**3GPP TSG-RAN Meeting #90e RP-20xxxx**

**Electronic Meeting, Dec 7-11, 2020**

**Agenda item:** 9.1.4

**Source:** China Unicom (Moderator)

**Title:** Summary for Email discussion on [90E][15][HP\_FDD]

**Document for:** Discussion

# Introduction

This document is a summary of the following email discussion,

*Goal: Generate an agreeable SID*

*Input contributions covered: 2284, 2285*

*Moderator: Basaier Jialade*

**Final deadline for technical comments**: 12:29h UTC 10th December

# Discussion

**RP-202284**

Title: **New SID: Study on high power UE (power class 2) for one NR FDD band**

Agenda Item: 9.1.4

For: Approval

Source: China Unicom

SI Objectives

The objectives of the SID are as follows:

1. Study the applicable scheme(s) for new power class 2 UE for one NR FDD band to comply with the SAR limits with 26dBm UE Tx power, the example band for this study is NR band n1.
2. Study interference issues (e.g. self-desense, cross device coexistence…).
3. Study the possible UE implementations, e.g. RF front-end capability, UE architectures, etc., in achieving 26dBm in FDD bands.

Companies are encouraged to provide their views on the objectives.

2.1 Initial Email Discussion

1. Comments about the objectives of the SID:

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| **Objective 1** | |
| Company Name | Comments |
| Apple | There is no duty cycle concept in FDD bands. P-MPR would limit the UE maximum output power to no more than 23 dBm to fulfill the SAR requirement. |
| LGE | It is quite different operating scenarios between PC2 for FDD+TDD DC UE and PC2 UE in a single carrier NR FDD band.  In PC2 DC UE, the max power is 23dBm for FDD LTE band, but the max output power in FDD NR band is 26dBm in this WID. So need to study the SAR regulatory requirements where 26dBm power class in FDD bands is allowed. |
| Qualcomm | This objective could be ok, however, based on the discussions so far, it seems difficult to conclude on any schemes given there could be multiple. |
| Intel | Objective is generally ok.  Overall, we observe a very big amount of HPUE work items which may have an overlapping scope in terms of applicable schemes. So, there is a big risk that different solutions are used for different scenarios which would overcomplicate UE implementations. Also, some unification of the schemes is recommended to avoid duplicated work. |
| OPPO | Solving the SAR issue with introduction of duty cycle capability is not something new for all the HPUE in Rel-15/16, however, this is quite new for the FDD band.  The concept of duty cycle capability is simple, but how it will be handled by FDD NW actually hasn’t been discussed up to now.  With many UEs in FDD NWs reporting different UL duty cycle capabilities, the scheduling complexity will increase dramatically and how to handle them is unknown. This is different from TDD SA HPUEs which in real NWs the NR TDD deployments mostly use fixed UL/DL configuration whose UL duty cycle is below UE capability. If one fixed UL/DL configuration be used for FDD band to reduce the complexity then it will finally change FDD to TDD operation. How NWs will be deployed to support FDD HPUE and how UE be scheduled when PC2/PC3 UEs exists with different UL duty cycle capabilities should be understood better.  Besides, in our understanding the most fundamental advantage of FDD band comparing to TDD band is the small time delay and high throughput. If FDD bands are restricted by UL/DL configurations to solve the SAR issue caused by HPUE, then we need to understand better how much gain can be derived with the sacrifice of FDD nature. This is none trivial change to the FDD operation. |
| ZTE | We support the WID.  In order to fulfill the SAR limit, a concept similar to duty cycle may need to be introduced to FDD. |
| China Unicom | In discussion of FDD+TDD EN-DC HPUE WI, reference TDM configuration was introduced for LTE FDD carrier. The idea can be borrowed to introduce TDM (duty cycle) for NR FDD band.  The max power for FDD LTE is set to 23dBm because power headroom is reserved for NR TDD to comply with SAR, which is not the case for NR FDD PC2 where it is the only UL transmission source.  The problem of how duty cycle are handled by FDD NW can be studied in the SI. The gain of introducing PC2 in FDD band is elaborated in comments of Objective 3. |
| Huawei, HiSilicon | We support this SI.  The main issue for FDD HPUE is how to comply with SAR requirements. SAR solutions for other HPUE WIs, e.g. P-MPR, dutycycle capability, etc. can be starting point for FDD HPUE. The objective is ok for us. |

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| **Objective 2** | |
| Company Name | Comments |
| Apple | In addition to SAR issue, the duplexer power handling capability also needs to be considered. Redesign of duplexer may be needed to handle higher transmission power and provide better isolation to Rx band to prevent further REFSENS degradation. |
| LGE | Firstly, RAN4 need to study the coexistence evaluation to protect legacy system with max. output power. Based on the coexistence evaluation results, RAN4 need to discuss the detail RF requirements for PC2 UE in FDD band not only the self-desense but also detail Tx requirements such as MPR/A-MPR and so on. |
| Qualcomm | This objective is too generic, it has to clarified and fine tuned. What kind of co-existence study is sought? Is this also about having a adjacent channel co-existence study? |
| Intel | The objective is quite generic and more details should be provided |
| OPPO | More detailed objectives are needed, currently it only says study the interference issue which gives too much room for interpretation. |
| Skyworks | We agree with Apple that duplexer power handling is an issue that requires attention. Note that this is sensitive to both peak power and average power (thermal which in turns creates wider frequency shift in the filters). REFSENS will need reevaluation for self desense but also some band protection and AMPR/NS |
| ZTE | This objective can be further elaborated. In addition to assessment of self-desense, in-device interference caused by a higher peak power would also be investigated. |
| China Unicom | In our view, the UE implementation issues can be studied in Objective 3. The coexistence evaluation can be carried out in this SI, it is suggested to consider n1 for coexistence study. |
| Huawei, HiSilicon | In our view, the interfering can be classified to two types, one is to evaluate the impact of increased Tx noise to Rx, i.e. self-interference. The other one is the adjacent channel co-existence issue. But we don’t think that it will have big difference as that for TDD HPUE with Mont Carlo based simulation. Some analysis would be enough, but it can be further discussed in the SI stage. |

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| **Objective 3** | |
| Company Name | Comments |
| T-Mobile USA | We have a fundamental question about the motivation for this WI. With TDD the duty cycle is limited to less than 100%, so it is obvious that there is benefit for transmitting higher power, and SAR requirements can be met due to the duty cycle. With FDD it is not clear why there would be a benefit for PC2. For instance, if UE 1 is assigned 1 PRB with 100% duty cycle and is limited to PC3, and UE 2 is assigned 2 PRBs with 50% duty cycle and can transmit at PC2, the PSD would be the same in both cases, so the throughput should be the same. We know there were simulation results in the motivation paper, but we’d like to understand the theoretical benefit, especially given the workload in RAN4. It would be helpful if we could have an explanation of why there should be improvement with PC2 with 50% duty cycle vs. PC3 with 100% duty cycle. Intuitively it seems like an even trade. |
| Apple | The SAR issue needs to be resolved first before we can discuss the possible UE implementation.  We also have the same question as raised by T-Mobile USA on why the PC2 throughput would be better between the two operation scenarios as exemplified. |
| LGE | For, Objective1, LGE would like to capture study on the detail SAR regulation requirements based on the regional regulatory in countries where 26dBm power class in FDD bands is allowed.  Also we need to clarify how to resolve the SAR issues with max. 26dBm Tx power in FDD bands. Only possible way might be to restrict duty-cycle in FDD bands. It is not clear what is beneficial point for system operating perspective. |
| Qualcomm | This objective should also discuss the feasibility of building components that can handle higher power and their impact on device implementation. |
| OPPO | Agree with Tmobile USA, the benefit of his feature needs to be justified. Regarding UE implementations, to achieve PC2 requires UE double PA implementations which will cause trouble to complexity, costs, power consumption, etc. especially considering UE needs to support so many bands/combinations in small form factor. All these factors actually needs to be analyzed. Without big improvement of system performance, the necessity of introducing FDD HPUE needs to be discussed further. |
| China Unicom | From the simulation results, it shows that there is a system gain from UE side. But from network side, more (doubles in case of 50% UL duty cycle) UL resources are released which can be scheduled by gNB to serve other UEs, which means that UL network capacity increases without loss in UE performance, even with a small gain for each UE.  Current NR specification supports repetition for PUSCH coverage enhancement. Ideally, with N repetitions, a maximum 10log\_10 (N) dB SNR gain can be achieved by combining detection. However, the noise affects the channel estimation accuracy and limits the SNR gain from combining detection. The potential gain from the power concentration is 1 dB or more as shown in R1-2007583.  Higher power also facilitate UEs with small packets. One example is that the UE may complete the uplink transmission during the on period in the duty cycle and thus a higher up to doubled throughput is experienced by the UE as simulated in RP-202285. |
| Huawei, HiSilicon | The UE implementation related issues can be studied. It is noted that some issues are not for FDD only, as we know that TDD band is allowed to report 100% dutycycle capability, and if the network schedules the UE with almost UL in a certain period, the case would be similar to a FDD HPUE. |

2. Are there any other objectives to be added to the SID?

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| Company Name | Comments |
| Qualcomm | We believe that first the system level gains from this feature should be understood. The proponent has shown some gains, however, it is not clear which aspects were taken into account. For example, was the impact of added Tx noise taken into account? How is the rise over thermal due to increase UL power modeled/quantified? This could lead to some REFSENS degradation. If there is a study on this feature, the first step should be system study to evaluate the gains. |
| Intel | Agree with Qualcomm and T-Mobile USA that system level gains should be clarified. For instance, the results show big gains for cell center UEs which may not necessarily use full TX power. The baseline assumptions on UL Duty cycle for PC3 and PC2 in the system level simulations are unclear. Is 50% or 100% UL duty cycle assumed for PC3? |
| OPPO | For the motivations, we would like to understand better. In the motivation paper, it mentioned that the coverage will be reduced due to larger CBW introduced in NR, our understanding is that this issue depends on several factors which might not be so straight forward since UEs in the cell edge most likely will be scheduled with partial RBs in the CBW. If same RBs are scheduled and other factors like MCS are same then LTE and NR will have same coverage, if more RBs are scheduled in NR and other factors like MCS are same, then the coverage might have some impact. Therefore, the benefit and impacts to NW and UE of introducing FDD HPUE in the NW needs to be analyzed. |
| ZTE | This objective can be treated as a further enhancement expecting more gain from a high power FDD. The focus at current stage should be the first two objectives. |
| China Unicom | The benefit of introducing FDD PC2 is elaborated in our comments for Objective 3.  For clarification, 100% UL duty cycle is assumed for PC3 in the simulation.  Also it was not mentioned in the motivation paper that the coverage will be reduced due to larger CBW introduced in NR. |
| vivo | It is understood there can be performance gain as in the motivation paper shows. However, still some clarifications may be needed for the various assumptions selected. |

3. The target completion date is RAN#93 (3 quarters), any comments on the timeline?

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| Company Name | Comments |
| Qualcomm | It seems very difficult to complete such a study in just 3 meetings given that some system level study is also needed. Even if the study was just on how to implement such a UE, we believe it is very unlikely that conclusions can be reached in just 3 quarters. |
| China Unicom | We set the completion date as originally scheduled Rel-17 completion date. But if it is identified the study requires more time units to complete, then the completion date could be further delayed within Rel-17 timeline. |

2.2 Intermediate Summary

**Objective 1**: Study the applicable scheme(s) for new power class 2 UE for one NR FDD band to comply with the SAR limits with 26dBm UE Tx power, the example band for this study is NR band n1.

According to initial round discussion, Power Class 2 for NR FDD band haven’t been studied in previous/ ongoing RAN4 SI/WI. Sub-bullets for **objective 1** are summarized:

* Study candidate SAR solutions, e.g. P-MPR, duty cycle capability, etc.
* Study the SAR regulatory requirements where 26dBm power class in FDD bands is allowed.

Companies are encouraged to provide views on the three sub-bullets

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| Company Name | Comments |
| Qualcomm | For the 2nd sub-bullet, the regulatory requirements are not just SAR. There could be other requlations limiting maximum power. Should be re-worded to: Study regulatory requirements related to 26dBm Tx power in FDD bands including SAR. |
| LGE | Yes, agree with QC proposal |
| Intel | Suggest to add a note that it is preferable to reuse existing SAR solutions for other HPUEs (e.g. “Prioritize studies for the existing SAR solutions”) |
| Huawei, HiSilicon | Agree with proposed changes by Qualcomm. |
| Skyworks | Implementation limitations should also be studied for filter power handling (average power, duration of 100% duty cycle…) |
| China Unicom | We are ok to modify the wording proposed by Qualcomm and Intel.  Objective 1 sub-bullet 2 are modified with note added:  - Study regulatory requirements related to 26dBm Tx power in FDD bands including SAR.  Note: Prioritize studies for the existing SAR solutions. |
| ZTE | Agree with Moderator’s latest update on Objective 1 |

**Objective 2**: Study interference issues (e.g. self-desense, cross device coexistence…).

According to initial round discussion, sub-bullets for **objective 2** are summarized:

* Study RF requirements for PC2 UE in FDD band (n1), including self-desense requirements, Tx requirements such as A-MPR, and so on.
* Study adjacent channel co-existence for FDD band (n1).
* Investigate in-device interference caused by a higher peak power.

Companies are encouraged to provide views on the above sub-bullets

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| Company Name | Comments |
| Qualcomm | For the first sub-bullet, shouldn’t MPR be included before A-MPR?  For the 2nd sub-bullet, the study should be generic, not related to a band.  The 3rd sub-bullet is probably better re-worded as: Investigate issues related to in-device interference … |
| Apple | The impact to duplexer performance due to higher transmission power should also be studied before the analysis of self-desense. For the 2nd bullet, does it mean the coexistence study to determine the ACLR requirement? It is not clear for the 3rd bullet. Does it mean the interference to other RATs in the same device? |
| Huawei, HiSilicon | The SI is spectrum related, which is not supposed to study general MPR requirement and we think that MPR is applicable for both TDD and FDD bands.  We are also fine not limit the SI study to specific band. |
| Skyworks | As discussed above, the filter characteristic may be impacted by the higher power and must be studied and may impact self desense, self band protection… overall BW. From that prospective Band 1 with a large duplex gap is not representative of a worst case. a band with a smaller duplex gap would help understand the issues better. |
| China Unicom | Firstly, we would like to clarify that we prefer to study NR band n1 and n3 as example bands according to commercial demand.  We also prefer to have a clear definition for ‘in-device interference’, so that we can identify the impact caused by ‘in-device interference’. We propose to modify this sub-bullet as below:  - Investigate issues related to in-device interference, if identified. |
| ZTE | We are fine with Moderator’s latest update on “in-device interference” |

**Objective 3**: Study the possible UE implementations, e.g. RF front-end capability, UE architectures, etc., in achieving 26dBm in FDD bands.

According to initial round discussion, sub-bullets for **objective 3** are summarized:

* Study UE implementation related issues, the impact of building components that can handle higher power on device implementation

Companies are encouraged to provide views on the above sub-bullets

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| Company Name | Comments |
| LGE | We support and revised objective as follow.   * Study UE implementation related issues such as RF component feasibility to support 26dBm output power in FDD band, in other word, the impact of building components that can handle higher power on device implementation   When UE support 26dBm max. output power in FDD NR band, then RAN4 need to study the status of art technology of RF components such as Power Amplifier/ filter/Duplexer and so on. In our understanding, the RF components are not guarantee the performance when UE transmit over the upper limited max. power level as 28~29 dBm. Maybe when we consider RFFE loss term with 4~5dB, then RF component will support up to 30~31 dBm max. output power. So it is also need to study in the SI phase. |
| Huawei, HiSilicon | We are ok to have some study for the components power handling for the SI. But we already agreed that TDD HPUE can report 100% dutycycle capability. In our view, there is no big difference for the components capability for TDD or FDD bands for this case. |
| Skyworks | We disagree with Huawei statement that FDD is same than TDD. FDD Duplex filters have to guarantee DL band protection and DL channel REFSENS and with small duplex gaps are very sensitive to raised thermal. Again a example band with low duplex gap should be chosen or the WI must clarify that this is only applicable to band with large duplex gap (we can detail a criteria) |
| China Unicom | We are ok with the wording proposed by LGE.  We propose to modify Objective 3 as  - Study UE implementation related issues such as RF component feasibility to support 26dBm output power in FDD band. |
| Skyworks | To China Unicom: Since band n1 is used as the example band and it does not have a small duplex gap and thus would not reveal filter issues. Could you add to your proposed update on bullet 3 that the use of other example bands for the study is not precluded. |
| ZTE | Eventually the implementation issues related to a PC2 UE is band-specific, so we suggest to put a higher priority on the example band in the WID, and a lower priority for other example bands, something like:  - Study UE implementation related issues such as RF component feasibility to support 26dBm output power in band n1 at first and then other example FDD bands if needed. |

Other objectives to be added to the SID:

* Evaluate system performance gains to support FDD HPUE for n1 in the SI phase

Companies are encouraged to provide views on the above sub-bullets

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| Company Name | Comments |
| Qualcomm | This should be the first objective in the SID and the most important in our view. Without having a good understanding of what the gains are, this feature would not be useful. |
| Apple | Can such study only be done after the approval of SI? What if the SI is approved and the study shows there would not be much performance gain, should the SI be continued to proceed with other objectives? |
| LGE | Agree with Qualcomm. To Apple, maybe the SI will be closed with the conclusion. |
| Intel | There is no need to mention “in the SI phase” since this is a SI |
| Huawei, HiSilicon | From the coverage enhancement perspective, HPUE would always be useful. If possible reduced dutycycle may counteract the benefit of FDD HPUE, why PC1 TDD HPUE discussed in this RAN meeting with further reduced dutycycle compared to PC 1.5 is not questionable? |
| Skyworks | Again band 1 is not necessarily the right example band. We should add that aspects related to FDD bands with small duplex gap should be studied too. |
| T-Mobile USA | To Huawei: We may be mistaken but our understanding is that PC1 is being proposed for FWA, where SAR is not an issue. For PC2 orPC1.5, our understanding was that since the duty cycle was already 50% or 25%, why not increase the power by 3 dB or 6 dB and take advantage of the lower duty cycle? The same trade off is not clear for FDD.  Now, at the risk of answering my own question from above, maybe the problem is that I was starting with the assumption of a UE with 100% duty cycle. Is the primary benefit of PC2 for FDD that if a UE that  could meet its minimum throughput requirement with only 1 PRB and PC2 with 50% duty cycle there would be a benefit because it could not be allocated ½ of a PRB at 100% duty cycle? So at the lowest granularity of PRB allocation there is a benefit? Or maybe whenever a UE has an UL assignment with less than 100% duty cycle, the UE could potentially transmit at a higher power and higher MCS, so that it requires less resources? Or is higher power just one more degree of freedom for which to optimize the use of resources? |
| China Unicom | In our motivation paper, the simulation results proved the improvement of spectrum efficiency and UL Throughput. In our view, we encourage interested companies to provide performance evaluation results for spectrum efficiency during the study phase in RAN4.  By the way, we propose n1 and/or n3 as example band, we can further decide which band will be studied.  We propose the following modification on Objective 4:  - Evaluate system performance gains on spectrum efficiency to support NR FDD HPUE. |
| ZTE | If n3 is also added as the second example band, should it also be added into the previous objectives? Or n3 is only intended in the system evaluations? |

The target completion date is RAN#93 (3 quarters), any comments on the timeline?

If it is identified the study requires more time units, the completion time could be adjusted within Rel-17 timeline (more than 3 quarter).

Companies are encouraged to provide views on the above sub-bullets

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| Company Name | Comments |
| Qualcomm | As already stated , 3 quarters(at most 3 meetings?) cannot be enough. A co-existence study cannot be concluded in 3 meetings considering that system simulations are involved. The same goes for the system study to understand the gains.  In total, we believe that at least 6 work group meetings would be needed to do a meaningful work. |
| LGE | We prefer SI will be studied until Rel-17 timeline. |
| Huawei, HiSilicon | We are supportive with the moderator’s proposal to consider RAN#93 firstly. How many meeting cycles are reasonable depends on progress in RAN4, which will be clear during the study. Setting the target to the end of Rel-17 is not useful to guide the RAN4 study. |
| China Unicom | We agree the proposal from Qualcomm/LGE/Huawei. We propose to request for 3 quarters in RAN4 meeting. We can further adjust the schedule according to RAN4 progress. |

# Summary and final proposal