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

**e-Meeting, October 11th – 19th, 2021**

**Agenda Item: 8.8.1.3**

**Source: Moderator (China Telecom)**

**Title: [106bis-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 joint channel estimation for PUSCH.

1. Summary of contributions

## 2.1 Conditions to keep power consistency and phase continuity

Based on the LSs between RAN1 and RAN4 [3]-[10], the conditions for UE to keep power consistency and phase continuity among PUSCH transmissions for different scenarios can be summarized as follows:

**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.
* Applying the same TPMI precoder across PUSCH transmissions.
* 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.

**Non-back-to-back transmission with non-zero gap in-between adjacent transmissions**

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 conditions for Back-to-back transmissions:

* No downlink reception in-between the PUSCH or PUCCH repetition in the same band for TDD case.
	+ 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.
	+ 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.
	+ 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.
* 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), 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. RAN4 has further agreed that the 13-symbol is the maximum length for the gap for all SCS, and that the 14-symbol or 1ms will not be discussed in RAN4 anymore for un-scheduled gap in Rel-17 [8].
* In scenario of other UL channels in-between PUCCH or PUSCH repetitions, e.g., SRS or other PUCCH, at least if the other scheduled signals/channels during the non-zero gap have the same settings in antenna port, allocated number and locations of PRBs transmitted, and PAPR and average power, e.g., PUSCH/PUCCH part of repetitions and SRS has same PAPR and average power, it is feasible to maintain the phase continuity and power consistency across the repetitions. RAN4 has agreed that it is not considered for UE to transmit other channels in the gap with different settings.
* RAN4 has not agreed detailed requirement for phase continuity and plans to revisit the above agreement in the scenario of other UL signals/channels in the gap once the requirement is defined. Therefore, RAN4 would like to ask RAN1 what are the consequences if phase continuity cannot be maintained in that scenario?

In [10], RAN1 provide the following information to RAN4 on the scenario when “downlink reception” from UE point of view includes downlink symbols without actual DL transmission from gNB to UE and UE is not assumed to do DL monitoring:

* In RAN1 understanding, regarding to the “downlink reception”, there are actually three scenarios:
	+ Scenario 1: downlink or flexible symbols with actual DL transmission from gNB to UE, with/without DL monitoring occasion configured.
	+ Scenario 2: downlink or flexible symbols without actual DL transmission from gNB to UE, but with DL monitoring occasion configured.
	+ Scenario 3: downlink or flexible symbols without DL monitoring occasion configured.

RAN1 further respectfully asks RAN4 to provide answer to the following question.

* Question 1: In additional to scenario 1 and 2, does the “downlink reception” in RAN4 reply LS R4-2103393 (“No downlink reception in-between the PUSCH or PUCCH repetition in the same band for TDD case”) further include scenario 3?

**The maximum duration**

In the latest LS from RAN4 [9], RAN4 replied RAN1’s questions related to the maximum duration and provided further agreement for the gap between PUSCH/PUCCH transmissions, details are listed as follows:

|  |  |
| --- | --- |
| **RAN1’s questions** | **RAN 4’s answers** |
| 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? | Yes, there is a maximum duration but RAN4 has not agreed how many slots it is. |
| What factors determine the maximum duration? | RAN4 has agreed that TA adjustment should be avoided across the PUSCH/PUCCH transmissions (i.e., from start of first transmission until the end of last transmission) for joint channel estimation. RAN4 is still investigating other factors impact in more detail. |
| Whether the maximum duration should be the same for different cases for both PUSCH and PUCCH? | Yes. |
| Whether the maximum duration is dependent on the modulation order of transmission, e.g., QPSK, 16QAM, 64QAM? | Considering the scenario of coverage extension, RAN4 recommends to only focus on modulation orders not higher than QPSK, i.e., focus on QPSK (PUCCH and PUSCH), Pi/2 BPSK (PUCCH and PUSCH), BPSK (PUCCH). RAN4 is still discussing whether maximum duration depends on modulation order for the above modulation schemes. |
| Whether the maximum duration is dependent on UL waveform (DFT-s-OFDM vs. OFDM)? | 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. | Still under discussion in RAN4. |

## 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. In addition, during online discussion of RAN1 #106-e meeting, according to the guidance from Chair there would be no further discussion for transmissions with different TBs. 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 | **No further discussion** | Working Assumption |
| 4: Non-B2B PUSCH transmissions across consecutive slots | Support(4a) | Support(4a) | **No further discussion** | TBD |
| TBD(4b) | TBD(4b) |
| 5: PUSCH transmissions across non-consecutive slots | TBD | TBD | **No further discussion** | TBD |

Thus, it can be seen that only TBoMS (Use case 3 and Use case 4a), Use case 4b and Use case 5 are remained to be discussed.

### 2.2.1 TBoMS for Use case 3 and Use case 4a

Regarding TBoMS for Use case 3, a working assumption was achieved in RAN1 #104-e meeting as follows:

|  |
| --- |
| **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
 |

Regarding TBoMS for Use case 4a, 4 companies (Spreadtrum, CTC, Sony, WILUS) propose to support it.

One company (LG) proposes that reusing the technology for PUSCH repetition type A can be considered for TBoMS and do not support the technology dedicated for TBoMS.

### 2.2.2 Use case 4b

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

* Use case 4b: non-back-to-back PUSCH transmissions across consecutive slots w/ other uplink transmissions in the middle of two PUSCH transmissions.
	+ **Support**: Sony (TBoMS), Nokia, NSB, InterDigital (?)
	+ **Not Support**: ZTE, Spreadtrum, vivo, TCL, Panasonic, Qualcomm

**Nokia:** For non-back-to-back PUSCH transmissions, in case the other UL transmission in between two successive PUSCHs has different settings than PUSCH, 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.

Dropping/transmitting only part of the UL transmissions with different settings within the repetition period/time-domain window is also possible and should be indicated by the gNB.

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

**Sony**: Introduce a capability defining if UE support of JCE with UL transmissions in between two PUSCH transmissions.

### 2.2.3 Use case 5

For use case 5, Companies’ views are summarized as follows:

* Use case 5a: PUSCH transmissions across non-consecutive slots w/ no uplink transmission in the middle of two PUSCH transmissions.
	+ **Not Support**: ZTE, vivo, CTC, CMCC, Intel, Sierra Wireless, WILUS, Qualcomm
* Use case 4b: PUSCH transmissions across non-consecutive slots w/ other uplink transmissions in the middle of two PUSCH transmissions.
	+ **Not Support**: ZTE, vivo, CTC, CMCC, Panasonic, Intel, Sierra Wireless, WILUS, Qualcomm

### 2.2.4 Use case for UL CA

One company (ZTE) analyzes the benefit of using two carriers w/ Tx switching over single carrier under UL CA scenario. As shown in the following figure, there are two inter-band carriers with unaligned frame boundary, if Tx switching is considered It is also pointed out that the phase continuity can be kept for CA at least when PUSCH is only transmitted in one carrier at a given time.



Fig. Tx switching with unaligned frame boundary for CA

## 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. In RAN1 #106-e meeting, a working assumption for the framework of TDW is achieved, but there are some FFS needs further discussion. In this section, companies’ views on the TDW design are summarized.

### 2.3.1 Configured time domain window

Based on companies’ contributions, several issues about configured TDW are discussed. The issues as well as companies’ views are summarized as follows.

#### Issue #1: The window length *L* of the configured TDW

**Issue #1-1: The maximum value of *L***

* **Option 1:** The maximum value of window length *L* should not exceed the maximum duration.
	+ **Support**: HW, HiSilicon, ZTE, Spreadtrum, vivo, OPPO, CATT, CMCC, Samsung, MediaTek, Intel, Sierra Wireless, InterDigital, Lenovo, Motorola Mobility, WILUS, Sharp, Qualcomm, WILUS, Panasonic
* **Option 2:** The maximum value of window length *L* can exceed the maximum duration e.g. equals to the duration of all repetitions.
	+ **Support**: CTC, Apple, LG, Nokia, NSB, Ericsson

If the maximum value of window length *L* exceeds the maximum duration, some companies find that misalignment on actual TDW between gNB and UE may happen, e.g. if events are triggered by dynamic signaling and the dynamic signaling is missed, error propagation may be raised. However, some companies point out that on one hand, only dynamic events may cause error propagation; on the other hand, unicast PDCCH should always be considered as a reliable channel, even in coverage shortage scenario. Thus, “missing DCI” can be considered as a corner case.

Regarding the issue of error propagation, one company (Nokia) proposes the following options to handle it by gNB:

* If the gNB anticipates that there is a chance of missing DCI, it may configure a short configured TDW size L such that the impact of error propagation is minimized.
* The gNB may try to detect the dynamic event and know whether the actual TDWs are determined without or with the dynamic event by the UE and perform JCE accordingly.
* The gNB may apply a conservative approach by performing JCE only on the PUSCHs repetitions that are not impacted by the error propagation.

**Issue #1-2: Configuration/Indication of *L***

* Configured by RRC or indicate by DCI?

Three companies (HW, Sharp, vivo) propose that *L* could be configured by RRC, while one company (NTT DOCOMO) propose to indicate *L* by DCI dynamically, according to PUSCH resource allocation, interval of updating power and frequency offsets, gain of joint channel estimation, and effect of error propagation.

One company (Panasonic) supports to use an entry of TDRA table to signal the window length *L* of the configured TDW(s) for DG-PUSCH and Type 2 CG-PUSCH and use RRC configuration to signal *L* for CG type 1.

* Configured per BWP or per channel?

Two companies (HW, Sharp) propose that *L* could be configured per UL BWP by RRC, while one company (vivo) proposes to configure *L* per channel/signal instead of per BWP and support to configure *L* separately for PUSCH and PUCCH.

* Default value of *L*

When L is not configured by network, one company (Lenovo) thinks the value of *L* be equal to the maximum duration while one company (Ericsson) thinks the value of *L* be equal to the scheduled duration of the repeated PUSCH.

#### Issue #2: The determination of configured TDW

**Issue #2-1: The start of the first configured TDW**

In the agreed working assumption, the start of the first configured TDW is the first PUSCH transmission. However, whether the start of the first configured TDW is the first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission needs further discussion. Companies’ views are summarized as:

* **Option 1:** The start of the first configured TDW is the first available slot for the first PUSCH transmission.
	+ **Support**: HW, HiSilicon, vivo, CATT, CMCC, Samsung, InterDigital, WILUS, Nokia, NSB, Qualcomm, OPPO, Sharp, LG, Apple, Intel
* **Option 2:** The start of the first configured TDW is the first available symbol for the first PUSCH transmission.
	+ **Support**: Spreadtrum, vivo, Samsung
* **Option 3:** The start of the first configured TDW is the first physical slot for the first PUSCH transmission.
	+ **Support**: ZTE, CATT, CTC, MediaTek, OPPO, Sharp, Apple, Intel

**Issue #2-2: The start of other configured TDW**

In the agreed working assumption, the start of other configured TDWs can be implicitly determined prior to first repetition, details need further discussion. Companies’ views are summarized as:

For paired spectrum, it seems all companies support that the configured TDWs are consecutive.

For SUL band, companies (CTC, CMCC, WILUS) support that the configured TDWs are consecutive.

For unpaired spectrum, companies (CMCC, TCL, Intel, WILUS, Qualcomm, vivo) support that the start of the configured TDWs is implicitly determined based on semi-static DL/UL configuration. To be more specific, one company (CTC) proposes the start of other configured TDWs to be the physical slots right after DL slots for PUSCH transmission based on *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-Configuration Dedicated*. One company (Sony) propose to avoid using UL/DL configuration for definition of start of other configured TDW.

Some companies (Sharp, Nokia, NSB, ZTE) also think the configured TDWs can be consecutive regardless of paired spectrum/SUL band or unpaired spectrum.

Thus, in summary, there are three options as follows:

* **Option 1:** The configured TDWs are consecutive regardless of paired spectrum/SUL band and unpaired spectrum, i.e. the start of other configured TDWs is the first physical slot right after the previous TDW.
* **Option 2:** The start of other configured TDW is different for paired spectrum/SUL band and unpaired spectrum as follows:
	+ For paired spectrum/SUL band, the configured TDWs are consecutive, i.e. the start of other configured TDWs is the first physical slot right after the last TDW.
	+ For unpaired spectrum, the start of the configured TDWs is implicitly determined based on semi-static DL/UL configuration.

**Issue #2-3: The end of the last configured TDW**

In the agreed working assumption, the end of the last configured TDW is the end of the last PUSCH transmission. However, whether the end of the last configured TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission needs further discussion. Companies’ views are summarized as:

* **Option 1:** The end of the last configured TDW is the last available slot for the last PUSCH transmission.
	+ **Support**: CATT, CMCC, InterDigital, WILUS, Nokia, NSB, Samsung, OPPO, Sharp, LG, Apple, Intel
* **Option 2:** The end of the last configured TDW is the last available symbol for the last PUSCH transmission.
	+ **Support**: Spreadtrum, HW, HiSilicon
* **Option 3:** The end of the last configured TDW is the last physical slot for the last PUSCH transmission.
	+ **Support**:ZTE, CATT, CTC, MediaTek, OPPO, Sharp, Apple, Intel, Qualcomm

### 2.3.2 Actual time domain window

Based on companies’ contributions, several issues about actual TDW are discussed. The issues as well as companies’ views are summarized as follows.

#### Issue #3: The determination of actual TDW

**Issue #3-1: The start of the first actual TDW**

In the agreed working assumption, the start of the first actual TDW is the first PUSCH transmission within the configured TDW. However, whether it is the first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission needs further discussion. Companies’ views are summarized as follows.

* **Option 1:** The start of the first actual TDW is the first available slot for the first PUSCH transmission.
	+ **Support**: HW, HiSilicon, ZTE, MediaTek, CMCC, Lenovo, Motorola Mobility, WILUS, InterDigital, Samsung, OPPO, LG, Apple, Intel
* **Option 2:** The start of the first actual TDW is the first available symbol for the first PUSCH transmission.
	+ **Support**: ZTE, MediaTek, CATT, CTC, Lenovo, Motorola Mobility, Nokia, NSB, InterDigital, Samsung, Sharp
* **Option 3:** The start of the first actual TDW is the first physical symbol for the first PUSCH transmission.
	+ **Support**: CATT

**Issue #3-2: The end of the actual TDW**

In the agreed working assumption, after one actual TDW starts, UE is expected to maintain the power consistency and phase continuity until one of the following conditions is met, then the actual TDW is ended.

* Condition 1: The actual TDW reaches the end of the last PUSCH transmission within the configured TDW.
* Condition 2: An event occurs that violates power consistency and phase continuity.

Regarding condition 1, whether the end of the actual TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission within the configured TDW needs further discussion. Companies’ views are summarized as:

* **Option 1:** The end of the actual TDW is the last available slot for the last PUSCH transmission within the configured TDW.
	+ **Support**: ZTE, MediaTek, CMCC, Samsung, InterDigital, Lenovo, Motorola Mobility, WILUS, OPPO, Apple, Intel
* **Option 2:** The end of the actual TDW is the last available symbol for the last PUSCH transmission within the configured TDW.
	+ **Support**: HW, HiSilicon, ZTE, MediaTek, CATT, CTC, InterDigital, Lenovo, Motorola Mobility, Nokia, NSB, Sharp
* **Option 3:** The end of the actual TDW is the last physical symbol for the last PUSCH transmission within the configured TDW.
	+ **Support**: CATT

Regarding condition 2, whether the end of the actual TDW is the last available slot/symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated needs further discussion. Companies’ views are summarized as:

* **Option 1:** The end of the actual TDW is the last available slot of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
	+ **Support**:ZTE, MediaTek, Samsung, InterDigital, Lenovo, Motorola Mobility, WILUS, OPPO, LG, Apple, Intel
* **Option 2:** The end of the actual TDW is the last available symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
	+ **Support**: HW, HiSilicon, ZTE, MediaTek, CATT, CTC, CMCC, InterDigital, Lenovo, Motorola Mobility, Nokia, NSB, Sharp

**Issue #3-3: Events that violate power consistency and phase continuity**

There are two types of events, i.e., semi-static events and dynamic events. The potential events are summarized based on companies’ views.

|  |  |
| --- | --- |
| **Event type** | **Potential events** |
| Semi-static event | DL slot or DL reception/monitoring based on DL/UL configuration for unpaired spectrum |
| SSB transmission |
| CORESET0 with Type0-PDCCH CSS set |
| Invalid UL symbols |
| The actual TDW reaches the maximum duration |
| Frequency hopping (depend on whether it is an event) |
| Beam switching |
|  |
| Dynamic event | High priority transmission |
| Transmission gap of more than 13 un-scheduled symbols |
| Transmission of an UL transmission with different settings than PUSCH repetitions in the middle of two PUSCH transmissions |
| Dynamic SFI |
| UL CI |
| TPC command (depend on whether it is an event) |
| TA adjustment (depend on whether it is an event) |
|  | Precoder cycling (?) |

**Other considerations:**

**ZTE**: Existing Rel-15/16 dropping/cancellation rules for PUSCH repetition type A and repetition type B are all defined as events that violate power consistency and phase continuity, including both semi-static and dynamic events need to be considered.

**LG**: The classification of event is necessary considering the start of actual time domain window.

* Event type 1 (e.g., downlink reception/monitoring and other uplink transmission): the start of following actual time domain window after the event should be postponed at least one slot.
* Event type 2 (e.g., applying TPC command and TA adjustment): the start of following actual time domain window after the event can be adjacent slot.



Fig. Illustration of Event type 1 and Event type 2

**Issue #3-4: Restarting DMRS bundling**

In the agreed working assumption, if the power consistency and phase continuity are violated due to an event, whether a new actual TDW is created is subject to UE capability of supporting restarting DMRS bundling.

Regarding this UE capability, two companies (vivo, CATT) think UE capability of restarting DMRS bundling is applied only to dynamic events. One company (Samsung) think the additional UE capability of supporting restarting DMRS bundling is not needed. One company (CMCC) proposes to discuss whether the resuming of capability to maintain the phase continuity and power consistency would cost some time.

Thus, there are two options for UE capability of restarting DMRS bundling:

* Option 1: UE capability of restarting DMRS bundling is applied only to dynamic events.
* Option 2: UE capability of restarting DMRS bundling is applied to both semi-static events and dynamic events.

If UE is capable of restarting DM-RS bundling, one new actual TDW is created after the event, companies’ views on whether the start of the new actual TDW is the first available slot or symbol for PUSCH transmission after the event are summarized as follows:

* **Option 1:** The start of the new actual TDW is the first available slot for PUSCH transmission after the event.
	+ **Support**: HW, HiSilicon, ZTE, MediaTek, InterDigital, WILUS, Lenovo, Motorola Mobility, Samsung, OPPO
* **Option 2:** The start of the new actual TDW is the first available symbol for PUSCH transmission after the event.
	+ **Support**: ZTE, MediaTek, CATT, CTC, InterDigital, Nokia, NSB, Lenovo, Motorola Mobility

**Other considerations:**

**Samsung**: When a new actual TDW is generated after the event, the minimum length of an actual TDW is 2 slots.

**Apple**: Actual time domain window is determined in the order of TDD UL/DL configuration, maximum duration, and event triggered by dynamic signalling.

### 2.3.3 TDW determination for PUSCH repetition type B

Although current TDW design is mainly for PUSCH repetition type A, companies (HW, HiSilicon, CTC, InterDigital) propose that the mechanism of TDW determination can be reused for PUSCH repetition type B.

**CATT:** For PUSCH transmissions (of the same TB) for repetition Type B across consecutive slots, it has been agreed to be supported if it only reuses those joint channel estimation specification enhancements defined to support repetition Type A. However, the ‘reuse range’ is unclear. Whether it includes the use of configured time domain window, the bundle size of inter-slot frequency hopping or something else needs further clarification.

**Lenovo:** For PUSCH coverage enhancement in NR Rel-17, joint channel estimation 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.

### 2.3.4 Coherent transmission indication

In RAN1#106-e, it was discussed the following scenarios that UE may lose transmission coherence (cannot perform DM-RS bundling) during the time domain window while gNB is not aware of it.

* transmission power drop due to dynamic power sharing of DC
* transmission is dropped due to uplink collision of CA/DC
* UE operates fine timing tracking to adjust FFT boundary when UE receive DL signal
* autonomous timing adjustment
* open loop power control
* large temperature variations

Based on the discussion, it seems companies acknowledge that UE may lose transmission coherence while gNB is not aware of it for CA/DC, but most companies think CA/DC is not a typical scenario for coverage enhancement. For “fine timing tracking”, “open loop power control” and “autonomous timing adjustment”, most companies think these should not be done during a TDW. Some companies thinks the UE should report DMRS bundling is not supported in case of large temperature variations. Then it seems the key point is whether CA/DC should be considered for coverage enhancements.

**Qualcomm**: 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.

**LG**: UE report the end of actual time domain window due to the dynamic event and/or start of the following actual time domain window by using DMRS resource (e.g., DMRS port, DMRS phase).

**Sierra Wireless**: dynamic coherent transmission indication by the UE is not supported in Rel-17.

### 2.3.5 The maximum duration

Based on the contributions, companies’ views about maximum duration are summarized below.

* **UE report its capability for the maximum duration**
	+ **Support**: Spreadtrum, xiaomi (in initial access), Panasonic, Samsung

**CATT**: Whether the maximum duration should be reported by UE or not is up to the number of the maximum duration determined by RAN4.

**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.

## 2.4 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 and companies’ views are summarized as follows:

* 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.

Based on the working assumption, there are two kinds of TDWs, i.e., configured TDW and actual TDW, then Option 1 can further be split into two sub-options as follows.

* Option 1-1: The actual TDWs are determined first, then the time domain hopping intervals are implicitly determined based on the actual TDWs.

Note: There may be multiple time domain hopping intervals, each one equals to the length of corresponding actual TDW.

* + **Support**: Nokia, NSB, LG (?), ZTE, Apple (?)
* Option 1-2: The configured TDWs are determined first, then the time domain hopping interval is implicitly determined based on the configured TDWs.

Note: There is only one time domain hopping interval, which equals to the length L of configured TDWs.

* + **Support**: HW, HiSilicon, vivo, NTT DOCOMO, Sharp, Panasonic

For original Option 2, it can be further updated as:

* Option 2: The time domain hopping interval is configured or implicitly derived based on the number of repetitions. Inter-slot frequency hopping with inter-slot bundling is an event that violates power consistency and phase continuity.
	+ FFS: Whether the time domain hopping interval is the divisor of the window length of the configured TDW
	+ FFS: Whether the time domain hopping interval can be larger than the window length of the configured TDW

Note: The time domain hopping interval can be different from the window length of configured TDW and actual TDW.

* + **Support**: Qualcomm, OPPO, CATT, CTC, TCL, xiaomi, CMCC, Intel, Ericsson

The above three options are illustrated below:



Fig. Illustration of Option 1-1



Fig. Illustration of Option 1-2



Fig. Illustration of Option 2 (time domain hopping interval < configured TDWs window length)



Fig. Illustration of Option 2 (time domain hopping interval > configured TDWs window length)

For option 2, regarding how to determine the time domain hopping interval, there can be two alternatives.

* Alt 1: Inter-slot bundle size is implicitly determined by the number of repetitions K within one actual time domain window, e.g., M=K or floor (K/2) or cell(K/2).
* Alt 2: Inter-slot bundle size is RRC configured or dynamically indicated to a UE.

**Other considerations:**

**CTC**: Whether the bundle size can be configured larger than the window length of the configured TDWs needs further study.

**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.



**Ericsson:** The network is able to configure the FH configuration independently of any JCE windows, and the patterns should be configurable for all UEs, even if they do not use DMRS bundling.

**FL comments:** This issue is discussed under AI 8.8.2.

## 2.5 TPC command

In RAN1 106-e, down-selection is agreed to be made between the following two alternatives about TPC command:

* Alt 1: UE is not expected to receive TPC commands during the current time domain window.
* Alt 2: UE receives and accumulates TPC commands without taking effect during the current time domain window.

In RAN1 106-e, it was further discussed on the two alternatives below. Companies’ views are summarized as follows.

* Alt 1: UE is not expected to receive TPC commands that would take into effect after the start of a time domain window.
	+ - FFS: Such TPC commands constitute events for TDW determination
	+ **Support**: ZTE, Intel, Ericsson, Sharp, Qualcomm, CATT
* Alt 2: If UE receives TPC commands that would take into effect after the start of a time domain window, UE accumulates TPC commands without taking effect during the current time domain window.
	+ **Support**: HW, HiSilicon, Spreadtrum, vivo, OPPO, CMCC, xiaomi, Panasonic, Samsung, NTT DOCOMO, Sony, Sierra Wireless, LG, InterDigital, Sharp, Nokia, NSB

|  |  |
| --- | --- |
| **Alternative** | **Companies’ views** |
|  Alt 1 | * May lead to power control deviation especially when the window length is large.
* It requires more restriction for gNB scheduling. DCI format 2\_2 is a group-common DCI serving multiple UEs simultaneously. Restriction on group-common DCI may have very large impact on scheduling.
* If the UE is configured with group common power control command reception of DCI format 2\_2, e.g. for configured grant operation, it is not likely that power control latency is a crucial problem.
* For UEs in coverage enhancement mode, it is expected that UE would apply maximum transmit power for the transmission of PUSCH repetitions. In this case, power control accumulation mechanism may not be necessary for DMRS bundling.
* There is no spec change while the scheduler has to adjust transmission timing of TPC command such that the UE is not expected to receive the TPC command during the TDW.
* When the TDWs are back-to-back during a PUSCH transmission, the TPC commands would have to be sent between PUSCH transmissions which could be a long time, it seems Alt1 can’t work well for this case.
 |
| Alt 2 | * Based on current specification, the received TPC command is accumulated for a certain time, which means TPC command would not be immediately applied. Even though TPC is received during the current TDW, UE can accumulate TPC command and take effect after a certain time.
* It is more straightforward to restrict UE not to adjust the transmission power during the JCE window instead of further limiting the gNB behavior.
* It will get the better performance by adjusting the power according to channel condition.
* For TPC handling, since the TPC command for PUSCH is indicated via DCI, the scenario of receiving TPC command within an actual TDW is invalid. Indeed, with the maximum unscheduled gap being equal to 13 symbols, JCE (and hence actual TDW) should happen between consecutive UL slots only, at least for TDD. The only potentially valid scenario is for FDD, if PDCCH is within the valid unscheduled gap and if PDCCH reception/monitoring does not break phase continuity in FDD.
 |

Another important issue is to further clarify whether the TDW referred to in the above agreements is the actual TDW or the configured TDW.

**Other considerations:**

**Sony**: propose a UE capability indicating if a UE support DL within a TDW or an actual TDW.

**Apple**: Wait RAN4’s input to determine which power control alternative is adopted.

**Sharp**: For CG-PUSCH repetitions, If UE receives TPC commands that would take into effect after the start of a TDW, UE should accumulate TPC commands without taking effect during the current TDW or UE should not be expected to receive TPC commands that would take into effect after the start of the TDW. Moreover, the transmission occasion i should be defined as the configured TDW if UE receives TPC commands during the TDW and accumulates the TPC commands without taking effect during the current TDW. For DG-PUSCH with accumulation mode, no special handling is necessary.

## 2.6 TA adjustment

Companies’ views on TA adjustment are summaries as follows:

* **Option 1**: UE does not expect to receive TA commands indicating TA adjustment during the TDW.
	+ **Support**: Qualcomm, ZTE
* **Option 2**: UE ignores the TA command which indicates TA adjustment during the TDW.
	+ **Support**: CMCC
* **Option 3**: UE performs TA adjustment after the TDW if it receives any TA command indicating TA adjustment during the TDW.
	+ **Support**: Spreadtrum, vivo, Panasonic, NTT DOCOMO, Sony, Apple, InterDigital, Ericsson, Sharp, Nokia, NSB

**HW**: TA adjustment should be performed timely and taken as an event for the determination of actual TDWs.



**xiaomi**: UE should not perform TA adjustment during the time domain window. Similar to TPC command, we suggest UE receive but ignore the TA command without taking effect during the TDW. For TA adjustment, a lifecycle P of TA adjustment command should be introduced. If the command is still within the lifecycle after the TDW of joint channel estimation, continue to perform TA adjustment.



## 2.7 Others

**Dynamic signaling to enable/disable joint channel estimation for PUSCH**

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:** Sierra Wireless

**Not support:** Intel, LG

**FL comments:** This issue is discussed under AI 8.8.2.

**Phase drifting**

**CMCC**: The impact of phase drifting to the performance of joint channel estimation under a large number of consecutive slots should be studied.

**Samsung:** Support a same power, precoding, RV, and frequency position within time domain window.



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

**Power consistency for high power UE**

**vivo:** 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. Thus, for high power UE, if joint channel estimation is enabled during the TDWs, a certain power class should be determined prior to the first PUSCH transmission.



**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.

**Phase correction at gNB**

**Ericsson**: gNB can correct for a wideband phase error between repetitions of an uplink channel in different slots, such that the performance is relatively close to where the ideal relative phase is known. Thus, 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.

1. Email discussion (1st round)

## 3.1 Use cases for joint channel estimation

**Use case 3 (TBoMS):**

**Proposal:** **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 are encouraged to provide comments on the above proposal.

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| **Companies** | **Comments** |
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**Use case 4a (TBoMS):**

**Proposal:**

* For non-back-to-back PUSCH transmissions across consecutive slots (no uplink transmission in the middle of two PUSCH transmissions), support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following case:
	+ Over non-back-to-back PUSCH transmissions for one TB processed over multiple slots
		- It’s subject to UE capability

Companies are encouraged to provide comments on the above proposal.

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| **Companies** | **Comments** |
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**Use case 4b:**

**Companies are encouraged to provide views on whether use case 4b (other uplink transmission in the middle of two PUSCH transmissions has the same setting with PUSCH) is supported or not.**

**Companies are encouraged to provide comments on the following options to handle the case that the other UL transmission in between two successive PUSCHs has different settings than PUSCH.**

* 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.

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| **Companies** | **Comments** |
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**Use case 5:**

**Proposal:**

* Joint channel estimation over PUSCH transmissions across non-consecutive slots is not supported in Rel-17.

Companies are encouraged to provide comments on the above proposal.

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| **Companies** | **Comments** |
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## 3.2 Time domain window

**Proposal: Confirm the following working assumption**

|  |
| --- |
| **Working assumption:**For joint channel estimation for PUSCH repetition type A of PUSCH repetitions of the same TB, all the repetitions are covered by one or multiple consecutive/non-consecutive configured TDWs.* Each configured TDW consists of one or multiple consecutive physical slots.
* The window length *L* of the configured TDW(s) can be explicitly configured with a single value ~~and~~ *~~L~~* ~~is no longer than the maximum duration~~.
	+ FFS: The maximum value of *L* ~~is the duration of all repetitions~~
	+ FFS: Solutions to error propagation issue if ~~for~~ *L* is longer than the maximum duration is to be discussed further.
	+ FFS: The window length *L* is configured per UL BWP
* The start of the first configured TDW is the first PUSCH transmission
	+ FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission.
* The start of other configured TDWs can be implicitly determined prior to first repetition.
	+ FFS: The configured TDWs are consecutive for paired spectrum/SUL band
	+ FFS: The start of the configured TDWs for unpaired spectrum is implicitly determined based on semi-static DL/UL configuration.
* The end of the last configured TDW is the end of the last PUSCH transmission.
	+ FFS: The end of the configured TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission.
* Within one configured TDW, one or multiple actual TDWs can be implicitly determined:
	+ The start of the first actual TDW is the first PUSCH transmission within the configured TDW.
		- FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission.
	+ After one actual TDW starts, UE is expected to maintain the power consistency and phase continuity until one of the following conditions is met, then the actual TDW is ended.
		- The actual TDW reaches the end of the last PUSCH transmission within the configured TDW.
			* FFS: The end of the actual TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission.
		- An event occurs that violates power consistency and phase continuity
			* FFS: The events may include e.g., a DL slot based on DL/UL configuration for unpaired spectrum, the actual TDW reaches the maximum duration, DL reception/monitoring occasion for unpaired spectrum, high priority transmission, frequency hopping, precoder cycling.
			* FFS: The end of the actual TDW is the last available slot/symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
	+ If the power consistency and phase continuity are violated due to an event, whether a new actual TDW is created is subject to UE capability of supporting restarting DMRS bundling.
		- If UE is capable of restarting DM-RS bundling, one new actual TDW is created after the event,
			* FFS: The start of the new actual TDW is the first available slot/symbol for PUSCH transmission after the event.
		- If UE is not capable of restarting DM-RS bundling, no new actual TDW is created until the end of the configured TDW.
		- FFS: UE capability of restarting DMRS bundling is applied only to dynamic event or not

Note 1: A ‘configured TDW’ refers to a time domain window whose length can be configured to ‘L’ and whose start and end is determined as described above. Note 2: An ‘actual TDW’ refers to a time domain window during whose entire duration the DM-RS bundling is actually applied. An ‘actual TDW’ duration is always less than or equal to the ‘configure TDW’ duration.Note 3: Whether the terms ‘configured TDW’ and ‘actual TDW’ are revised to other terms and if such terminology is used in specifications is to be further discussed. |

Companies are encouraged to provide comments on the above proposal.

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| **Companies** | **Comments** |
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### 3.2.1 Configured TDW

#### Issue #1: The window length L of the configured TDW

**Issue #1-1: The maximum value of *L***

**FL comments:** Based on companies’ views, if L can be configured as the whole duration of all repetition, it can achieve the best performance in case of no events or only semi-static events. However, there may be error propagation in case of dynamic events, if the window length L of the configured TDW exceeds the maximum duration. From FL understanding, if the window length L of the configured TDW exceeds the maximum duration, restricting to only semi-static events can potentially solve the problem. Thus, a compromised proposal is proposed.

**Proposal:**

* The maximum value of the window length L of the configured TDW is the duration of all repetitions.
* If the window length L of the configured TDW is longer than the maximum duration, UE does not expect dynamic events.
	+ FFS: details of dynamic events.

Companies are encouraged to provide comments on the above proposal.

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| **Companies** | **Comments** |
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**Issue #1-2: Configuration/Indication of *L***

**Companies are encouraged to provide views on the configuration/ indication of L.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Configured by RRC | Indicated by DCI | Add an entry of TDRA table to signal L |
| DG-PUSCH | [Company name] |  |  |
| Type 1 CG-PUSCH |  |  |  |
| Type 2 CG-PUSCH |  |  |  |

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| **Companies** | **Comments** |
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**Companies are encouraged to provide views on the granularity of signaling of L.**

|  |  |
| --- | --- |
| Per BWP | Per Channel |
| [Company name] | [Company name] |

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| **Companies** | **Comments** |
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**Companies are encouraged to provide answers to the following questions.**

**Q1: Whether default value of L is needed?**

**Q2: If the answer to Q1 is yes, what’s the default value?**

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| **Companies** | **Comments** |
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#### Issue #2: The determination of configured TDW

**Issue #2-1: The start of the first configured TDW**

**FL comments:** It seems the majority support the start is slot-level. The key point is whether physical slot or available slot. The difference between physical slot and available slot is demonstrated in the following figure.



* **Option 1:** The start of the first configured TDW is the first available slot for the first PUSCH transmission.
	+ **Support**: HW, HiSilicon, vivo, CATT, CMCC, Samsung, InterDigital, WILUS, Nokia, NSB, Qualcomm, OPPO, Sharp, LG, Apple, Intel
* **Option 3:** The start of the first configured TDW is the first physical slot for the first PUSCH transmission.
	+ **Support**: ZTE, CATT, CTC, MediaTek, OPPO, Sharp, Apple, Intel

Companies are encouraged to provide comments on the above two options.

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| **Companies** | **Comments** |
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**Issue #2-2: The start of the other configured TDW**

* **Option 1:** The configured TDWs are consecutive regardless of paired spectrum/SUL band and unpaired spectrum, i.e. the start of other configured TDWs is the first physical slot right after the previous TDW.
* **Option 2:** The start of other configured TDW is different for paired spectrum/SUL band and unpaired spectrum.
	+ For paired spectrum/SUL band, the configured TDWs are consecutive, i.e. the start of other configured TDWs is the first physical slot right after the last TDW.
	+ For unpaired spectrum, the start of the configured TDWs is implicitly determined based on semi-static DL/UL configuration.

Companies are encouraged to provide comments on the above two options.

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| **Companies** | **Comments** |
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**Issue #2-3: The end of the last configured TDW**

**FL comments:** It seems the majority support the start is slot-level. The key point is whether physical slot or available slot. The difference between physical slot and available slot is demonstrated in the following figure.

****

* **Option 1:** The end of the last configured TDW is the last available slot for the last PUSCH transmission.
	+ **Support**: CATT, CMCC, InterDigital, WILUS, Nokia, NSB, Samsung, OPPO, Sharp, LG, Apple, Intel
* **Option 3:** The end of the last configured TDW is the last physical slot for the last PUSCH transmission.
	+ **Support**:ZTE, CATT, CTC, MediaTek, OPPO, Sharp, Apple, Intel, Qualcomm

Companies are encouraged to provide comments on the above two options.

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| **Companies** | **Comments** |
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### 3.2.2 Actual TDW

#### Issue #3: The determination of actual TDW

**Issue #3-1: The start of the first actual TDW**

**FL comments:** It seems the majority support the start is first available slot or first available symbol. It has been agreed repetition type B will reuse the mechanism of repetition type A. From FL understanding, if the start of the first actual TDW is the first available slot, then additional specification enhancements may be needed otherwise repetition type B may not work properly. Second, there can be unavailable symbols e.g., DL symbols in special slots, that UE cannot maintain power consistency and phase continuity. The difference between available slot and available symbol is demonstrated in the following figure.



* **Option 1:** The start of the first actual TDW is the first available slot for the first PUSCH transmission.
	+ **Support**: HW, HiSilicon, ZTE, MediaTek, CMCC, Lenovo, Motorola Mobility, WILUS, InterDigital, Samsung, OPPO, LG, Apple, Intel
* **Option 2:** The start of the first actual TDW is the first available symbol for the first PUSCH transmission.
	+ **Support**: ZTE, MediaTek, CATT, CTC, Lenovo, Motorola Mobility, Nokia, NSB, InterDigital, Samsung, Sharp

Companies are encouraged to provide comments on the above two options.

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| **Companies** | **Comments** |
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**Issue #3-2: The end of the actual TDW**

**FL comments:** It seems the majority support the end is last available slot or last available symbol. The difference between last available slot and last available symbol is demonstrated in the following figure.



Fig. Illustration of the end of actual TDW is the last available slot



Fig. Illustration of the end of actual TDW is the last available symbol

Condition 1: The actual TDW reaches the end of the last PUSCH transmission within the configured TDW.

* **Option 1:** The end of the actual TDW is the last available slot for the last PUSCH transmission within the configured TDW.
	+ **Support**: ZTE, MediaTek, CMCC, Samsung, InterDigital, Lenovo, Motorola Mobility, WILUS, OPPO, Apple, Intel
* **Option 2:** The end of the actual TDW is the last available symbol for the last PUSCH transmission within the configured TDW.
	+ **Support**: HW, HiSilicon, ZTE, MediaTek, CATT, CTC, InterDigital, Lenovo, Motorola Mobility, Nokia, NSB, Sharp

Condition 2: An event occurs that violates power consistency and phase continuity.

* **Option 1:** The end of the actual TDW is the last available slot of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
	+ **Support**:ZTE, MediaTek, Samsung, InterDigital, Lenovo, Motorola Mobility, WILUS, OPPO, LG, Apple, Intel
* **Option 2:** The end of the actual TDW is the last available symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
	+ **Support**: HW, HiSilicon, ZTE, MediaTek, CATT, CTC, CMCC, InterDigital, Lenovo, Motorola Mobility, Nokia, NSB, Sharp

Companies are encouraged to provide comments on the above two options.

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| **Companies** | **Comments** |
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**Issue #3-3: Events that violate power consistency and phase continuity**

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| --- | --- |
| **Event type** | **Potential events** |
| Semi-static event | DL slot or DL reception/monitoring based on DL/UL configuration for unpaired spectrum |
| SSB transmission |
| CORESET0 with Type0-PDCCH CSS set |
| Invalid UL symbols |
| The actual TDW reaches the maximum duration |
| Frequency hopping (depend on whether it is an event) |
| Beam switching |
|  |
| Dynamic event | High priority transmission |
| Transmission gap of more than 13 un-scheduled symbols |
| Transmission of an UL transmission with different settings than PUSCH repetitions in the middle of two PUSCH transmissions |
| Dynamic SFI |
| UL CI |
| TPC command (depend on whether it is an event) |
| TA adjustment (depend on whether it is an event) |
|  | Precoder cycling (?) |

**Companies are encouraged to provide views on the above events.**

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| **Companies** | **Comments** |
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**Issue #3-4: Restarting DMRS bundling**

* **Option 1:** UE capability of restarting DMRS bundling is applied only to dynamic events.
* **Option 2:** UE capability of restarting DMRS bundling is applied to both semi-static events and dynamic events.

Companies are encouraged to provide comments on the above two options.

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| **Companies** | **Comments** |
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If UE is capable of restarting DM-RS bundling, one new actual TDW is created after the event.

* **Option 1:** The start of the new actual TDW is the first available slot for PUSCH transmission after the event.
	+ **Support**: HW, HiSilicon, ZTE, MediaTek, InterDigital, WILUS, Lenovo, Motorola Mobility, Samsung, OPPO
* **Option 2:** The start of the new actual TDW is the first available symbol for PUSCH transmission after the event.
	+ **Support:** ZTE, MediaTek, CATT, CTC, InterDigital, Nokia, NSB, Lenovo, Motorola Mobility

Companies are encouraged to provide comments on the above two options.

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| **Companies** | **Comments** |
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## 3.3 TPC command

* Alt 1: UE is not expected to receive TPC commands that would take into effect after the start of a time domain window.
	+ - FFS: Such TPC commands constitute events for TDW determination
	+ **Support**: ZTE, Intel, Ericsson, Sharp, Qualcomm, CATT
* Alt 2: If UE receives TPC commands that would take into effect after the start of a time domain window, UE accumulates TPC commands without taking effect during the current time domain window.
	+ **Support**: HW, HiSilicon, Spreadtrum, vivo, OPPO, CMCC, xiaomi, Panasonic, Samsung, NTT DOCOMO, Sony, Sierra Wireless, LG, InterDigital, Sharp, Nokia, NSB

Companies are encouraged to provide comments on the above alternatives and clarify whether the TDW is the actual TDW or the configured TDW.

|  |  |  |
| --- | --- | --- |
|  | Alt 1 | Alt 2 |
| Configured TDW | [Company name] |  |
| Actual TDW |  |  |

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| --- | --- |
| **Companies** | **Comments** |
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## 3.4 TA adjustment

* **Option 1**: UE does not expect to receive TA commands indicating TA adjustment during the TDW.
	+ **Support**: Qualcomm, ZTE
* **Option 2**: UE ignores the TA command which indicates TA adjustment during the TDW.
	+ **Support**: CMCC
* **Option 3**: UE performs TA adjustment after the TDW if it receives any TA command indicating TA adjustment during the TDW.
	+ **Support**: Spreadtrum, vivo, Panasonic, NTT DOCOMO, Sony, Apple, InterDigital, Ericsson, Sharp, Nokia, NSB

Companies are encouraged to provide comments on the above three options and clarify whether the TDW is the actual TDW or the configured TDW.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Option 1 | Option 2 | Option 3 |
| Configured TDW | [Company name] |  |  |
| Actual TDW |  |  |  |

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| **Companies** | **Comments** |
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1. Agreements at RAN1#106-e

**Agreement: 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.

**Conclusion**

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

**Agreement**

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

**Make down-selection between the following two alternatives:**

* Alt 1: UE is not expected to receive TPC commands during the current time domain window.
* Alt 2: UE receives and accumulates TPC commands without taking effect during the current time domain window.

**Agreement**

* UE should not perform TA adjustment during the time domain window.
	+ FFS: UE does not expect to receive TA command to indicate TA adjustment during the TDW.
	+ FFS: UE ignores any TA command which indicates TA adjustment during the TDW.
	+ FFS: UE performs TA adjustment after the TDW if it receives any TA command indicating TA adjustment during the TDW.

**Working assumption:**

For joint channel estimation for PUSCH repetition type A of PUSCH repetitions of the same TB, all the repetitions are covered by one or multiple consecutive/non-consecutive configured TDWs.

* Each configured TDW consists of one or multiple consecutive physical slots.
* The window length *L* of the configured TDW(s) can be explicitly configured with a single value ~~and~~ *~~L~~* ~~is no longer than the maximum duration~~.
	+ FFS: The maximum value of *L* ~~is the duration of all repetitions~~
	+ FFS: Solutions to error propagation issue if ~~for~~ *L* is longer than the maximum duration is to be discussed further.
	+ FFS: The window length *L* is configured per UL BWP
* The start of the first configured TDW is the first PUSCH transmission
	+ FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission.
* The start of other configured TDWs can be implicitly determined prior to first repetition.
	+ FFS: The configured TDWs are consecutive for paired spectrum/SUL band
	+ FFS: The start of the configured TDWs for unpaired spectrum is implicitly determined based on semi-static DL/UL configuration.
* The end of the last configured TDW is the end of the last PUSCH transmission.
	+ FFS: The end of the configured TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission.
* Within one configured TDW, one or multiple actual TDWs can be implicitly determined:
	+ The start of the first actual TDW is the first PUSCH transmission within the configured TDW.
		- FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission.
	+ After one actual TDW starts, UE is expected to maintain the power consistency and phase continuity until one of the following conditions is met, then the actual TDW is ended.
		- The actual TDW reaches the end of the last PUSCH transmission within the configured TDW.
			* FFS: The end of the actual TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission.
		- An event occurs that violates power consistency and phase continuity
			* FFS: The events may include e.g., a DL slot based on DL/UL configuration for unpaired spectrum, the actual TDW reaches the maximum duration, DL reception/monitoring occasion for unpaired spectrum, high priority transmission, frequency hopping, precoder cycling.
			* FFS: The end of the actual TDW is the last available slot/symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
	+ If the power consistency and phase continuity are violated due to an event, whether a new actual TDW is created is subject to UE capability of supporting restarting DMRS bundling.
		- If UE is capable of restarting DM-RS bundling, one new actual TDW is created after the event,
			* FFS: The start of the new actual TDW is the first available slot/symbol for PUSCH transmission after the event.
		- If UE is not capable of restarting DM-RS bundling, no new actual TDW is created until the end of the configured TDW.
		- FFS: UE capability of restarting DMRS bundling is applied only to dynamic event or not

Note 1: A ‘configured TDW’ refers to a time domain window whose length can be configured to ‘L’ and whose start and end is determined as described above.

Note 2: An ‘actual TDW’ refers to a time domain window during whose entire duration the DM-RS bundling is actually applied. An ‘actual TDW’ duration is always less than or equal to the ‘configure TDW’ duration.

Note 3: Whether the terms ‘configured TDW’ and ‘actual TDW’ are revised to other terms and if such terminology is used in specifications is to be further discussed.

1. Agreements at RAN1#105-e

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.
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17. 3GPP R1-2109242 Discussion on joint channel estimation for PUSCH CATT
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20. 3GPP R1-2109330 Discussion on joint channel estimation for PUSCH TCL Communication Ltd.
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27. 3GPP R1-2109799 Views on Joint Channel Estimation for PUSCH Sony
28. 3GPP R1-2109888 Joint channel estimation for PUSCH coverage enhancements Nokia, Nokia Shanghai Bell
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30. 3GPP R1-2110002 Joint channel estimation for multiple PUSCH transmission Sharp
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