integer units of RBs.**
* **FFS:**
	+ **Sideband size**
	+ **Sideband size ~~indication~~ determination**
	+ **Whether PRTs are added only to data or also DMRS symbols**
 |
| Intel | Similar comment as for FDSS-FD. As this is for study and not intended to make decision, we may need to change the main bullet as “study”. It may be good to also align the terminology in the FFS. We suggest the following update: **Study the following design aspects of tone reservation (TR)~~, are considered for Rel-18:~~*** **Sideband tone reservation size is expressed in integer units of RBs.**
* **FFS:**
	+ **Sideband tone reservation size**
	+ **Sideband tone reservation size indication**
	+ **Whether PRTs are added only to data or also DMRS symbols**
 |
| vivo | We propose to deprioritize this TR evaluation as we commented earlier. |
| Panasonic  | We are open to discuss the FL’s proposal 5.  |
| Samsung | RAN4 can decide these design aspects. |
| Huawei, HiSilicon | In our analysis, the tone reservation is of higher complexity than FDSS-SE but no gain. Therefore, the tone reservation technique should not be further considered. |
| Nokia, NSB | Agree in principle.Additionally, it would be good to align the excess band sizes between the following cases:* FDSS w/ SE
* Tone reservation
 |
| ZTE | Compared to FDSS, we also prefer to deprioritize TR. But at this stage, we are also ok to further study it, i.e., we are also ok with the revisions suggested by Intel.  |
| Sharp | Similar to proposal 4. For spectrum extension size, we are option to consider another alternative as well. Ericsson’s update looks fine. |
| Lenovo | We have similar view with Intel. |
| InterDigital | Support proposal and also fine with leaving open the aspect of sideband tone reservation size. |

**3.1.4-Q1**

|  |  |
| --- | --- |
| Company | Views |
| QC | The exact algorithm used can be left to each company’s choice. SCR-TR is a well-known algorithm used in this context. It can serve as a useful baseline if required. Can be left to RAN4.Note that reserved tones can be used for other purposes too and not just for PAPR reduction. |
| Ericsson | We do not see a need to restrict the tone generation algorithm/approach at this stage. We think both RAN1 and RAN4 can study tone reservation, although some coordination of the work may be beneficial. |
| Intel | Our understanding is that the specific algorithm for the tone reservation is not defined in the specification. If supported, RAN4 would only define a set of requirements on the targeted performance metric, e.g., EVM, OOB, ACLR, etc.In this regard, we tend to think that RAN4 would be leading WG to study tone reservation solution as MPR typically is being used in RAN4. |
| Samsung | RAN4 can decide these design aspects. |
| Huawei, HiSilicon | In our analysis, the tone reservation is of higher complexity than FDSS-SE but no gain. Therefore, the tone reservation technique should not be further considered. |
| Nokia, NSB | Similar view as for FDSS. |
| ZTE | For evaluation purpose, it’s good to the align tone generation algorithm/approach for better comparison. We prefer to leave the decision to RAN4 as they are responsible for the evaluation work.  |
| InterDigital | Suggest to identify a baseline scheme (such as proposed to Qualcomm) as minimum, and allow evaluation with additional schemes. |

**FL’s comment on October 12**

In the initial round of discussions, 3 companies agree with FL’s proposal 5, 4 companies agree in principle and suggest modifications on the wording and one company prefers waiting for RAN4 input. On the other hand, 3 companies prefer deprioritizing tone reservation. From FL’s perspective, given that we are in the study phase, and more than one companies wishes to study this solution, it is too early to deprioritize tone reservation. Therefore, FL’s proposal 5 is updated as follows, considering concerns from Ericsson, Intel, Sharp and Lenovo.

Please note that similar considerations made for FDSS-SE concerning the sideband tone reservation size apply.

**FL’s proposal 5-v1**

**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 ~~indication~~ determination**
	+ **Whether PRTs are added only to data or also DMRS symbols**

Concerning question 3.1.4-Q1, the majority view is that a reserved tones generation algorithm/approach is not needed in RAN1. At the same time, more than one company see the merit in either having a baseline or reporting the PRT generation algorithm. Indeed, I think it is fair to say that results, if any, could be compared more easily if the PRT generation algorithm was reported by companies. Furthermore, I do not think it is completely accurate to state that this aspect falls within RAN4 expertise, since it is about baseband signal generation, with a direct impact on the PAPR of the baseband signal (and only as a consequence on MPR). Having said this, I am not sure it makes sense to continue the discussion about this aspect in the section, given that it does not seem excessively controversial and may be more suitable for a discussion in Section 3.2.1, where evaluation methodology is discussed and corresponding proposals are made (please see how this aspect is captured in what seems to be a suitable proposal in that section).

FL’s recommendation is to further discuss about **FL’s proposal 5-v1.** Companies are invited to input their views in the corresponding table below. Constructive attitude in this regard is greatly appreciated. In this sense, if you cannot support the proposal, please propose an alternative formulation which considers the current spirit.

**FL’s proposal 5-v1**

|  |  |
| --- | --- |
| Company | Views |
| DOCOMO | Fine with the proposal |
| Intel | We are fine with the proposal. |
| OPPO | Fine with the proposal. |
| Spreadtrum | Support  |
| FL | Thank you for the comments. No modification to FL’s proposal 5-v2 is proposed. |
| QC | Support |
| ZTE  | Fine |
| InterDigital | Support |
| Ericsson | OK |
| Samsung | Fine |

**FL’s comment on October 14**

Thank you for adding your views.

FL’s proposal 5-v1 looks stable and will be shared in the reflector for email approval.

## Mid priority aspects

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

1. Evaluation methodology
2. Parameterization for evaluations

Significant attention has been given by several companies to such aspects in the submitted contributions. These are very important aspect which could be labeled as high priority is the work RAN1/RAN4 split was such that RAN1 is responsible of the performance evaluation. This is not the case at the beginning of RAN1 #110b-e. For this reason, the discussion on these two aspects is paused for the time being, and will start if and when need arises, regardless of how many high priority aspects are still being discussed. FL’s comments/proposals on these aspects are not included yet, given the above.

### [OPEN] Evaluation methodology

Several contributions acknowledged the fundamental nature of this aspect and discussed it in detail. A high-level summary of companies’ preferences based on the contributions is as follows:

* One company (Huawei/HiSi [2]) proposes adopting the metrics of coverage enhancement gain, PAPR, CM, and reduced SNR for evaluations on coverage performance improvement of Rel-18 NR power domain enhancements as follows:
	+ The coverage enhancement gain is given by $G=∆CM+∆SNR$;
	+ $∆SNR$ is the SNR degradation under the requirement BLER=10-1;
	+ $∆CM$ is the improvement of CM at the 99-percentile of the CDF.
* One company (Ericsson [15]) proposes:
	+ Quantifying relative link performance of a given transmission configuration as SNR0+OBO, where SNR0 is the SNR (in dB) needed to reach a target BLER, and OBO is the output power backoff for the configuration (in dB).
	+ Comparing schemes at the link level using a same amount of time-frequency resource and at a same spectral efficiency and assuming Rel-17 resource allocation mechanisms.
	+ Transparent MPR reduction schemes are baselines to which non-transparent schemes are compared.
* One company (Qualcomm [19]) proposes that:
	+ For evaluating the benefits of tone reservation, use legacy R17 PUSCH waveforms as a baseline, with the excess bandwidth included in the total allocated bandwidth.
	+ For FDSS with bandwidth expansion, link-level performance evaluations are required to assess the overall coverage gains. In particular, evaluate the impact of (a) the amount power spent in the excess bandwidth region and (b) gNB receiver handling of the excess bandwidth when receiving the PUSCH transmission for further processing.
	+ For FDSS with bandwidth expansion, evaluate the impact of gNB not knowing the pulse shaping filter used by the UE (but aware of bandwidth expansion).
* One company (CATT [7]) proposes that FDSS should be carefully studied taking performance, overhead, implementation complexity and standardization efforts into account.
* One company (vivo [5]) proposes that FDSS enhancement in Rel-18 should be carefully studied and should not be specified unless justified by obvious power boost gain.
* One company (Samsung [16]) proposes further studying techniques to reduce MPR/PAR taking into consideration the implementation impact at both the UE and the gNB.
* One company (Nokia/NSB [20]) proposes that actual conclusion of the MPR/PAR reduction methods should be based on net coverage gain results combining transmitter and receiver performance.

**FL’s comment on October 12**

From companies’ inputs for question 3.1.1-Q2, the majority supports performing link-level simulation (LLS) in RAN1. LLS may not provide meaningful and comparable results unless a common evaluation methodology is adopted by all companies performing the simulations. Therefore, this section is now open for discussion. From the above inputs from companies, and discussion and proposals in previous sections, the following proposals are formulated.

**FL’s proposal 9**

**For link-level performance evaluation:**

* **R17 PUSCH waveforms are 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 OFDM symbols**
* **Same TBS**
* **Same RB allocation**

**FL’s proposal 10**

**For link-level performance evaluation, at least the following metrics are considered for assessing the performance of the considered solutions:**

* $∆SNR$**, defined as the SNR degradation w.r.t. baseline under the requirement BLER=10-1.**
* $∆CM$**, defined as the improvement of CM at the 99-percentile of the CDF.**

**FL’s proposal 11**

**For link-level performance evaluation, configuration details of the following aspects should be reported by companies, 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**

In addition, given limited inputs from companies’ contributions on this topic, the following question 3.2.1-Q1 is also formulated.

|  |
| --- |
| **3.2.1-Q1 *Are there any other aspects that RAN1 should consider for (link-level) evaluation methodology?******Note: parameterization for evaluation is discussed in the next section.*** |

#### First round of discussions

FL’s recommendation is to have a first round of discussion about **FL’s proposal 9**, **FL’s proposal 10**, **FL’s proposal 11** and **3.2.1-Q1**.Companies are invited to input their views in the corresponding tables below. Please remember that the goal is to advance as much as we can, without hindering possible further refinements. Therefore, constructive attitude in this regard is greatly appreciated. In this sense, if you cannot support the proposal, please propose an alternative formulation which considers the current spirit.

**FL’s proposal 9**

|  |  |
| --- | --- |
| Company | Views |
| QC | Agree in principle. Exactly same TBS may sometimes be hard to achieve when using MCS values. For example, MCS 3 + 10 RB allocation vs MCS 4 + 8 RB allocation + 2 reserved RBs. |
| Ericsson | Same view as QC with respect to identical spectral efficiency. But I think the proposal should be clear enough.While we would prefer that transparent schemes are the benchmark, it may be hard to align on one, so ‘can be’ is OK for us.One clarification: we should not compare e.g. an enhanced DFT-S-OFDM to CP-OFDM, so: * **R17 PUSCH waveforms are the baseline for performance comparison**

**Comparisons are for the same waveform**  |
|  |  |

**FL’s proposal 10**

|  |  |
| --- | --- |
| Company | Views |
| QC | As mentioned by other companies, $∆CM$ is not a predictor of how much power gains there can be. It gives us some insight on the nature of the waveform, but very hard to extrapolate based on this. $∆CM$ and PAPR can be considered for some basic guidance, but beyond that they are not great predictors. Companies are free to report, but we should not be driving decisions based on these metrics. |
| Ericsson | 10% BLER is OK at least as a starting point.Cubic metric is OK, but I would like to check on using the mean CM vs. a percentile CM.And again, while CM is generally better than PAPR, it still is difficult to characterize MPR using only baseband simulations. Methods that use RF simulations should * quantify relative link performance of a given transmission configuration as SNR\_0+OBO, where SNR\_0 is the SNR (in dB) needed to reach a target BLER, and OBO is the output power backoff for the configuration (in dB).
* determine PA output backoff using RF simulations and according to RAN4 requirements for error vector magnitude, in band emissions, spectrum flatness, spectrum emission mask, and adjacent channel leakage, spurious and accounting for counter-IM3.
 |
|  |  |

**FL’s proposal 11**

|  |  |
| --- | --- |
| Company | Views |
| QC | As a general comment, can we avoid using “should be”? Can we instead say, “companies are expected to report the following aspects” |
| Ericsson | Agree |
|  |  |

**3.2.1-Q1**

|  |  |
| --- | --- |
| Company | Views |
| QC | Can we have some discussion on gNB receivers? What is considered feasible/practical? How are the tones in the extended portion of the spectrum expected to be handled? |
| Ericsson | Companies should report if the used filter matches the RAN4 spectrum flatness requirements. It should be possible to check this if the filters are reported, but it would save a lot of time than if each other company has to check. Also, RAN1 evaluations may not naturally consider this. |
|  |  |

#### Second round of discussions

**FL’s comment on October 14**

In the previous round of discussion, two companies provided views on FL’s proposals 9, 10, 11 and question 3.2.1-Q1.

For FL’s proposal 9, both comments made by companies are captured in the following updated version of the proposal, where the comment on the TBS is captured by a Note.

**FL’s proposal 9-v1**

**For link-level performance evaluation:**

* **R17 PUSCH waveforms are the baseline for performance comparison**
	+ **Comparisons are for the same waveform**
* **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 OFDM symbols**
* **Same TBS**
* **Same RB allocation**

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

For FL’s proposal 10, no objection was raised although comments were received. FL’s opinion on the matters raised by these comments is as follows

* @Qualcomm: The agreement made for work split includes the following sentence: “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”. It seems fair to include all these metrics in the list (I will modify it to be more aligned with the agreement). At the same time, we have the “at least” in the main sentence of the proposal and in the reported sentence of the agreement. This allows companies to study and report results for other metrics as well. I hope this can clarify the situation and you can live with the updated proposal.
* @Ericsson: The following sentence was captured in the agreement made for work split: “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”

Therefore, it is normal for proposal to focus on the metrics that can be evaluated by RAN1 (other than RF simulations). This is aligned with what was done in Rel-17 SI when we discussed assumptions for baseline performance evaluation of LLS and did not agree on assumptions for SLS (which were still allowed and performed by some companies). I hope you can agree with this logic and live with the updated proposal.

FL’s proposal 10 is then updated as follows.

**FL’s proposal 10-v1**

**For link-level performance evaluation, at least the following metrics are considered for assessing the performance of the considered solutions:**

* $∆SNR$**, defined as the SNR variation ~~degradation~~ w.r.t. baseline under the requirement BLER=10-1.**
* $∆CM$**~~, defined as the improvement of CM at the 99-percentile of the CDF.~~**

**Other metrics can be reported, e.g., mean CM, improvement of CM at the 99-percentile of the CDF (i.e., ∆CM), EVM (as defined in TS 38.101-1 and TS 38.101-2).**

For FL’s question 3.2.1-Q1:

* One company (Qualcomm) requested to further discuss about gNB receiver assumptions about the use of the spectrum extension. From FL’s perspective this is a very valid point, and I would recommend companies to report such assumptions and configurations to ensure that results are fully comparable between each other.
* One company (Ericsson) requested to further discuss about whether the used filter matches the RAN4 spectrum flatness requirements or not should be reported by companies. From FL’s perspective, and following what has been done in previous releases, e.g., for RAN4 Rel-17 study on pi/2-BPSK, if the assumed filter at the Tx does not fulfil RAN4 spectrum flatness requirements, we would deal with a very unrealistic assumption. Additionally, the obtained results would be scarcely useful in practice, especially during future interactions between RAN1 and RAN4, given that such Tx filter would not be practically usable. For the sake of an efficient use of RAN1’s time and resources, I would recommend ensuring that spectrum flatness requirement is not violated by the Tx filter used in simulations.

Given the two above observations, I think it is wiser to put FL’s proposal 11 on hold for the time being, even if it seemed acceptable with some minor and straightforward modifications for clarification. These modifications will be captured in the following updated version when a discussion on the aspects raised by Qualcomm and Ericsson will have taken place.

The following question is then formulated based on this logic.

|  |
| --- |
| **3.2.1-Q2 Please provide your answers to the following questions*****a) Do you agree that companies should be expected to report how the extended portion of the spectrum is handled by the receiver in the simulations?******b) Do you agree that the Tx filter used in the simulation should fulfil the RAN4 spectrum flatness requirements to ensure that realistic and practically relevant results, also for future interactions between RAN1 and RAN4, are obtained?***  |

Companies are invited to input **only strong concerns**, if any, on **FL’s proposal 9-v1** and **FL’s proposal 10-v1** in the tables below. Please do not comment if you can live with them.

**FL’s proposal 9-v1**

|  |  |
| --- | --- |
| Company | Concerns |
| Ericsson | Revised proposal looks good. Thanks.  |
| QC  | Looks good. No comments. |
| ZTE | Based on FL’s proposal 1-v2, DFT-s-OFDM is the target waveform, and therefore should be the baseline waveform for evaluation. For evaluation for OFDM waveform, the following bullet in proposal 1-v2 is already sufficient. * **Results concerning the application of solutions for DFT-s-OFDM to CP-OFDM can be presented by companies in their contributions.**

Therefore, we suggest the following modifications. **FL’s proposal 9-v1****For link-level performance evaluation:*** **R17 PUSCH DFT-s-OFDM waveform~~s~~ are the baseline for performance comparison**
	+ **~~Comparisons are for the same waveform~~**
* **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.~~** |
| Samsung | OK with ZTE edits |
| vivo2 | Fine. |

**FL’s proposal 10-v1**

|  |  |
| --- | --- |
| Company | Concerns |
| Ericsson | Thanks for the flexibility on the cubic metric statistic. In the absence of RF evaluations, it’s important that we have the “next best” kind of metrics to make the most informed decision we can in RAN1. As evaluations proceed, it may be more clear which metrics are the best predictors of MPR reduction. So, can we have an FFS to encourage further refinements of the metrics?**For link-level performance evaluation, at least the following metrics are considered for assessing the performance of the considered solutions:*** $∆SNR$**, defined as the SNR variation ~~degradation~~ w.r.t. baseline under the requirement BLER=10-1.**
* $∆CM$**~~, defined as the improvement of CM at the 99-percentile of the CDF.~~**

**Other metrics can be reported, e.g., mean CM, improvement of CM at the 99-percentile of the CDF (i.e., ∆CM), EVM (as defined in TS 38.101-1 and TS 38.101-2).*** **FFS: refinement and/or downselection of MPR/PAR metrics**
 |
| QC | Looks good to us.  |
|  ZTE | We can understand the comment that ∆CM cannot be directly used to obtain the power boost gain. But, ∆CM is an important metric for assessing the performances, and should be listed in parallel with SNR. Otherwise, if we only consider SNR, it most possibly ends up with SNR degradation for the MPR reduction solutions. Then, what’s the meaning of the study? In the end, RAN1 may provide both results of ∆SNR and ∆CM to RAN4 as information for their final decision. We are ok not to consider PAPR if ∆CM is used.  |
| Samsung | Support **FL’s proposal 10-v1** |
| vivo2 | Fine with FL’s proposal. |

Additionally, companies are invited to input their views concerning **3.2.1-Q2** in the table below.

**3.2.1-Q2**

|  |  |
| --- | --- |
| Company | Views |
| Ericsson | 1. Yes; this is a good point. The performance/complexity tradeoffs resulting from how the extended portion of spectrum is used need to be discussed.
2. Absolutely. Neglecting such constraints could lead to incorrect conclusions.
 |
| QC | 1. Yes, it is important to know whether the gNB receiver uses the excess BW or discards it. This can potentially impact how the excess BW is used by the UE. Like Ericsson mentions, performance vs. complexity trade-off can dictate the directions we choose to pursue.
2. For FDSS, the tx filter must comply with a set of spectrum flatness constraints. Whether it needs to be the same set of constraints as in the current RAN4 spec or not will need further discussions.
 |
| ZTE | 1. Ok to report. It’s good to see the potential ways for receiver implementation, and the trade-off between complexity and performance.
2. Yes.
 |
| Nokia/NSB | 1. Yes, this would help for comparing simulation results from companies.
2. Yes, realistic and practically relevant results should always be considered.
 |
| Samsung | Both are valid points to be considered in the study. |
| vivo2 | Yes to both. And we should align with RAN4 if RAN4 has any agreements on these aspects as well. |

### [OPEN] Parameterization for evaluations

One company (Ericsson [15]) explicitly proposes a specific set of parameter configurations for performance evaluation. More precisely, it is proposed to determine PA output backoff using RF simulations and according to RAN4 requirements for error vector magnitude, in band emissions, spectrum flatness, spectrum emission mask, and adjacent channel leakage, spurious and accounting for counter-IM3. In addition**.** as a starting point, using the parameters in below table for RF simulations, and select remaining parameters that are needed for link simulations from TR 38.830, appendices A.1 and A.2.

|  |  |
| --- | --- |
| **Parameter**  | **Value** |
| Filter coefficient  | TBD (may vary according to MPR reduction scheme) |
| Modulation scheme | QPSK, 16QAM, [64QAM and 256QAM] |
| Waveform | DFT-s-OFDM |
| Carrier frequency and duplex mode | 700MHz (FDD), 4GHz (TDD), 28GHz (TDD) |
| Subcarrier spacing | 700MHz: 15 kHz, 4GHz: 30 kHz, 28GHz: 120 kHz |
| System Bandwidth | 700 MHz: 20 MHz, 4 GHz: 100 MHz, 28 GHz: [100 MHz, 400 MHz]  |
| Number of RBs and starting RB | Sweep different combination |
| Counter-IM3 | 60 dB |

**FL’s comment on October 12**

From companies’ inputs for question 3.1.1-Q2, the majority supports performing link-level simulation (LLS) in RAN1. Therefore, this section can be opened for discussion on LLS parameters. A discussion on how to parameterize RF simulations does not seem needed as of now.

Only one company provided an explicit proposal on parameterization for evaluations in their contribution, whereas other companies reported it as accompanying information for the results included in their contribution.

FL would like to collect more views on this topic. The following question is then formulated for further discussions, using elements that can be find in different companies’ contributions.

|  |
| --- |
| **3.2.2-Q1 *Do you agree that the LLS parameters used for Rel-17 SI, and detailed in Annex A of TR 38.830, can be used to parameterize the PUSCH in the LLS for this Rel-18 study?******If YES: which target scenario, e.g., Urban scenario at 4GHz for FR1 and 28GHz for FR2, should be considered?*** ***If NO: which parameterization should be used instead?******Note 1: this does not include modulation order or RB allocation (which are discussed in FL’s proposal 2-v1)*** |

#### First round of discussions

FL’s recommendation is to have a first round of discussion about **3.2.2-Q1**.Companies are invited to input their views in the corresponding tables below.

**3.2.2-Q1**

|  |  |  |
| --- | --- | --- |
| Company | Answer (Y/N) | Other comments |
| vivo | N | In our understanding, this study should be similar to the study “Optimizations of pi/2 BPSK uplink power in NR” for which the SI report is summarized in [38868-h00.zip](https://www.3gpp.org/ftp/Specs/archive/38_series/38.868/38868-h00.zip).Therefore, we propose to consider the common LLS parameters assumed in section 5 of 38.868 where LLS parameters assumed by a couple of companies are provided. For the parameters that were different among companies can be reported separately. |
| QC |  | We are okay to use 38.830 and 38.868 for guidance on simulation parameters. Regarding bands of interest, E//’s list (similar to 38.830) is good to use: 700 MHz: 20 MHz, 4 GHz: 100 MHz, 28 GHz: [100 MHz, 400 MHz] |
| Ericsson | Y | Urban should be fine for 4 GHz and 28 GHz, with rural for 700 MHz.While it looks like 38.868 could also be used as vivo points out, different companies often picked different settings. While the methodologies in 38.868 seem useful, 38.830 seems to have a more converged set of scenarios. That being said, if something is missing, we are open to taking from 38.868 as well. |

#### Second round of discussions

**FL’s comment on October 14**

Thank you for adding your views. From my understanding, and as also pointed out by Ericsson, methodology used for TR 38.868 seems to be that different companies report different settings. Indeed, Section 5 of TR 38.868 captures results from different companies, wherein each company reports the adopted parameter list. This may lead to inconsistencies across parameterizations which we may want to avoid. At the same time, many of the reported parameters are aligned in TR 38.868. I decided to summarize such common values from the parameters reported by companies in TR 38.868 in a table, which can be used for baseline evaluation to simplify the comparison between results obtained by different companies. In addition, given the above comments from Qualcomm and Ericsson on the carrier frequency and scenario, I tried to match the carrier frequencies, scenarios, and channel models so that they are aligned with both TR 38.868 and TR 38.830. I hope that the following proposal which consider both TR 38.868 and TR 38.830 is acceptable for everyone as a starting point for parameterization for evaluations.

**FL’s proposal 14**

**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 | 700MHz (Rural), 4GHz (Urban), 28GHz (Urban) |
| Channel BW | 20MHz for Rural, 100MHz for Urban |
| SCS | 15 kHz (700 MHz), 30 kHz (4GHz), 120 kHz (28GHz) |
| 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 |
| Number of Rx antennas | 4 |
| Number of DMRS symbols | 2 |
| Number of PUSCH data symbols | 12 |
| HARQ configuration | No retransmissions |
| Number of PRBs | According to agreements[2,4,8,16,64] is encouraged |
| 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 |
| 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.**

**Note: other configurations and scenarios can be studied, and corresponding results can be reported.**

Companies are invited to input their views on **FL’s proposal 14** in the table below. **Constructive attitude and comments are greatly appreciated**. If you cannot agree with the current formulation of the proposal, please provide an alternative formulation.

**FL’s proposal 14**

|  |  |
| --- | --- |
| Company | Answer/Views |
| QC | Looks good to us. Thanks for pulling in all the relevant information. |
| Ericsson | Looks good overall. A few suggestions* 4 Rx antennas is probably too many for FR2; suggest 2
* At least FR2 commonly uses two Tx. While power statistics per Tx chain should be pretty independent, if there is Tx diversity gain, then BLER operating points could be impacted, and the relative performance of MPR reduction schemes could be different. Suggest to make 2 Tx optional (as we did for the Rel-17 cov enh study)
* The number of PRBs seems to be from 38.868, which concentrates on Pi/2 and 4 GHz. Coherence bandwidth for 30ns is ~30MHz, and so from a frequency diversity standpoint, 64 PRBs is a bit on the small side even for 30 kHz SCS. If we have to pick something now, we could try something like [2,4,8,16,Nprb/3,Nprb/2,Nprb], where Nprb is 106, 173, {66, 264} for 700 MHz, 4 GHz, 28 GHz respectively.

In summary:

|  |  |
| --- | --- |
| Number of Tx antennas | 1, Optional: 2 for FR1 |
| Number of Rx antennas | 4 for FR1, 2 for FR2 |
| Number of PRBs | According to agreements~~[2,4,8,16,64] is encouraged~~As a starting point: [2,4,8,16,Nrb/3,Nrb/2,Nrb], where Nrb is 106, 173, {66, 264} for 700 MHz, 4 GHz, 28 GHz respectively |

 |
| ZTE | Support the proposal in principle.The assumption of extension factor (α) is also important. To have more aligned evaluation results, we suggest to add a row for this assumption:

|  |  |
| --- | --- |
| Extension factor (α) | [1/8, 1/4, 3/8] is encouraged.  |

 |
| Nokia/NSB | Support. |
| vivo2 | We propose to wait for RAN4 and align parameters with RAN4. RAN4 is discussing the options as well. There’s no need to introduce different assumptions between RAN4 and RAN1. |

## Others

As discussed at the beginning of Section 3, discussions on different aspects of enhancements for reduction MPR/PAR have been prioritized to ensure that constructive discussions and effective progress can be achieved during RAN1 #110b-e. Priority has been given to the aspects and topics discussed in sections 3.1 and 3.2, which mostly focus on way of working, evaluation methodology, and design aspects of considered MPR/PAR reduction techniques. All other aspects are listed in this section, i.e., 3.3, where proposals made by companies in their contributions are reported and described in detail.

These aspects may not be handled during RAN1 #110b-e unless 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 discussions for 3.1 and 3.2 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] Complementary enhancements

One company (Huawei/HiSi [2]) proposes studying whether/how to enhance the power control to consider the difference of power spectral density of the REs due to the FDSS.

# [CLOSED] Proposals for GTW

**FL’s proposal 1-v2**

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

* Results concerning the application of solutions for DFT-s-OFDM to CP-OFDM can be presented by companies in their contributions.

**FL’s proposal 2-v4**

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

* At least pi/2-BPSK and QPSK modulation are considered
	+ 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
	+ FFS:
		- Whether restrictions on the number of allocated RB or on the starting RB of the allocation are considered.
	+ ~~Whether other modulations are considered.~~

**FL’s proposal 3-v3**

At least the following non-transparent candidate solutions for MPR/PAR reduction will be studied in RAN1 ~~Rel-18~~.

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

Companies can study and present results for any other transparent scheme, e.g., FDSS Frequency domain spectrum shaping w/o spectrum extension, which could be used as benchmark for assessing the performance of non-transparent solutions.

~~Whether other solutions will be studied as well will be decided before the end of RAN1 #110b-e.~~

**FL’s proposal 13**

For enhancements to realize increasing UE power high limit for CA and DC, RAN1 will study

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

**FL’s proposal 14**

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 | 700MHz (Rural), 4GHz (Urban), 28GHz (Urban) |
| Channel BW | 20MHz for Rural, 100MHz for Urban |
| SCS | 15 kHz (700 MHz), 30 kHz (4GHz), 120 kHz (28GHz) |
| 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 |
| Number of Rx antennas | 4 |
| Number of DMRS symbols | 2 |
| Number of PUSCH data symbols | 12 |
| HARQ configuration | No retransmissions |
| Number of PRBs | According to agreements[2,4,8,16,64] is encouraged |
| 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 |
| 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.

Note: other configurations and scenarios can be studied, and corresponding results can be reported.

# 5 [CLOSED] Agreements during RAN1 #110b-e

**Agreements**

The following work split principles will be adopted in RAN1 for power domain enhancement throughout Rel-18 from RAN1 perspective and send an 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.

# References

1. RP-221858 Revised WID on Further NR coverage enhancements, China Telecom, Jun. 2022.
2. R1-2208412 Discussion on coverage enhancement in power domain Huawei, HiSilicon
3. R1-2208489 Discussion on power domain enhancements ZTE
4. R1-2208576 Discussion on power domain enhancements Spreadtrum
5. R1-2208672 Discussions on power domain enhancements vivo
6. R1-2208847 The study of power domain enhancements OPPO
7. R1-2208964 Discussion on power domain enhancements CATT
8. R1-2209026 Discussion on power domain enhancements for CA/DC Fujitsu
9. R1-2209079 Discussions on power domain enhancement Intel Corporation
10. R1-2209224 Power domain enhancements Lenovo
11. R1-2209364 Discussion on power domain enhancements CMCC
12. R1-2209522 Discussion on power-domain enhancements MediaTek Inc.
13. R1-2209609 Discussion on power domain coverage enhancement Apple
14. R1-2209662 Uplink power enhancements InterDigital, Inc.
15. R1-2209673 Power Domain Enhancement Evaluation Methodology and Schemes Ericsson
16. R1-2209760 Power domain enhancements Samsung
17. R1-2209789 Power domain enhancements for Rel-18 CovEnh Sharp
18. R1-2209926 Discussion on power domain enhancements NTT DOCOMO, INC.
19. R1-2210014 Power-domain enhancements Qualcomm Incorporated
20. R1-2210166 RAN1 impacts for power domain enhancements Nokia, Nokia Shanghai Bell

# 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

**Coordination with RAN4**

|  |
| --- |
| **R1-2208489 ZTE*****Proposal 6:*** *RAN4 should lead the discussion on whether/how to introduce additional cases for increasing UE power high limit for CA and DC.***R1-2209760 Samsung*****Proposal 1:*** *Send an LS to RAN4 asking which potential enhancements RAN4 is planning to consider for this objective.* |

**RAN1 scope clarification**

|  |
| --- |
| **R1-2208489 ZTE*****Proposal 7:*** *RAN1 needs to clarify whether any RAN1 enhancement is needed, and any enhancement requiring large RAN1 specification impact without clear performance gain is not pursued.* **R1-2209364 CMCC*****Proposal 1:*** *The impact for RAN1 spec needs more discussion.***R1-2209926 NTT DOCOMO*****Proposal 1:*** *Clarify the objective more to have a well-focused target for RAN1 work* |

**De-prioritization of HPUE related power domain enhancement**

|  |
| --- |
| **R1-2208672 vivo*****Proposal 1:*** *HPUE related power domain enhancement should be deprioritized in Rel-18 coverage enhancement topic.* |

**New signaling aspects**

|  |
| --- |
| **R1-2209026 Fujitsu*****Proposal 1:*** *A new signaling/report from UE to gNB should be introduced to let gNB know the timing about UE autonomous Tx suspension due to SAR limit** *FFS: Details of signaling/report*

**R1-2209662 InterDigital*****Proposal 3****: Support indication of aggregated power class in power headroom report.***R1-2209926 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***R1-2210014 Qualcomm*****Proposal 8:*** *To facilitate higher power transmission in CA and DC scenarios, introduce signalling mechanisms between UE and gNB focused on* 1. *increasing awareness of power or energy budget available at the UE for each carrier/band,*
2. *aiding the selection of the best band combination for UL CA, and*
3. *aiding scheduling policy when UE is configured with multiple bands in UL CA, for e.g., selecting preferred carrier for servicing uplink, or adaptive load sharing across carriers.*

***Proposal 9:*** *Introduce signaling to allow UE to report aspects related to power management and RF exposure.****Proposal 10:*** *Enhance the current power headroom reporting framework to allow a user to also report P-MPR (via MPE field) for FR1 carriers.****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****: Introduce MAC-CE signaling to allow UE to report energy headroom for each of the bands in a CA/DC configuration given to the UE.* *FFS: signaling details, including, periodicity, reporting triggers, relation to PHR, how to handle multiple bands, reference power, etc.* |

## A.2 Enhancements for reducing MPR/PAR

### A.2.1 Way of working (RAN1 and RAN4 work split)

|  |
| --- |
| **R1-2208489 ZTE*****Proposal 1:*** *RAN1 should target to clarify and determine the work split between RAN1 and RAN4 for power domain enhancements in RAN1#110.* **R1-2208964 CATT*****Proposal 1:*** *The MPR/PAR reduction by FDSS with and without spectrum extension and tone reservation should be first studied in RAN 4 focusing on relevant waveform and modulation order for coverage limited UEs.***R1-2209522 MediaTek*****Proposal 1:*** *Reach a conclusion stating that RAN1 keeps power-domain enhancements related discussions on hold and waits for RAN4 progress on these objectives.***R1-2209609 Apple*****Proposal 1:*** *More RAN4 inputs are required to progress in RAN1 on enhancement on increasing maximum power limit.***R1-2210166 Nokia, NSB*****Proposal 1:*** *RAN WG4 should be the (key) responsible WG for the performance evaluations related to MPR/PAR objective***R1-2209364 CMCC*****Proposal 2:*** *Potential RAN1 impact should be discussed for spectrum shaping and tone reservation.* |

### A.2.2 Performance evaluation

**Evaluation methodology**

|  |
| --- |
| **R1-2208412 Huawei/HiSi*****Proposal 1:*** *Adopt the metrics of coverage enhancement gain, PAPR, CM, and reduced SNR for evaluations on coverage performance improvement of Rel-18 NR power domain enhancements:** *The coverage enhancement gain is given by*$G=∆CM+∆SNR$*;*
* $∆SNR$ *is the SNR degradation under the requirement BLER=10-1;*
* $∆CM$ *is the* *improvement of CM at the 99-percentile of the CDF.*

**R1-2209673 Ericsson*****Proposal 1.*** *Quantify relative link performance of a given transmission configuration as SNR0+OBO, where SNR0 is the SNR (in dB) needed to reach a target BLER, and OBO is the output power backoff for the configuration (in dB).****Proposal 3.*** *Compare schemes at the link level using a same amount of time-frequency resource and at a same spectral efficiency, and assuming Rel-17 resource allocation mechanisms.****Proposal 5*** *Transparent MPR reduction schemes are baselines to which non-transparent schemes are compared.***R1-2210014 Qualcomm*****Proposal 4:*** *For evaluating the benefits of tone reservation, use legacy R17 PUSCH waveforms as a baseline, with the excess bandwidth included in the total allocated bandwidth.****Proposal 6:*** *For FDSS with bandwidth expansion, link-level performance evaluations are required to assess the overall coverage gains. In particular, evaluate the impact of (a) the amount power spent in the excess bandwidth region and (b) gNB receiver handling of the excess bandwidth when receiving the PUSCH transmission for further processing.****Proposal 7:*** *For FDSS with bandwidth expansion, evaluate the impact of gNB not knowing the pulse shaping filter used by the UE (but aware of bandwidth expansion).***R1-2208964 CATT*****Proposal 2:*** *FDSS should be carefully studied taking performance, overhead, implementation complexity and standardization efforts into account.***R1-2208672 vivo*****Proposal 2:*** *FDSS enhancement in Rel-18 should be carefully studied and should not be specified unless justified by obvious power boost gain.***R1-2209760 Samsung*****Proposal 2:*** *Further study techniques to reduce MPR/PAR to assess the gains for coverage enhancement.****Proposal 4:*** *Further study techniques to reduce MPR/PAR taking into consideration the implementation impact at both the UE and the gNB***R1-2210166 Nokia, NSB*****Proposal 2:*** *Actual conclusion of the MPR/PAR reduction methods should be based on net coverage gain results combining transmitter and receiver performance.* |

**Evaluation parameters**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **R1-2209673 Ericsson*****Proposal 2.*** *Determine PA output backoff using RF simulations and according to RAN4 requirements for error vector magnitude, in band emissions, spectrum flatness, spectrum emission mask, and adjacent channel leakage, spurious and accounting for counter-IM3.****Proposal 4.*** *As a starting point, use the parameters in Table 1 for RF simulations, and select remaining parameters not given by Table 1 that are needed for link simulations from TR 38.830, appendices A.1 and A.2.*Table 1: RF simulation (‘Step 1’) parameters

|  |  |
| --- | --- |
| **Parameter**  | **Value** |
| Filter coefficient  | TBD (may vary according to MPR reduction scheme) |
| Modulation scheme | QPSK, 16QAM, [64QAM and 256QAM] |
| Waveform | DFT-s-OFDM |
| Carrier frequency and duplex mode | 700MHz (FDD), 4GHz (TDD), 28GHz (TDD) |
| Subcarrier spacing | 700MHz: 15 kHz, 4GHz: 30 kHz, 28GHz: 120 kHz |
| System Bandwidth | 700 MHz: 20 MHz, 4 GHz: 100 MHz, 28 GHz: [100 MHz, 400 MHz]  |
| Number of RBs and starting RB | Sweep different combination |
| Counter-IM3 | 60 dB |

 |

**Others**

|  |
| --- |
| **R1-2208489 ZTE*****Proposal 2:*** *RAN1 needs to first agree on the evaluation methodology and simulation assumptions for the proposed RAN1 enhancements in the power domain.*  |

### A.2.3 MPR/PAR reduction techniques

|  |
| --- |
| **R1-2208412 Huawei/HiSi*****Proposal 5:*** *Continue to evaluate FDSS with SE. The tone reservation technique should not be further considered.* **R1-2208489 ZTE*****Proposal 3:*** *For both pi/2-BPSK and QPSK, tone reservation is not supported in Rel-18 CE WI.****Proposal 4:*** *For pi/2-BPSK, FDSS with spectrum extension can be further studied in Rel-18 CE WI.****Proposal 5:*** *For QPSK, FDSS with or without spectrum extension can be further studied in Rel-18 CE WI.***R1-2208576 Spreadtrum**1. *Enhanced FDSS without spectrum extension applied for other modulations can be further studied.*

**R1-2208847 OPPO*****Proposal 1:*** *Consider tone reservation for DFT-s-OFDM and CP-OFDM waveforms to further reduce PAPR.***R1-2209079 Intel*****Proposal 1:*** *Study frequency domain spectrum filtering for DFT-s-OFDM waveform for PAPR reduction.* **R1-2209224 Lenovo*****Proposal 1:*** *Sub-PRB based transmission could be considered as one method to realize lower MPR/PAR in Rel-18.****Proposal 2:*** *The spectral shaping framework defined in Rel-15 (for pi/2 BPSK) could also be extended to QPSK scenario to realize lower MPR/PAR in Rel-18.****Proposal 3:*** *Tone reservation principle could be used to realize lower MPR/PAR in Rel-18.***R1-2209609 Apple*****Proposal 2:*** *RAN1 to evaluate the QPSK FDSS performance with and without bandwidth extension.***R1-2209662 InterDigital*****Proposal 1****: Support methods to minimize MPR of the waveform.****Proposal 2****: Study the support of tone reservation technique to enable transmission with higher power.***R1-2209673 Ericsson*****Proposal 6*** *Candidate* *transparent MPR reduction schemes to consider include clipping and filtering, companding, and digital predistortion.***R1-2209760 Samsung*****Proposal 3:*** *Further study advanced receivers to support reduced MPR. FFS spec impacts.***R1-2209789 Sharp*****Proposal 1:*** *Study the spectral extension for MPR reduction.* **R1-2209926 NTT DOCOMO*****Proposal 3:*** *Unless a large gain is evaluated, no need for RAN1 to discuss on spectrum extension or tone reservation in Rel-18***R1-2210014 Qualcomm*****Proposal 1:*** *For power-domain enhancements targeting MPR/PAPR optimization focus on the following class of waveforms:* * *DFT-S-OFDM*
* *QPSK modulation*
* *Inner and outer RB allocations*
* *Small RB allocation (1-16 RBs)*

***Proposal 2:*** *Study non-transparent techniques 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 3:*** *Study sideband tone reservation as a non-transparent waveform shaping technique to transmit DFT-S-OFM waveforms at a higher transmit power.* * *Sideband tone reservation is given in units of RBs*

***Proposal 5:*** *Study FDSS with bandwidth expansion as a non-transparent waveform shaping technique to transmit DFT-S-OFM waveforms at a higher transmit power.* * *Excess bandwidth is given in units of RBs*
* *DMRS and data symbols undergo spectrum shaping*

**R1-2210166 Nokia, NSB*****Proposal 3:*** *Prioritize scenarios involving spectrum extension (and deprioritize scenarios without spectrum extension).****Proposal 4:*** *Prioritize DFT-s-OFDM for power domain enhancements in Rel-18 (& deprioritize CP-OFDM)****Proposal 5:*** *Prioritize PUSCH and the associated DMRS for power domain enhancements in Rel-18(& deprioritize other channels and signals)****Proposal 6:*** *Prioritize QPSK modulation for power domain enhancements in Rel-18(& deprioritize other modulation schemes).* ***Proposal 7:*** *Support FDSS with spectrum extension in Rel-18**• FFS: whether and how other solutions are supported.* |

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

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| **R1-2208412 Huawei/HiSi*****Proposal 3:*** *Study the handling of DMRS symbol of a PUSCH with FDSS-SE** *DMRS symbol should be filtered by FDSS.*
* *Whether the DMRS sequence is extended to the resource elements that are used for spectrum extension.*

**R1-2210014 Qualcomm*****Proposal 5:*** *Study FDSS with bandwidth expansion as a non-transparent waveform shaping technique to transmit DFT-S-OFM waveforms at a higher transmit power.* * *Excess bandwidth is given in units of RBs*
* *DMRS and data symbols undergo spectrum shaping*

**R1-2210166 Nokia, NSB*****Proposal 8****: Define Extension factor () as Excess band size / Total allocation size.* ***Proposal 9:*** *Support FDSS w/ spectrum extension without limitations to supported PRB allocations.* ***Proposal 10:*** *Support  = 0.25.* ***Proposal 11:*** *Study solutions to yield only integer numbers of PRB allocations for the excess band, i.e., spectrum extension.****Proposal 12:*** *RAN1 should study how to use the existing FDRA indicator in the context of FDSS-SE.****Proposal 13****: Study solutions for FDSS-SE to guarantee low CM of DMRS.* |

### A.2.5 Design aspects of tone reservation

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| **R1-2208847 OPPO*****Proposal 2:*** *Allocation mechanism of PRTs to a UE should be studied, including location of PRTs, the number of subcarriers of PRTs, etc.***R1-2210014 Qualcomm*****Proposal 3:*** *Study sideband tone reservation as a non-transparent waveform shaping technique to transmit DFT-S-OFM waveforms at a higher transmit power.* * *Sideband tone reservation is given in units of RBs*
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### A.2.6 Other enhancements on top of MPR/PAR reduction techniques

**Power control**

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| **R1-2208412 Huawei/HiSi*****Proposal* 4*:*** *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.*  |