**3GPP TSG RAN WG1 #106-e R1-** **21xxxxx**

**e-Meeting, August 16th – 27th, 2021**

**Agenda Item: 8.8.1.3**

**Source: Moderator (China Telecom)**

**Title: [106-e-NR-R17-CovEnh-03] Summary of email discussion on joint channel estimation for PUSCH**

**Document for: Discussion**

1. Introduction

In RAN #90 e-meeting, a new Rel-17 work item on NR coverage enhancements was approved [1] and was revised in [2]. The objective of this work item is to specify enhancements for PUSCH, PUCCH and Msg3 PUSCH for both FR1 and FR2 as well as TDD and FDD.

The detailed objectives are as follows.

* *Specification of PUSCH enhancements [RAN1, RAN4]*
  + *Specify the following mechanisms for enhancements on PUSCH repetition type A [RAN1]*
    - *Increasing the maximum number of repetitions up to a number to be determined during the course of the work.*
    - *The number of repetitions counted on the basis of available UL slots.*
  + *Specify mechanism(s) to support TB processing over multi-slot PUSCH [RAN1]*
    - *TBS determined based on multiple slots and transmitted over multiple slots.*
  + *Specify mechanism(s) to enable joint channel estimation [RAN1, RAN4]*
    - *Mechanism(s) to enable joint channel estimation over multiple PUSCH transmissions, based on the conditions to keep power consistency and phase continuity to be investigated and specified if necessary by RAN4 [RAN1, RAN4]*
      * *Potential optimization of DMRS location/granularity in time domain is not precluded*
    - *Inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation [RAN1]*
* *Specification of PUCCH enhancements [RAN1, RAN4]*
  + *Specify signaling mechanism to support dynamic PUCCH repetition factor indication [RAN1]*
  + *Specify mechanism to support DMRS bundling across PUCCH repetitions [RAN1, RAN4]*
    - *When applicable, based on similar mechanism(s) for enabling joint channel estimation for PUSCH*
* *Specify mechanism(s) to support Type A PUSCH repetitions for Msg3 [RAN1, RAN2]*

This contribution is a summary of the following email discussion:

[106-e-NR-R17-CovEnh-03] Email discussion regarding joint channel estimation for PUSCH – Jianchi (China Telecom)

* 1st check point: August 19
* 2nd check point: August 24
* Final check: August 27

1. Summary of contributions

## 2.1 Conditions to keep power consistency and phase continuity

An LS [3] was sent to RAN4 asking the conditions for UE to keep power consistency and phase continuity among PUSCH transmissions. The reply LS was send by RAN4 [4]. Based on the reply LS, if the conditions for phase continuity among PUSCH transmissions are fulfilled, the same power level (with certain tolerance level) can also be achieved. The certain tolerance level is still under discussion in RAN4.

For back-to-back transmissions with zero gap in-between adjacent transmissions, in order to maintain phase continuity, the following conditions should be met:

* Modulation order does not change.
* RB allocation in terms of length and frequency position should not be changed, and intra-slot and inter-slot frequency hopping is not enabled within a repetition bundle.
* No change on transmission power level of its own CC, i.e., no change on the power control parameters specified in TS 38.213, and also when own CC is not impacted by other concurrent CC(s) that are configured for inter-band CA or DC for same UE with dynamic power sharing and no change in any configured CC s that are part of configured intra-band uplink CA or DC.
* No UL beam switching for FR2 UE occurs

For non-back-to-back transmission with non-zero gap in-between adjacent transmissions, RAN4 concluded that at least following additional condition also need to be met in addition to the above conditions:

* No downlink reception in-between the PUSCH or PUCCH repetition in the same band for TDD case.

In scenario of no more than *X* un-scheduled OFDM symbols in-between the PUSCH or PUCCH repetition (e.g., *X* = 0, 1, 2, …, 14), and scenario of other physical signals/channels in-between PUCCH or PUSCH repetitions from the UE perspective, e.g., SRS or PUCCH transmission in-between the PUSCH repetition for the UE, RAN4 is still discussing if *X* can be non-zero value and UE can maintain phase continuity.

Another LS [5] was sent by RAN4 about non-back-to-back transmissions. RAN4 confirms the feasibility of phase continuity and power consistency for non-zero un-scheduled gap case for a gap less than 14 symbols when UE is not required to meet the existing off power requirements. Whether new or existing off power requirements for shorter duration than 1 msec as well as the maximum value of X un-scheduled symbols will be introduced are pending on further RAN4 discussions. For the case with other UL channels in between repetitions, at least 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, it is feasible to maintain the phase continuity and power consistency across the repetitions.

In [6], RAN1 asked RAN4 to provide answers to the following questions.

Question 1: In addition to the conditions provided in R4-2103393, can RAN4 please confirm that “Applying the same TPMI precoder across PUSCH transmissions” is also a necessary condition to keep phase continuity across PUSCH transmissions?

Question 2: Whether “no TA adjustment in between PUCCH transmissions or PUSCH transmissions” is another necessary condition to keep phase continuity across PUCCH repetitions or PUSCH transmissions?

Question 3: There are two different interpretation in RAN1 regarding the “downlink reception” in “No downlink reception in-between the PUSCH or PUCCH repetition in the same band for TDD case” (in R4-2103393)

1. “downlink reception” refers to downlink symbols with actual DL transmission from gNB to UE.
2. “downlink reception” refers to downlink symbols with actual DL transmission from gNB to UE and/or downlink symbols without actual DL transmission from gNB to UE and/or no DL monitoring occasions configured.

Can RAN4 please confirm which interpretation is correct?

The latest LS from RAN4 [7]:

* 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. If new RF requirements for UE during the gap are needed, is under discussion in RAN4.
* Regarding whether “*Applying the same TPMI precoder across PUSCH transmissions*” is also a necessary condition to keep phase continuity across PUSCH transmissions, RAN4 answer is that applying the same TPMI precoder across PUSCH transmissions is a necessary condition to apply joint channel estimation.
* Regarding whether “*no TA adjustment in between PUCCH transmissions or PUSCH transmissions*” is another necessary condition to keep phase continuity across PUCCH repetitions or PUSCH transmissions, RAN4 answer is that TA adjustment and UE uplink timing autonomous adjustments cause the phase to change. RAN4 is still investigating the full impacts of the detailed scenarios, and will provide a final view about this at the next RAN4 meeting.
* Regarding “*downlink reception*” related questions, RAN4 answer is as follows:

1) The “downlink reception” means downlink symbols with actual DL transmission from gNB to UE and/or DL monitoring with the assumption that UE is receiving information.

2) Regarding whether “downlink reception” include downlink symbols without actual DL transmission from gNB to UE and without DL monitoring, it would be helpful if RAN1 could provide more information on the exact scenario.

3) Phase discontinuity tolerance LLS is ongoing in RAN4 study and conditions of whether the phase continuity can be maintained in TDD case that has downlink reception in-between the PUSCH or PUCCH repetition could be revisited in future meeting with consideration of phase discontinuity tolerance. RAN4 is also still checking whether there are any optional UE antenna configurations where a UE could overcome this problem and still gain from using the feature

## 2.2 Use cases for joint channel estimation

RAN1 has identified the potential use cases for joint channel estimation for PUSCH.

* Use case 1: back-to-back PUSCH transmissions within one slot.
* Use case 2: non-back-to-back PUSCH transmissions within one slot.
  + Use case 2a: no uplink transmission in the middle of two PUSCH transmissions
  + Use case 2b: other uplink transmissions in the middle of two PUSCH transmissions
* Use case 3: back-to-back PUSCH transmissions across consecutive slots.
* Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.
  + Use case 4a: no uplink transmission in the middle of two PUSCH transmissions
  + Use case 4b: other uplink transmissions in the middle of two PUSCH transmissions
* Use case 5: PUSCH transmissions across non-consecutive slots.
  + Use case 5a: no uplink transmission in the middle of two PUSCH transmissions
  + Use case 5b: other uplink transmissions in the middle of two PUSCH transmissions

Note: RAN1 assumes “back-to-back PUSCH transmission” has zero gap in-between adjacent PUSCH transmissions.

Note: intervening “other uplink transmissions” can be either on the same component carrier or a different component carrier.

In the past RAN1 meetings, it was discussed whether joint channel estimation can be applied to the above uses cases. Based on the discussion and agreements so far, the situation is summarized in the following table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Use cases | Repetition type A for the same TB | Repetition type B for the same TB | Transmissions with different TBs | TBoMS |
| 1: B2B PUSCH transmission within one slot | / | Support | Not support | / |
| 2: Non-B2B PUSCH transmission within one slot | / | Not support | Not support | / |
| 3: B2B PUSCH transmissions across consecutive slots | Support | Support | To be determined | Working Assumption |
| 4: Non-B2B PUSCH transmissions across consecutive slots | Working Assumption  (4a) | Working Assumption  (4a) | To be determined | To be determined |
| To be determined  (4b) | To be determined  (4b) |
| 5: PUSCH transmissions across non-consecutive slots | To be determined | To be determined | To be determined | To be determined |

**It can be observed that use case 3/4/5 still need further discussion. For use case 4b & 5, we should wait for RAN 4’s feedback. Thus, FL suggests focusing on use case 3 and 4a in this meeting.**

### 2.2.1 Use case 3: back-to-back PUSCH transmissions across consecutive slots

For use case 3, based on the contributions in RAN1 #106-e, companies’ views on transmissions with different TBs and TBoMS are summarized as follows.

* **Transmissions with different TBs**

**Support:** CTC, TCL, Nokia, NSB, HW, HiSilicon, CMCC, Sierra Wireless, ZTE

**Not support:** Qualcomm, Intel, Ericsson, Samsung

|  |  |
| --- | --- |
| **Positive arguments** | **Negative arguments** |
| * There are many simulation results of joint channel estimation among different TBs with large gains are provided by companies, which are captured in TR 38.830, e.g. R1-2008626, R1-2007583, R1-2008874, R1-2008026, R1-2008559, etc. * Huawei/HiSilicon: By joint channel estimation across consecutive PUSCH transmissions of different TBs, 1.4 dB and 2.1 dB SNR gains are obtained at 10% BLER for 2 and 3 slots joint channel estimation, respectively. * Vivo: about 0.6 dB for PUSCH transmissions with different TBs. * As long as the the condition of power consistency and phase continuity can be maintained, joint channel estimation can be applied. * A higher data rate is required for PUSCH transmission in coverage enhancement, e.g. 1Mbps for eMBB, where the number of repetitions is limited; Also, A medium or low date rate is required for PUSCH transmission in coverage enhancement, e.g. 12.2 kbps for VoIP, where different TBs with repetitions are transmitted across consecutive slots. Thus it’s a very common case of joint channel estimation among different TBs to meet the medium-to-high data rate requirements in uplink coverage enhancement. | * Not targeted for coverage enhancement. * Additional complexity and significant restrictions on the base station scheduler, and the fact that its unlikely to benefit a cell-edge UE. * Restrictions on scheduling of multiple TBs, same number of PRBs/same frequency location, same transmission power, same TPMI precoder etc. |

* **TBoMS**

In RAN1 #104b-e, 24 companies (Huawei, HiSilicon, vivo, CATT, LG, InterDigital, CMCC, Samsung, Xiaomi, China Telecom, NTT DOCOMO, Sony, Intel, ZTE, Sharp, Panasonic, Apple, Nokia, NSB, WILUS, OPPO, Lenovo, Motorola Mobility, Ericsson) support to confirm the following working assumption. In RAN1 #105-e, two more companies (TCL, Spreadtrum) support to confirm the following working assumption. Based on the contributions in RAN1 #106-e, 5 companies (ZTE, Apple, InterDigital, Panasonic, NTT DOCOMO) support to confirm the following working assumption.

|  |
| --- |
| **Working assumption:**   * For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following case:   + Over back-to-back PUSCH transmissions for one TB processed over multiple slots     - It’s subject to UE capability |

### 2.2.2 Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.

* **Use case 4a: no uplink transmission in the middle of two PUSCH transmissions**

For use case 4a, Companies’ views are summarized as follows.

|  |  |
| --- | --- |
| **Detailed cases** | **Companies’ views** |
| Repetition type A for the same TB (WA) | **Confirm the working assumption:** TCL, LG, WILUS, Nokia, NSB, HW, HiSilicon, ZTE, Sierra Wireless |
| Repetition type B for the same TB (WA) | **Confirm the working assumption:** TCL, LG, WILUS, Nokia, NSB, HW, HiSilicon, ZTE, Sierra Wireless |
| Transmissions with different TBs | **Support:** Spreadtrum, CTC, Nokia, NSB, HW, HiSilicon, ZTE, Sierra Wireless  **Not support:** Lenovo, Motorola Mobility, Qualcomm, Intel, Ericsson |
| TBoMS | **Support:** HW, HiSilicon, ZTE |

**Other considerations for use case 4a:**

**Nokia/NSB:** When there is no “DL reception” in-between the two successive PUSCHs, support PUSCH transmissions with different TBs if the following constraints are satisfied:

* Constraints for joint channel estimation in case of back-to-back PUSCHs;
* The duration between the two successive PUSCHs is not greater than the maximum “non-zero unscheduled gap” provided by RAN4.
* The UE does not expect to receive or monitor any DL transmission within the “non-zero unscheduled gap”.

When there is “DL reception” in-between the two successive PUSCHs, for non-back-to-back PUSCH transmissions, the gNB indicates whether and which DL reception occasion should be monitored by the UE.

**MediaTek:** Support JCE for non-back-to-back PUSCH transmissions with short gap symbols (e.g., 1 or 2 symbols) can be up to UE implementation; No need to support JCE for non-back-to-back PUSCH transmissions with long gap symbols (e.g., >2 symbols)

* **Use case 4b: other uplink transmissions in the middle of two PUSCH transmissions**

For use case 4b, companies’ views are summarized as follows.

|  |  |
| --- | --- |
| **Detailed cases** | **Companies’ views** |
| Repetition type A for the same TB | **Support:** Nokia, NSB (other UL transmission have the same settings), HW, HiSilicon (when other UL is SRS)  **Not support:** Qualcomm |
| Repetition type B for the same TB | **Support:** Nokia, NSB (other UL transmission have the same settings) , HW, HiSilicon (when other UL is SRS)  **Not support:** Qualcomm |
| Transmissions with different TBs | **Support:** Nokia, NSB (other UL transmission have the same settings), Sierra Wireless, HW, HiSilicon (when other UL is SRS)  **Not support:** Qualcomm, Intel, Ericsson |
| TBoMS | **Support:** HW, HiSilicon (when other UL is SRS)  **Not support:** Qualcomm |

**Other considerations for use case 4b:**

**HW, HiSilicon:** If SRS has same transmission power and antenna port with PUSCH transmissions, phase continuity can be ensured between two PUSCH transmissions with same RB allocation, even a SRS with different RB allocation is transmitted in-between two PUSCH transmissions.

**Nokia/NSB:** The same settings include: antenna port, occupied PRBs and UL power as the PUSCH repetitions. When the “other UL transmission” has different settings than PUSCHs, the gNB indicates one of the following options to the UE:

* Option 1: Adapt the settings of the other UL transmission to make it be the same as PUSCHs.
* Option 2: Multiplex the data of the other UL transmission on PUSCH.
* Option 3: Drop the other UL transmission with different settings.
* Option 4: Transmit the other UL transmission with different settings and break the phase continuity.

|  |
| --- |
| Option 1 Option 2 Option 3 |

### 2.2.3 Other considerations

**Vivo:** For joint channel estimation among PUSCHs with different TBs, the time domain window configured per UE is preferable.

**Sony:** For non-back-to-back PUSCH transmission, A UE shall be able to signal its capability of supporting ‘no UL’, ‘other UL’, or ‘DL’ transmissions between successive PUSCH transmissions.

**LG:** To support joint channel estimation for different TBs, all of power control parameters between those different TBs should be aligned to satisfy requirements for joint channel estimation.

**Lenovo, Motorola Mobility:** For PUSCH coverage enhancement in NR Rel-17, JCE is applied to PUSCH repetition type B within a slot only when actual repetitions are back-to-back, and no specific enhancements are needed on top of enhancements for PUSCH repetition type-A; Moreover, JCE is applied to PUSCH repetition type B across consecutive slots with similar enhancements as for PUSCH repetition type A, i.e., no specific enhancements are needed on top of enhancements for PUSCH repetition type-A.

**ZTE:** Joint channel estimation is supported in case of UL CA.



**Panasonic:** For multiple TBs scheduled by a DCI, joint channel estimation should wait for the progress of the discussion of NR from 52.6GHz to 71 GHz.

**LG:** Rules for uplink collision handling and power sharing in CA/DC scenarios are required.

## 2.3 Time domain window for joint channel estimation

In RAN1 #104b-e meeting, a time domain window (TDW) was agreed to be specified, during which **UE is expected to** maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements. In RAN1 #105-e meeting, the maximum duration is defined to facilitate the discussion (whether it is specified is up to RAN4), during which **UE is able** to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements. It is understood that for a UE, the maximum duration is no less than the time domain window duration.

### 2.3.1 The maximum duration

In RAN1 #105-e, an LS was sent to RAN4 asking the following questions:

* 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

Based on the contributions in RAN1 #106-e, companies’ views about maximum duration are summarized below.

|  |  |
| --- | --- |
| Specify the maximum duration in RAN1 | **Support:** CMCC, InterDigital |
| UE report the maximum duration | **Support:** Spreadtrum, Sony (a specified one), Xiaomi (in initial access), CMCC, InterDigital |

**Other considerations**

**CATT:** Whether the maximum duration should be reported by UE or not is up to the number of the maximum duration determined by RAN4 (if there are more than one candidate values of the maximum duration determined by RAN4, UE should report one of the maximum durations used as a reference for gNB when configuring the time domain window size).

**Sharp:** The term maximum duration should be reserved for signalling UE capability (if supported). A new parameter (maximum time domain window length) should be indicated by the gNB for adaptation of the time domain window.

**CMCC:** The time domain window during which a UE is expected to maintain power consistency and phase continuity among PUSCH transmission should be at least a UE capability. It should be defined in RAN1 and the specific values should be studied in RAN4.

### 2.3.2 Time domain window design

In RAN1 105-e, two alternatives related to TDW were agreed to be down selected for JCE for PUSCH repetition type A of PUSCH repetitions of the same TB. Based on the contributions in RAN1 #106-e, companies’ views are summarized as follows:

* Alt 1: All the repetitions are covered by one single time domain window

**Support:** Sony, vivo, Sierra Wireless, InterDigital

* Alt 2: All the repetitions are covered by one or multiple time domain windows

**Support:** Spreadtrum, CATT, CTC, TCL, Apple, Sharp, WILUS, Nokia, NSB, HW, HiSilicon, Samsung, Qualcomm, Intel, Panasonic, NTT DOCOMO, (ZTE?), (LG?)

Details of Alt.1 and Alt.2 are summarized as follows:

* **Alt 1: All the repetitions are covered by one single time domain window**

For Alt.1, one single time domain window is configured, the illustrations of Alt.1 for paired and unpaired spectrum are shown as follows:



Illustration of Alt.1 for paired spectrum



Illustration of Alt.1 for unpaired spectrum

**Start of TDW**

Regarding the start of TDW, following options can be considered:

* Option 1a: The first available slot for PUSCH transmissions.
* Option 1b: The first available symbol for PUSCH transmissions.
* Option 2a: The first physical slot allocated for PUSCH transmissions.
* Option 2b: The first physical symbol allocated for PUSCH transmissions.

**Segmentation of TDW**

If some events, which break the prerequisite of JCE, happen in-between the configured TDW, the TDW may be fragmented into multiple sub windows. These events are summarized as follows based on companies’ contributions:

* DL/UL configuration for unpaired spectrum;
* The TDW exceeds the maximum duration;
* The maximum unscheduled gap between two successive PUSCHs is exceeded;
* DL reception/monitoring occasion for unpaired spectrum during the TDW;
* High priority transmission, dynamic SFI for unpaired spectrum, CI and etc. during the TDW.

**Sub windows**

Regarding the start and end of the sub windows, companies’ views are summarized as follows:

1) The start of the other sub windows

* Option 1: The first available slot for PUSCH transmission after the previous sub window.
* Option 2: The first available symbol for PUSCH transmission after the previous sub window.

2) The end of sub windows (except the last sub window)

* Option 1: The last slot of the PUSCH transmission right before an event such that the power consistency and phase continuity are broken.
* Option 2: The last symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are broken.

3) The end of the last sub window

* The end of the last sub window is the end of the last PUSCH transmission.
* **Alt 2: All the repetitions are covered by one or multiple time domain windows**

For Alt.2, there can be two kinds of TDW configurations based on companies’ contributions as follows:

1) **Alt 2-A: multiple consecutive windows with same window length**

For Alt 2-A, although multiple windows are configured, only the start of the first window and one common window length needs to be configured. TDW is then repeated within the transmission duration. The start of the other TDWs and the length of the last TDW can be derived without explicit configuration. The illustrations of Alt.2-A for paired and unpaired spectrum (if use case 5 is supported) are shown as follows:



Illustration of Alt.2-A for paired spectrum



Illustration of Alt. 2-A for unpaired spectrum (if use case 5 is supported)

**Start of TDW**

Regarding the start of the first TDW, following options can be considered:

* Option 1a: The first available slot for PUSCH transmissions.
* Option 1b: The first available symbol for PUSCH transmissions.
* Option 2a: The first physical slot allocated for PUSCH transmissions.
* Option 2b: The first physical symbol allocated for PUSCH transmissions.

**Length of TDW**

Regarding the length of one window, it can be configurable but no longer than the maximum duration.

**Segmentation of TDW**

If some events, which break the prerequisite of JCE, happen in-between the configured TDW, the TDWs may be fragmented into multiple sub windows. These events are summarized as follows based on companies’ contributions:

* DL/UL configuration for unpaired spectrum;
* The maximum unscheduled gap between two successive PUSCHs is exceeded;
* DL reception/monitoring occasion for unpaired spectrum during the TDW;
* High priority transmission, dynamic SFI for unpaired spectrum, CI and etc. during the TDW.

2) Alt 2-B: multiple windows (consecutive or non-consecutive)

For Alt 2-B, it needs to define the **start of each window** as well as **the end of each window**. The illustration of Alt.2-B for unpaired spectrum is shown as follows:



Illustration of Alt.2-B for unpaired spectrum

**Start of TDW**

Regarding the start of the first TDW, following options can be considered:

* Option 1a: The first available slot for PUSCH transmissions.
* Option 1b: The first available symbol for PUSCH transmissions.
* Option 2a: The first physical slot allocated for PUSCH transmissions.
* Option 2b: The first physical symbol allocated for PUSCH transmissions.

**Start of the other TDWs**

Regarding the start of other TDWs, companies’ views are summarized as follows:

* Option 1: The first available slot for PUSCH transmission after the previous TDW.
* Option 2: The first available symbol for PUSCH transmission after the previous TDW.

**End of TDWs**

Regarding the end of TDWs, companies’ views are summarized as follows:

* Option 1: The last slot of the PUSCH transmission right before an event such that the power consistency and phase continuity are broken.
* Option 2: The last symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are broken.
* The end of the last TDW is the end of the last PUSCH transmission.

The event mentioned above can be:

* DL/UL configuration for unpaired spectrum;
* The TWD exceeds the maximum duration;
* The maximum unscheduled gap between two successive PUSCHs is exceeded;
* DL reception/monitoring occasion for unpaired spectrum during the TDW;
* High priority transmission, dynamic SFI for unpaired spectrum, CI and etc. during the TDW.

**Other considerations:**

**Nokia/NSB:** For Alt 1, within the repetition duration, there could be one or more than one “actual duration” wherein the UE is able to maintain the power consistency and phase continuity.

In case TDW is defined for any PUSCH transmissions, RAN1 to further discuss on whether to define a time-duration which can be dynamically indicated and used as “repetition duration” (similar to the case of JCE across PUSCH repetitions).

**Samsung:** Support an indication to a UE to apply power consistency and phase continuity conditions over a number of repetitions or slots (i.e. window size) for a PUSCH transmission with repetitions.

**Qualcomm:** Within each window, if conditions for bundling, as specified by RAN4, are violated, then bundling is not resumed within that window.

**NTT DOCOMO:** Time domain window size should be determined dynamically according to the channel quality.

**LG:** Further clarification is needed for one or multiple time domain window. In our understanding: single time domain window case means that when joint channel estimation is indicated, a window of a single size is (repeatedly) applied until it is disabled, and multiple time domain window case means that when joint channel estimation is indicated, windows of various sizes can be applied until disabled.

**Ericsson:** Windows are implicitly determined according to continuity/consistency requirements

* If Alt 1 is pursued, the UE is expected to maintain continuity/consistency for repetitions meeting the requirements, which can be one or more portions of the repetitions
* If Alt 2 is pursued, the windows covering the repetitions can have different lengths, and all repetitions within each window meet continuity/consistency requirements.

**Sharp:** Adaptation of the time domain window length by the gNB should be supported. (For a high-speed UE, the gain of joint channel estimation may be limited. In that case, the gNB may configure multiple time domain windows with short length (e.g., 2 or 4 slots) such that frequency diversity or spatial diversity (e.g., precoder cycling) can be exploited. On the other hand, for a low speed UE, time domain window length can be set to longer to fully exploit joint channel estimation gain. Therefore, depending on the UE condition, time domain window length should be adapted.)

**Lenovo, Motorola Mobility:** If the maximum duration is greater than or equal to the entire duration of the scheduled PUSCHs, then Alt 1 should suffice, otherwise more than one time domain windows are needed. For the case of frequency hopping, multiple TDW can be specified where the duration of the time domain window can be equal to the hop duration

**CMCC:** If a large number of consecutive slots are indicated for the joint channel estimation, the phase of the later part transmissions could drift significantly compared with the first few transmissions. The impact of phase drifting should be considered for the performance of joint channel estimation.

**Panasonic:** When inter-slot frequency hopping and/or inter-slot precoder cycling are applied, the length of time domain window should be the subset of the time domain resource allocation. Proposal 7: When some slot(s) are dropped by the other dynamic signaling (e.g., UL CI, DCI for high priority channel), the length of time domain window should be the subset of the time domain resource allocation.

### 2.3.3 Enable/disable of Joint channel estimation and time domain window

In RAN1 #105-e, it was agreed that JCE for PUSCH transmissions is enabled or disabled via RRC configuration. Based on companies’ contribution in RAN1 #106-e, companies’ views on whether the TDW needs to be separately enabled/disabled are summarized as follows:

* Option 1: Joint enabling/disabling between JCE and TDW.

**Support:** Lenovo, Motorola Mobility, CMCC, CATT, TCL, ZTE

* Option 2: Separate enabling/disabling between JCE and TDW.

**Support:** vivo (DCI or configured grant)

Regarding whether additional dynamic signaling is needed to enable/disable joint channel estimation for PUSCH transmissions, companies’ views are summarized as follows:

* Dynamic signaling to enable/disable JCE for PUSCH transmissions.

**Support:** InterDigital, Sierra Wireless (UL grant), Samsung

**Not support:** Spreadtrum, OPPO, Intel

### 2.3.4 Coherent transmission indication

Based on companies’ contributions, two companies (Nokia, NSB) proposed that UE indicates via suitable DMRS configuration whether the transmission is coherent with respect to the other PUSCH transmissions. One company (Qualcomm) proposed that UE signals a bundling indication in the UCI multiplexing with PUSCH transmission to indicate whether a PUSCH transmission is coherent with respect to the other PUSCH transmission. The motivation of the coherent transmission indication is due to the fact that some events on the UE side may impact the phase continuity but such change may not be known to the gNB. These events may include: frequency error correction, timing correction, RF calibration, antenna virtualization and etc. One company (LG) proposed to consider UE reporting when the UE cannot transmit by satisfying the requirement for joint channel estimation during the configured time window. One company (InterDigital) proposed a grant-type dependent index which indicates which PUSCH(s) to bundle.

### 2.3.5 The unit of time domain window

For the unit of time domain window, companies’ views are summarized as follows:

* Option 1: The unit of the time domain window is defined separately for the following PUSCH transmissions:
  + PUSCH repetition type A
  + PUSCH repetition type B
  + TBoMS, if agreed
  + Different TB, if agreed

**Support:** Xiaomi, OPPO, TCL

|  |  |
| --- | --- |
| Cases | Companies’ views about the unit of time domain window |
| PUSCH repetition type A | * In unit of repetitions   + Ericsson, Samsung * In unit of slots   + OPPO, Apple, Xiaomi, Intel, Samsung |
| PUSCH repetition type B | * In unit of repetitions   + OPPO, Intel, NTT DOCOMO, Ericsson, Samsung * In unit of symbols   + Xiaomi, * In unit of slots   + Apple |
| TBoMS | * In unit of slots   + Xiaomi, Ericsson |
| Different TB | - |

* Option 2: The unit of the time domain window is the same for the following PUSCH transmission:
  + PUSCH repetition type A
  + PUSCH repetition type B
  + TBoMS, if agreed
  + Different TB, if agreed

**Support:** CATT (Slot), ZTE (Slot for maximum time duration and nominal TDW configured by gNB), CMCC (slot or symbol), Qualcomm (Physical slot)

**Other considerations:**

**TCL:** A uniform set of TDW unit for each PUSCH transmission pattern should be used for paired spectrum and unpaired spectrum. (We don’t support that the time domain window is implicitly determined by DL/UL configuration).

* + For PUSCH repetition type A: slot, repetition
  + For PUSCH repetition type B: slot, nominal repetition and/or actual repetition
  + For different TBs: slot, TB
  + For TBoMS: slot, or a single time domain window across the entire TB

Different TDW units are applied to each PUSCH transmission pattern.

**LG:** For the unit of time domain window for joint channel estimation, it would be appropriate to be a slot or repetition.

## 2.4 Inter-slot frequency hopping with inter-slot bundling

In RAN1 #104b-e meeting, two options were agreed to be down selected about the bundle size of inter-slot frequency hopping with inter-slot bundling:

* Option 1: The bundle size (time domain hopping interval) equals to the time domain window size.

**Support:** Apple, Samsung, Lenovo, Motorola Mobility, CMCC, NTT DOCOMO

* Option 2: The bundle size (time domain hopping interval) can be different from the time domain window.
  + FFS: Whether the bundle size (time domain hopping interval) is explicitly configured or implicitly determined.
  + FFS: Whether/How the bundle size (time domain hopping interval) is defined separately for FDD and TDD.
  + FFS: relation between the bundle size (time domain hopping interval) and the time domain window size

**Support:** CTC, OPPO, LG, Xiaomi, vivo, CMCC, Intel, ZTE, CATT, NTT DOCOMO

**Other considerations:**

**CATT:** Further study how to indicate UE to adopt the inter-slot frequency hopping with inter-slot bundling. (e.g. 1. add a candidate option in *PUSCH-config* when configuring the frequency hopping method; 2. UE can be implicitly indicated to enable the inter-bundling hopping when the UE is configured with RRC parameters related to joint channel estimation (e.g. enabling/disabling joint channel estimation and/or time domain window size.))

**OPPO:** The bundle size is explicitly informed to the UE.

**Sharp:** A new hopping pattern other than an alternating pattern on hopping bundles can be considered to maximize frequency hopping gain.

**Xiaomi:** Support time window split mechanism when there are more than X un-scheduled OFDM symbols/slots exists in a nominal time window and the effect on DMRS bundle size should be taken into consideration. Moreover, support inserting DMRS into DMRS bundle if there is no available DMRS after splitting.



**WILUS:** For inter-slot frequency hopping with inter-slot bundling, up to M’ consecutive UL slots are determined as the same frequency hop index (Option 3), where M’ is no more than the configured/indicated number of slots for an inter-slot bundling.



**Nokia/NSB:** For inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation, the UE switches frequency hop for the PUSCH repetitions whenever one of the following happens:

* The “maximum capable duration” is exceeded.
* The “maximum unscheduled gap” between two successive PUSCHs is exceeded.
* The UE is expected to monitor/receive a DL reception occasion.
* The UE is expected to transmit an UL transmission with different settings than PUSCH repetitions.

If the “repetition duration” is less than “the maximum capable duration”, and no other event that breaks phase continuity occurs, then the number of repetitions can be split in two halves, each transmitted on one frequency hop.



**vivo:** The actual time domain window derived for joint channel estimation should be less than N slots, where N is configured bundle size of inter-slot bundling.

**ZTE:** For the determination of inter-slot bundling size for inter-slot FH, RAN1 down-selects from the two options below.

* Option 1: Inter-slot bundling size is implicitly determined by the number of repetitions K within one actual time domain window.
* Option 2: Inter-slot bundling size is RRC configured or dynamically indicated to a UE.

**Samsung:** A UE performs PUSCH frequency hopping per number of M>1 PUSCH repetitions. The number M can be predetermined or RRC configured as either M=constant value or as a fraction of the number of repetitions N (e.g., M=N/2 or M=N/4 and so on).



**Qualcomm:** Consider the following procedure for inter-slot frequency hopping with DMRS bundling:

* Identify available slots for PUSCH/PUCCH reps
* Determine frequency hopping index for each available slot based on the configured hopping pattern for DMRS bundling
* Determine TDWs for DMRS bundling assuming frequency hop allocations made in Step 2. UE ensures that no two slots with different hop indices are bundled together.



**CMCC:** According to the reply from RAN4, *X* consecutive slots could be configured for the joint channel estimation. And the inter-slot frequency hopping could be configured every *X* consecutive slots.

**Ericsson:** Allowing the gNB to independently control the frequency hopping pattern and time domain windows separately can potentially avoid unnecessarily restricting and complicating network scheduling.

* The bundle size is gNB implementation and follows from the hopping pattern and time domain window size, and so frequency hopping bundling size does not need explicit configuration.
* Not all UEs may benefit from, or support, DMRS bundling, but such UEs should be able to hop with the same patterns used by DMRS bundling UEs in the same cell.

## 2.5 Optimization of DMRS location in time domain

Companies’ vies on additional DMRS located in special slots are summarized as follows:

|  |  |
| --- | --- |
| Pros | Cons |
| * Although the special slot can be used for PUCCH or SRS transmission, which makes it unavailable for PUSCH joint channel estimation occasionally, it’s worthwhile to further study the utilization mechanism of special slot, where a significant gain can be obtained from the utilization of either 1 or 2 DMRS located special slot. | * The practical benefit of using DMRS located in special slot for joint CE is not evident. * Significant spec impact may be needed to support such an enhancement as follows:   1) Need to define where to place the DMRS and how to do that because allocating DMRS without data is not compatible with the current DMRS allocation procedure.  2) Need to agree on how many DMRS symbols can be allocated if there is more than one available UL symbol in the S slot.  3) Need to agree on a concept of enabling and disabling the allocation of DMRS on the S slots, which should be a separate discussion from the enabling/disabling of the Joint-CE feature.  4) Impacts on the processing timeline for PUSCH should also be resolved.  5) Impacts on the definition/indication of the time-domain window, which also needs to include, at least the DMRS symbols in the special slots.  6) How to handle the collision of the DMRS symbols in the S slot with any other UL channels is not clear. |

Simulation results on additional DMRS located in special slots are summarized below.

One company (HW) shows JCE w/ 1/2 DMRS located in special slot can improve the performance of PUSCH transmissions by 0.75/1.3dB at 10% BLER in typical TDD mode ‘DDDSUDDSUU’ compared to the baseline of UL slot with 1 DMRS w/o JCE. Additionally, JCE w/ 1/2 DMRS located in special slot can improve the performance of PUSCH transmissions by 0.45/0.65dB at 10% BLER in typical TDD mode ‘DDDSUDDSUU’ compared to the baseline of UL slot with 2 DMRS w/o JCE.

One company (InterDigital) shows JCE w/ 1 DMRS located in special slot can provide 0.5 and 0.8dB gain at 10% BLER in TDD configuration ‘DDDSU’, with 2 DMRS in the UL slot with the baseline and optimized DM-RS placement in the uplink slot, respectively, compare to the baseline DM-RS placement in the uplink slot in TDD configuration ‘DDDDU’.

One company (vivo) shows JCE w/ 1 DMRS located in special slot can provide 0.7dB gain at 10% BLER with 2 repetitions, TDD configuration ‘DDSUU’ and 1 DMRS symbol per UL slot. Moreover, the performance gain is not sensitivity to the DMRS pattern.

One company (Intel) shows JCE w/ 1 DMRS located in special slot can provide ~0.5 dB gain at 10% BLER with 2 and 4 repetitions, TDD and 2 DMRS symbol per UL slot.

One company (Ericsson) observes jointly estimated DMRS in special slot can theoretically improve channel estimation performance slightly, but in a fair comparison, where the total amount of system resources used by the UE is kept unchanged and 14% of the UL is needed for A/N or SRS, no net gains from having DMRS in special slot are observed in the simulations.

## 2.6 Others

**PTRS:**

**InterDigital:** Support to include PTRS in a DMRS bundle. Parameters of PTRS in the DMRS bundle depend on duration of the time window, SCS, bandwidth for PUSCH, and MCS used with DMRS bundling

**Qualcomm:** Support different criteria for activation of PTRS or its density for the case of joint channel estimation.

**TPC command:**

**Samsung:** Support a same power, precoding, RV, and frequency position within time domain window. A UE updates the CLPC adjustment state per time domain window.



**Illustration of power control method over multiple PUSCH repetitions for joint channel estimation**

**HW:** In order to maintain power consistency and phase continuity, the power adjustments need be disabled during a time domain window, which may include multiple transmission occasions. However, in Rel-15/Rel-16, the PUSCH power control is performed per transmission occasion.



When joint channel estimation is enabled, a larger window size means a longer adjustment period and convergence time of power control, which maybe lead to larger power control deviation. To obtain correct transmit power for each time domain window, some optimization of power control adjustment mechanism for joint channel estimation may be necessary. The following solutions can be considered:

- Alt 1: Receiving and accumulating TPC commands without taking effect during the current time domain window.

- Alt 2: Modifying the TPC commands accumulation range so that power control is performed per timw domain window.

**LG:** In relation to power control, power consistency can be maintained only if close loop power control is not indicated or not applied even if indicated.

**Phase correction at gNB**

**Ericsson:** proposed further study the benefit of gNB estimated inter-slot relative phase correction for PUSCH, addressing how frequency selective such phase corrections would need to be for UEs and/or conditions that do not sufficiently support maintaining inter-slot relative phase.

**TA adjustment**

**LG:** In reply LS of RAN4, it was answered that TA adjustment affects phase continuity. Therefore, the UE should not perform TA adjustment when the DMRS bundling is configured.

**Ericsson:** The UE should not apply TA updates between transmissions belonging to the same DMRS bundle.

**Power consistency for high power UE**

**vivo:** For high power UE, according to Section 6.2.1 in TS 38.101-1, if the number of uplink symbols transmitted in a certain evaluation period exceeds the duty cycle, UE need to reduce the transmission power. However, how the duty cycle is counted is not specified. That means, NW is not aware of the transmission power change for a high power UE once the duty cycle exceeds the threshold. Thus, for high power UE, if the uplink duty cycle exceeds the threshold during the time domain window for joint channel estimation, and UE changes the transmission power, the power consistency across repetitions cannot be fulfilled.



1. Email discussion (1st round)

## 3.1 Use cases

**FL comments: It has been intensively discussed on the use case of PUSCH transmissions with different TBs. From FL understanding, there may additional specification impact compared with the case of PUSCH transmissions with the same TB, e.g., time domain window. As we have only three RAN1 meetings left, we have to make decision in this meeting.**

**Proposal 1:** **Make down selection on the following two alternatives in RAN1 #106-e.**

Alt 1:

* For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over back-to-back PUSCH transmissions with different TBs
* For non-back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over non-back-to-back PUSCH transmissions with different TBs

Alt 2:

* Joint channel estimation over back-to-back PUSCH transmissions with different TBs is not supported in Rel-17.
* Joint channel estimation over non-back-to-back PUSCH transmissions with different TBs is not supported in Rel-17.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | Our view is Alt.2 because we would like to prioritize to complete a general design concept of joint CE for PUSCH repetition type A/B with the same TB in Rel. 17. Based on that, we would discuss joint CE for different TBs in Rel. 18 because we foresee additional specification impact that needs to be considered in this case, as compared with the case of PUSCH transmissions with the same TB. For instance, if multiple TBs are indicated by multiple DCIs, how to indicate these DCIs needs to be jointly identified by UE, how gNB managed one of false/miss detected DCI needs to be resolved. Moreover, if multiple TBs are indicated by single DCI, the similar design can be obtained from the discussion for 52.6GHz to 71 GHz but the design is not concluded. |
| ZTE | Fine with the proposal with Alt 1 preferred. As well summarized by FL, joint channel estimation can provide clear performance gain for different TB case as shown by several companies. As for the scheduling restriction of gNB, we think a separate RRC signaling for enabling joint channel estimation dedicated for different TB case could be considered. In such case, it will not impact the scheduling of other cases, e.g., repetition or TBoMS. And it’s always up to the network implementation considering both the performance gain and scheduling restriction. |
| Apple | Alt 2 is preferred. (non-) or back-to-back PUSCH transmissions with different TBs are out of the target of coverage enhancement. The potential gain and scheduling restrictions should be studied carefully. If possible, these can be discussed in future Release. |

**Proposal 2:** **Confirm the following working assumption.**

**Working assumption:**

* For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following case:
  + Over back-to-back PUSCH transmissions for one TB processed over multiple slots
    - It’s subject to UE capability

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | We agree with the proposal. |
| ZTE | Support. We don’t identify any additional specification efforts to support this use case compared to PUSCH repetition. |
| Apple | One clarification question on this working assumption, this working assumption is only applied to TBoMS with one ToT. If TBoMS is configured with multiple ToT, this WA is not applied, right? |

**Proposal 3:** **Confirm the following working assumption.**

**Working assumption:**

* For non-back-to-back PUSCH transmissions (at least for the case of the same TB) across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over non-back-to-back PUSCH transmissions (of the same TB) for repetition type A scheduled by dynamic grant or configured grant.
  + Over non-back-to-back PUSCH transmissions (of the same TB) for repetition type B scheduled by dynamic grant or configured grant, if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A.
    - FFS: additional specification enhancements on top of that defined to support repetition Type A
    - Only for single layer transmissions
    - Subject to UE capability
  + FFS: Over non-back-to-back PUSCH transmissions with different TBs
  + FFS: Over non-back-to-back PUSCH transmissions for TBoMS
  + For the non-back-to-back PUSCH transmissions, it is defined as at least when there is no UL transmission between the two successive PUSCH transmissions
  + Subject to UE capability with details FFS (e.g., separate vs. joint capability for type A & type B, w.r.t. OFF power requirements, etc.)
* FFS: Joint channel estimation over non-back-to-back PUSCH transmissions with other uplink transmissions between the two successive PUSCH transmissions across consecutive slot.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | We agree with the proposal. |
| ZTE | Support  Based on RAN4 output, it is feasible for UE to satisfy the related requirements in case of non-back-to-back PUSCH transmissions across consecutive slots. |
| Apple | We are ok to confirm the working assumption. |

## 3.2 Time domain window

**FL comments: In RAN1 #105-e, two candidate alternatives were discussed. It seems there are different understanding on the two alternatives. Before making down selection between the two alternatives of the time domain window, we need to discuss the details for each alternative.**

* Alt 1: All the repetitions are covered by one single TDW
  + The TDW may be fragmented into multiple sub windows due to the following events such that the power consistency and phase continuity are violated.
    - DL/UL configuration for unpaired spectrum;
    - The TDW exceeds the maximum duration;
    - The maximum unscheduled gap between two successive PUSCHs is exceeded;
    - DL reception/monitoring occasion for unpaired spectrum during the TDW;
    - High priority transmission, dynamic SFI for unpaired spectrum, CI and etc. during the TDW.
  + The start of the TDW or first sub window is the first PUSCH transmission
    - Option 1a: The first available slot for PUSCH transmissions.
    - Option 1b: The first available symbol for PUSCH transmissions.
    - Option 2a: The first physical slot allocated for PUSCH transmissions.
    - Option 2b: The first physical symbol allocated for PUSCH transmissions.
  + The start of one sub window (except the first sub window) is,
    - Option 1: The first available slot for PUSCH transmission after the previous sub window.
    - Option 2: The first available symbol for PUSCH transmission after the previous sub window.
  + The end of one sub window (except the last sub window) is,
    - Option 1: The last slot of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
    - Option 2: The last symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
  + The end of the TDW or the last sub window is the end of the last PUSCH transmission.
  + FFS: frequency hopping and precoder cycling

Companies are encouraged to provide views on the above details for Alt 1.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | It looks that the current formulation of Alt.1 generally converges to Alt.2 because sub-window in Alt.1 corresponds to TDW in Alt.2. According to the past agreements, the power consistency and phase continuity are kept in TDW. On the other hand, in Alt.1, the period to keep the power consistency and phase continuity are only within sub-window, which need to revise the past agreements. Therefore, our view is to take Alt.2. |
| ZTE | We would like to first clarify the following understanding:   1. Is the single TDW configured by gNB? 2. If the answer above is yes, is it possible gNB configure a TDW with length smaller than the duration of all PUSCH repetitions? If possible, does it mean the UE does not expect to keep phase and power continuity for the rest of repetitions that out of the single TDW? If the answer is yes, it seems contradicting with the second last bullet. If the answer is no, what’s the difference with Alt2?   In addition, we are not sure whether we need to list all detailed events that would violate the power consistency and phase continuity. It could be sufficient to say it is under the requirements defined by RAN4. |
| Apple | Trying to understand Alt 1, the power consistency and phase continuity are assumed within the sub-window, right? |

* Alt 2: All the repetitions are covered by one or multiple TDWs
  + Alt 2-A: All the repetitions are covered by one or multiple consecutive TDWs
    - All the TDWs have the same window length (expect the last TDW).
    - The window length can be configurable but no longer than the maximum duration.
    - The start of the first TDW is the first PUSCH transmission.
      * Option 1a: The first available slot for PUSCH transmissions.
      * Option 1b: The first available symbol for PUSCH transmissions.
      * Option 2a: The first physical slot allocated for PUSCH transmissions.
      * Option 2b: The first physical symbol allocated for PUSCH transmissions.
    - In case the power consistency and phase continuity are violated within one TDW due to the events,
      * Option 1: This TDW is fragmented into multiple sub windows.
        + FFS: details of sub windows
      * Option 2: DM-RS bundling is not assumed during this TDW.
      * The events may include.
        + DL/UL configuration for unpaired spectrum;
        + The maximum unscheduled gap between two successive PUSCHs is exceeded;
        + DL reception/monitoring occasion for unpaired spectrum during the TDW;
        + High priority transmission, dynamic SFI for unpaired spectrum, CI and etc. during the TDW.
    - FFS: frequency hopping and precoder cycling
  + Alt 2-B: All the repetitions are covered by one or multiple TDWs
    - Multiple TDWs can be consecutive or non-consecutive.
    - The start of the first TDW is the first PUSCH transmission
      * Option 1a: The first available slot for PUSCH transmissions.
      * Option 1b: The first available symbol for PUSCH transmissions.
      * Option 2a: The first physical slot allocated for PUSCH transmissions.
      * Option 2b: The first physical symbol allocated for PUSCH transmissions.
    - The start of one TDW (except the first window)
      * Option 1: The first available slot for PUSCH transmission after the previous TDW.
      * Option 2: The first available symbol for PUSCH transmission after the previous TDW.
    - One TDW is ended due to the events,
      * The end of one TDW (except the last TDW) is,
        + Option 1: The last slot of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
        + Option 2: The last symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
      * The event may include.
        + DL/UL configuration for unpaired spectrum;
        + The TWD exceeds the maximum duration;
        + The maximum unscheduled gap between two successive PUSCHs is exceeded;
        + DL reception/monitoring occasion for unpaired spectrum during the TDW;
        + High priority transmission, dynamic SFI for unpaired spectrum, CI and etc. during the TDW.
      * The end of the last TDW is the end of the last PUSCH transmission.
    - FFS: frequency hopping and precoder cycling

Companies are encouraged to provide views on the above details for Alt 2.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | We support Alt.2 as it keeps the power consistency and phase continuity over the TDW. |
| ZTE | We would like to first clarify the following understanding:   1. Are the one or multiple TDWs configured by gNB? 2. If the answer above is yes, how could gNB configure non-consecutive TDWs? Is it correct understanding that the TDW in Alt-2A is similar to the back-to-back nominal repetition configured for PUSCH repetition time B, while the TDW in Alt-2B is similar to the potential non-back-to-back actual repetition implicitly determined for PUSCH repetition time B?   In addition, we are not sure whether we need to list all detailed events that would violate the power consistency and phase continuity. It could be sufficient to say it is under the requirements defined by RAN4. |
| Apple | For Alt2 -A, “All the repetitions are covered by one or multiple consecutive TDWs”, we are not so clear about the multiple consecutive TDWs, does it mean the DL slots could be included in TDW for this alternative?  For Alt2-B, “One TDW is ended due to the events”, one TDW could be divided into two sub-TDW, are the power consistency and phase continuity are assumed for this TDW (i.e., the first sub-TDW)? How about the left slot(s) in this window? |

**FL comments: It seems the majority support joint enabling/disenabling of joint channel estimation and the time domain window.**

**Proposal 4:**

* Joint channel estimation for PUSCH transmissions and the time domain window are jointly enabled or disabled via RRC configuration for a UE.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | We agree with the proposal. |
| ZTE | Support. |
| Apple | OK with Proposal 4. |

**FL comments: Regarding whether additional dynamic signaling is needed to enable/disable joint channel estimation for PUSCH transmissions, companies are encouraged to provide further views.**

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | Depending on the event, the power consistency and phase continuity are violated. The DCI assignment may result not to satisfy the power consistency and phase continuity condition. In such case, it results disable joint channel estimation. We don't see the need of "explicit" disable joint channel estimation by DCI. |
| ZTE | At least for PUSCH with repetitions or TBoMS, we don’t identify any additional dynamic signaling for enable or disable joint channel estimation. |
|  |  |

**FL comments: Companies are encouraged to provide views on whether coherent transmission indication is necessary and the potential solutions summarized in section 2.3.4.**

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | Current view is not necessary, but we can wait RAN4 reply on the maximum length where UE can keep the power consistency and phase continuity. |
| ZTE | No need. Our understanding is, a UE is expected to maintain power consistency and phase continuity among PUSCH transmissions within a TDW, as long as a UE reports corresponding capability, e.g., the maximum duration. Thus, it would be an error case if the UE cannot maintain the power consistency and phase continuity within a TDW, i.e., no need additional transmission indication from UE side. In addition, even such indication is reported, it’s unclear what’s the benefits it could bring to gNB. |
|  |  |

## 3.3 Optimization of DMRS location in time domain

**FL comments: It has been intensively discussed on DMRS located in special slots. As we have only three RAN1 meetings left and considering the potential specification impacts, we have to make decision in this meeting.**

**Proposal 5:** **Make down selection on the following two alternatives in RAN1 #106-e.**

**Alt 1:**

* For joint channel estimation over PUSCH transmissions, DMRS located in special slots is supported in the following cases,
  + Additional DMRS is located in special slots for repetition type A, in case special slots cannot used for PUSCH transmission.
  + FFS: optimization of DMRS location in special slots for repetition type A
  + FFS: Transmission of different TBs

**Alt 2:**

* Optimization of DMRS location in time domain for PUSCH is not considered for joint channel estimation in Rel-17.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | Our view is Atl.2 as the TU is limited. |
| ZTE | Fine with the proposal, with preference on Alt2. |
| Apple | Alt 2 is preferred. |

## 2.6 Others

**FL comments: It is understood that the transmission power cannot be changed during the time domain window. There can be following alternatives.**

* Alt 1: UE is not expected to receive TPC commands during the current time domain window or sub window.
* Alt 2: UE Receives and accumulates TPC commands without taking effect during the current time domain window or sub window.
* Alt 3: Modifying the TPC commands accumulation range so that power control is performed per time domain window or sub window.

Companies are encouraged to provide views on the above alternatives.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | We think Alt.2 is a reasonable design as it allows to apply power control after the current time domain window or sub window. |
| ZTE | Alt 1 or Al 2 is more preferred as it would not change current power control granularity based on each PUSCH transmission. |
| Apple | Alt 2 is preferred. The accumulated TPC commands are applied to PUSCH in the next TDW. |

**FL comments: It is understood that the UE should not perform TA adjustment during the time domain window.**

**Proposal 6:**

* UE should not perform TA adjustment during the time domain window or sub window.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Panasonic | We agree with the proposal. |
| ZTE | Fine with the proposal in general, while it seems better to align with the decision on TPC command. |
| Apple | Ok with this proposal. |

1. Agreements at RAN1#105

Agreement**:**

* Joint channel estimation over non-back-to-back PUSCH transmissions within one slot is not supported.

Agreement:

* Definition of **the maximum duration**: a maximum time duration during which **UE is able to** maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.
* FFS whether or not such a definition is necessary for RAN1 specifications.
  + Note: whether such a definition is to be specified in RAN4 specifications is up to RAN4.
* FFS the maximum duration may be reported by UE.
* Note: it is understood that for a UE, the maximum duration is no less than the time domain window duration

Agreement:Send LS to RAN4 asking the following questions

* 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

Agreement:

* Optimization of DMRS granularity in time domain for PUSCH is not considered for joint channel estimation in Rel-17.

Agreement:

* For back-to-back PUSCH transmissions within one slot, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over back-to-back PUSCH transmissions (of the same TB) for repetition type B scheduled by dynamic grant or configured grant, if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A with consecutive slots
    - FFS: additional specification enhancements on top of that defined to support repetition Type A
    - Only for single layer transmissions
    - Subject to UE capability
* Joint channel estimation over back-to-back PUSCH transmissions with different TBs within one slot is not supported.

**Working assumption:**

* For non-back-to-back PUSCH transmissions (at least for the case of the same TB) across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over non-back-to-back PUSCH transmissions (of the same TB) for repetition type A scheduled by dynamic grant or configured grant.
  + Over non-back-to-back PUSCH transmissions (of the same TB) for repetition type B scheduled by dynamic grant or configured grant, if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A.
    - FFS: additional specification enhancements on top of that defined to support repetition Type A
    - Only for single layer transmissions
    - Subject to UE capability
  + FFS: Over non-back-to-back PUSCH transmissions with different TBs
  + FFS: Over non-back-to-back PUSCH transmissions for TBoMS
  + For the non-back-to-back PUSCH transmissions, it is defined as at least when there is no UL transmission between the two successive PUSCH transmissions
  + Subject to UE capability with details FFS (e.g., separate vs. joint capability for type A & type B, w.r.t. OFF power requirements, etc.)
* FFS: Joint channel estimation over non-back-to-back PUSCH transmissions with other uplink transmissions between the two successive PUSCH transmissions across consecutive slot.

Agreement:

* Joint channel estimation for PUSCH transmissions is enabled or disabled via RRC configuration for a UE
  + FFS: whether additional dynamic signaling is needed to enable/disable joint channel estimation for PUSCH transmissions
  + Note: the enabling of such a feature is subject to certain prerequisites
  + FFS RRC parameter details (including explicit vs. implicit configuration)
* FFS For joint channel estimation for PUSCH, the time domain window is not explicitly enabled or disabled separately from joint channel estimation.

Note: Enabling/disabling of joint channel estimation for PUSCH transmissions means enabling/disabling of DMRS bundling for PUSCH transmissions under the condition of power consistency and phase continuity.

Agreement:

For joint channel estimation for PUSCH repetition type A of PUSCH repetitions of the same TB, down select one of the following alternatives for the time domain window.

* Alt 1: All the repetitions are covered by one single time domain window
  + The start of the window is the first PUSCH transmission
  + FFS: how to handle non-consecutive physical slots for UL transmission, e.g., due to DL/UL configuration for unpaired spectrum
  + FFS: frequency hopping and precoder cycling
* Alt 2: All the repetitions are covered by one or multiple time domain windows
  + For the start of each window,
    - The start of the first window is the first PUSCH transmission.
    - FFS: how to determine the start of other windows, e.g., whether multiple windows are consecutive or non-consecutive, whether the start of the window depends on DL/UL configuration for unpaired spectrum
  + For the length of each window,
    - FFS Each window consists of at least two adjacent physical slots for UL transmission.
    - The length of each window is no longer than the maximum duration.
    - FFS: how to determine the length of each window
    - FFS: whether the length of each window depends on DL/UL configuration for unpaired spectrum
  + FFS: how to handle non-consecutive physical slots for UL transmission, e.g., due to DL/UL configuration for unpaired spectrum.
  + FFS: frequency hopping and precoder cycling
* Other alternatives are not precluded.

1. Agreements at RAN1#104b-e

Agreements:

* For joint channel estimation, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.
  + FFS how the time domain window is determined (e.g., via explicit configuration and/or implicitly derived) and whether or not to have the possibility of enabling/disabling the time domain window
  + FFS the units the time domain window (e.g. repetitions, slots, and/or symbols)
    - FFS : association between the potential use case(s) and units of the time window
  + FFS: single or multiple time domain windows
* FFS: relation with UE capability
* FFS: whether the term "time domain window" is used in the specification or replaced by other technical terms
* FFS whether or not to further consider impacting of timing advance

**Agreements:**

* A new DMRS pattern equally spaced among PUSCH transmissions is not considered for joint channel estimation in Rel-17.

**Agreements:**

* For inter-slot frequency hopping with inter-slot bundling, down select on the following two options:
  + Option 1: The bundle size (time domain hopping interval) equals to the time domain window size.
  + Option 2: The bundle size (time domain hopping interval) can be different from the time domain window size.
    - FFS: Whether the bundle size (time domain hopping interval) is explicitly configured or implicitly determined.
    - FFS: Whether/How the bundle size (time domain hopping interval) is defined separately for FDD and TDD.
    - FFS: relation between the bundle size (time domain hopping interval) and the time domain window size

**Conclusion:**

* For optimization of DMRS granularity in time domain with joint channel estimation, the proponents are encouraged to provide more simulation results in next meeting

**Agreements:**

* For the time domain window for joint channel estimation, down select on the following two options:
  + Option 1: The unit of the time domain window is defined separately for the following PUSCH transmissions:
    - PUSCH repetition type A
    - PUSCH repetition type B, if agreed
    - TBoMS, if agreed
    - Different TB, if agreed
  + Option 2: The unit of the time domain window is the same for the following PUSCH transmission:
    - PUSCH repetition type A
    - PUSCH repetition type B, if agreed
    - TBoMS, if agreed
    - Different TB, if agreed

**Agreement:**

* For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over back-to-back PUSCH transmissions (of the same TB) for repetition type B scheduled by dynamic grant or configured grant, if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A.
    - FFS: additional specification enhancements on top of that defined to support repetition Type A
    - Only for single layer transmissions
    - Subject to UE capability
  + FFS: Over back-to-back PUSCH transmissions with different TBs

1. Agreements at RAN1#104e

**Agreements**:

* Following potential use cases are considered for joint channel estimation for PUSCH:
  + Use case 1: back-to-back PUSCH transmissions within one slot.
  + Use case 2: non-back-to-back PUSCH transmissions within one slot.
  + Use case 3: back-to-back PUSCH transmissions across consecutive slots.
  + Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.
  + Use case 5: PUSCH transmissions across non-consecutive slots.

Note: RAN1 assumes “back-to-back PUSCH transmission” has zero gap in-between adjacent PUSCH transmissions.

Agreements:

* For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation at least for the following case:
  + Over back-to-back PUSCH transmissions (of the same TB) for repetition type A scheduled by dynamic grant or configured grant
  + FFS details (including possible other cases)

Agreements:

* For joint channel estimation, ~~define~~ a time domain window is introduced to facilitate further discussion, during which UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.
  + FFS: whether the window should be specified
  + FFS: the length of the time domain window is defined by a set of repetitions/slots/symbols
  + FFS: single or multiple time domain windows
* FFS: relation with UE capability
* FFS: the time domain window may or may not be configured ~~or specified~~.
* FFS: whether the term "time domain window" is used in the specification or replaced by other technical terms
* FFS: Whether the window is determined by the power consistency and phase continuity requirements and/or by other factors is to be decided.

Agreements:

* Companies are encouraged to study optimization of DMRS granularity in time domain with joint channel estimation, including:
  + Use cases
  + Simulations results
  + Enhanced schemes, e.g.,
    - Different DMRS density for different PUSCH transmissions
    - No DMRS for some PUSCH transmissions
  + If applicable, impact of dynamic changes, e.g., cancellation of a repetition and companies report the evaluation method.
* Companies are encouraged to study optimization of DMRS location in time domain with joint channel estimation, including:
  + Use cases
  + Simulations results
  + Enhanced schemes, e.g.,
    - DMRS equally spaced among PUSCH transmissions
    - DMRS located in special slots
    - Orphan symbol上 used for DMRS
  + If applicable, impact of dynamic changes, e.g., cancellation of a repetition and companies report the evaluation method.
* Note: the simulation assumptions for DM-RS in TR 38.830 are used as baseline for performance evaluation on optimization of DMRS location/granularity in time domain.
  + Take into account impairments such as frequency offset, and report corresponding parametrization together with the results. Further discuss impairment details.

**Working assumption:**

* For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following case:
  + Over back-to-back PUSCH transmissions for ~~TB processing~~ one TB processed over multiple slots
    - It’s subject to UE capability

Agreements:

* For joint channel estimation.
  + Take into account the residual frequency error, e.g., +/- 0.1 ppm as upper bound.
  + Companies can report other values and frequency error model.

1. Reference
2. 3GPP RP-202928, “New WID on NR coverage enhancements”, China Telecom, RAN#90e, December 7th – 11th, 2020.
3. 3GPP RP-211566, “Revised WID on NR coverage enhancements”, China Telecom, RAN#92e, June 14th – 18th, 2021.
4. 3GPP R1-2009784, “LS on PUCCH and PUSCH repetition”, Qualcomm, RAN1#103-e, October 26th – November 13th, 2020.
5. 3GPP R4-2103393, “Reply on LS on PUCCH and PUSCH repetition”, Qualcomm, RAN4#98-e, January 25th – February 5th, 2021.
6. 3GPP R4-2105417, “Reply LS on PUCCH and PUSCH repetition”, Qualcomm, RAN4#98b-e, April 12th – 20th April, 2021.
7. 3GPP R1-2104119, “Reply LS on PUCCH and PUSCH repetition”, Qualcomm, RAN1#104bis-e, April 12th – April 20th, 2021.
8. 3GPP R4-2107880, “Reply LS on PUCCH and PUSCH repetition”, Qualcomm, RAN4#99-e, May 2021.
9. R1-2106497 Discussion on joint channel estimation for PUSCH Huawei, HiSilicon
10. R1-2106613 Discussion on joint channel estimation for PUSCH vivo
11. R1-2106657 Joint channel estimation for PUSCH coverage enhancements Nokia, Nokia Shanghai Bell
12. R1-2106711 Discussion on joint channel estimation for PUSCH Spreadtrum Communications
13. R1-2106741 Discussion on joint channel estimation for PUSCH ZTE
14. R1-2106817 On joint channel estimation for PUSCH Sony
15. R1-2106904 Joint channel estimation for PUSCH Samsung
16. R1-2106990 Discussion on joint channel estimation for PUSCH CATT
17. R1-2107125 Discussion on joint channel estimation for PUSCH China Telecom
18. R1-2107192 Enhancements for joint channel estimation for multiple PUSCH Lenovo, Motorola Mobility
19. R1-2107199 Discussion on Joint channel estimation for PUSCH TCL Communication Ltd.
20. R1-2107258 Consideration on Joint channel estimation for PUSCH OPPO
21. R1-2107361 Joint channel estimation for PUSCH Qualcomm Incorporated
22. R1-2107419 Discussion on joint channel estimation for PUSCH CMCC
23. R1-2107524 Discussion on Joint channel estimation over multi-slot PUSCH MediaTek Inc.
24. R1-2107550 Discussions on joint channel estimation for PUSCH LG Electronics
25. R1-2107561 Joint Channel Estimation for PUSCH Ericsson
26. R1-2107604 Discussion on joint channel estimation for PUSCH Intel Corporation
27. R1-2107633 Design Considerations for Joint channel estimation for PUSCH Sierra Wireless, S.A.
28. R1-2107652 Joint channel estimation for PUSCH InterDigital, Inc.
29. R1-2107755 Discussion on joint channel estimation for PUSCH Apple
30. R1-2107801 Joint channel estimation for multiple PUSCH transmission Sharp
31. R1-2107832 Discussion on joint channel estimation for PUSCH Panasonic Corporation
32. R1-2107874 Joint channel estimation for PUSCH NTT DOCOMO, INC.
33. R1-2107937 Discussion on joint channel estimation for PUSCH Xiaomi
34. R1-2108159 Discussion on joint channel estimation for PUSCH WILUS Inc.