**3GPP TSG RAN WG1 Meeting #105-e R1-21xxxxx**

**E-Meeting, May 10th – 27th, 2021**

**Agenda Item: 8.8.1.3**

**Source: Moderator (China Telecom)**

**Title: [105-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]*
* *Specify mechanism(s) to support Type A PUSCH repetitions for Msg3 [RAN1]*

This contribution is a summary of the following email discussion:

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

* 1st check point: 5/21
* 2nd check point: 5/25
* Final check: 5/27
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 send 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.

## 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.

**Companies’ views are summarized in the following table.**

|  |  |  |
| --- | --- | --- |
| **Use cases** | **Companies’ view in RAN1 #104b-e** | **Companies’ additional views in RAN1 #105-e** |
| * Use case 1: back-to-back PUSCH transmissions within one slot.
 | * Repetition type B for the same TB

Support: Huawei, HiSilicon, vivo, CATT, InterDigital, CMCC, Samsung, Xiaomi, China Telecom, Sony, Intel, ZTE, Panasonic, Nokia, NSB, WILUS, OPPO, Lenovo, Motorola Mobility, Spreadtrum, NTT DOCOMONot support: Qualcomm, Sharp, Apple, Ericsson* PUSCH transmissions with different TBs

Support: Huawei, HiSilicon, LG, InterDigital, CMCC, Sony, ZTE, Nokia, NSB, Lenovo, Motorola MobilityFurther study: vivo, CATT, XiaomiNot support: Qualcomm, Samsung, Sharp, Panasonic, Apple, WILUS, OPPO, Ericsson | **Support:** CTC, ZTE, WILUS, Nokia, NSB,* Repetition type B for the same TB
	+ CTC, WILUS, Nokia, NSB,
* PUSCH transmissions with different TBs
	+ **Not** **support**: Intel

**Deprioritize:** LG**Not support:** Sierra Wireless, Ericsson |
| * Use case 2: non-back-to-back PUSCH transmissions within one slot.
 |  | **Support:** CTC, WILUS* Repetition type B for the same TB
	+ CTC, WILUS
* PUSCH transmissions with different TBs
	+ **Not** **support**: Intel

**Deprioritize:** LG, Lenovo, Motorola, MTK**Not support:** Qualcomm, Sierra Wireless, Ericsson |
| * Use case 3: back-to-back PUSCH transmissions across consecutive slots.
 | * PUSCH transmissions with different TBs

Support: Huawei, HiSilicon, CATT, LG, InterDigital, CMCC, China Telecom, Sony, ZTE, Sharp, Nokia, NSB, Lenovo, Motorola Mobility, Sierra WirelessFurther study: vivo, XiaomiNot support: Qualcomm, Panasonic, Apple, WILUS, OPPO, Ericsson, Intel | * PUSCH transmissions with different TBs
	+ **Support**: CTC, CMCC, HW, HiSilicon, ZTE, CATT, Sierra Wireless, Sharp, Lenovo, Motorola
	+ **Not support:** Intel, Ericsson, Samsung

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. |
| * Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.
 |  | **Support:** CTC, TCL, HW, HiSilicon, Qualcomm, Sony, Sierra Wireless, Sharp, WILUS, Nokia, NSB, Ericsson* Repetition type A for the same TB
	+ CTC, WILUS
* Repetition type B for the same TB
	+ CTC, WILUS
* PUSCH transmissions with different TBs
	+ **Support**: CTC, Sharp
	+ **Not** **support**: Intel, Ericsson
* TBoMS
	+ TCL

**Deprioritize:** Lenovo, Motorola, MTK |
| * Use case 5: PUSCH transmissions across non-consecutive slots.
 |  | **Support:** Qualcomm, Nokia, NSB**Deprioritize:** MTK, Lenovo, Motorola |

* 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
		- Not support: ZTE
* 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
		- Support: Huawei, HiSilicon, Qualcomm
	+ Use case 4b: other uplink transmissions in the middle of two PUSCH transmissions
		- Support: Huawei, HiSilicon
		- Not support: ZTE
* Use case 5: PUSCH transmissions across non-consecutive slots.
	+ Use case 5a: no uplink transmission in the middle of two PUSCH transmissions
		- Support: Qualcomm
	+ Use case 5b: other uplink transmissions in the middle of two PUSCH transmissions
		- Not support: ZTE

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.

|  |
| --- |
| **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
 |

**Other considerations:**

**Huawei, HiSilicon:** Compared to back-to-back PUSCH transmissions, the only difference for non-back-to-back PUSCH transmissions in scenario 1 (Repetition type A with S=0 and L<14, where there are 14-L un-scheduled symbols between PUSCH transmissions) is that UE may put its PA into energy-saving state during X un-scheduled OFDM symbols between PUSCH transmissions, especially in case of large X values. The state switching of PA between non-back-to-back PUSCH transmissions introduces random phase rotations and affects the phase continuity for joint channel estimation. Although retaining the UE PA state for phase continuity may cost a portion of UE energy consumption, but in return it can provide a significant coverage gain (e.g. 1~2 dB) with joint channel estimation among PUSCH transmissions.

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

**Sony**: RAN1 shall design necessary mechanisms to enhance JCE also for non-back-to-back slots with arbitrary UE configuration. Introduce a UE capability indicating that the UE supports non-zero gap with “UL with same configuration”, “UL with different configuration”, “UL and/or DL”, “no support/legacy”. We encourage RAN1 to further study how to ensure that both UE and gNB are aware of when conditions for JCE with non-back-to-back slots with DL in-between apply.

**MediaTek**: In order to maintain phase continuity during those unscheduled symbols between UL repetition, UE power consumption would get higher and the OFF power requirement cannot be met. Whether/how to support phase continuity and power consistency for UL repetition under CA and DC scenarios should be clarified with RAN4 feedback.

**Lenovo, Motorola**: No specific enhancements need to be discussed for transmission of same TB with PUSCH repetition type B and for transmission of different TBs with PUSCH repetition type A or type B.

**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:** If joint channel estimation between different TBs is supported, UE behavior when conflict between joint channel estimation and power control, precoder change, and TA adjustment of different TBs should be discussed.

Alt. 1) When the UE has configured time-domain window for joint channel estimation for different TBs, UE does not apply power control, precoder change, and TA adjustment of a latter TB to maintain consistency for joint channel estimation.

Alt. 2) When the UE has configured time-domain window for joint channel estimation for different TBs without consistency for joint channel estimation, UE assumes time-domain window is not configured.

**Nokia, NSB:** The maximum gap of unscheduled symbols between two adjacent PUSCH repetitions is less than 1ms subject to the existing OFF power requirement and is defined per SCS.

|  |  |
| --- | --- |
| SCS (kHz) | X symbols (where the unscheduled gap is less than X) |
| 15 | 14 |
| 30 | 28 |
| 60 | 56 |
| 120 | 112 |

**Nokia, NSB:** gNB to dynamically indicate whether and which DL reception occasion, or other UL transmission with different settings than PUSCH repetitions, should be monitored by the UE.



Open issues:

* Use case 1: back-to-back PUSCH transmissions within one slot.
	+ Repetition type B for the same TB
	+ PUSCH transmissions with different TBs
* Use case 2: non-back-to-back PUSCH transmissions within one slot.
	+ Repetition type B for the same TB
	+ PUSCH transmissions with different TBs
* Use case 3: back-to-back PUSCH transmissions across consecutive slots.
	+ PUSCH transmissions with different TBs
* Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.
	+ Repetition type A for the same TB
	+ Repetition type B for the same TB
	+ PUSCH transmissions with different TBs
	+ TBoMS
* Use case 5: PUSCH transmissions across non-consecutive slots.
* 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 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

## 2.3 Time domain window for joint channel estimation

In RAN1 #104b-e meeting, a time domain window is 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. Following issues related to the time-domain window are discussed:

**Issue 1: The unit of the time domain window**

Two options were agreed to be down selected. 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:** CTC, Xiaomi, Spreadtrum, TCL, Samsung, HW, HiSilicon, OPPO, InterDigital, Ericsson, NTT DOCOMO

|  |  |
| --- | --- |
| Cases | Companies’ views about the unit of time domain window |
| PUSCH repetition type A | * In unit of repetitions
	+ CTC, Samsung, Spreadtrum, HW, HiSilicon, Ericsson, NTT DOCOMO
* In unit of slots
	+ CTC, Xiaomi, HW, HiSilicon, OPPO, InterDigital
 |
| PUSCH repetition type B | * In unit of repetitions
	+ CTC, Samsung, Spreadtrum, HW, HiSilicon, OPPO, NTT DOCOMO
* In unit of symbols
	+ Xiaomi, HW, HiSilicon, InterDigital
 |
| TBoMS | * In unit of slots
	+ CTC, Xiaomi, HW, HiSilicon (w/ repetition type A-like TDRA), Ericsson
* In unit of symbols
	+ HW, HiSilicon (w/ repetition type B-like TDRA)
 |
| Different TB | * In unit of slots
	+ Spreadtrum, HW, HiSilicon, NTT DOCOMO (by slot)
* In unit of symbols
	+ Spreadtrum, HW, HiSilicon
 |

* 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:** CMCC (by slots and/or symbols), CATT (by slot), Intel (by repetition or slot), Apple (by slot), LG (by slot or transmission occasion), Lenovo, Motorola, Nokia, NSB (by slot), Qualcomm

**Other considerations:**

**NTT DOCOMO:** When joint channel estimation is applied only for the PUSCH resource conveying TB X, the time domain window should not cover the PUSCH resource conveying TB Y because UE might be able to improve performance by updating power or calibrating frequency offset between PUSCH conveying TB X and one conveying TB Y.



**Issue 2: The relation between time domain window configuration and UE capability**

Based on companies’ contributions, companies (CTC, Xiaomi, vivo, CMCC, ZTE, CATT, Sierra Wireless, Lenovo, Motorola, Nokia, NSB) think the configuration of time domain window depends on UE capability on the maximum duration of maintaining power consistency and phase continuity.

**Issue 3: The configuration of time domain window**

The configuration of time domain window are discussed by companies, two options are proposed and summarized as follows:

* Option1: explicitly configured, e.g., by RRC or DCI.

**Support:** vivo, Spreadtrum (for different TB), InterDigital, Intel, Apple (for FDD), Panasonic, Sharp (for FDD), NTT DOCOMO, WILUS

* Option2: implicitly derived, e.g., by the repetition factor, TDD frame structure.

**Support:** vivo, Spreadtrum (for PUSCH repetition type A/B), CMCC, HW, HiSilicon, CATT (at least for TDD), OPPO, Apple (for TDD), Sharp (for TDD), Ericsson (for the same TB), WILUS

**Other considerations:**

**vivo:** The RRC configured window can further split to multiple actual time domain windows based on the implicit rule, if conditions for joint channel estimation are not fulfilled in the window, e.g. due to DL reception, TDD frame structure, and etc.



**Spreadtrum**: Time domain windows can be implicitly inferred from its repetition factor, which starts from the 1st symbol of 1st PUSCH to the last symbol of last PUSCH within this window.

**ZTE**: Similar as the terminology introduced PUSCH repetition type B, introduce ‘nominal time domain window’ and ‘actual time domain window’ for joint channel estimation of PUSCH.



**ZTE:** For the start of nominal time domain window, it can be fixed in the time domain once configured. For instance, it can be aligned with the start of frame boundary or aligned with the start of one period for CG PUSCH. Alternatively, it can also be determined dynamically by DCI. Regarding the start of actual time domain window, it can be determined by a group of consecutive slots/symbols/repetitions based on the available transmission occasions.

**Issue 4: Single or multiple time domain windows**

Companies’ views are summarized as follows:

* Option1: Support single time domain window.

**Support:** InterDigital, Lenovo, Motorola

* Option2: Support multiple time domain windows.

**Support:** Xiaomi, Spreadtrum, HW, HiSilicon

**Issue 5: Enabling/disabling of the time domain window**

Based on companies’ contribution, companies (vivo, Samsung, CATT, InterDigital, Intel, LG, Sierra Wireless) think the enabling/disabling of the time domain window should be supported.

**Other considerations:**

**CTC:** Send an LS to RAN4 asking whether the maximum duration of maintaining power consistency and phase continuity among PUSCH transmissions will be defined based on UE capability and the length of maximum duration if defined.

**Lenovo**: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, enabling or disabling of joint channel estimation can be jointly indicated by the presence of signalling for time domain window duration

* Dynamic signalling of time domain window duration should be supported

**Qualcomm**: For each PUSCH transmission, the UE signals a bundling indication in the PUSCH transmission.



**Qualcomm**: Support one or multiple non-overlapping time domain windows for joint channel estimation over PUSCH repetitions (for the same TB).

• Window is determined based on semi-static slot format configuration.

• Window duration is in unit of physical slots.

• All windows have the same window duration.

• FFS: determine start of a window.

**OPPO**: There isn’t any relation between the time domain window and UE’s capability based on current RAN4’s feedback.

**Panasonic:** A length of time domain window should not be longer than the length determined by a DCI, i.e. a time domain window composed by the multiple DCIs should not be supported.

**InterDigital:** Support a grant-type dependent index which indicates which PUSCH(s) to bundle.

Open issues:

* Unit of the time window
* Start and length of the time window
* Relation with UE capability
* Single or multiple time domain windows
* Signalling design for the time window

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

In RAN1 #104b-e meeting, two options are 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:** vivo, CMCC, Samsung, HW, HiSilicon, ZTE, Qualcomm, Apple, Panasonic, LG, NTT DOCOMO, Lenovo, Motorola, Sharp (FDD)

* 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, Xiaomi, CMCC, CATT, OPPO, Intel, Panasonic, LG, Nokia, NSB, Ericsson, Sharp (TDD)

**Other considerations:**

**Xiaomi**: Introduce a configurable additional inter-slot frequency hopping patterns for inter-slot DMRS bundling, e.g. the frequency hopping interval can be larger than the DMRS bundling size.

**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).

**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.

**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:** Further study frequency hopping patterns, taking into account benefits of joint channel estimation and expected UE capability for time domain window size.

**LG:** In order to maintain the same PRB according to the joint channel estimation requirement, the frequency hopping boundary should be equal to or larger than the time-domain window.

**Sharp:** To maximize frequency hopping gain for TDD operation, support a new hopping pattern other than alternating hopping pattern of Rel-15/16 (e.g., first hop🡪second hop🡪second hop) for TDD operation.



**Nokia, NSB:** UE switches frequency hop for the repetitions after a DL reception occasion that the UE is expected/configured to monitor/receive or after an UL transmission with different settings (e.g., in antenna port, occupied PRBs and UL power) than the repeated PUSCH repetitions.



Open issues:

* The bundle size (time domain hopping interval)
* Signalling design
* Frequency hopping pattern for TDD

## 2.5 Optimization of DMRS location/granularity in time domain

**For optimization of DMRS granularity in time domain w/ JCE, the following scheme is considered and simulated by companies:**

* **Scheme:** No DMRS for some PUSCH transmissions

**Support:** CATT, ZTE, OPPO

**Not support**: Qualcomm, Panasonic

One company (ZTE) shows 2 DMRS symbols in every two repetitions w/ JCE can provide additional 2.52 dB, 2.43 dB, 0.15 dB, 0.81 dB and 0.87 dB gain over 1 DMRS symbol in each repetition w/o JCE, 2 DMRS symbols in each repetition w/o JEC, 1 DMRS symbol in each repetition w/ JCE, 2 DMRS symbols in each repetition w/ JEC, 1 DMRS symbol in every two repetitions w/ JCE respectively in 700MHz Rural scenario at 10% BLER. Other simulation assumptions are as include: 700MHz, 4PRBs, 8 repetitions, 3km/h, CFO ~ U[-0.1, 0.1] ppm.

One company (Intel) shows ~1.5dB degradation can be observed when DMRS symbols are not allocated in odd slots. Other simulation assumptions are as include: 4GHz, TBS = 288, 4 PRBs, 4 repetitions, 3km/h, bundling size of 2 slots with JCE, CFO ~ U[-0.1, 0.1] ppm.

One company (Panasonic) shows when TB size is small (TBS=128), performance degradation can be observed if DMRS symbols are not allocated in odd slots; when TB size is larger (TBS=608), only in some cases, such as the conventional DMRS configuration in odd slot is pos2 (the number of DMRS symbols per slot is 3) or pos3 (the number of DMRS symbols per slot is 4), 0.5~1dB performance gain can be observed if DMRS symbols are not allocated in odd slots.

**For optimization of DMRS location in time domain w/ JCE, three schemes are considered and simulated by companies:**

* **Scheme 1:** Additional DMRS located in special slots

**Support:** InterDigital, HW, HiSilicon, HiSilicon, vivo, LG, CMCC, Spreadtrum, Intel

**Lower priority:** Qualcomm

**Not support:** Ericsson

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.

* **Scheme 2:** Different DMRS locations

**Support:** OPPO

**Not support:** Qualcomm

One company (OPPO) shows 0.3dB gain can be found while DMRS placed on different symbol within the slot (1st and 11th symbol, respectively)

* **Scheme 3:** Orphan symbol used for DMRS

**Support:** vivo, LG

One company (vivo) shows JCE w/ 1 orphan DMRS symbol in-between type-B PUSCH repetitions can provide 0.8 dB gain at 10% BLER with 2 repetitions, 4GHz TDD and 1 DMRS symbol per UL slot.

**Other considerations:**

**Xiaomi:** Support maintain a DMRS configuration table containing more diverse DMRS patterns for dynamically indication and configuration.

**vivo:** If orphan symbol(s) used for DMRS or symbol in special slot used for DMRS is supported and located before the first symbol of this PUSCH transmission, the preparation time of this PUSCH need to be revised:

* Opt 1 : Redefine PUSCH preparation time $T\_{proc,2}$ considering the first symbol in the orphan symbol(s) or symbol(s) in special slot.
* Opt 2 : Additional time offset in $T\_{proc,2}$, which is related to the number of the orphan symbol(s) or symbol(s) in special slot.

Open issues:

* Whether to support optimization of DMRS granularity in time domain.
	+ Different DMRS density for different PUSCH transmissions
	+ No DMRS for some PUSCH transmissions
* Whether to support optimization of DMRS location in time domain
	+ Additional DMRS located in special slots
	+ Orphan symbol used for DMRS

## 2.6 Others

**PTRS:**

**InterDigital:** When DM-RS bundling is enabled, PTRS should be enabled as well, at least for FR2.

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

**Power control:**

**Samsung:** A UE updates the CLPC adjustment state per time domain window.



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

**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 command**

**LG:**The UE's behavior for a situation where the consistency of power, phase and TA within the window is ambiguous should be studied, or state in the specification that such a situation will not be configured.

* Alt. 1) When the UE has configured time-domain window for joint channel estimation, UE does not apply configured power control, TPMI/SRI change and TA adjustment during the time-domain window.
* Alt. 2) When the UE has configured time-domain window for joint channel estimation and configured with power control, TPMI/SRI change, TA adjustment within the time-domain window, the UE assumes time-domain window is not configured

**PUSCH transmission interrupted by other transmissions/procedures**

**vivo:** PUSCH transmissions within the time-domain window for joint channel estimation may be interrupted by other transmissions/procedures. PUSCH transmissions is cancelled by SFI, CI or higher priority transmissions.

1. Email discussion (1st round)

## 3.1 Use cases

**FL comments: According to the simulation results provided by Huawei and vivo, considerable gain can be obtained for joint channel estimation across consecutive PUSCH transmissions of different TBs. And as pointed out by some companies as long as power consistency and phase continuity can be maintained, joint channel estimation can be applied to PUSCH transmissions with different TBs. The following proposal is proposed.**

**Proposal 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

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| **Companies** | **Comments** |
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**FL comments: In RAN1 #104b-e, joint channel estimation over back-to-back PUSCH transmissions across consecutive slots for repetition type B is supported. Then joint channel estimation over back-to-back PUSCH transmissions within one slot for repetition type B can be supported as well. Regarding PUSCH transmissions with different TBs within one slot, many companies have concerns. The following proposal is proposed.**

**Proposal 2:**

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

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| **Companies** | **Comments** |
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**Proposal 3: 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

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| **Companies** | **Comments** |
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**FL comments: Based on the reply LS, joint channel estimation can be applied to non-back-to-back transmission 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. 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.**

**Proposal 4:**

* 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 (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 one TB processed over multiple slots

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| **Companies** | **Comments** |
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**FL comments: Based on the contributions, it seems not many support of use case 2.**

**Proposal 5:**

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

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| **Companies** | **Comments** |
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**FL comments: Only a few views on use case 5 so far. Companies are encourage to provide views on use case 5.**

* Use case 5: PUSCH transmissions across non-consecutive slots.

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

**FL comments: For the unit of the time domain window, two options were agreed to be down selected. No majority view can be observed so far. Companies are encouraged to provide further views on these two options, including pros and cons.**

* 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:** CTC, Xiaomi, Spreadtrum, TCL, Samsung, HW, HiSilicon, OPPO, InterDigital, Ericsson, NTT DOCOMO

* 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:** CMCC (by slots and/or symbols), CATT (by slot), Intel (by repetition or slot), Apple (by slot), LG (by slot or transmission occasion), Lenovo, Motorola, Nokia, NSB (by slot), Qualcomm

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| **Companies** | **Comments, including pros and cons for each option** |
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**FL comments: Based on companies’ contributions, companies (CTC, Xiaomi, vivo, CMCC, ZTE, CATT, Sierra Wireless, Lenovo, Motorola, Nokia, NSB) think the configuration of time domain window depends on UE capability on the maximum duration of maintaining power consistency and phase continuity.**

**Proposal 6:** Send LS to RAN4 asking the following question.

* How long is the maximum duration during which UE can maintain power consistency and phase continuity under certain tolerance level?

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| **Companies** | **Comments** |
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**FL comments: For the configuration of time domain window, it seems companies tend to share the view that the time domain window can be implicitly derived from the TDD frame structure.**

**Proposal 7:**

* For joint channel estimation for PUSCH,
	+ The time domain window can be implicitly derived from the DL/UL configuration for unpaired spectrum.
		- FFS: the start and the length of the time domain window.
	+ FFS: Whether the time domain window can be explicitly configured or implicitly derived for paired spectrum.
		- FFS: The time domain window can be implicitly derived from the repetition factors for PUSCH repetition type A or type B.
		- FFS: the start and the length of the time domain window.

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| **Companies** | **Comments** |
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**FL comments: Based on companies’ contribution, companies (vivo, Samsung, CATT, InterDigital, Intel, LG, Sierra Wireless) think the enabling/disabling of the time domain window should be supported. There can be two alternatives. Companies are encouraged to provide views on the following two alternatives.**

* Alt 1: For joint channel estimation for PUSCH, the enabling/disabling of the time domain window and the enabling/disabling of joint channel estimation are jointly configured.
* Alt 2: For joint channel estimation for PUSCH, the enabling/disabling of the time domain window is separated configured from the enabling/disabling of joint channel estimation.

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| **Companies** | **Comments** |
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## 3.3 Inter-slot frequency hopping with inter-slot bundling

**FL comments: For the bundle size (time domain hopping interval), two options were agreed to be down selected. No majority view can be observed so far. Companies are encouraged to provide further views on these two options, including pros and cons.**

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

**Support:** vivo, CMCC, Samsung, HW, HiSilicon, ZTE, Qualcomm, Apple, Panasonic, LG, NTT DOCOMO, Lenovo, Motorola, Sharp (FDD)

* 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, Xiaomi, CMCC, CATT, OPPO, Intel, Panasonic, LG, Nokia, NSB, Ericsson, Sharp (TDD)

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| **Companies** | **Comments, including pros and cons for each option** |
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## 3.4 Optimization of DMRS location/granularity in time domain

**FL comments: For optimization of DMRS granularity in time domain with joint channel estimation, for the case of no DMRS for some PUSCH transmissions, based on the simulation results, only one company show performance gain while two companies show performance degradation.**

**Proposal 8:**

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

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| **Companies** | **Comments** |
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**FL comments: Following simulation results are observed for DMRS located in special slots.**

* 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.

**Proposal 9:**

* For joint channel estimation for PUSCH, DMRS located in special slots is supported in the following cases,
	+ Additional DMRS is located in special slots for repetition type A
	+ FFS: optimization of DMRS location in special slots for repetition type A
	+ FFS: Transmission of different TBs

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| **Companies** | **Comments** |
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## 3.5 Others

**FL comments: Companies are encouraged to provide a list of items (e,g., SFI, UL CI, channel prioritization, PT-RS, TPC command, TA command, Phase correction at gNB, CA operation, DC operation) that may have impact on joint channel estimation for PUSCH, label each item with a priority for discussion, i.e., high priority, medium priority or low priority, and provide views on each item.**

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| **Companies** | **Comments** |
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1. Email discussion (2nd round)

## 4.1 Use cases

**FL comments: Companies having concerns on proposal 1 please check the following comments.**

* **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.**
* **As long as the condition of power consistency and phase continuity can be maintained, joint channel estimation can be applied.**
* **1 Mbps UL data rate is required for eMBB services under Urban scenario without repetition as the simulation baseline, 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.**

**Observations captured in TR 38.830.**

* **Eleven sources (R1-2008874, R1-2007743, R1-2008626, R1-2008399, R1-2008378, R1-2008026, R1-2007680, R1-2008419, R1-2009792, R1-2008479, R1-2007583) show 0.2~2.1 dB SNR gain for joint channel estimation over multiple slots for eMBB at 10% iBLER depending on the number of slots for FR1, compared to Rel-16 PUSCH transmission without joint channel estimation.**

**If companies still have concerns, please answer the following questions.**

* **For the 1 Mbps target UL data rate, whether different TBs or single TB with repetition should be considered?**
* **Is it beneficial if joint channel estimation is applied for PUSCH transmissions with different TBs?**

**Proposal 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

**Support:** Huawei, HiSilicon, CATT, LG, InterDigital, CMCC, China Telecom, Sony, ZTE, Sharp, Nokia, NSB, Lenovo, Motorola Mobility, Sierra Wireless, vivo, Sharp, DOCOMO

**Not support:** Qualcomm, Panasonic, Apple, WILUS, OPPO, Ericsson, Intel, Samsung

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| **Companies** | **Comments** |
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**FL comments: Proposal 2 is updated based on comments with adding the red part.**

**Proposal 2:**

* 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.
		- 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.

**Support:** InterDigital, CATT, CMCC, Nokia, NSB, Intel, vivo, Sharp, OPPO, WILUS, Lenovo, Motorola Mobility, Samsung, Panasonic, Huawei, HiSilicon, Xiaomi

**Not support:** Qualcomm

**Deprioritize:** Apple, LG, Sierra Wireless

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| **Companies** | **Comments** |
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**FL comments: It seems companies have different understandings on off-power requirement in RAN4 LS. As pointed out by Huawei, in TS 38.101-1, there is no off-power requirement for the case with less than 1ms gap. There is only requirement for no less than 1ms, which is in line with the RAN4 LS reply. Even if new off-power requirement is defined in RAN4, it seems it will not preclude the case of non-back-to-back PUSCH transmissions as mentioned by Qualcomm.**

**Proposal 4:**

* Joint channel estimation over non-back-to-back PUSCH transmissions with no uplink transmission in the middle of two PUSCH transmissions across consecutive slot is supported.
	+ Under the condition of power consistency and phase continuity
	+ FFS: other uplink transmissions in the middle of two PUSCH transmissions
* 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 (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

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| **Companies** | **Comments** |
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**FL comments: Proposal 5 is stable. Please refrain from any further comments.**

**Proposal 5:**

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

## 4.2 Time domain window

**For the time domain window, companies have different understandings. From FL understanding, there are two kinds of time durations, one is defined in RAN4 while the other is specified in RAN1. Before discussing other aspects of the time domain window, we need to align the understandings. Thus, proposal 10 is proposed.**

**Proposal 10:**

* Definition of **the time domain window**: a time duration during which **UE is expected to** maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.

Note 1: The time domain window is specified in RAN1.

Note 2: The time domain window may be explicitly configured by gNB or implicitly derived.

* Definition of **the maximum duration**: a time duration during which **UE is able to** maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.

Note 1: The maximum duration is defined in RAN4.

Note 2: The maximum duration may be reported by UE.

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| **Companies** | **Comments** |
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**FL comments: Since the design of the time domain window is highly related to the maximum duration, we need to send LS to RAN4 as early as possible.**

**Proposal 6:** 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 UE capability?

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| **Companies** | **Comments** |
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**FL comments: For the enabling and disabling of the time domain window, companies ask for clarification of Alt 2. The motivation of discussion on Alt 1 and Alt 2 is to handle the FFS in the agreements in RAN1#104b-e. Some companies think the time domain window can be separately enabled or disabled. Seen from the discussion, the majority think the time domain window is not explicitly enabled or disabled. Proposal 11 is proposed.**

**Proposal 11:**

* For joint channel estimation for PUSCH, the time domain window is not explicitly enabled or disabled.
	+ FFS: If the joint channel estimation for PUSCH is enabled or disabled, the time domain window is enabled or disabled implicitly.
	+ FFS: how the time domain window is determined (e.g., via explicit configuration and/or implicitly derived)

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| **Companies** | **Comments** |
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## 4.3 Optimization of DMRS location/granularity in time domain

**FL comments: The majority support proposal 8.**

**Proposal 8:**

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

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| **Companies** | **Comments** |
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**FL comments: Following simulation results are observed for DMRS located in special slots.**

* 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.

**FL comments: From FL perspective, a number of companies provided simulation results and most of the results show considerable gain. The proponents are encourage to provide the spec impact as requested by Intel. Companies having concerns please also provide the spec impact and provide simulation results, not just saying large impact, no gain.**

**@CMCC, If I understand correctly, the main motivation is to add additional DMRS in special slots for repetition type A, in case that special slots cannot used for PUSCH transmission. In case special slots can be used for PUSCH transmission, e.g., if the number of symbols indicated in TDRA is small, both DMRS and data can possibly be transmitted.**

**Proposal 9:**

* For joint channel estimation for PUSCH, 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

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| **Companies** | **Comments** |
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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-210855, “Revised WID on NR coverage enhancements”, China Telecom, RAN#91e, March 16th – 26th, 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. R1-2104241 Discussion on joint channel estimation for PUSCH Huawei, HiSilicon
8. R1-2104332 Discussion on joint channel estimation for PUSCH ZTE
9. R1-2104378 Discussion on Joint channel estimation for PUSCH vivo
10. R1-2104437 Discussion on joint channel estimation for PUSCH Spreadtrum Communications
11. R1-2104539 Discussion on joint channel estimation for PUSCH CATT
12. R1-2104627 Discussion on joint channel estimation for PUSCH CMCC
13. R1-2104687 Joint channel estimation for PUSCH Qualcomm Incorporated
14. R1-2104794 Consideration on Joint channel estimation for PUSCH OPPO
15. R1-2104848 Discussion on joint channel estimation for PUSCH China Telecom
16. R1-2104861 Joint channel estimation for PUSCH InterDigital, Inc.
17. R1-2104882 Discussion on joint channel estimation for PUSCH TCL Communication Ltd.
18. R1-2104921 Discussion on joint channel estimation for PUSCH Intel Corporation
19. R1-2105121 Discussion on joint channel estimation for PUSCH Apple
20. R1-2105176 Joint channel estimation for PUSCH Sony
21. R1-2105327 Joint channel estimation for PUSCH Samsung
22. R1-2105394 Discussion on joint channel estimation for PUSCH MediaTek Inc.
23. R1-2105397 Discussion on joint channel estimation for PUSCH Panasonic Corporation
24. R1-2105490 Discussions on joint channel estimation for PUSCH LG Electronics
25. R1-2105509 Design Considerations for Joint channel estimation for PUSCH Sierra Wireless, S.A.
26. R1-2105577 Joint channel estimation for PUSCH Xiaomi
27. R1-2105642 Joint channel estimation for multi-slot PUSCH Sharp
28. R1-2105654 Joint Channel Estimation for PUSCH Ericsson
29. R1-2105713 Joint channel estimation for PUSCH NTT DOCOMO, INC.
30. R1-2105775 Enhancements for joint channel estimation for multiple PUSCH Lenovo, Motorola Mobility
31. R1-2105879 Discussion on joint channel estimation for PUSCH WILUS Inc.
32. R1-2105903 Joint channel estimation for PUSCH coverage enhancements Nokia, Nokia Shanghai Bell
33. Appendix

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| --- | --- |
| **Company/Tdoc** | **Views** |
| Huawei/R1-2104241 | *Observation 1: By joint channel estimation across consecutive PUSCH transmissions of different TBs, a large coverage gain can be achieved as compared to the baseline of PUSCH transmissions without joint channel estimation, i.e., 1.4 dB and 2.1 dB SNR gains are obtained at 10% BLER for 2 and 3 slots joint channel estimation, respectively.**Observation 2: Phase continuity for joint channel estimation can be also achieved for non-back-to-back PUSCH transmissions on the same conditions agreed in RAN4 LS for back-to-back PUSCH transmission and only one additional condition that UE PA state for the first PUSCH transmission is retained until the start of the next transmission at a potential cost of UE energy consumption.**Observation 3: 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 SRS is transmitted in-between two PUSCH transmissions.**Observation 4: joint channel estimation by utilization of DMRS located S slot in TDD (‘DDDSUDDSUU’) can improve the performance of PUSCH transmissions:** *Compared to the baseline of UL slot with 1DMRS without joint channel estimation, 0.75dB and 1.3dB gain can be obtained by joint channel estimation with S slot of 1 DMRS and 2DMRS, respectively.*
* *Compared to the baseline of UL slot with 2DMRS without joint channel estimation, 0.45dB and 0.65dB gain can be obtained by joint channel estimation with S slot of 1 DMRS and 2DMRS, respectively.*

*Proposal 1: Joint channel estimation should be supported for back-to-back PUSCH transmission of different TBs across slots, subject to requirements of phase continuity provided by RAN4, e.g. the same PRB allocation among different TBs.* *Proposal 2: Joint channel estimation should be supported for non-back-to-back PUSCH transmissions, subject to the further confirmation of phase continuity provided by RAN4.* * *FFS: whether and how to minimize the UE energy consumption caused by retaining PA state for phase continuity between successive PUSCH transmissions*

*Proposal 3: Joint channel estimation should be supported for the very common scenario where a SRS with different RB allocation is transmitted* *in-between PUSCH transmissions** *FFS: Mechanism to support joint channel estimation for SRS transmitted in-between PUSCH transmissions.*

*Proposal 4: For joint channel estimation among multiple PUSCH transmissions, time domain window can be determined implicitly by the duration of phase continuity.** *Dis-continuous time domain resource allocation, different RB allocations, different transmission powers with PA state switching, etc., will impact the phase continuity and determine multiple time domain windows.*

*Proposal 5: For joint channel estimation among multiple PUSCH transmissions, the maximum size of the time domain window should be limited.**Proposal 6: The unit of time domain window is determined according to use cases, for example:** *The unit of time domain window for PUSCH repetition type A can be slots or repetitions*
* *The unit of time domain window for PUSCH repetition type B can be symbols or repetitions*
* *The unit of time domain window for TBoMS with repetition type A-like TDRA can be slots*
* *The unit of time domain window for TBoMS with repetition type B-like TDRA can be symbols*
* *The unit of time domain window for different TBs can be slots or symbols.*

*Proposal 7: DMRS located special slot should be supported for joint channel estimation.** *FFS: utilization mechanism of special slot for PUCCH transmission, SRS transmission or located as DMRS for PUSCH joint channel estimation.*

*Proposal 8: The DMRS bundle size (time domain hopping interval) in inter-slot frequency hopping should equal to the time domain window size.* |
| ZTE/R1-2104332 | *Proposal 1: Confirm the working assumption for back-to-back PUSCH transmissions for one TB processed over multiple slots.* *Proposal 2: Support joint channel estimation in case of back-to-back PUSCH transmissions with different TBs.**Proposal 3: Support use case 1 (back-to-back PUSCH transmissions within one slot) for joint channel estimation for PUSCH.**Proposal 4: Decide whether to support Use case 2a/4a/5a for PUCCH repetitions depending on RAN4 further discussion.**Proposal 5: Do not support joint channel estimation for Use case 2b/4b/5b for PUCCH repetitions.* *Proposal 6: A UE reports a maximum time domain window size for joint channel estimation of PUSCH.* *Proposal 7: Similar as the terminology introduced* *PUSCH repetition type B, introduce ‘nominal time domain window’ and ‘actual time domain window’ for joint channel estimation of PUSCH.* * *gNB configures a nominal time domain window applicable for all use cases supported.*
* *The actual time domain window could be different among different use cases.*

*Proposal 8: Further discuss how to specify the start of the nominal/actual time domain window.* *Observation 1: Inter-slot FH with inter-slot bundling to enable joint channel estimation can provide up to 2.66 dB gain for PUSCH with 8 repetitions in 700MHz rural scenario.* *Proposal 9: 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.*

*Observation 2: Using two carriers with Tx switching for PUSCH transmission can provide about 3 dB performance gain compared to single carrier case.* *Proposal 10:* *Joint channel estimation is supported in case of UL CA.* *Observation 3: Optimization of DMRS granularity in the time domain can provide 0.15~2.52 dB gain for PUSCH repetitions in 700MHz Rural* *scenario.* *Proposal 11: Consider to support optimization of DMRS location/granularity in the time domain with minimized specification impacts by at last the following conditions.* * *DMRS optimization is only applied for PUSCH repetition type A.*
* *DMRS pattern in each repetition is not changed.*
* *Consider to reuse the repetition bundle defined for inter-slot FH for DMRS optimization.*
 |
| vivo/R1-2104378 | *Observation 1: The following factors have impacts on the determination of the time-domain window,* * *UE capability*
* *Power consistency and phase continuity requirements*
* *Network indication*
* *TDD frame structure*

*Observation 2: Inter-slot bundling with joint channel estimation for frequency hopping could achieve better performance.**Observation 3: For PUSCH transmissions with different TBs, some extra conditions and restrictions are required, following parameters should be unchanged across the multiple TBs.** *TB size, TPMI, SRI and pathloss RS.*

*Observation 4: Joint channel estimation could provide improved performance for PUSCH transmissions with same TB or with different TBs.**Observation 5: If orphan DMRS symbol in special slot is introduced, further optimization on DMRS location in adjacent UL slot does not provide remarkable performance gain.**Observation 6: DMRS on orphan symbol combined with joint channel estimation could provide performance gain.* *Observation 7: Further optimization on DMRS pattern of adjacent PUSCH does not provide remarkable performance gain, if orphan symbol DMRS is introduced in-between the PUSCH repetitions.**Proposal 1: Support determination of the time domain window based on explicit indication.**Proposal 2: Support determination of the time domain window based on implicit rule.**Proposal 3: The RRC configured window can further split to multiple actual time domain windows based on the implicit rule, if conditions for joint channel estimation are not fulfilled in the window, e.g. due to DL reception, TDD frame structure, and etc.**Proposal 4: Support enabling/disabling of the time domain window.* *Proposal 5: If inter-slot frequency hopping is enabled, support the bundle size equal to the actual time domain window size.**Proposal 6: DMRS on orphan symbol in-between the PUSCH repetitions can be used for joint channel estimation for adjacent PUSCH transmissions.* *Proposal 7: If orphan symbol(s) used for DMRS or symbol in special slot used for DMRS is supported and located before the first symbol of this PUSCH transmission, the preparation time of this PUSCH need to be revised:** *Opt 1 : Redefine PUSCH preparation time* $T\_{proc,2}$ *considering the first symbol in the orphan symbol(s) or symbol(s) in special slot.*
* *Opt 2 : Additional time offset in* $T\_{proc,2}$*, which is related to the number of the orphan symbol(s) or symbol(s) in special slot.*
 |
| Spreadtrum/R1-2104437 | *Proposal 1: For PUSCH repetition type A/B, time domain windows can be implicitly inferred from its repetition factor, which starts from the 1st symbol of 1st PUSCH to the last symbol of last PUSCH within this window.**Proposal 2: For different PUSCHs, time domain windows can be explicitly indicated via DCI, of which the granularity can be slot/symbols.**Proposal 3. Multiple time domain windows should be supported.**-FFS: Further investigation on collisions of time domain windows.**Proposal 4. For time domain window of inter-slot frequency hopping with inter-slot bundling, we should wait for RAN4’s response first.* |
| CATT/R1-2104539 |  |
| CMCC/R1-2104627 | Observations 1:* Currently only back-to-back with zero gap in-between adjacent transmissions could keep the power consistency and phase continuity.
* No frequency hopping is allowed if joint channel is implemented.
* No power change between the transmissions
* No downlink receptions between the adjacent transmissions are allowed if joint channel estimation is implemented.
* Non-back-to-back transmission with non-zero gap in-between adjacent transmissions, there is no conclusion

Observation 2:For the non-back-to-back transmission with non-zero gap in-between adjacent transmissions, * Currently, it is feasible to maintain phase continuity and power consistency if less than 14 un-scheduled symbols happen in-between the repetitions, when UE is not required to meet the existing off power requirements.
* It is feasible to maintain phase continuity and power consistency, at least the other scheduled signals/channels during the non-zero gap should have the same setting in the antenna port, occupied PRBs and UL power as the repeated transmission signals/channels.

Observation 3:Besides the power consistency and phase continuity, a same transmission precoding and channel coherence should be maintained during the multiple slot transmission under the joint channel estimation. Observation 4:In the typical TDD UL-DL configurations, special slot bundled with one or two uplink slots could work under joint channel estimation. And the DMRS optimization could be further studied under this condition. Proposal 1:The use case or using scenarios of non-zero gaps between PUSCH transmissions, including scheduled and un-scheduled symbols, should be clarified for further discussion of the use cases.Proposal 2:The optimization of DMRS granularity and locations are encouraged to be studied under the typical configurations with consecutive slots of one special slot and one/two uplink slots.Proposal 3:The length or the slot numbers of the joint channel estimation should be limited to reduce the impact to the other physical signals and channels.Proposal 4:Confirm the working assumption that joint channel estimation could be enabled for the back-to-back transmission for one TB processed over multiple slots.Proposal 5: The multiple TBs transmission in consecutive slots, e.g. last two uplink slots and last three slots (one special slot and two uplink slots), should be considered and supported in the joint channel estimation.Proposal 6: Support the over back-to-back PUSCH transmissions with different TBs.Proposal 7: From the perspective of scheduling, there is no need to specify explicit indication of time domain window. Additional indication of joint channel estimation combined with scheduling signaling is enough to enable the function.Proposal 8:The impact of phase drifting to the performance of joint channel estimation under a large number of consecutive slots should be studied.Proposal 9:A maximum slot number should be defined considering the impact of phase drifting of UE and the phase tolerance level for the joint channel estimation. The maximum slot number could be upper bound of joint channel estimation.Proposal 10: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. Proposal 11:The units of the time domain window should be slots and/or symbols.Proposal 12：Since the time domain window is a UE capability, the unit of the time domain window is the same regardless the PUSCH transmissions are based on repetitions, TBoMS or multiple TBs. Namely, the option 2 is preferred.Proposal 13: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.Proposal 14:The bundle size should not exceed the time domain window defined for joint channel estimation. Both equal (option 1) and less than (parts of option 2) the time domain window are acceptable. |
| Qualcomm/R1-2104687 | Observation 1: Motivation on having joint channel estimation across PUSCHs scheduled to carry different transport blocks is unclear for coverage enhancement.Observation 2: Within a single time domain DMRS bundling window, intra-slot and inter-slot frequency hopping is to be disabled based on RAN4 feedback.Proposal 1: Support for the following cases:* 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 5: PUSCH transmissions across non-consecutive slots.

‐   Use case 5a: no uplink transmission in the middle of two PUSCH transmissions Proposal 2: Do not support the following case: * Use case 2: non-back-to-back PUSCH transmissions within one slot.

Proposal 3: Support one or multiple non-overlapping time domain windows for joint channel estimation over PUSCH repetitions (for the same TB). * Window is determined based on semi-static slot format configuration.
* Window duration is in unit of physical slots
* All windows have the same window duration
* FFS: determine start of a window.

Proposal 4: For each PUSCH transmission, the UE signals a bundling indication in the PUSCH transmission.Proposal 5: When inter-slot frequency hopping is configured with DMRS bundling, all PUSCH transmissions in a single time domain DMRS bundling window belong to the same hop.Proposal 6: For inter-slot frequency hopping with inter-slot bundling, the bundle size (time domain hopping interval) equals to the time domain window size (Option 1).Proposal 7: Support different criteria for activation of PTRS or its density for the case of joint channel estimation.Proposal 8: Maintain the same DMRS granularity across all PUSCH transmissions that are configured for DMRS bundling.Proposal 9: No change in DMRS locations compared to R15/ R16 for PUSCH transmissions that are configured with DMRS bundling.Proposal 10: Due to potentially large specification impact and decreasing gains as PUSCH repetitions increase (with large bundling window), DMRS locations in S slot can be considered with a lower priority.  |
| OPPO/R1-2104794 | *Observation 1: There may be single or multiple time domain window.**Observation 2: There isn’t any relation between the time domain window and UE’s capability based on current RAN4’s feedback.**Observation 3: Joint channel estimation may be impacted due to power reduction during PUSCH repetition.**Proposal 1: The time domain window shall be implicitly derived taking into account factors such as TDD UL/DL configuration, TDRA and other uplink transmission.* *Proposal 2: The unit of the time domain window can be slots for PUSCH repetition type A while it can be repetitions for repetition type B.**Proposal 3: PUSCH can be hopped across different slot bundles to enable joint channel estimation.**Proposal 4: The bundle size (time domain hopping interval) can be different from the time domain window size.**Proposal 5: The bundle size (time domain hopping interval) is explicitly informed to the UE.**Proposal 6: Same DMRS antenna ports, same transmission power, same codebook, same Tx spatial parameters and same frequency domain resource allocation shall be applied among multiple PUSCH slots to enable joint channel estimation.**Proposal 7: DMRS-less, optimized DMRS pattern and non-uniform distributing DMRS can be considered for PUSCH repetition.* |
| China Telecom/R1-2104848 | Proposal 1:* For back-to-back PUSCH transmissions within one slot, if power consistency and phase continuity can be maintained.
	+ Joint channel estimation over back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.

Proposal 2:* For back-to-back PUSCH transmissions across consecutive slots, if power consistency and phase continuity can be maintained.
	+ Joint channel estimation over back-to-back PUSCH transmissions for different TBs scheduled by dynamic grant or configured grant is supported.

Proposal 3:* For non-back-to-back PUSCH transmissions within one slot, if power consistency and phase continuity can be maintained.
	+ Joint channel estimation over non-back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.
* For non-back-to-back PUSCH transmissions across consecutive slots, if power consistency and phase continuity can be maintained.
	+ Joint channel estimation over non-back-to-back PUSCH transmissions for repetition type A scheduled by dynamic grant or configured grant is supported.
	+ Joint channel estimation over non-back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.
	+ Joint channel estimation over non-back-to-back PUSCH transmissions for different TBs scheduled by dynamic grant or configured grant is supported.

Proposal 4: * The unit of the time domain window is defined separately for the following PUSCH transmissions.
	+ PUSCH repetition type A
	+ PUSCH repetition type B
	+ TBoMS
	+ Different TB

Proposal 5: * Send an LS to RAN4 asking whether the duration of maintaining power consistency and phase continuity among PUSCH transmissions will be defined based on UE capability and the length of maximum duration if defined.

Proposal 6:* If the time domain window is explicitly configured,
	+ For PUSCH transmissions scheduled by dynamic grant or configured grant type 2, the start and the length of the window is indicated by DCI.
	+ For PUSCH transmissions scheduled by dynamic grant or configured grant type 1, the length of the window is indicated by RRC while the start of the window is the start of the first PUSCH transmission.

Proposal 7: * For inter-slot frequency hopping with inter-slot bundling, the bundle size can be can be different from the time domain window size, but cannot be larger than the length of duration based on UE capability or the size of the time domain window.
 |
| InterDigital/R1-2104861 |  |
| TCL/R1-2104882 | Proposal 1: Joint channel estimation should be supported for TBoMS PUSCH transmission. Proposal 2: For non-back-to-back transmission with non-zero gap in-between adjacent transmission, the time domain window can be configured in terms of slot and with a zero gap in-between adjacent windows.Proposal 3: For non-back-to-back transmission with non-zero gap in-between adjacent transmission, the time domain window can be configured in terms of transmission and with a non-zero gap in-between adjacent windows.* In this non-zero gap, UE can perform other uplink transmissions with different phase/power or downlink reception.

Proposal 4: For back-to-back transmission with zero gap in-between adjacent transmission, the time domain window can be configured in terms of slot.Proposal 5: For back-to-back transmission with zero gap in-between adjacent transmission, the time domain window can be configured in terms of repetition or TB.Proposal 6: A rule for avoiding or handling the collision between the time domain window and the bundling should be specified. |
| Intel/R1-2104921 | Observation 1* *For PUSCH with 2 and 4 repetitions and joint channel estimation with bundle size of 2 slots, ~0.5dB performance gain can be achieved when an additional DMRS symbol is inserted in the special slot for PUSCH repetition.*

Observation 2* *For PUSCH with 4 repetitions, when employing joint channel estimation with bundle size of 2 slots, ~1.0dB performance gain can be achieved by inter-slot frequency hopping with inter-slot bundling of 4 slots, compared to the case without frequency hopping.*

Proposal 1* *Joint channel estimation is not supported for PUSCH transmission with different TBs.*

Proposal 2* *The time domain window for joint channel estimation is defined based on the number of repetitions or slots.*
	+ *The time domain window can be configured by higher layers.*
	+ *When inter-slot frequency hopping with inter-slot bundling is applied, the time domain window is determined by the bundle size.*
	+ *Enabling or disabling the time domain window can be configured by higher layers.*
* *Within the time domain window, UE needs to maintain same Tx power, precoder and frequency resource for joint channel estimation over multiple PUSCHs.*

Proposal 3* *FFS: additional DMRS symbols located in the special slot for PUSCH enhancement.*

Proposal 4* *For inter-slot frequency hopping with inter-slot bundling,* *the bundle size can be different from the time domain window size.*
	+ *The bundle size may be configured by higher layers or determined based on the number of repetitions for PUSCH.*
 |
| Apple/R1-2105121 |  |
| Sony/R1-2105176 | Proposal 1: RAN1 shall design necessary mechanisms to enhance JCE also for non-back-to-back slots with arbitrary UE configuration. Proposal 2: Introduce a UE capability indicating that the UE supports non-zero gap with “UL with same configuration”, “UL with different configuration”, “UL and/or DL”, “no support/legacy”. Proposal 3: We encourage RAN1 to further study how to ensure that both UE and gNB are aware of when conditions for JCE with non-back-to-back slots with DL in-between apply. Observation 1: Independent beam management for UL and DL beam is already supported in Rel.15/16.Observation 2: If the phase is randomly changing among UL periods and is distributed as U[-180,180], single UL period channel estimation is preferable due to its simplicity; an optimal MAP receiver cannot cope with such large phase discontinuity.Observation 3: If the phase is randomly changing among UL periods and is distributed as U[-180,180], channel estimation across several UL blocks and ignoring the phase discontinuity degrades performance.Observation 4: For the phase discontinuities up to about 10o, channel estimation can be performed across multiple UL periods while ignoring phase discontinuities.Observation 5: If three independent channel coefficients share the same phase discontinuity, then these phase values can be jointly estimated together with the propagation channel, which results in better performance that with single UL period estimation. |
| Samsung/R1-2105327 | *Proposal 1: A UE determines the enabling/disabling of joint channel estimation based on the explicit configuration of time domain window.**Proposal 2: A UE determines the unit of a time domain window for joint channel estimation based on TDRA for PUSCH transmissions. For example, the unit of a time domain window is the number of PUSCH repetitions for PUSCH repetition type A and the number of nominal/actual repetitions for PUSCH repetition type B.**Proposal 3: Support a same power, precoding, RV, and frequency position within time domain window.**Proposal 4: A UE updates the CLPC adjustment state per time domain window.**Proposal 5: The number of repetitions where a UE transmits using same power/precoding/RV/RBs is either the number of repetitions per frequency hop or is configured by higher layers.**Proposal 6: A UE performs the inter-slot frequency hopping with inter-slot bundling based on the bundle size equal to the time domain window size.**Proposal 7: 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).**Proposal 8: Support a same power, precoding and frequency position for a number of repetitions of a PUCCH transmission.* |
| MediaTek/R1-2105394 | Observation 1. In order to maintain phase continuity during those unscheduled symbols between UL repetition, UE power consumption would get higher and the OFF power requirement cannot be met.Proposal 1: UE power consumption should be taken into accountObservation 2: The use case to remain phase continuity and power consistency for UL repetition is not clear under CA scenario. Proposal 2: Whether/how to support phase continuity and power consistency for UL repetition under CA scenario should be clarified with RAN4 feedback.Proposal 3: Whether/how to support phase continuity and power consistency for UL repetition under DC scenarioProposal 4: phase cannot be guaranteed to be maintained if other signals are present during the gap with different power settings or different PRB configuration.Proposal 5: The same TPMI precoder is supported to guarantee phase continuity.Proposal 6: “no TA adjustment” is preferred to keep phase continuity. |
| Panasonic/R1-2105397 | Proposal 1: A length of time domain window should not be longer than the length determined by a DCI, i.e. a time domain window composed by the multiple DCIs should not be supported.Proposal 2: A length of time domain window is at least determined by the time domain resource allocation of dynamic grant and by activated DCI for CG type 2, as well as RRC configuration for CG type 1.Proposal 3: 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 4: For multiple TBs indicated by a DCI, joint channel estimation should wait for the progress of the discussion of NR from 52.6GHz to 71 GHz.Proposal 5: A length of time domain window and a length of inter-slot FH are the same or not depending on the pattern of inter-slot FH.Proposal 6: DMRS granularity optimization such as no DMRS transmission in some slots is not necessary.Observation 1: Joint channel estimation with inter-slot frequency hopping provides an improvement of gain of 1.0 ~1.5 dB, as compared with that of joint channel estimation without inter-slot frequency hopping and doubling a length of time domain window. |
| LG/R1-2105490 | *Proposal 1: Potential use case 1 and 2 should be deprioritized and wait for RAN4’s input for potential use case 4 and 5.**Proposal 2: If joint channel estimation between different TBs is supported, UE behavior when conflict between joint channel estimation and power control, precoder change, and TA adjustment of different TBs should be discussed.** *Alt. 1) When the UE has configured time-domain window for joint channel estimation for different TBs, UE does not apply power control, precoder change, and TA adjustment of a latter TB to maintain consistency for joint channel estimation.*
* *Alt. 2) When the UE has configured time-domain window for joint channel estimation for different TBs without consistency for joint channel estimation, UE assumes time-domain window is not configured.*

*Proposal 3: In addition to maintaining power consistency and phase continuity within the joint channel estimation time window, maintaining TA continuity also should be included in the following sentence.** *“For joint channel estimation, specify a time domain window during which a UE is expected to maintain power consistency, phase continuity and UL Tx timing consistency among PUSCH transmissions subject to power consistency and phase continuity requirements.”*

*Proposal 4: The UE's behavior for a situation where the consistency of power, phase and TA within the window is ambiguous should be studied, or state in the specification that such a situation will not be configured.** *Alt. 1) When the UE has configured time-domain window for joint channel estimation, UE does not apply configured power control, TPMI/SRI change and TA adjustment during the time-domain window.*
* *Alt. 2) When the UE has configured time-domain window for joint channel estimation and configured with power control, TPMI/SRI change, TA adjustment within the time-domain window, the UE assumes time-domain window is not configured.*

*Proposal 5: For the unit of time-domain window, consider continuous slot(s) or transmission occasion.**Proposal 6: Consider UE-specific time-domain window which has multiple relation among UEs.**Proposal 7: Discuss uplink collision in CA/DC with different carrier with joint channel estimation.**Proposal 8: Cell-specific wise time domain resource grid for inter-slot frequency hopping should be applied.* |
| Sierra Wireless/R1-2105509 | Observation 1: For the FDD eMBB scenario, JCE can provide ~1.5 dB of coverage gain.Observation 2: For the FDD VoIP scenario, JCE can provide ~3.5 dB of coverage gain.Observation 3: For the TDD DDDSU eMBB scenario, JCE across non-continuous slots can provide ~1.1 dB coverage gain.Observation 4: For the TDD DDDSU VoIP scenario, JCE across non-continuous slots can provide ~2.2 dB coverage gain.Proposal 1: Make a RAN1 Conclusion: There is no need to consider these use cases in Rel 17:• Use case 1: back-to-back PUSCH transmissions within one slot.• Use case 2: non-back-to-back PUSCH transmissions within one slot.Proposal 2: Use case 4 “non-back-to-back PUSCH transmissions across consecutive slots” shall be supported.Observation 5: In TDD bands, the gNB will be required to schedule “PUSCH transmissions across non-consecutive slots” Proposal 3: Wait for RAN4 LS response to determine if use case 5 “PUSCH transmissions across non-consecutive slots” can be supported.Proposal 4: JCE should be supported when gNB schedule “back-to-back PUSCH transmissions with different TB”Proposal 5: The UL Grant can at least signal, either implicitly or explicitly, whether the JCE and the phase continuity time domain window is enabled or disabled.Proposal 6: Based at least on UE capabilities, the gNB would signal only phase continuity time domain windows which the UE supports. |
| Xiaomi/R1-2105577 | *Proposal 1: Time domain window is related to UE capability.**Proposal 2: DMRS bundling mechanism can be triggered by gNB or UE.**Proposal 3: The length of the time window should be final configured and indicated by gNB.**Proposal 4 : Support to configure N multiple time windows per cell through RRC, and at any given time, only M time window can be supported simultaneously for each UE through DCI.**Proposal 5 : Support* *the unit of the time domain window should be defined separately for the different PUSCH transmissions**Proposal 6: Support maintain a DMRS configuration table containing more diverse DMRS patterns for dynamically indication and configuration**Proposal 7：We prefer Option 2, the bundle size can be different from the time window size and both explicit and implicit configuration should be supported.**Proposal 8：Introduce a configurable additional inter-slot frequency hopping patterns for inter-slot DMRS bundling.* |
| Sharp/R1-2105642 | *Proposal 1: Joint channel estimation across slots for a non-back-to-back PUSCH repetition with unscheduled gap with X symbols is supported if the downlink reception/monitoring is not performed in the gap.**Proposal 2: Joint channel estimation across slots for a non-back-to-back PUSCH repetition with a scheduled gap for other signals/channels with X symbols is supported if the other signals/channels have the same settings in antenna port, occupied PRBs and UL power than the PUSCH repetition.**Proposal 3: Joint channel estimation across slots for PUSCHs with different TB is supported.**Proposal 4: Time domain window size is provided by the gNB either by RRC signalling or DCI format scheduling a PUSCH for FDD operation.**Proposal 5: First time domain window starts at the first slot of the PUSCH repetition.**Proposal 6: The time domain window configuration should be determined implicitly by TDD pattern.* Proposal 7: A time domain window should be defined by a cycle of DL region🡪flexible region🡪UL region.*Proposal 8: TBoMS-specific time domain window configuration is not necessary. TBoMS can reuse window design for repetition type A.**Proposal 9: The starting slot and size of the time domain window is provided by the gNB via RRC signalling for joint channel estimation for different TB.**Proposal 10: It is supported that Time domain window and hopping bundle are provided by the gNB by single parameter in RRC signalling or in DCI format scheduling a PUSCH for FDD operation if joint channel estimation and frequency hopping are configured.**Proposal 11: To maximize frequency hopping gain for TDD operation, support a new hopping pattern other than alternating hopping pattern of Rel-15/16 (e.g., first hop🡪second hop🡪second hop) for TDD operation.* |
| Ericsson/R1-2105654 | Observations:1. A time domain window defined by slots or symbols in theory allows more flexibility, but does not seem to in practice.
2. A time domain window defined according to resources occupied by a TB appears to be the best fit for joint channel estimation.
3. Allowing the gNB to configure the frequency hopping pattern and time domain windows separately can potentially avoid unnecessarily restricting and complicating network scheduling.
4. Gain tradeoffs from joint channel estimation and frequency hopping can vary e.g. with speed, or on channel conditions for a given UE.
5. In a number of scenarios, a receiver 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.
6. The use of wideband relative phase estimation to facilitate cross-slot channel estimation seems promising at least when the UE can’t adequately maintain relative phase between slots.
7. For a fair assessment of the gains from joint channel estimation, the carrier frequency offset (CFO) should be modeled in simulations.
8. If the UE can maintain phase coherence between slots, joint channel estimation can give gains of about 1.3 dB for FDD at 3 km/h.
	* Similar gains are seen also for TDD with non-back-to-back slots.
	* Further studies at higher speeds are needed.
9. Even with fully random wide-band transmitter phase offsets between slots, joint estimation was found to be able to yield similar gains as in the absence of phase offsets, as long as the receiver can estimate and compensate for the phase offsets.
10. Joint channel estimation brings gains, but further study is needed on how much needs to be specified vs. what can be done in gNB implementation (e.g. by estimating wideband phase corrections to combine slots).
11. Even without explicit phase offset compensation in the receiver, joint channel estimation can perform well if the phase offsets between slots are not too large (e.g. phase offsets up to in the order of 20° between consecutive slots in the simulated scenario).
12. Joint channel estimation brings gains also in the case of frequency hopping, both for inter-slot FH and intra-slot FH.
	* Inter-slot FH was generally found to perform better than intra-slot FH under the used simulation assumptions.
13. 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.

Based on the observations and discussions, we have following proposals.Proposals:1. The time domain window comprises transmissions of a same transport block
	* Window units are slots of a TBoMS or repetitions of a PUSCH.
	* The window begins with the first transmission of a PUSCH
2. Both Rel-17 enhanced and Rel-15 repetition type A are supported by joint channel estimation
3. The specification impact, net gains, and use cases of TBoMS support for special slot is further studied.
4. Further study frequency hopping patterns, taking into account benefits of joint channel estimation and expected UE capability for time domain window size.
5. 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.
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| NTT DOCOMO/R1-2105713 | Proposal 1: For time domain windows, the unit of time domain window should be defined separately for use cases, e.g. repetition for single TB or slot for multiple TBs, of joint channel estimation.Proposal 2: Determine a starting point and size of time domain windows based on allocated PUSCH resources.Proposal 3: Indicate the time domain window size by DCI for PUSCH transmissions dynamically scheduled by an UL grant in DCI and by RRC signalings for configured grant type 1 PUSCH transmissions.Proposal 4: The duration per frequency hop should be implicitly determined by the time domain window, where the duration per frequency hop is equal to a time domain window size for joint channel estimation.Observation 1: A time domain window should not be longer than necessary to update power and frequency offsets frequently enough.Observation 2: Applying joint channel estimation over 2 slots and 4 slots brings a gain of 0.72 dB and 1.02 dB, respectively. Observation 3: Frequency diversity gain is almost the same regardless of durations per hop, as long as frequency hops in PUSCH repetitions. Observation 4: A longer duration per hop introduces a higher joint channel estimation gain. The largest gain can be achieved when the duration per hop is equal to the time domain window size.Observation 5: The duration per frequency hop should be equal to or longer than a time domain window for joint channel estimation, considering the total gain of frequency diversity and joint channel estimation. |
| Lenovo/R1-2105775 | *Proposal 1: For specifying joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, use cases with non-back-to-back PUSCH transmission within one slot and across multiple slots should be deprioritized in RAN1#105, pending further discussion in RAN4.**Proposal 2: For specifying joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17 for transmission of same TB with PUSCH repetition type B, joint channel estimation should be applied across the actual transmissions that are back-to-back within a time-domain window** *No specific enhancements need to be discussed if the actual transmissions within a time-domain window are non-back-to-back, at least until, the requirements are fully clarified by RAN4.*

*Proposal 3: For specifying joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17 for transmission of different TBs, agreements made for same TB transmission could be applied.**Proposal 4: For specifying joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17 with inter-slot frequency hopping, support the option where the bundle size (time domain hopping interval) equals to the time domain window size and only one parameter needs to be indicated to the UE.**Proposal 5: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, following details related to time domain window should be supported:** *Maximum duration for the time-domain window should be determined based on the minimum of following two durations:*
	+ *Maximum duration for which power consistency and phase continuity can be maintained*
	+ *Maximum duration of PUSCH transmissions (depend on maximum value of repetition factor)*
* *Depending upon coverage requirements, the duration of the time-domain window can be configured/indicated (duration value could be smaller than the maximum duration)*
* *For a burst of PUSCH transmissions with joint channel estimation, only a single duration of the time domain window should be configured/indicated*
* *DM-RS bundling duration could be possible considered as a term to be included in specifications.*

*Proposal 6: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, same time unit of the time domain window should be specified for all the following use cases:** + - *PUSCH repetition type A*
		- *PUSCH repetition type B, if agreed*
		- *TBoMS, if agreed*
		- *Different TB, if agreed*

*Proposal 7: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, enabling or disabling of joint channel estimation can be jointly indicated by the presence of signalling for time domain window duration** *Dynamic signalling of time domain window duration should be supported*
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| WILUS/R1-2105879 | Proposal 1: For back-to-back or non-back-to-back PUSCH transmissions, prioritize PUSCH repetition type A and PUSCH repetition type B for joint channel estimation.Proposal 2: For back-to-back or non-back-to-back PUSCH transmissions with repetition case, the unit of the time domain window can be configured by a set of repetitions explicitly or implicitly.Proposal 3: 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/R1-2105903 | *Proposal 1. The agreement in RAN1#104-bis-e on supporting necessary design aspects to enable joint CE for PUSCH repetition type B under the scenario of back-to-back PUSCH transmissions across consecutive slots (Use case 3) should also be applied for the scenario of back-to-back PUSCH transmissions within a slot (Use case 1).**Proposal 2. For back-to-back PUSCH transmissions with zero gap in-between adjacent transmissions, RAN1 to further support necessary design aspects to enable joint channel estimation at least for all scenarios in which:* *• 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.**Proposal 3. For non-back-to-back PUSCH transmissions with non-zero gap in-between adjacent transmissions:**• RAN1 to support necessary design aspects to enable joint channel estimation at least for the following scenarios:**o non-back-to-back PUSCH transmissions across consecutive slots.**o PUSCH transmissions across non-consecutive slots.**• The maximum gap of unscheduled symbols between two adjacent PUSCH repetitions is less than 1ms subject to the existing OFF power requirement and is defined per SCS.**• gNB to dynamically indicate whether and which DL reception occasion, or other UL transmission with different settings than PUSCH repetitions, should be monitored by the UE.* *Proposal 4. For the time-domain window for joint channel estimation:** The time domain window for joint CE for PUSCH is expressed in units of physical slots.** In case of PUSCH repetition type A or type B, the time-domain window is defined as the time duration spanned by the repetitions and indication of the time-domain window is not needed.**Proposal 5. For inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation:** The bundle size (time domain hopping interval) can be different from the time domain window size** RAN1 to specify at least the following frequency hopping approach:**o UE switches frequency hop for the repetitions after a DL reception occasion that the UE is expected/configured to monitor/receive or after an UL transmission with different settings (e.g., in antenna port, occupied PRBs and UL power) than the repeated PUSCH repetitions.* |