**3GPP TSG-RAN WG4 Meeting #100-e R4-210XXXX**

**Electronic Meeting, Aug 16 - 27, 2021**

**Agenda item:** 9.18

**Source:** Moderator (China Telecom)

**Title:** Email discussion summary for [100-e][140] NR\_cov\_enh

**Document for:** Information

# Introduction

This email thread discusses the phase continuity and power consistency across PUSCH/PUCCH transmissions and the corresponding RF requirements for NR coverage enhancements WI in AI 9.18, including the following sub-topics:

* [Sub-topic 1-1: Non-zero un-scheduled gap in-between repetitions](#_Toc79478138)
* [Sub-topic 1-2: Non-zero gap with other uplink transmissions](#_Toc79478139)
* [Sub-topic 1-3: TA adjustment impact on phase continuity](#_Toc79478140)
* [Sub-topic 1-4: Phase continuity and power consistency tolerance](#_Toc79478141)
* [Sub-topic 1-5: Maximum duration for joint channel estimation](#_Toc79478142)
* [Sub-topic 1-6: DL slot(s) in-between repetition](#_Toc79478143)
* [Sub-topic 1-7: Work plan](#_Toc79478144)

List of candidate target of email discussion for 1st round and 2nd round:

* 1st round: Invite companies to review the recommended WF and provide comments directly under each issue in section 1.2.
* 2nd round: Prepare the WF and reply LS to RAN1.

# Topic #1: Phase continuity and power consistency for PUSCH and PUCCH transmissions

## Companies’ contributions summary

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| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2111901 | InterDigital Communications | **Observation 1:** RAN4 should concentrate on multi-slot phase continuity study for JCE.  **Observation 2:** The single versus multiple time domain windows for JCE choices are related to the phase continuity RAN4 discussions and conclusions on phase continuity tolerance.  **Observation 3:** TheJCE for non-back-to-back design or restrictions is pending RAN4 phase continuity study conclusions.  **Observation 4:** The JCE window length dimensioning is not the goal of the current simulation campaign.  **Observation 5:** Known factors that may impact the JCE window length:   * The phase continuity disruption magnitude is expected to impact differently the modulations order under discussion in terms of supported phase tolerance level. * Since the phase noise is very different in FR1 versus FR2, it is expected that at least for FR1 and FR2 spectrum split phase continuity tolerance level to have a different impact.   **Observation 6**: The UE may need to signal JCE maximum window length as a UE capability per case.  **Observation 7:** The UE timing adjustment, TA errors and non-back-to-back phase continuity issues are studied without any mitigation methods, and this has a direct impact on JCE window length.  **Observation 8:** The use of PT-RS may influence determination of JCE window length.  **Proposal 1:** For JCE window length determination discuss the addition of PT-RS for simulation assumptions for the cases where phase continuity tolerance prove to be problematic for the JCE feature gain. |
| R4-2112230 | China Telecom | RAN4 RF work plan for NR coverage enhancements WI.  In addition, the RAN1/4 LS and WF approved in previous meetings are summarized in the Annex of this contribution. |
| R4-2112231 | China Telecom | **Observation 1:** To analyze the impact on phase continuity, the timing adjustments can be categorized into two types:  1) Network commanded TA adjustment, which is known to both UE and BS. The corresponding phase change can be pre-compensated at UE baseband processing or compensated at BS baseband processing.  2) TA adjustment tolerance and UE autonomous adjustment, which it is known to UE and probably not known to the BS. The corresponding phase change can be pre-compensated at UE baseband processing. Or alternatively, BS can estimate the timing tolerance/adjustment based on uplink reference signal and compensate the corresponding phase change in baseband processing.  **Observation 2:** There will be a maximum duration during which UE is able to maintain power consistency and phase continuity under certain tolerance level. |
| R4-2112804 | Nokia, Nokia Shanghai Bell | In this contribution, we proposed the following for phase continuity and power consistency for PUSCH and PUCCH repetitions:  Proposal 1. For power consistency and phase continuity for PUSCH and PUCCH repetitions, OFF power requirements for shorter duration than 1 msec should not be considered.  Proposal 2. For power consistency and phase continuity for PUSCH and PUCCH repetitions, maximum value of X un-scheduled symbols between adjacent PUSCH/PUCCH repetitions should be defined per subcarrier spacing and equal to 1ms. The non-zero un-scheduled gap of less than 14, 28, 56, and 112 symbols for SCS of 15, 30, 60, and 120 kHz, respectively, should be considered.  Proposal 3. RAN4 should not focus only on the energy consumption to maintain at least the transmit RF chain active throughout the time window for joint channel estimation, but rather on the overall energy efficiency of this operation.  Proposal 4. The maximum duration should be the same for both PUSCH and PUCCH and the maximum duration should not depend on UL waveform or be band specific  Proposal 5. Applicability of the joint channel estimation feature depends on UE capabilities subject to a minimum maximum duration RAN4 requirement.  In addition, the following is observed:  Observation 1. The likely larger energy consumption to maintain at least the transmit RF chain active throughout the time window for joint channel estimation is expected to be compensated adequately by the benefits in UL link performance given by joint channel estimation are, in turn yielding higher energy efficiency overall. |
| R4-2112889 | Sony | In this contribution, we have discussed phase continuity for PUCCH and PUSCH repetition and UE configuration for enhanced Joint Channel Estimation in TDD. The following observations and proposals are made:  Observation 1: The feasibility of a use case and UE implementation complexity is up to the acceptable phase/amplitude tolerance for the network to perform a joint channel estimation over PUCCH and PUSCH repetition.  Observation 2: A guard period is needed for devices to retune their clock in order to maintain the phase/magnitude consistency in the case of different channel/transmission in between two repetitions.  Observation 3: A phase variation within 40 degrees with joint channel estimation can outperform single slot channel estimation under the proposed simulation model.  Observation 4: The performance of joint channel estimation can be further improved with optimized estimator design, in other words, allow larger phase tolerance.  Observation 5: The impact of power inconsistencies across UL slots is neglectable with a uniformly distributed power variation of 2 dB no matter the phase inconsistency.  Observation 6: It is possible for a UE to retune the phase so that the phase continuity when there is DL slot(s) in-between repetitions can be maintained.  Observation 7: The cases of a downlink reception without actual DL transmission/ DL monitoring occasions and an un-scheduled symbol between PUSCH or PUCCH repetition are similar. Therefore, it is possible to have a DL slot while maintaining the phase/amplitude continuity under such a scenario.  Observation 8: Though the Rx performance may degrade due to the noise leaking from the PA, the overall cell coverage may still be improved in the scenario that the uplink coverage is the bottleneck  Observation 9: Enable phase/amplitude continuity when there is a DL slot between PUSCH or PUCCH repetition can improve the uplink coverage under high UL/DL ratio scenarios, e.g., uplink video streaming.  Proposal 1: RAN4 should study the acceptable phase/amplitude variation tolerance under different channels, numerology, waveform and modulation scheme before concluding the feasibility of a specific use case.  Proposal 2: RAN4 needs to agree the model of phase variation for aligning the simulation setup.  Proposal 3: RAN4 further studies the scenario where DL slots between PUSCH or PUCCH repetition from UE implementation and network tolerance aspects conclude its feasibility. |
| R4-2113504 | MediaTek (Chengdu) Inc. | Proposal 1: Use the simulation results provided to further derive phase tolerance requirements.  Proposal 2: Confirm that OFF power level cannot be achieved during non-zero un-scheduled gap, and that any power level requirements in the gap would need to adhere to existing Carrier Leakage requirements.  Proposal 3: Firstly gain a common understanding on likely acceptable phase tolerance before making further agreements on whether feasible gap lengths.  Proposal 4: Agree that phase cannot be guaranteed to be maintained from UE perspective if intermediate signals are present during the gap that require different resulting output power levels (after any MPR) and RF configuration changes. Occupation of different specific PRBs by the intermediate signal could be acceptable.  Proposal 5: It is proposed that UL configuration should be restricted to maintain the same output power level and RF configuration as the repeated signal, and that no guard period is specified.  Proposal 6: Agree not to cover the scenario where TA is modified between start of the first and end of the last repetition for JCE.  Proposal 7: Do not consider further the case where there is a DL slot within a non-zero gap.  Proposal 8: It is proposed to provide a response to RAN1 in line with the viewpoints documented in section 4 of this document.   * For joint channel estimation, is there a maximum duration during which UE is able to maintain power consistency and phase continuity under certain tolerance level? If any, how long is it?   + What factors determine the maximum duration?   Response: Thermal changes at the UE impact the ability to maintain a certain level of phase and power continuity. The acceptable tolerances will be affected by the modulation scheme used.   * + Whether the maximum duration should be the same for different cases for both PUSCH and PUCCH?   Response: PUCCH and PUSCH could be similar if QPSK is used for PUSCH. Duration would likely be less if higher order modulation used for PUSCH.   * + Whether the maximum duration is dependent on the modulation order of transmission, e.g., QPSK, 16QAM, 64QAM?   Response: Higher orders of modulation will likely lead to lower acceptable phase and power tolerance, and therefore limit the duration compared to the case where larger tolerance is applicable. Furthermore, given that the motivation of JCE is for coverage extension, it is questionable why higher modulation orders would be relevant.   * + Whether the maximum duration is dependent on UL waveform (DFT-s-OFDM vs. OFDM)?   Response: Given that the aim of this work is coverage extension, it is unclear to us why RAN1 is not purely considering DFT-s-OFDM, given that this was agreed to be specified for the purposes of maximising coverage in the first place.   * + Whether the maximum duration is band specific?   Response: There may be a difference in acceptable duration between FR1 and FR2 bands, with FR2 requiring more restrictions.   * Besides the factors listed above, whether or not the maximum duration is further dependent on UE capabilities (e.g., multiple possible values for a given set of factor(s)), and if so, whether the UE should report such a duration. Response: There may be some dependency on UE capability, but lots of different configuration capabilities would be undesirable if the feature is targeting commercial success, and complexity versus gain of the overall feature should be considered. |
| R4-2113925 | ZTE Corporation | * **For joint channel estimation, is there a maximum duration during which UE is able to maintain power consistency and phase continuity under certain tolerance level? If any, how long is it?**   Proposed reply: yes, there is a maximum duration, the tolerance level for phase continuity and power consistency are still under discussion in RAN4.   * + **What factors determine the maximum duration?**   Proposed reply: downlink pathloss/RSRP and timing/frequency variation within the duration, the phase error/frequency error from PLL and PA output power stabilization in RF Tx chain;   * + **Whether the maximum duration should be the same for different cases for both PUSCH and PUCCH?**   Proposed reply: yes, this should be same for PUSCH and PUCCH;   * + **Whether the maximum duration is dependent on the modulation order of transmission, e.g., QPSK, 16QAM, 64QAM?**   Proposed reply: this maximum duration is not dependent on modulation order.   * + **Whether the maximum duration is dependent on UL waveform (DFT-s-OFDM vs. OFDM)?**   Proposed reply: this maximum duration is not related with DFT-s-OFDM or CP-OFDM;   * + **Whether the maximum duration is band specific?**   Proposed reply: this maximum duration is not band specific;   * + **Besides the factors listed above, whether or not the maximum duration is further dependent on UE capabilities (e.g., multiple possible values for a given set of factor(s)), and if so, whether the UE should report such a duration**   Proposed reply: single maximum duration is preferred, otherwise this might cause more UE fragmentation and scheduling difficulties from network perspective. |
| R4-2113926 | ZTE Corporation | Proposal 1: the length of non-zero un-scheduled gap could be up to 1ms for different SCS.  Proposal 2: OFF power requirement for non-zero un-scheduled gap should still be guaranteed and some extended testing uncertainty could be considered due to less measurement time compared with Rel-15/16.  Proposal 3: support the option 2 for scenario 1 Non-zero gap with other signals/channels for the UE.  Proposal 4: not consider non-zero gap with other signals/channels with different configurations (e.g. power, PRB content) for UE in Rel-17.  Proposal 5: TA adjustment between different repetitions could be avoided and not encouraged and UE autonomous adjustment error should be left up to UE implementation.  Proposal 6: propose the phase error between different repetitions within 10o-30o.  Proposal 7: propose the amplitude error between different repetitions less than 0.5dB. |
| R4-2114331 | Ericsson | In this contribution, the phase continuity definition is defined with below proposal:  For the same signal transmitted repeatedly in a multiple time slot set, the difference between the phase of the complex received signal of this data in different time slot at the reference point is within a pre-defined tolerance range.  **Proposal-1: RAN4 define the “phase continuity” considering the above proposal as a starting point.** |
| R4-2114332 | Ericsson | In this contribution, the link level simulation assumption is discussed for phase discontinuity tolerance study on JCE with below proposal:  Proposal-1: derive the phase discontinuity tolerance considering both PUSCH and PUCCH.  Observation #1: Results herein use joint channel estimation across a relatively large number of slots, and therefore can be seen as an upper bound to sensitivity for TDD configurations, and used as a starting point for further studies.  Observation #2: Joint channel estimation can perform well if wideband phase offsets between PUSCH repetitions are not too large (e.g. phase offsets up to in the order of 20 between consecutive slots in the simulated scenario).  Observation #3: The tolerance to wideband phase error for FR2 is similar to that of FR1 as 20°.  Observation #4:  The sensitivity for imperfect phase continuity between PUCCH slot when doing cross-slot channel estimation increases with the number of repetitions. In the simulated example we can have up to roughly 40 degree’s STD for 2 repetition and 20 degree’s STD for 8 repetition.  Observation-5: There is still substantial gain (> 1 dB) considering the CFO and time error inaccuracy and time error of +/- 130ns has no big impact for RB allocation = 4 RB.  Observation-6: There is no JCE gain and even has negative JCE gain for wider RB allocation = 30 RB.  Proposal-2: BS receiver seems to tolerate the UE time error for narrowband RB allocation. For wider RB allocation the time error is not ignorable, the UE time error should be avoided system level.  Observation#7: The frequency error added additional phase rotation has negative impact on coherent combining for JCE.  Observation#8: It is desirable to assume the constant frequency error between the repetition interval for JCE otherwise JCE may not work well.  Proposal-3: CFO should be compensated for JCE specifically  Proposal-4: Send a LS question to RAN1 regarding the prerequisite of JCE |
| R4-2114333 | Ericsson | Proposal-1: The existing TX OFF requirement should be applied to avoid the degraded SINR at network. Option 2&3 is our preference.  Proposal-2: wait the tolerance of phase discontinuity decision and option 3 is our preference  Proposal-3: RAN4 discuss whether the measurement of the phase/amplitude variation should be defined together with the potential RF requirements relating the UE coherence transmission. |
| R4-2114334 | Ericsson | In this contribution, we provide our answer on the LS reply:   * For joint channel estimation, is there a maximum duration during which UE is able to maintain power consistency and phase continuity under certain tolerance level? If any, how long is it?   **[answer] The maximum duration should depend on the interval where the UE does not make frequency adjustment. Such maximum duration could be counted as the length of the SSB periodicity and depending on UE implementation. The minimum duration should be 160ms which corresponds to the largest SSB period in NR Rel-15.**   * + What factors determine the maximum duration?   **[answer] The maximum time the UE not adjusting its frequency/time but still meet the 3GPP requirements.**   * + Whether the maximum duration should be the same for different cases for both PUSCH and PUCCH?   **[answer] As the factors are not related to the modulated signal, the conclusion should be the same for both PUSCH and PUCCH.**   * + Whether the maximum duration is dependent on the modulation order of transmission, e.g., QPSK, 16QAM, 64QAM?   **[answer] no**   * + Whether the maximum duration is dependent on UL waveform (DFT-s-OFDM vs. OFDM)?   **[answer] no**   * + Whether the maximum duration is band specific?   **[answer] no.**  Besides the factors listed above, whether or not the maximum duration is further dependent on UE capabilities (e.g., multiple possible values for a given set of factor(s)), and if so, whether the UE should report such a duration  **[answer] If 160ms could be a minimum duration, the repetition perhaps should be done and no need to define longer time than this.** |
| R4-2114496 | Huawei, HiSilicon | Observation 1: For 60kHz SCS, unscheduled gap with 1OS length is not sufficient for on-off and off-on transitions.  Proposal 1: For non-zero unscheduled gap in-between repetitions case, off power can be ensured only when:  • On-off and off-on transient period is allowed during the gap as in fig 1. During the transients, off power is not required.  • The repetitions meet the conditions to maintain the phase continuity, i.e. Modulation order does not change, RB allocation in terms of length and frequency position should not be changed, No change on transmission power level.  Proposal 2: define time mask requirement for the un-scheduled OS in-between repetitions case.  Proposal 3: The maximum length of non-zero un-scheduled gap could be 14OS for all SCS.  Proposal 4: For 60kHz SCS, we provide solutions to solve off-power requirement:  Option 1: the minimum length of non-zero un-scheduled gap is 2OS  Option 2: off power requirement is not required during the unscheduled gap  • If option 2 is selected, whether to define a new transmit power requirement during the gap FFS.  Proposal 5: We provide 2 options for this <1ms transmit off power clarification:  Option 1: RAN4 do nothing on this issue, transmit off power is only measured with at least 1ms duration.  Option 2: Define additional off power requirement for <1ms duration case, the definition is -50dBm-10log(X/1ms)  Proposal 6: RAN4 reply RAN1 LS on TA adjustment issue: it is not expected to have network commanded TA adjusting within the JCE ‘time window’.  For UE autonomous adjustments, leave it to implementation within certain level phase tolerance.  Proposal 7: For DL slots that refers to actual DL transmission, and/or without actual DL transmission from gNB to UE in-between repetitions, UE cannot maintain phase continuity for PUSCH or PUCCH repetition.  Proposal 8: For DL slots that refers to no real DL service and no DL monitoring occasions configured, phase continuity for PUSCH or PUCCH repetition can be maintained but not recommended. Additional on-off and off-on time mask definition is needed.  Observation 2: Frequency error impact on the phase continuity could be benefited from the compensation of gNB and ‘short stability’ of PLL physics. We can only focus on the gNB compensation leftover for frequency error factor.  Proposal 9: The reply to question in RAN1 LS is drafted as below:  The determining factors on maximum duration to maintain power consistency and phase continuity under certain tolerance level are as follows:  • The compensation leftover for frequency error on gNB side across repetitions  • Modulation order may has impact on phase continuity, but the impact on JCE may need further evaluation  • Band dependent  • Channel Bandwidth  However, JCE is not only related to Maximum duration, but also the propagation channel, the conditions captured in the last LSs[3][4], and conditions RAN4 still discuss on, e.g. un-scheduled gap between repetitions. |
| R4-2114549 | Qualcomm Incorporated | Not available |
| R4-2114550 | Qualcomm Incorporated | We discussed open items for phase continuity requirement for UEs and made following observations:  Observation 1: RAN4 has not discussed aggregated phase continuity requirement over all transmissions that are part of same repetition bundle.  Observation 2: Phase drift due to CFO is a problem regardless of gaps between repetitions and need to be solved in the receiver.  Observation 3: TA adjustment in between repetitions will cause phase to be discontinuous in all cases.  And made the following proposals:  Proposal 1: Frequency error is compensated in the receiver in the phase continuity test for joint channel estimation  Proposal 2: In the case of different channel in between two repetitions, a guard period before returning to the repetition transmission is allowed to the UE. Length of guard period Y is FFS but shall not exceed 2 symbols.  Proposal 3: Maximum gap length between the repetitions is no more than 14 symbols for every SCS  Proposal 4: TA adjustments are disabled in UE during repetitions.  Proposal 5: If OFF power measurement period is made shorter, the dBm value for OFF power should be relaxed.  We also proposed to reply to RAN1 about the maximum duration according to the text in the appendix  Proposal 6: Reply to RAN1 according to the text in the appendix  **RAN1 question:** For joint channel estimation, is there a maximum duration during which UE is able to maintain power consistency and phase continuity under certain tolerance level? If any, how long is it?  **RAN4 answer:** Yes, there is a maximum duration but RAN4 has not agreed how many slots it is.   * **RAN1 question:** What factors determine the maximum duration?   + **RAN4 answer:** Factors determining could include UE ability to defer frequency error corrections, timing corrections, etc. If a certain level of performance relative to ideal DMRS bundling is to be ensured, then maximum duration also depends on the phase jitter observed across slots. * **RAN1 question:** Whether the maximum duration should be the same for different cases for both PUSCH and PUCCH?   + **RAN4 answer:** Yes * **RAN1 question:** Whether the maximum duration is dependent on the modulation order of transmission, e.g., QPSK, 16QAM, 64QAM?   + **RAN4 answer:** If a certain level of performance relative to ideal DMRS bundling is to be ensured, then maximum duration depends on modulation order. * **RAN1 question:** Whether the maximum duration is dependent on UL waveform (DFT-s-OFDM vs. OFDM)?   + **RAN4 answer:** No * **RAN1 question:** Whether the maximum duration is band specific?   + **RAN4 answer:** It is FR dependent, maybe band dependent as well. * **RAN1 question:** Besides the factors listed above, whether or not the maximum duration is further dependent on UE capabilities (e.g., multiple possible values for a given set of factor(s)), and if so, whether the UE should report such a duration   + **RAN4 answer:** Yes |

## Open issues summary

### Sub-topic 1-1: Non-zero un-scheduled gap in-between repetitions

**Issue 1-1-1: Maximum length of un-scheduled gap, i.e., feasibility of 14 symbols or 1 ms for different SCSs for the un-scheduled gap**

* *RAN4 #99e agreements (in LS R4-2107880)*
  + *RAN4 has continued discussing the un-scheduled gap consisting of unscheduled symbols between two PUCCH repetitions or PUSCH transmissions and reached a conclusion that it is feasible for UE to maintain phase continuity when the gap is 13 symbols or less. RAN4 is still discussing the feasibility of 14 symbols or 1 ms for different SCSs for the un-scheduled gap. Main drawback RAN4 sees with long gaps is UE energy efficiency since it needs to maintain TX parts active but UE is not transmitting and the issue of existing OFF power requirements not being satisfied for less 1ms duration.*
* Proposals
  + Option 1: Less than 14, 28, 56, and 112 symbols for SCS of 15, 30, 60, and 120 kHz, respectively (Nokia)
  + Option 2: 1ms for different SCS (ZTE)
  + Option 3: 14 symbols for all SCS (HW, QC)
    - HW: If too much gap slots is allowed be in-between the repetitions, it will add implementation complexity to UE. If we use 1ms, it means more than 1 slot for >15kHz SCS would be there, so we prefer to use the number of OFDM symbol for all SCS other than use time length.
    - QC: Exceeding 14 symbols maybe possible but not preferrable since all the circuitry needed to maintain the phase consumes power and from UE point of view, the benefit of repetitions compared to a higher power amplifier implementation diminishes with long gaps because of this idle current consumption. With > 14 symbols gaps it seems there is only losses on both network and UE sides.
  + Option 4: Need further study (MTK)
    - MTK: Firstly gain a common understanding on likely acceptable phase tolerance before making further agreements on whether feasible gap lengths.
* Recommended WF
  + Is it agreeable to go with option 3, which looks a compromise among different options?

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| **Company** | **Comments** |
| Ericsson | Option 4. There is two track discussion ongoing related to the phase continuity. One track is to maintain a tight phase continuity without the BS phase discontinuity tolerance simulation and investigation, this track is based on the UE PA will be kept power On during un-scheduled or non-zero gap period; the other track is to reach consensus of phase discontinuity tolerance and investigate how UE could meet this tolerance with proper design. One track may be needed, or give a clearly assumption on the first track on what phase continuity magnitude it is and maybe it will be helpful later on to see if such assumption should be revisit after phase discontinuity tolerance would be agreed.  Companies also see this scenario as an unrealistic scenario considering the UE power consumption if the period is too long and the “gain” may be loss if the period is too short. Considering also the related RF OFF power requirement, such scenario could be down-prioritized as another alternative. |
| ZTE | From our understandings, the gap length should reply on the phase/power shift during the non-scheduled gap, this should be similar for different SCS, we would like to further discuss this with other companies. In addition, I think option 1 (Nokia) and option 2 (ZTE) is the same proposal just in different form. |
| Huawei, HiSilicon | Option 3. For SCS other than 15kHz, allowing 1ms gap means >1slot length gap, it has impact on SW design and HW design. So we prefer the gap length takes symbol granularity for all SCS. |
| MediaTek | Option 3 could be acceptable. However, we would like to emphasize the UE battery consumption, constraints such as lack of Timing adjustment. Regarding Nokia comment (in their doc) on UE power consumption, of course if the gap can be kept minimal then everybody wins. So RAN1 should also justify also why they need such a long gap and why limiting to a few symbols is not enough, and whether with such long gaps they actually see the JCE gains they were expecting. |
| Sony | Maybe option 4 is the best until we conclude the phase tolerance. Then, the exact value may need to be FFS since RAN4 has not concluded the phase/amplitude tolerance value. However, we believe the value should depend on absolute time rather than a fixed number of symbols. |

**Issue 1-1-2: RF requirements for the non-scheduled gap**

* *RAN4 #99e agreement (in WF R4-2107881)*
  + *For transmit power on the gap symbols that less than or equal to 1ms, RAN4 down select solution from following options:*
    - *Option 1: define new transmit off power for gap symbols less than or equal to 1ms explicitly for Rel-17 coverage enhancement case*
    - *Option 2: RAN4 do not introduce new transmit off power*
    - *Option 3: The existing OFF power requirement apply to the un-scheduled gap*
* Proposals
  + Option 1: Define new transmit off power for gap symbols less than ~~or equal to~~ 1ms explicitly for Rel-17 coverage enhancement case (HW, QC, [MTK])
    - HW: Define additional off power requirement for <1ms duration case, the definition is -50dBm-10log(X/1ms)
    - QC: If OFF power measurement period is made shorter, the dBm value for OFF power should be relaxed, due to the difference on the integration time for OFF power, as explained below.



* + - MTK: Confirm that OFF power level cannot be achieved during non-zero un-scheduled gap, and that any power level requirements in the gap would need to adhere to existing Carrier Leakage requirements.
      * While the UE transmitter is ON during the gap, Carrier Leakage may be present.
      * If the UE requires repetitions, then this would likely be because the UE already has its transmitter configured for maximum output power, meaning that the residual power level observed during the gap could be in the region of -5dBm for a PC3 UE, and -2dBm for a PC2 UE.
  + Option 2: RAN4 do not introduce new transmit off power for less than 1ms (Nokia)
    - Nokia: RAN4 should avoid extra specification efforts that do not yield the complete benefit on the new feature.
  + Option 3: The existing OFF power requirement apply to the [1ms] un-scheduled gap (E///, ZTE, HW)
    - E///: The existing TX OFF requirement should be applied to avoid the degraded SINR at network.
    - ZTE: OFF power requirement for non-zero un-scheduled gap should still be guaranteed.
    - HW: If RAN4 do nothing for the < 1ms duration, transmit off power is only measured with at least 1ms duration.
* Recommended WF
  + Further discuss/clarify the following aspects:
    - For option 1 with less than 1 ms OFF power measurement period, it seems the proposed dBm values for OFF power are quite different. Further clarification/discussion on the values is needed.
    - Option 2 is an alternative option for less than 1ms gap.
    - For option 3, can we clarify that this option is only applicable for 1ms gap (if agreed in Issue 1-1-1)?

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| **Company** | **Comments** |
| Ericsson | Option 3. It will be difficult to agree a new RF OFF requirement between (-40 dBm Min output power to -50 dBm OFF power). If the new “OFF” power would be agreed by any means, what does the “Old” OFF power suppose to mean? But maybe it would be ok to discuss the transient time due to the legacy measurement time of 1ms. If more symbol is used to be gap filler for the OFF power requirement, the usefulness of this scenario would be doubtful and thus could be deprioritized in RAN4. |
| ZTE | Option 3: we think ON-OFF transition period in the gap should be still ensured, in other words, UE still switch from ON-OFF after the ON-OFF transition period, however due to the shorter measurement time for OFF power, then some measurement uncertainty could be introduced if necessary, however this should be RAN5 discussion instead of RAN4 for measurement uncertainty. |
| Huawei, HiSilicon | Option 1/2/3 are OK for us. For option 1, both new relaxed off power and LO leakage works for us. for on-off and off-on time mask, should the current requirement 10us applies for FR1. |
| MediaTek | **Option 2 is preferred for sub-1ms gap.** *Also, just to clarify that in our paper we were not proposing to define an OFF value, we were just highlighting the likely impacts - based on current specs - in case one was defined.*  **Regarding the 1ms gap,** the issues discussed in our paper are valid here too. We never said that this was only for sub-1ms case I believe. Phase maintenance requires different operating assumptions compared to the legacy scenario in which the OFF power requirements were established, and it is not just about the time length.  So we prefer **“*Option 4: For 1ms gap, the existing OFF power requirements are not valid either and do not define any new requirement*”.** |
| Qualcomm | Option 2 is our preference. Our proposal (Option 1) is condition, “if new req is introduced” the limit should be considered and not just shorten the evaluation period. |

### Sub-topic 1-2: Non-zero gap with other uplink transmissions

**Issue 1-2-1: Non-zero gap with other uplink transmissions for the UE**

* *Agreement in RAN4 #99e (in WF R4-2107881)*
  + *Scenario 1: if the other scheduled signals/channels during the non-zero gap have the* ***same*** *settings in antenna port, occupied PRBs and UL power than the repeated transmission signals/channels*
    - *Whether it is beneficial to define a Guard period for scenario 1:*
      * *Option 1: In the case of different channel in between two repetitions, a guard period before returning to the repetitions is defined. Length of guard period is Y is FFS but shall not exceed 2 symbols.*
      * *Option 2: FFS. It is not clear why guard period can help make the phase aligned with before transmission.*
  + *Scenario 2: If the other scheduled signals/channels during the non-zero gap have the* ***different*** *settings in antenna port, occupied PRBs or UL power than the repeated transmission signals/channels*
    - *Option 1: a guard period before returning to the repetitions is defined. Guard allows also different RBs and power levels for the other channels as agreed to be studied in the previous WF. Length of guard period is Y is FFS but shall not exceed 2 symbols.*
    - *Option 2: Phase continuity and power consistency cannot be guaranteed.*
    - *Option 3: Further investigation is needed* 
      * *If the phase discontinuity for non-zero gap with other uplink transmission is within such tolerance value, this case can be supported.*
* Proposals for the above scenario 1
  + Guard period for scenario 1
    - Option 1: A guard period is needed (Sony, QC)
    - Option 2: not needed (MTK, ZTE)
  + Conditions for scenario 1
    - Issue 1 on RB location (MTK)
      * Occupation of **different specific PRBs** by the intermediate signal could be acceptable, if the resulting power levels (after any MPR) and RF configuration do not change during the gap
    - Issue 2 on modulation order (QC)
      * Earlier agreement in LS does not mention that modulation order of the other channels needs to be the same
* Proposals for the above scenario 2
  + Option 1: A guard period is needed (Sony, QC)
  + Option 2: Phase continuity and power consistency cannot be guaranteed (MTK, ZTE)
    - MTK: phase cannot be guaranteed to be maintained from UE perspective if intermediate signals are present during the gap that require different resulting output power levels (after any MPR) and RF configuration changes.
  + Option 3: Further investigation is needed (E///)
* Recommended WF
  + Further discuss for the two scenarios.

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| **Company** | **Comments** |
| Ericsson | Scenario 1: option 2, scenario 2: option 3.  The guard period issue relates to the CFO impact and it is not clear how the retuning impact on the BS CFO estimation and compensation. As this is related to the phase discontinuity tolerance so it could be revisited after the phase discontinuity is agreed. The condition especially could be tied to the phase discontinuity tolerance. |
| ZTE | For scenario 1: support option 2, whether these RB locations are also the same as repetition signals should be clarified after, the current wording,only the occupied PRBs is mentioned.  For scenario 2: support option 2  e still have some concerns on how to store the original phase and return back. If this possible, why is this not applicable for lots of other cases.e.g. ON-OFF transition period and frequency hopping, antenna switching etc. |
| Huawei, HiSilicon | For scenario 1, gap period is not needed. For modulation order, if it mainly relates to the transmit power considering MPR, then same out power already includes this aspect.  For scenario 2, if guard period is used for PLL adjusting, that would be time consuming. From RRM requirement perspective, more than 1 slot is impacted(how may slots depends on SCS). If above understanding is correct, we need to further evaluate the gain by using this method. To QC, what is the expected UE behavior during the period? |
| IDC | In our view, if phase mitigation measures are used, like insertion of the PT-RS, from the first slot in the bundling window and in each following repetition slots, the gNB receiver can estimate and correct the phase continuity related issues.  We propose to consider for this kind of gap related scenarios to use PT-RS that would resolve the phase continuity issues. |
| MediaTek | Scenario 1: Option 2  Scenario 2: Option 2. This adds UE complexity and still unclear to us how it would work. It should also be understood why Scenario 1 is not sufficient from a system operation perspective. |
| Sony | To our understanding, we think a guard period is needed as long as the phase/amplitude retuning is performed.   * For scenario 1, if RAN4 would conclude that retuning is not be needed, then the guard period can be skipped. Otherwise, the guard period would still be required. * For scenario 2, we think it is crucial to allow UE to perform retuning phase/amplitude to enable the JCE under more scenarios. Therefore, a guard period would be needed. We would also like to point out this operation can also support the case where the DL slots are in between UL repetitions since the phase can be turned back. |
| Qualcomm | Scenario 1: option 1, scenario 2: option 1.  For scenario 1, it is fairly difficult to ensure the UL power is the same for other channels in between repetitions since the independent power control process. Ran4 should discuss how same power can be ensured. In regards Huawei comment “it is not clear” seems like an implementation question and academic literature has many examples on how to return to the specific phase. We can agree not to have the guard period for scenario 1 once we know more about the conditions for retaining the mentioned parameters, such as ensuring PUSCH/PUCCH part of repetitions and SRS has same PAPR and AVG power.  For scenario 2, since this is requires UE to change its settings, guard is definitely needed but we are ok to exclude the case completely. |

### Sub-topic 1-3: TA adjustment impact on phase continuity

* *Agreement in RAN4 #99e (in WF R4-2107881)*

*For RAN1 Question 1 on TPMI change and Question 2 on TA impact: there are transmission timing errors associated with TA adjustment and UE uplink timing autonomous adjustments. Transmission timing errors cause the phase change.*

* + *For network commanded TA adjustments:*
    - *It is known by both gNB side and UE side.*
    - *FFS how to handle the transmission timing error in TA inaccuracy.*
  + *For UE autonomous adjustments:*
    - *FFS whether the autonomous adjustments can be handled by UE or BS and how to handle.*

**Issue 1-3-1: For network commanded TA adjustment**

* Proposal
  + Option 1: Network commanded TA adjustments should be avoided in betweenthe repetition (MTK, ZTE, E///, HW, QC)
    - E///: BS receiver seems to tolerate the UE time error for narrowband RB allocation. For wider RB allocation the time error is not ignorable, the UE time error should be avoided system level.
  + Option 2: (CTC)
    - For network commanded TA adjustment, which is known to both UE and BS, the corresponding phase change can be pre-compensated at UE baseband processing or compensated at BS baseband processing.
    - For TA adjustment tolerance, which it is known to UE and probably not known to the BS, the corresponding phase change can be pre-compensated at UE baseband processing, or alternatively, BS can estimate the timing tolerance/adjustment based on uplink reference signal and compensate the corresponding phase change in baseband processing.
* Recommended WF
  + Is it possible to agree with option 1 based on majority companies’ support?

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| **Company** | **Comments** |
| Ericsson | Option 1. TA should be avoided. As a matter of fact, the BS also introduce the “time error” due to the TA granularity. |
| ZTE | Option 1.TA command during the different repetitions would introduce TA inaccuracy resulting in high phase shift for different repetitions, this should be avoided. |
| Huawei, HiSilicon | Option 1, this is because it is hard to define UE or gNB behavior on TA compensation, it is better to avoid any adjustment during JCE window to ensure on the performance gain. |
| IDC | Option 1. Since TA commands are under gNB control, they can be avoided. Or the UE can delay TA application until the end of the bundling window. |
| MediaTek | Option 1, for same reasons as others above. |
| Sony | Option 1. |
| Qualcomm | Option 1 is preferred. For CTC, the error still remains if UE tries to compensate. It is not possible for UE to know the error it has. |

**Issue 1-3-2: For UE autonomous adjustment**

* Proposal
  + Option 1: UE autonomous adjustment is not expected in betweenthe repetition (MTK, [E///], QC)
    - E///: 1) BS receiver seems to tolerate the UE time error for narrowband RB allocation. For wider RB allocation the time error is not ignorable, the UE time error should be avoided system level. 2) If the UE autonomous uplink time adjustment is disabled, the RAN1 specification impact is not avoidable.
  + Option 2: Up to UE implementation (ZTE, HW)
  + Option 3: The corresponding phase change can be pre-compensated at UE baseband processing, or estimated and compensated at BS baseband processing. (CTC)
    - CTC: For UE autonomous adjustment, it applies when the transmission timing error between the UE and the reference timing exceeds a threshold, i.e., when the propagation delay between the BS and UE changes due to UE movement.
* Recommended WF
  + Further discuss the following aspects:
    - For option 1, do we need to ask RAN1 to check if there is any RAN1 spec impact?
    - For option 2, if UE autonomous adjustment is allowed but not (pre-)compensated, would it be possible to still keep phase tolerance within certain level?
    - For option 3, feasibility of the (pre-)compensation at UE/BS baseband processing needs to be checked.

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| **Company** | **Comments** |
| Ericsson | Option 1. It is difficult to be compensated at BS for the time error associated with either TA or autonomous UL time adjustment. This issue also may be coupled to the constant CFO which BS receiver would expect for the JCE to work well. So if constant CFO could be guaranteed at UE, maybe there would not be autonomous UL time adjustment, this, however, need UE vendor confirmation. |
| ZTE | Option 1 might be also fine for us since UE autonomous adjustment is larger than TA command inaccuracy, however how to mandate UE not to any UE autonomous adjustment should be further clarified in UE RRM spec. |
| Huawei, HiSilicon | We prefer option 2. We cannot just avoid UE autonomous adjustment considering the user behavior and environment change. But this phase variation can be included in the phase tolerance and evaluated upon UE implementation. |
| IDC | Option 3: Using the PT-RS as a mitigation measure, a normal UE operation can be allowed, as the gNB may detect [phase changes and correct them using PT-RS reference from the first repetition slot in the bundling window. |
| MediaTek | Option 1 as a baseline. Regarding Huawei proposal, if this were included in the tolerance, would this not result in reducing the tolerance budget for the UE due to other implementation aspects? |
| Sony | Option 1. |
| Qualcomm | Option1, ask ran1 is possible or then just agree to disable the TA adjustement. Or then we can ask ran1 if it is feasible to disable. This is related to max duration, if duration is very long, TA may be needed, if short, it maybe ok to disable. |

### Sub-topic 1-4: Phase continuity and power consistency tolerance

**Issue 1-4-1: Phase continuity tolerance**

* Proposed phase continuity tolerance **between two adjacent UL transmissions** based on simulation results
  + Option 1: within 40 degrees (Sony)
    - Sony: Simulation for PUCCH format 3, total 8 PUCCH transmissions in every second slot
      * The performance of joint channel estimation can be further improved with optimized estimator design, in other words, allow larger phase tolerance.
  + Option 2: within 30 degrees (MTK, ZTE)
    - MTK: Simulation for PUSCH QPSK
    - ZTE: Simulation for PUSCH QPSK, two UL transmissions
  + Option 3: (E///)
    - For PUSCH QPSK, in the order of 20 degrees for 8 repetitions
    - For PUCCH format 3, 40 degree’s STD for 2 repetition and 20 degree’s STD for 8 repetition
* Recommended WF
  + Encourage feedback from chipset/UE side on the implementation feasibility for the above numbers

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| **Company** | **Comments** |
| Ericsson | Option 3, this is initial simulation results and we need further to align with different companies simulation result with simulation assumption. |
| ZTE | Option 2, maybe stable and agreeable simulation assumptions for NR coverage enhancement in this meeting is preferred for further progress. |
| Huawei, HiSilicon | We prefer option 1. |
| MediaTek | Option 1/2. But probably instead of picking values derived from different input assumptions, we should focus on further aligning the assumptions. |
| Sony | We are open for further discussion, and it is needed to align the simulation assumption further before we can agree on any number. In our view, the phase variation model and the gNB receiver design are important aspects to be agreed upon. |

**Issue 1-4-2: Model of phase variation**

* *Agreement in RAN4 #99e (in WF R4-2107881)*
  + *Explicit Phase offset:*
    - *Option 1: Gaussian, std deviation (10°, 20°, 30°, 40°, 50°)*
    - *Option 2:* *uniform distribution*

*[-0°,0°], ~, [-90°,90°] for BPSK*

*[-0°,0°], ~, [-40°,40°] for QPSK*

*[-0°,0°], ~, [-10°,10°] for 16QAM*

* + - *Option 3: fixed values (10°, 20°, 30°, 40°, 50°,60°)*
    - *Other option not precluded*
* Proposals
  + Summary of phase offset models used in the simulations
    - Option 1: Gaussian, std deviation (E///)
    - Option 2: uniform distribution (Sony, MTK)
    - Option 3: fixed values (ZTE)
  + Proposal 1: RAN4 needs to agree the model of phase variation for aligning the simulation setup(Sony)
* Recommended WF
  + Encourage further discussion

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| **Company** | **Comments** |
| Ericsson | Option 1.  It would be easier to understand to use gaussian or uniform districution as to pick up a number for each repetition slot from the Gaussian or Uniform generator, so each repetition slot irrespective in which time slot always compare to the initial transmission time slots with the random phase addition. The fixed value behaviour need to be clarified, for two repetition, it would be ok, for more repetition, would all the repetition time slot except the initial one has the same phase offset relative to the initial time slot which in turn between any two of these time slots the phase offset will be zero? Or the fixed phase offset is between any two repetition time slot? Then the total phase offset for 8 repetition if reference to the initial time slot would be 8 \* fixed offset = 8 \* 40 = 320 degree? |
| ZTE | Option 3: for two repetitions with fixed values should be fine since this is worst case for evaluation otherwise phase error impact might be reduced at the end. Like TAE evaluation in UTRA or frequency error 0.1ppm, we always use fixed value instead of random distributed value. For multiple repetition cases, then maybe gaussian or uniform districution could be considered, however I have one question why this phase offset value could be randomly distributed among different repetitions if option 1 and option 2 is approved, is that aligned with practical UE implementation. |
| Huawei, HiSilicon | We prefer uniform distribution, the probability on the phase variation for each slot is the same within a range. |
| IDC | We prefer Option 2. Random phase offset, modelled as a uniformly distributed random variable, can be generated for each slot. |
| MediaTek | Will add more detailed comments tomorrow on the different options. |
| Sony | No strong opinion on the candidates, but we think it is important to align the model. |

**Issue 1-4-3: Definition of phase continuity tolerance**

* Proposals
  + Issue A: Definition for the requirements and reference point
    - Option 1: RAN4 define the “phase continuity” considering the proposal below as a starting point. (E///)
      * For the same signal transmitted repeatedly in a multiple time slot set, the difference between the phase of the complex received signal of this data in different time slot at the reference point is within a pre-defined tolerance range.



* + Issue B: Definition of measurement point
    - Option 1: RAN4 discuss whether the measurement of the phase/amplitude variation should be defined together with the potential RF requirements relating the UE coherence transmission. (E///)



* + Issue C: RAN4 has not discussed **aggregated** phase continuity requirement over all transmissions that are part of same repetition bundle. (QC)
* Recommended WF
  + Encourage feedback on the three issues.

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| **Company** | **Comments** |
| Ericsson | Issue A: it will be good to use this definition to align the understanding between companies. The phase continuity is referenced before the channel estimation, otherwise there is no need to ask UE to have tight coherence transmission.  Issue B: This is the first time to discuss the measurement issue, it will be good to have companes input on this. |
| ZTE | We intend to agree this should be discussed, however how to measure phase continuity could be FFS.  From my initial understanding, this should be similar as frequency error estimation, this could be done by correlation of DMRS estimation in different repetitions. |
| Huawei, HiSilicon | Issue A: we are OK to align the definition. To Ericsson, for the proposed definition, is the “phase difference” mean “average phase difference within a time period”? Do we assume the completion phase of the 1st PUSCH(transmission) and the start phase of the 2nd PUSCH(tranmission) are the same(within some level tolerance) or the gap will change the phase accordingly? The phase is defined on the maximum difference within the repetitions or the difference between slots?  Issue B: we need to further check on this reference point. We have a question on TE side, do we need some additional step compared with current measurement, e.g. we need to ensure on the RF compensation method, it is done for each slot or across slots/repetitions? |
| MediaTek | Issue A: Good starting point, but it would be better to talk about transmission instances rather than slots. Also the RF impairment compensation function and the channel function would need further clarification.  Issue B: We are fine to discuss this further, but may be done at a later stage?  Issue C: We assume that some level of aggregate requirement would be needed across the repetition bundle. |
| Sony | Issue A: we are fine with the proposed definition of the requirements. |

**Issue 1-4-4: Power consistency tolerance**

* Proposals based on simulation results
  + Option 1: 2 dB power variation with uniform distribution (Sony)
    - Sony: The impact of power inconsistencies across UL slots is neglectable with a uniformly distributed power variation of 2 dB no matter the phase inconsistency.
  + Option 2: 1 dB fixed power offset (0.5 dB amplitude offset) (ZTE)
* Recommended WF
  + Encourage feedback from more companies.

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| **Company** | **Comments** |
| Ericsson | Option 3 (to be decided) , we need time to simulate it and will provide the result next meeting. |
| ZTE | maybe stable and agreeable simulation assumptions for NR coverage enhancement in this meeting is preferred for further progress. |
| Huawei, HiSilicon | We want more time to check on power inconsistency. One comment would be, if impact of power inconsistencies across UL slots is neglectable, do we need to define the requirement for JCE? |
| MediaTek | For QPSK we came to similar conclusion as Sony. However, if there is any value in defining JCE for higher order modulation (which we doubt, on the basis that the UE is at the edge of coverage), then the impact of power inconsistencies for those modulation schemes would need further evaluation from our side. |
| Sony | We are fine to have further discussion on this point. Based on our simulation results, we have not observed a significant impact from amplitude on the JCE gain. |
| Qualcomm | It should separately analysed for no gap, unscheduled gap, with other UL channels with same parameters and gap with other channels with different parameters. Can we assume these are for no other UL channel in the gap? |

**Issue 1-4-5: Impact from frequency offset**

* Proposals
  + Option 1: CFO/frequency offset compensation at the receiver is considered (Sony, MTK, E///, QC)
    - Sony: The frequency offset needs to be taken care of by the receiver side, and its effect can be mitigated.
    - MTK: Our results include CFO compensation at the receiver, as when we evaluated in the absence of CFO compensation the performance for both JCE and non-JCE was heavily degraded. However, Base Station vendors should give feedback on feasible CFO compensation with JCE.
    - E///: CFO should be compensated for JCE specifically.
      * The frequency error added additional phase rotation has negative impact on coherent combining for JCE.
      * It is desirable to assume the constant frequency error between the repetition interval for JCE otherwise JCE may not work well.
      * There is no specific UE behavior on when UE make the frequency adjustment in RAN1 specification.
    - QC: Phase drift due to CFO is a problem regardless of gaps between repetitions and need to be solved in the receiver.
* Recommended WF
  + Agree with option 1 based on companies’ proposals.

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| **Company** | **Comments** |
| Ericsson | CFO always should be compensated in BS, this is not new for JCE. The new CFO condition for JCE to work well is the constant CFO between repetition time slot otherwise BS will not sure how to compensate CFO between the non-zero gap between repetition transmission. For zero-gap repetition, it will be hard to image the CFO would be changed as in each time slot transmission the CFO should be kept constant, so overall, the constant CFO should be a prerequisite for BS compensation. |
| ZTE | We support option 1 |
| Huawei, HiSilicon | CFO is always be compensated by BS, including CFO on UE and BS side, and also Doppler shift. The only problem is the leftover phase offset after compensation will have impact on the JCE performance. We should not consider 0.1PPM CFO into perf evaluation, but the leftover. |
| IDC | Option 1. We suggest again to use the PT-RS as mitigation measure.  Insert PT-RS in each repetition slot and then measure the phase continuity against the first slot in the bundling window and compensate accordingly. |
| MediaTek | Option 1 needs to be clarified a bit. Should say something like “*full compensation of CFO is assumed to be performed at the receiver*” |
| Sony | We are fine with the recommended WF. |
| Qualcomm | Agree with recommended WF. |

### Sub-topic 1-5: Maximum duration for joint channel estimation

*RAN1 questions in R1-2106212:*

* *For joint channel estimation, is there a maximum duration during which UE is able to maintain power consistency and phase continuity under certain tolerance level? If any, how long is it?*
  + *What factors determine the maximum duration?*
  + *Whether the maximum duration should be the same for different cases for both PUSCH and PUCCH?*
  + *Whether the maximum duration is dependent on the modulation order of transmission, e.g., QPSK, 16QAM, 64QAM?*
  + *Whether the maximum duration is dependent on UL waveform (DFT-s-OFDM vs. OFDM)?*
  + *Whether the maximum duration is band specific?*
  + *Besides the factors listed above, whether or not the maximum duration is further dependent on UE capabilities (e.g., multiple possible values for a given set of factor(s)), and if so, whether the UE should report such a duration*

**Issue 1-5-1: For joint channel estimation, is there a maximum duration during which UE is able to maintain power consistency and phase continuity under certain tolerance level?**

* Proposals
  + Option 1: Yes (Nokia, China Telecom, ZTE, E///, HW, QC)
* Recommended WF
  + Agree with option 1 based on companies’ proposals.

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| **Company** | **Comments** |
| Ericsson | Option 1. |
| ZTE | Option 1. |
| Huawei, HiSilicon | If UE meets the EVM requirement of each modulation order, there should be limited impact on JCE, but the phase continuity of each sampling could be impacted by different modulation order. This depends on how to define the phase continuity across slot/transmission. RAN4 should make clear on modulation order impact to JCE other than phase. |
| IDC | Option 1. |
| MediaTek | Agree with Option 1. |
| Sony | Option 1. |
| Qualcomm | Yes, option 1 |

**Issue 1-5-2: If there is a maximum duration, how long is it?**

* Proposals
  + Option 1: The maximum duration should depend on the interval where the UE does not make frequency adjustment. Such maximum duration could be counted as the length of the SSB periodicity and depending on UE implementation. (E///)
    - The minimum maximum duration should be 160ms which corresponds to the largest SSB period in NR Rel-15. (E///)
* Recommended WF
  + Is it agreeable that the length of the maximum duration is up to SSB periodicity? Any other proposals on the candidate value or the upper bound?

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| **Company** | **Comments** |
| Ericsson | Option 1. |
| ZTE | More discussion might be needed |
| Huawei, HiSilicon | During connected mode, UE is not required to re-sync with SSB. The MD is highly dependent on the gNB frequency offset compensation accuracy even within a sync periodicity. |
| IDC | Option 1. But probably is related to the UE implementation/capability as well. |
| MediaTek | Option 1 does not take into account any restrictions/complexity at the UE side and the gain of JCE over long time bounds.  Further consideration is needed on this before responding to RAN1, and an understanding of acceptable phase tolerance seems a pre-requisite for that. |
| Qualcomm | That would depend on requirements. We should ask ran1 or then agree what is the requirement, such as what is the benefit of JCE in SNR improvement with certain UE requirements and then find out how long UE can maintain Tx these requirements. |

**Issue 1-5-3: What factors determine the maximum duration?**

* Proposals
  + Proposal 1: Energy efficiency and thermal changes (MTK, [Nokia])
    - Nokia: RAN4 should not focus only on the energy consumption to maintain at least the transmit RF chain active throughout the time window for joint channel estimation, but rather on the overall energy efficiency of this operation.
  + Proposal 2: The maximum time the UE not adjusting its frequency/time. (E///, QC)
    - QC: Factors determining could include UE ability to defer frequency error corrections, timing corrections, etc.
  + Proposal 3: Phase tolerance within the duration (ZTE, QC)
    - ZTE: Downlink pathloss/RSRP and timing/frequency variation within the duration, the phase error/frequency error from PLL and PA output power stabilization in RF Tx chain
    - QC: If a certain level of performance relative to ideal DMRS bundling is to be ensured, then maximum duration also depends on the phase jitter observed across slots.
  + Proposal 4: Channel BW (HW)
    - HW: In addition to the other factors, channel BW has impact on the accuracy of frequency offset evaluation
  + Proposal 5: For JCE window length determination, discuss the addition of PT-RS for simulation assumptions for the cases where phase continuity tolerance prove to be problematic for the JCE feature gain. (IDC)
* Recommended WF
  + Encourage feedback on each of the above proposals.

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| **Company** | **Comments** |
| Ericsson | The clock stability is one factor for defining the maximum duration. To relate the maximum time duration also to the PA design would need more discussion. The phase continuity performance relates to the how the PA is controlled and also the thermal change, but there is doubt that RAN4 would define a complex phase discontinuity tolerance requirement with different condition (switch on/off PA, thermal change condition, different PA design, the power difference between different time slot etc etc). If the repetition is up to 8 and even less, some condition may be not critical. The PA behavior (phase/amplitude response) is more statistical rather than related to time from testing perspective. |
| ZTE | All factor proposed could be merged if agreeable |
| Huawei, HiSilicon | The key issue is, the left over frequency offset across slots on gNB side we can expect. |
| IDC | We believe that it is important for a consistent window duration determination to use PT-RS insertion in each repetition slot as a mitigation method, at least for the problematic/difficult scenarios. |
| MediaTek | At least proposals 1, 2, 3.  Proposal 4 requires more clarification.  Proposal 5 may need further clarification in RAN1 of the resulting gains? |
| Sony | At least proposal 3. In our view, the duration needs to be estimated under a certain phase tolerance. Therefore, to agree on the phase tolerance is the first step to derive the duration time.  Under a certain phase tolerance, we also observed that the channel BW could affect the JCE gain. The larger BW that DMRS can spread over, The better JCE gain can be obtained based on our simulation results. |
| Qualcomm | That would depend on requirements. We should ask ran1 or then agree what is the requirement, such as what is the benefit of JCE in SNR improvement with certain UE requirements and then find out how long UE can maintain Tx these requirements. |

**Issue 1-5-3: Whether the maximum duration should be the same for different cases for both PUSCH and PUCCH?**

* Proposals
  + Option 1: the same (Nokia, ZTE, E///, QC)
  + Option 2: the same, when the moderation order is the same (MTK)
* Recommended WF
  + Can we agree that: the maximum duration should be the same for different cases for both PUSCH and PUCCH when the moderation order is the same?
  + The case of different modulation orders can be discussed separately in Issue 1-5-4.

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| **Company** | **Comments** |
| Ericsson | Option 1. |
| ZTE | Option 1. |
| Huawei, HiSilicon | Not a factor. |
| IDC | Irrelevant to the channel type. The maximum duration may depend on UE capability. |
| MediaTek | Recommended WF seems fine, but should say “modulation order”. |

**Issue 1-5-4: Whether the maximum duration is dependent on the modulation order of transmission, e.g., QPSK, 16QAM, 64QAM?**

* Proposals
  + Option 1: Not dependent on the modulation order (ZTE, E///)
  + Option 2: Modulation order (may) have impact on the maximum duration (MTK, HW, QC)
    - Option 2A: Shorter duration for higher modulation order (MTK)
      * MTK: Higher orders of modulation will likely lead to lower acceptable phase and power tolerance
    - Option 2B: Modulation order may has impact on phase continuity, but the impact on JCE may need further evaluation (HW)
    - Option 2C: If a certain level of performance relative to ideal DMRS bundling is to be ensured, then maximum duration depends on modulation order. (QC)
* Recommended WF
  + Encourage further discussion

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| **Company** | **Comments** |
| Ericsson | Simulation shows there is no gain for JCE for higher modulation, considering also even more tighter phase /amplitude tolerance, this should be deprioritized. |
| ZTE | We support option1, if for different modualtion order to define different phase tolerance, then this might introduce more scheduling restriction at the end ,therefore single value should be preferred. |
| Huawei, HiSilicon | If UE meets the EVM requirement of each modulation order, there should be lilmited impact on JCE, but the phase continuity of each sampling could be impacted by different modulation order. This depends on how to define the phase continuity across slot/transmission. RAN4 should make clear on modulation order impact to JCE other than phase. |
| IDC | May depend on at least modulation order but there could be other factors as well. |
| MediaTek | If there is tighter phase tolerance due to modulation order, then we assume it would impact the duration hence why we proposed Option 2A. So it was purely answering the question.  However, the rationale for the channels selected to optimize were that these were bottlenecks at the edge of coverage. So in principle we wonder why the UE would be operating higher order modulation in uplink in an edge of coverage scenario. Why not go to QPSK first? |
| Sony | In general, we think the modulation order has an impact on the JCE gain (the higher order the lower JCE gain). However, we also share similar view as MTK that the JCE would not likely be performed under a high-order modulation scheme since it is mainly used under a UL-limited scenario. |

**Issue 1-5-5: Whether the maximum duration is dependent on UL waveform (DFT-s-OFDM vs. OFDM)?**

* Proposals
  + Option 1: Not dependent on UL waveform (Nokia, ZTE, E///, QC)
  + Option 2: Only consider DFT-s-OFDM for coverage extension scenario (MTK)
* Recommended WF
  + Considering RAN1 LS has already considered both DFT-s-OFDM and OFDM waveforms, can we go with option 1?

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| **Company** | **Comments** |
| Ericss | Option 1 |
| ZTE | Option 1 |
| Huawei, HiSilicon | Option 1 |
| IDC | Option 1 |
| MediaTek | We understand that Option 1 is ok, but if DFT-s-OFDM was purely specified to improve uplink coverage, why is the UE operating OFDM in this scenario? |

**Issue 1-5-6: Whether the maximum duration is band specific?**

* Proposals
  + Issue A: whether it is FR dependent
    - (Maybe) Yes: QC, Nokia, HW,ZTE
    - No: E///
  + Issue B: whether it is band dependent for the same FR
    - (Maybe) Yes: QC, HW
      * HW: Different operating frequency may cause the ‘compensation leftover for frequency error’ be different. And UE’s ability on different RF components to maintain the phase continuity could be different.
    - No: Nokia, ZTE, E///
* Recommended WF
  + Encourage further discussion

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| **Company** | **Comments** |
| Ericsson | Issue A: No, Issue B. No. However, we need to agree the factors impacting the maximum duration then it will be easier for this issue to discuss. |
| ZTE | Issue A: Yes, more simulation might be needed for FR1 and FR2  Issue B: No |
| Huawei, HiSilicon | Issue A: Yes  Issue B: Yes |
| IDC | Issue A: Yes  Issue B: It depends, as FDD vs. TDD bands would have a different window behavior/determination due to TDRA. |
| MediaTek | Issue A: Yes likely.  Issue B: The gains of different configurations for different bands is not clear to us, and the complexity could be huge and harm the success of the feature. |
| Qualcomm | It is fairly hard to analyse RF for all bands so safe to say it is band dependent. |

**Issue 1-5-7: Besides the factors listed above, whether or not the maximum duration is further dependent on UE capabilities (e.g., multiple possible values for a given set of factor(s)), and if so, whether the UE should report such a duration**

* Proposals
  + Option 1: Yes (QC)
  + Option 2: Subject to a single maximum duration (Nokia, ZTE)
    - Nokia: A RAN4 requirement on a minimum maximum duration could help ensuring that a minimum maximum duration is at least supported by all UEs, hence enabling a minimum degree of enhanced reliability in coverage shortage NR scenarios.
    - ZTE: Otherwise this might cause more UE fragmentation and scheduling difficulties from network perspective.
* Recommended WF
  + Encourage further discussion

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| **Company** | **Comments** |
| Ericsson | Option 2, the minimum maximum duration is good to have from scheduling perspective. Avoid the definition of the new signaling and easier for scheder design. |
| ZTE | Option 2 |
| Huawei, HiSilicon | If Option 1, we may need to have assumption that gNB would compensate the CFO to a certain accuracy. |
| IDC | Option 1. (Using phase compensation mitigation methods) and UE needs to report the duration. |
| MediaTek | This will depend on the direction of the broader functional discussion points, and the resulting gain of enabling different JCE configurations considering realistic UE constraints, so probably best to discuss this later. |
| Qualcomm | Not sure how max duration would work between Fr1 and Fr2. Also low bands FDD and Ultra highbands with TDD might have different max durations just because of completely different RF designs. |

### Sub-topic 1-6: DL slot(s) in-between repetition

**Issue 1-6: DL slot(s) in-between repetition**

* *Agreement in RAN4 #99e (in WF R4-2107881)*
  + *RAN4 further study on the feasibility of phase continuity when there is DL slot(s) in-between repetitions*
* Proposals
  + Option 1: RAN4 further studies the scenario where DL slots between PUSCH or PUCCH repetition from UE implementation and network tolerance aspects conclude its feasibility. (Sony)
    - It is possible for a UE to retune the phase so that the phase continuity when there is DL slot(s) in-between repetitions can be maintained.
    - The cases of a downlink reception without actual DL transmission/ DL monitoring occasions and an un-scheduled symbol between PUSCH or PUCCH repetition are similar. Therefore, it is possible to have a DL slot while maintaining the phase/amplitude continuity under such a scenario.
    - Though the Rx performance may degrade due to the noise leaking from the PA, the overall cell coverage may still be improved in the scenario that the uplink coverage is the bottleneck
    - Enable phase/amplitude continuity when there is a DL slot between PUSCH or PUCCH repetition can improve the uplink coverage under high UL/DL ratio scenarios, e.g., uplink video streaming.
  + Option 2: Do not consider further the case where there is a DL slot within a non-zero gap. (MTK)
  + Option 3 (HW):
    - For DL slots that refers to actual DL transmission, and/or without actual DL transmission from gNB to UE in-between repetitions, UE cannot maintain phase continuity for PUSCH or PUCCH repetition.
    - For DL slots that refers to no real DL service and no DL monitoring occasions configured, phase continuity for PUSCH or PUCCH repetition can be maintained but not recommended. Additional on-off and off-on time mask definition is needed.
* Recommended WF
  + Further discuss for the two cases: 1) downlink reception without actual DL transmission/DL monitoring occasions configured, 2) downlink reception with actual DL transmission/DL monitoring occasions

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| **Company** | **Comments** |
| Ercisson | Agree with option 1 with further investigation needed after the phase continuity tolerance defined. |
| Huawei, HiSilicon | Both Option 2 and 3 are OK for us. While for option 3, we don’t think the case that no real DL service and no DL monitoring occasions configured case really exists. So with this, we think option 3 is equal to option 2. |
| IDC | Option 1. Further study may be required. |
| MediaTek | Option 2. Similarly to Huawei, we are also unclear what Case 1 is in the end. |
| Sony | Option 1.   * When an actual DL transmission/DL monitoring occasion is configured, UE can retune the phase/amplitude or through separate Tx/Rx antennas as we have analyzed in our paper. The first method requires a guard period, as discussed in Issue 1-2-1, while the latter method may lead to some Rx performance degradation but still benefit for the uplink limited scenario. Since it may require some dedicated UE implementation, we are ok to take it as a possible optional feature for UE. * When there is no actual DL transmission/DL monitoring occasion configured, we think the same principle as actual DL transmission/DL monitoring occasions configured can be applied, or it can also be seen as none scheduled case where UE could stay on the Tx chain and keep the RF components on. In either case, phase continuity can be maintained.   Overall, it is feasible to maintain the phase/amplitude continuity when DL slots are configured in between UL repetitions from UE implementation, and there is no need to exclude it from the RAN4 aspect. |
| Qualcomm | It might be better to just keep the agreement in R4-2103393 and no conclude that DL signals in the gap. If for some reason ran4 decides to pursue, the returning gap would be needed to maintain the phase. |

### Sub-topic 1-7: Work plan

**Issue 1-7: Work plan**

* Proposals
  + Proposed RAN4 RF work plan for NR coverage enhancements WI in R4-2112230. (CTC)
* Recommended WF
  + Can we agree the work plan? Any comments or suggestions?

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| **Company** | **Comments** |
| Ericsson | Missing the CFO impact. |
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## Companies views’ collection for 1st round

*Provided under each issue in section 1.2*

## Summary for 1st round

### Open issues

*Moderator tries to summarize discussion status for 1st round, list all the identified open issues and tentative agreements or candidate options and suggestion for 2nd round i.e. WF assignment.*

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|  | **Status summary** |
| **Sub-topic#1** | *Tentative agreements:*  *Candidate options:*  *Recommendations for 2nd round:* |

## Discussion on 2nd round

1. Recommendations for Tdocs
   1. 1st round

**New tdocs**

|  |  |  |
| --- | --- | --- |
| **Title** | **Source** | **Comments** |
| WF on … | YYY |  |
| LS on … | ZZZ | To: RAN\_X; Cc: RAN\_Y |
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**Existing tdocs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tdoc number** | **Title** | **Source** | **Recommendation** | **Comments** |
| R4-210xxxx | CR on … | XXX | Agreeable, Revised, Merged, Postponed, Not Pursued |  |
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Notes:

1. Please include the summary of recommendations for all tdocs across all sub-topics incl. existing and new tdocs.
2. For the Recommendation column please include one of the following:
   1. CRs/TPs: Agreeable, Revised, Merged, Postponed, Not Pursued
   2. Other documents: Agreeable, Revised, Noted
3. For new LS documents, please include information on To/Cc WGs in the comments column
4. Do not include hyper-links in the documents
   1. 2nd round

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| **Tdoc number** | **Title** | **Source** | **Recommendation** | **Comments** |
| R4-210xxxx | CR on … | XXX | Agreeable, Revised, Merged, Postponed, Not Pursued |  |
| R4-210xxxx | WF on … | YYY | Agreeable, Revised, Noted |  |
| R4-210xxxx | LS on … | ZZZ | Agreeable, Revised, Noted |  |
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Notes:

1. Please include the summary of recommendations for all tdocs across all sub-topics.
2. For the Recommendation column please include one of the following:
   1. CRs/TPs: Agreeable, Revised, Merged, Postponed, Not Pursued
   2. Other documents: Agreeable, Revised, Noted
3. Do not include hyper-links in the documents

# Annex

Contact information

|  |  |  |
| --- | --- | --- |
| **Company** | **Name** | **Email address** |
|  |  |  |

Note:

1. Please add your contact information in above table once you make comments on this email thread.
2. If multiple delegates from the same company make comments on single email thread, please add you name as suffix after company name when make comments i.e. Company A (XX, XX)