**3GPP TSG RAN WG1 Meeting #104bis-e R1-21xxxxx**

**E-Meeting, April 12th – 20th, 2021**

**Agenda Item: 8.8.1.3**

**Source: Moderator (China Telecom)**

**Title: [104b-e-NR-R17-CovEnh-02] 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:

[104b-e-NR-R17-CovEnh-02] Email discussion on joint channel estimation for PUSCH– Jianchi (China Telecom)

* 1st check point: 4/15
* 2nd check point: 4/19
* 3rd check point: 4/20
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.

## 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 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.

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

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| **Use cases** | **Companies view** |
| * Use case 1: back-to-back PUSCH transmissions within one slot.
 | **Support:** ZTE, Nokia, NSB, Lenovo, Motorola, Spreadtrum, CATT, CTC, Panasonic, CMCC, WILUS, HW, HiSilicon, NTT DOCOMO, Samsung* Repetition type B for the same TB
	+ ZTE, Spreadtrum, CTC, Panasonic, WILUS, NTT DOCOMO, Lenovo, Motorola
* PUSCH transmissions with different TBs
	+ CATT

**Deprioritize:** Qualcomm**Not support:** Apple, Ericsson |
| * Use case 2: non-back-to-back PUSCH transmissions within one slot.
 | **Support:** ZTE, Nokia, NSB, Panasonic, HW, HiSilicon, CTC, Samsung* Repetition type B for the same TB
* PUSCH transmissions with different TBs

**Deprioritize:** MediaTek, Qualcomm**Further discussed after RAN4’s conclusion:** WILUS, Lenovo, Motorola, CMCC, CATT**Not support:** Spreadtrum, Apple, Ericsson |
| * Use case 3: back-to-back PUSCH transmissions across consecutive slots.
 | **Support:** WILUS, Nokia, NSB, CMCC, Spreadtrum, Lenovo, Motorola, NTT DOCOMO**,** CATT, CTC, Panasonic, Samsung* Repetition type B for the same TB
	+ Panasonic, WILUS, Nokia, NSB, NTT DOCOMO, CTC, Samsung
* PUSCH transmissions with different TBs
	+ Support: Nokia, NSB, CMCC, HW, HiSilicon, CTC, CATT
	+ Not support: Qualcomm
 |
| * Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.
 | **Support:** LG, Sharp, ZTE, Panasonic, HW, HiSilicon, Nokia, NSB, CTC, Sony, Ericsson* Repetition type A for the same TB
	+ LG, Sharp
* Repetition type B for the same TB
* PUSCH transmissions with different TBs
* TBoMS

**Deprioritize:** MediaTek**Further discussed after RAN4’s conclusion:** WILUS, Lenovo, Motorola, CMCC, CATT, Qualcomm**Not support:** Spreadtrum, Apple |
| * Use case 5: PUSCH transmissions across non-consecutive slots.
 | **Support:** LG, Ericsson, Nokia, NSB* Repetition type A for the same TB
	+ LG

**Deprioritize:** ZTE, MediaTek**Further discussed after RAN4’s conclusion:** Qualcomm**Not support:** Apple, CATT, Spreadtrum |

**Additional views from companies:**

**MediaTek:**

* Considering CA and DC scenario, whether/how to support phase continuity and power consistency for UL repetition should be clarified with RAN4 feedback.

**Sony:**

* Method to enable N-BtB JCE include: DL-blanking (keeping the Tx active without transmitting), separate UL / DL antennas in FR1 (configure the UE to use different antenna ports) and separate UL/DL panels in FR2.

**Nokia/NSB:**

* gNB dynamically indicate whether and which DL reception occasion should be monitored/skipped by the UE to facilitate JCE.

Support to confirm the following working assumption: CMCC, Apple, CATT, Interdigital, Panasonic, Nokia, NSB, Spreadtrum, CATT

**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

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.
	+ Repetition type B for the same TB
	+ 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.
* CA or DC

## 2.3 Time-domain window for joint channel estimation

In RAN1 #104e, a time domain window is agreed to be 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.
* 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.

**Pros and cons of whether or not to specify the time domain window are summarized below:**

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| **Specify a time domain window** | **Pros** | * Make sure that the condition for joint channel estimation is met during the time window.
* If DMRS transmissions for joint channel estimation over long time require the processing load, the time window specified per UE can reduce the UE complexity.
* Help the UE to know when and how long it should maintain power/phase continuity.
* Facilitate the optimization of DMRS for JCE. The DMRS location/granularity in different slots within one time domain window can be jointly designed.
* Facilitate the design of inter-slot frequency hopping with inter-slot bundling.
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| **Cons** | * More standardization efforts.
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| **NOT specify a time domain window** | **Pros** | * Less standardization efforts.
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| **Cons** | * Misunderstanding between gNB and UE may occur in some cases.
* It may be difficult to expect improvement in channel estimation performance even if the gNB performs joint channel estimation since there is no expected behaviour of UE which makes UE to operate arbitrarily.
* UE may try to keep power consistency and phase continuity as much as possible for all PUSCH transmissions, while gNB may try to jointly estimate channel based on all DMRS symbols over PUSCH transmissions.
* If the UE must maintain the phase continuity across scheduled PUSCH transmissions for a very long period, the UE may have to forgo events such as uplink tracking loop, UE calibration, antenna virtualization etc., leading to possible performance degradation.
* More UE power consumption.
 |

**Companies’ views are summarized as follows:**

**1. Whether to specify the window?**

**Support:** WILUS, Lenovo, Motorola, LG, Sharp, NTT DOCOMO, Nokia, NSB, InterDigital, Qualcomm, Xiaomi, CATT, CTC, vivo, HW, HiSilicon, Sierra Wireless, Samsung

**Not support:** CMCC (if only back-to-back PUSCH transmissions are supported), OPPO, Ericsson

**2. How to define the length of the time window?**

* Option1: The time window is defined in units of repetitions.

**Support:** WILUS, InterDigital, Samsung

* Option2: The time window is defined in units of slots.

**Support:** LG, CATT

**3. How to configure the parameters of this time window?**

* Option1: explicitly configured by RRC or DCI.

**Support:** Nokia, NSB, Panasonic, InterDigital, Xiaomi, Sierra Wireless, Lenovo, Motorola

* Option2: implicitly determined, e.g. by the repetition factor.

**Support:** Spreadtrum, Sharp

* Option3: UE report capability on the length of time domain window or signals a bundling indication.

**Support:** Nokia, NSB, vivo, Sierra Wireless, Qualcomm

**4. Single or multiple time windows?**

* Option1: Support single time window.

**Support:** Lenovo, Motorola, LG

* Option2: Support multiple time windows.

**Support:** InterDigital, Qualcomm, Xiaomi, CATT

**Other considerations:**

**NTT DOCOMO:** There are two options to specify the time window per UE.

* Opt1: A time domain window is determined based on the specification, according to the UE capability.
* Opt2: A time window is configured, according to the UE capability and channel quality.

Samsung: Support a same power, precoding, RV, and frequency position for a number of repetitions of a PUSCH transmission. And during a time window, the UE skips application of TPC commands and does not update the CLPC adjustment state

**CTC:** 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 duration if defined.

Sierra Wireless: UE signals a time window capability & gNB signals a required time window.

**Qualcomm:** proposed to allow UE to signal indication in the UCI multiplexing with PUSCH transmission. The indication can indicate whether the PUSCH transmission is coherent with respect to the previous PUSCH transmission or whether the PUSCH transmission is coherent with respect to the next PUSCH transmission as illustrated.

**Lenovo/Motorola:** the 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)

Open issues:

* Whether to specify the window
* Length of the time window
* Single or multiple time domain windows
* Relation with UE capability
* Signalling design for the time window

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

**Companies’ views are summarized as follows:**

**Issue 1:** The relationship between the size of time window and the bundle size (time domain hopping interval).

* Option 1: Smaller than the size of time domain window
	+ CTC
* Option 2: Equal to the size of time domain window
	+ CTC, LG, NTT DOCOMO
* Option 3: Large than the size of time domain window
	+ LG

**Issue 2:** Explicit or implicit.

* Option 1: Explicit indicated by signaling, e.g. RRC or DCI
	+ ZTE, WILUS, NTT DOCOMO, Intel, Samsung
* Option 2: Implicitly determined by the number of repetitions.
	+ ZTE, NTT DOCOMO, Intel, Samsung

Issue 3: Cell-specific or UE-specific.

* Option 1: Cell-specific
	+ LG
* Option 2: UE-specific
	+ HW, HiSilicon

Issue 4: Frequency hopping pattern for TDD.

* Option 1: UE perform frequency hopping between non-consecutive UL slots and only bundling consecutive UL slots for JCE.
	+ vivo
* Option 2: UE perform frequency hopping for every K UL slots.
* Option 3: UE perform frequency hopping after a DL reception occasion, and applies a time-domain window starting from the hopping slot. After the time-domain window expires, UE perform frequency hopping again.
	+ Nokia, NSB

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

Companies’ views are summarized as follows:

* Optimization of DMRS granularity in time domain w/ JCE.
	+ Support: CATT, ZTE, CMCC, OPPO
	+ Deprioritize: LG
	+ Not support: Qualcomm, Intel
* Optimization of DMRS location in time domain w/ JCE.
	+ Support: Lenovo, Motorola, Xiaomi, Interdigital, HW, HiSilicon, vivo, OPPO, CMCC, ZTE, Motorola
	+ Not support: Qualcomm

For optimization of DMRS granularity in time domain w/ JCE, two schemes are considered and simulated by companies:

* **Scheme a-1:** No DMRS for some PUSCH transmissions
	+ Support: CATT, ZTE, OPPO
	+ Not support: Intel

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.

One company (Intel) shows ~1.5dB degradation can be observed when DMRS symbols are not allocated in odd slots.

* **Scheme a-2:** Higher DMRS density
	+ Not support: Intel

One company (Intel) shows 4 DMRS symbols can achieve better link level performance than 6 DMRS symbols for PUSCH w/ 8 repetitions and inter-slot frequency hopping.

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

* **Scheme b-1:** Equally spaced DMRS pattern.
	+ Support: Lenovo, Motorola, Xiaomi
	+ Not support: vivo, Intel

One company (vivo) shows no gain for equally spaced DMRS pattern.

One company (Intel) shows the performance difference is negligible between existing DMRS pattern as defined in Rel-15 and equally spaced DMRS pattern.

* **Scheme b-2:** DMRS located in special slots
	+ Support: Interdigital, HW, HiSilicon, vivo, LG, CMCC, Spreadtrum
	+ Not support: Intel

One company (HW) shows JCE w/ 2 DMRS located in special slot can improve the performance of PUSCH transmissions by 1.2dB at 10% BLER in typical TDD mode ‘DDDSUDDSUU’.

One company (Interdigital) shows JCE w/ 1 DMRS located in special slot can provide 0.5~0.8dB gain at 10% BLER in TDD mode ‘DDDSU’.

One company (vivo) shows JCE w/ 1 DMRS located in special slot can provide 0.7dB gain. 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 ~0.1dB gain at 10% BLER in TDD mode ‘DDDSU’.

* **Scheme b-3:** Different DMRS locations
	+ Support: OPPO

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 b-4:** Orphan symbol used for DMRS
	+ Support: vivo, LG

One company (vivo) shows 0.8 dB gain if orphan DMRS symbol in-between PUSCH repetitions is utilized for JCE.

Other consideration:

Sierra Wireless: This residual frequency error is NOT the UE’s carrier frequency offset. The residual frequency error is the remain error after the gNB has compensated for the UE’s carrier frequency offset. The RAN4 specification [4] of +/- 0.1 ppm defines the UE’s requirement for frequency error and does not include gNB frequency error compensation and is therefore is a poor choice for simulation assumptions, as the higher RFE would decrease the gain of joint channel estimation. For a 4GHz carrier frequency, the +/- 0.1 ppm results in a RFE of +/- 400 Hz which is too large. The amount of residual frequency error will depend on base station vendors’ proprietary methods of limiting the residual frequency error.

**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
	+ DMRS equally spaced among PUSCH transmissions
	+ 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 number of repetitions corresponding to the DM-RS interpolation 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:**It should be adopted that received TA command is not applied within time-domain window for joint channel estimation when TA command is indicated to the UE.

Grant-type dependent index

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

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 for joint channel estimation

**Companies are encouraged to answer whether joint channel estimation should be supported for the following use case and provide the reasons:**

* Use case 1: back-to-back PUSCH transmissions within one slot.
	+ Repetition type B for the same TB
	+ PUSCH transmissions with different TBs

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| **Companies** | **Yes/No** | **Reasons** |
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**Companies are encouraged to answer whether joint channel estimation should be supported for the following use case and provide the reasons:**

* Use case 3: back-to-back PUSCH transmissions across consecutive slots
	+ Repetition type B for the same TB
	+ PUSCH transmissions with different TBs

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| **Companies** | **Yes/No** | **Reasons** |
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**Proposal: Confirm the following working assumption**

**Working assumption:**

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

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| **Companies** | **Comments** |
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**Companies are encouraged to provide views whether the following cases are considered for joint channel estimation for non-back-to-back PUSCH transmissions.**

* For non-back-to-back PUSCH transmissions within one slot:
	+ Non-zero gap in-between adjacent PUSCH transmissions due to invalid symbol(s) for PUSCH repetition type B
	+ Non-zero gap in-between adjacent PUSCH transmissions for different TBs scheduled by network.
* For non-back-to-back PUSCH transmissions across slots:
	+ Non-zero gap in-between adjacent PUSCH transmissions due to SRS or PUCCH transmission from other UE(s) in-between adjacent PUSCH transmissions
	+ Non-zero gap in-between adjacent PUSCH transmissions due to invalid symbol(s)/orphan symbol for PUSCH repetition type B
	+ Non-zero gap in-between adjacent PUSCH transmissions for different TBs scheduled by network.

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

**RAN1 waits for RAN4’s additional information to decide whether joint channel estimation should be supported for the following use cases.**

* Use case 2: non-back-to-back PUSCH transmissions within one slot.
* Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.
* Use case 5: PUSCH transmissions across non-consecutive slots.

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| **Companies** | **Comments** |
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**Companies are encouraged to provide views on joint channel estimation for PUSCH for intra-band CA/inter-band CA and DC.**

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| **Companies** | **Comments** |
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## 3.2 Time-domain window for joint channel estimation

**Based on the analysis of pros and cons for the time domain window and the majority views summarized in section 2.3, it is proposed to specify the time domain window.**

**Proposal:**

* For joint channel estimation, specify a time domain window during which UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.

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

* What’s the technical problem of specifying a time domain window other than more standardization efforts?
* What’s the benefit of not specifying a time domain window other than less standardization efforts?
* How to handle the problems of not specifying a time domain window summarized in section 2.3?

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| **Companies** | **Comments** |
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**Companies are encouraged to provide views on the following aspects of the time domain window if it is specified.**

* Whether the time domain window should be defined independently for each use case, e.g., by a set of repetitions/slots/symbols?
* Whether the time domain window depends on UE capability?
* Whether single or multiple time domain windows should be defined?
* Whether the time domain window is explicitly configured or implicitly determined?

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

**Companies are encouraged to provide views on the following aspects of inter-slot frequency hopping with inter-slot bundling.**

* Whether the bundle size (time domain hopping interval) can be independently configured from the time domain window?
* Whether the bundle size (time domain hopping interval) should be defined separated for FDD and TDD?
* Whether the bundle size (time domain hopping interval) is explicitly configured or implicitly determined, e.g., derived from the number of repetition?

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

**Based on the simulation results, following observations are proposed:**

**Observation:**

* For optimization of DMRS granularity in time domain with joint channel estimation
	+ 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.
	+ One company (Intel) shows ~1.5dB degradation can be observed when DMRS symbols are not allocated in odd slots.

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

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| **Companies** | **Comments** |
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**Observation:**

* For DMRS equally spaced among PUSCH transmissions with joint channel estimation
	+ One company (vivo) shows no gain for equally spaced DMRS pattern.
	+ One company (Intel) shows the performance difference is negligible between existing DMRS pattern as defined in Rel-15 and equally spaced DMRS pattern.

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

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| **Companies** | **Comments** |
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**Observation:**

* For DMRS located in special slots with joint channel estimation
	+ One company (HW) shows JCE w/ 2 DMRS located in special slot can improve the performance of PUSCH transmissions by 1.2dB at 10% BLER in typical TDD mode ‘DDDSUDDSUU’.
	+ One company (Interdigital) shows JCE w/ 1 DMRS located in special slot can provide 0.5~0.8dB gain at 10% BLER in TDD mode ‘DDDSU’.
	+ One company (vivo) shows JCE w/ 1 DMRS located in special slot can provide 0.7dB gain. 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 ~0.1dB gain at 10% BLER in TDD mode ‘DDDSU’.

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

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| **Companies** | **Comments** |
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**Observation:**

* For orphan symbol used for DMRS with joint channel estimation
	+ One company (vivo) shows 0.8 dB gain if orphan DMRS symbol in-between PUSCH repetitions is utilized for JCE.

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

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| **Companies** | **Comments** |
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**Observation:**

* For different DMRS locations with joint channel estimation
	+ One company (OPPO) shows 0.3dB gain can be found while DMRS placed on different symbol within the slot (1st and 11th symbol, respectively)

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

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| **Companies** | **Comments** |
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**Companies are encouraged to provide views on whether +/- 0.1 ppm is the appropriate value for the residual frequency error.**

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

**Companies are encouraged to provide views on PT-RS.**

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| **Companies** | **Comments** |
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**Companies are encouraged to provide views on power control.**

* Whether the mechanism of power control should be adjusted for joint channel estimation?

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| **Companies** | **Comments** |
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**Companies are encouraged to provide views on whether phase correction at gNB should be considered.**

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| **Companies** | **Comments** |
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**Companies are encouraged to provide views on TA command.**

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| **Companies** | **Comments** |
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**Companies are encouraged to provide views on grant type dependent signalling: bundling group index.**

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| **Companies** | **Comments** |
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Companies are encouraged to provide views on the case PUSCH transmission interrupted by other transmissions/procedures.

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| **Companies** | **Comments** |
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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 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. R1-2102313 Discussion on Joint channel estimation for PUSCH Huawei, HiSilicon
7. R1-2102409 Consideration on Joint channel estimation for PUSCH OPPO
8. R1-2102465 Consideration on joint channel estimation over multi-PUSCH Spreadtrum Communications
9. R1-2102499 Discussion on joint channel estimation for PUSCH ZTE
10. R1-2102536 Discussion on Joint channel estimation for PUSCH vivo
11. R1-2102645 Discussion on joint channel estimation for PUSCH CATT
12. R1-2102692 Discussion on joint channel estimation for PUSCH MediaTek Inc.
13. R1-2102862 Discussion on joint channel estimation for PUSCH China Telecom
14. R1-2102895 Discussion on joint channel estimation for PUSCH CMCC
15. R1-2102994 Joint channel estimation for PUSCH Xiaomi
16. R1-2103009 Discussions on joint channel estimation for PUSCH InterDigital, Inc.
17. R1-2103044 Discussion on joint channel estimation for PUSCH Intel Corporation
18. R1-2103118 Discussion on joint channel estimation for PUSCH Apple
19. R1-2103180 Joint channel estimation for PUSCH Qualcomm Incorporated
20. R1-2103253 Joint channel estimation for PUSCH Samsung
21. R1-2103312 UE configuration for enhanced JCE in TDD Sony
22. R1-2103382 Joint channel estimation for PUSCH coverage enhancements Nokia, Nokia Shanghai Bell
23. R1-2103446 Joint Channel Estimation for PUSCH Ericsson
24. R1-2103458 Discussion on joint channel estimation for PUSCH Panasonic Corporation
25. R1-2103460 Design Considerations for Joint channel estimation for PUSCH Sierra Wireless, S.A.
26. R1-2103481 Joint channel estimation for multi-slot PUSCH Sharp
27. R1-2103589 Joint channel estimation for PUSCH NTT DOCOMO, INC.
28. R1-2103617 Enhancements for joint channel estimation for multiple PUSCH Lenovo, Motorola Mobility
29. R1-2103626 Discussions on joint channel estimation for PUSCH LG Electronics
30. R1-2103701 Discussion on joint channel estimation for PUSCH WILUS Inc.
31. Appendix

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| **Company/Tdoc** | **Views** |
| Huawei/ R1-2102313 | ***Observation 1****: 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 2:*** *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 3:*** *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 4****: Joint channel estimation with DMRS located in special slot can improve the performance of PUSCH transmissions by 1.2dB at 10% BLER in typical TDD mode ‘DDDSUDDSUU’ with 2 symbols of DMRS in S slot and 1 symbol of DMRS in U slot.****Proposal 1****:**Joint channel estimation should be supported for non-back-to-back PUSCH transmissions** *FFS: whether and how to minimize the UE energy consumption caused by retaining PA state for phase continuity between successive PUSCH transmissions*

***Proposal 2****:**Joint channel estimation should be supported for the very common scenario where SRS is transmitted in-between PUSCH transmissions** *FFS: Mechanism to support joint channel estimation for SRS transmitted in-between PUSCH transmissions.*

***Proposal 3****:**Joint channel estimation should be supported among different TBs.****Proposal 4****:**With a time window and an indication of joint channel estimation among different PUSCH transmissions, UE is expected to maintain phase continuity during this time window.** *e.g. UE retains PA state, no antenna switching, etc.*

***Proposal 5****: DMRS located in special slot should be supported for joint channel estimation*.***Proposal 6****:**For inter-slot frequency hopping with inter-slot DMRS bundling, frequency hopping is performed every K slots.****Proposal 7****: UE specific signaling is preferred in configuring the time domain interval K for DMRS bundling in inter-slot frequency hopping, while candidate values of K can be further discussed.* |
| OPPO/ R1-2102409 | ***Observation 1: Performance gain of joint channel estimation still keep increasing as the length of joint estimation window increases in case of residual frequency offset of +/- 0.1 ppm.******Observation 2: The Performance gain loss due to residual frequency offset is not sensitive to the length of joint estimation window.******Observation 3: Joint channel estimation may be impacted due to power reduction during PUSCH repetition.******Proposal 1: 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 2: Study potential interoperation of joint channel estimation and pre-coder cycling.*** ***Proposal 3: PUSCH can be hopped across different slot bundles to enable joint channel estimation.******Proposal 4: It is not necessary to introduce an additional time domain window to restrict UE’s PUSCH transmission behaviors.******Proposal 5: DMRS-less, optimized DMRS pattern and non-uniform distributing DMRS can be considered for PUSCH repetition.*** |
| Spreadtrum/ R1-2102465 | ***Proposal 1. Only back-to-back PUSCH transmissions with the same TB is considered in Rel-17.******Proposal 2. For back-to-back PUSCH transmissions with the same TB, time domain window can be implicitly determined by the repetition factor.******Proposal 3. For DMRS unbalanced issues, we can replace the unbalanced DMRS pattern by balanced pattern.******Proposal 4. Within time domain window, DMRS is only located in special slots.*** |
| ZTE/ R1-2102499 | ***Proposal 1:*** *Support use case 1 (back-to-back PUSCH transmissions within one slot) for joint channel estimation for PUSCH.* * *Joint channel estimation for PUSCH repetition type B is supported while optimization specific for PUSCH repetition type B is not considered.*

***Proposal 2:*** *As long as the condition of power consistency and phase continuity defined by RAN4 can be met, support use case 2 (non-back-to-back PUSCH transmissions within one slot) and use case 4 (non-back-to-back PUSCH transmissions across consecutive slots) for joint channel estimation for PUSCH.* ***Proposal 3:*** *De-prioritize use case 5 for joint channel estimation for PUSCH.* ***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 4:*** *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, e.g., floor (K/2) or cell(K/2).*
* *Option 2: Inter-slot bundling size is RRC configured or dynamically indicated to a UE.*

***Proposal 5:*** *FFS the inter-slot FH bundling pattern for TDD operation.* ***Observation 2:*** *The performance impact due to frequency offset error is negligible in 700MHz Rural scenario.* ***Observation 3:*** *Optimization of DMRS location/granularity in the time domain can provide 0.15~2.52 dB gain for PUSCH repetitions in 700MHz Rural* *scenario.* ***Proposal 6:*** *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.*
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| vivo/ R1-2102536 | ***Observation 1: 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 2: Joint channel estimation could provide improved performance for PUSCH transmissions with same TB or with different TBs.*** ***Observation 3: Equally spaced DMRS pattern provides no performance gain.*** ***Observation 4: 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 5: DMRS on orphan symbol combined with joint channel estimation could provide performance gain.*** ***Observation 6: 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:*** ***Time-domain window for joint channel estimation should be specified.**** + ***UE report capability on the length of time domain window, in which phase continuity and power consistency can meet the requirement for joint channel estimation.***
		- ***The details of capability can be discussed in RAN4.***
	+ ***The time domain window for joint channel estimation should be configurable.***

***Proposal 2: Inter-slot bundling for hopping pattern should take the TDD frame structure into consideration.******Proposal 3: No need to support equally spaced DMRS pattern.******Proposal 4: DMRS on orphan symbol in-between the PUSCH repetitions can be used for joint channel estimation for adjacent PUSCH transmissions.*** ***Proposal 5: 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.***

***Proposal 6: PUSCH transmissions within the time-domain window for joint channel estimation may be interrupted by other transmissions/procedures, and whether and how to ensure phase continuity in these cases should be further studied. The interruptions can be caused in the following cases**** ***PUSCH transmissions is cancelled by SFI, CI or higher priority transmissions.***
* ***UL transmission in another serving cell, when intra band CA is configured.***
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| CATT/ R1-2102645 | ***Observation 1: The use case of non-back-to-back PUSCH transmissions across consecutive slots need to be discussed after receiving the reply from RAN4.******Observation 2: The use case of PUSCH transmissions across non-consecutive slots should not be supported in joint channel estimation.******Proposal 1: Cross-slot channel estimation can be applied to the back-to-back PUSCH transmissions for one TB processed over multiple slots.******Proposal 2: Cross-slot channel estimation can be applied to the back-to-back PUSCH transmissions with different TBs.******Proposal 3: A time domain window should be introduced in which the enhanced FH pattern and the optimization of DMRS location/granularity in time domain can be further studied.******Proposal 4: The length of the time domain window should be defined by a set of slots.******Proposal 5: Multiple time domain windows can be defined to adapt to different channel conditions.**** ***One of the defined windows can be configured/indicated by gNB.***

***Proposal 6: New DMRS patterns on continuous slots with lower DMRS density should be further studied.******Proposal 7: Frequency hopping pattern with inter-slot bundling can be determined according to the bundling window size.*** |
| MediaTek/ R1-2102692 | ***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:*** *Deprioritize the non-back-2-back UL repetition scenario.**Observation 2: SRS typically has very different settings on antenna port, occupied PRBs and UL power to PUCCH and PUSCH. It is an extreme corner case to see all these settings are exactly the same between SRS and PUSCH/PUCCH.****Proposal 2:*** *No support of the scenario of other physical signals/channels in-between PUCCH or PUSCH repetitions for phase continuity and power consistency.**Observation 3: The use case to remain phase continuity and power consistency for UL repetition is not clear under CA scenario.* ***Proposal 3:*** *Whether/how to support phase continuity and power consistency for UL repetition under CA scenario should be clarified with RAN4 feedback.****Proposal 4:*** *Whether/how to support phase continuity and power consistency for UL repetition under DC scenario* |
| China Telecom/ R1-2102862 | **Proposal 1: Reply to RAN4:*** **Following potential use cases are considered for joint channel estimation for PUSCH for both paired spectrum and unpaired spectrum in RAN1:**
	+ **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.**
* **For non-back-to-back PUSCH transmissions within one slot, RAN1 is considering the following case:**
	+ **Non-zero gap in-between adjacent PUSCH transmissions due to invalid symbol(s) for PUSCH repetition type B**
	+ **Non-zero gap in-between adjacent PUSCH transmissions for different TBs scheduled by network.**
* **For non-back-to-back PUSCH transmissions across slots, RAN1 is considering the following case:**
	+ **Non-zero gap in-between adjacent PUSCH transmissions due to SRS or PUCCH transmission from other UE(s) in-between adjacent PUSCH transmissions**
	+ **Non-zero gap in-between adjacent PUSCH transmissions due to invalid symbol(s)/orphan symbol for PUSCH repetition type B**
	+ **Non-zero gap in-between adjacent PUSCH transmissions for different TBs scheduled by network.**

**Proposal 2:*** **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.**
* **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 repetition type B scheduled by dynamic grant or configured grant is supported.**

**Proposal 3:** * **Specify a time domain window during which UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.**

**Proposal 4:** * **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 duration if defined.**

**Proposal 5:** * **For inter-slot frequency hopping with inter-slot bundling, the bundle size can be independently configured, but cannot be larger than the length of duration based on UE capability or the size of the time domain window.**
 |
| CMCC/ R1-2102895 | **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:****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 3:****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:****Non-back-to-back PUSCH transmissions should be suspended until RAN4 gets a conclusion. Back-to-back PUSCH transmission should be prioritized for further discussion.****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:****If no other conditions except power consistency and phase continuity should be maintained, only the consecutive slots/symbols intended for joint channel estimation should be indicated. The time domain window for joint channel estimation should not be defined.****Proposal 7:****The impact of phase drifting to the performance of joint channel estimation under a large number of consecutive slots should be studied.****Proposal 8:****If the impact of phase drifting is verified, the maximum consecutive slot number should be defined as the upper bound for the joint channel estimation.****Proposal 9:****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.** |
| Xiaomi/ R1-2102994 | ***Proposal 1: Proper granularity for DMRS bundling or a DMRS bundling time window need to be introduced and specified if joint channel estimation is supported.******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 through RRC, and at any given time, only M time window can be activated and supported for each UE simultaneously through DCI.******Proposal 5: Support maintain a DMRS configuration table containing more diverse DMRS patterns for dynamically indication and configuration******Proposal 6：The maximum number of DMRS symbols and DMRS interval in a DMRS bundling time window should be defined and configured for equally spacing DMRS among PUSCH transmissions.*** |
| InterDigital/ R1- 2103009 | **Observation 1: Maintenance of phase and power continuity across bundled PUSCH(s) is critical to enable DMRS bundling** **Observation 2: The UE may have a limitation of how long the UE can maintain power/phase continuity****Observation 3: The UE needs a specific interval to bundle DM-RS symbols in PUSCH****Observation 4: Expressing the length of the bundling window in terms of symbols or slots provide granularities for DM-RS bundling****Observation 5: Expressing the length of the bundling window in terms of the number of repetitions provide alignment with PUSCH transmission****Observation 6: Considering different grant types for PUSCH(s), an indication mechanism that is adjustable for grant type offers flexibility and robustness****Observation 7: In the presence of CFO, PT-RS insertion may assist the gNB for the phase continuity maintenance within an acceptable range so the DM-RS coherence is maintained.****Observation 8: DMRS in special slot brings performance benefits****Observation 9: DMRS placement in a slot according to the DMRS in the special slot brings additional benefits****Observation 10: Joint channel estimation for TBoMS will provide additional performance gain from the receiver side****Proposal 1: Define a time window during which the UE is expected to maintain power or phase continuity****Proposal 2: Support at least the number of repetitions to indicate the length of the DM-RS bundling window****Proposal 3: Support a higher layer signaling (RRC) to enable DMRS bundling****Proposal 4 : Time window configuration is associated to repetition configurations in configured grant** **Proposal 5: Support a grant-type dependent index which indicates PUSCH(s) to bundle****Proposal 6: Support multiple DM-RS bundling windows****Proposal 7: When DM-RS bundling is enabled, PTRS should be enabled as well, at least for FR2.****Proposal 8: Support DM-RS placement in a special slot in DM-RS bundling when a special slot and uplink slot are placed continuously****Proposal 9: Confirm the working assumption from RAN1#104b and support joint channel estimation for the TBoMS transmission for back-to-back PUSCH transmission****Proposal 10: Disable DM-RS bundling if flexible symbols or slots included in the time window turn to downlink symbols/slots due to SFI.****Proposal 11: RAN4 evaluation should include at least Use case 1 (BtB transmission for consecutive slots) and Use case 3 (BtB transmission for consecutive symbols within a slot)**  |
| Intel/ R1-2103044 | **Observation 1*** *For PUSCH with 8 repetitions and inter-slot frequency hopping, 4 DMRS symbols can achieve better link level performance than 6 DMRS symbols for PUSCH.*

**Observation 2*** *For PUSCH with 4 repetitions and inter-slot frequency hopping with bundling size of 2 slots, relatively large performance degradation, i.e., ~1.5dB can be observed for lower DMRS density, i.e., when DMRS symbols are not allocated in odd slots compared to the case when DMRS symbols are allocated in every slot.*

**Observation 3*** *For PUSCH with 4 repetitions and joint channel estimation with bundling size of 2 slots, ~0.1dB performance gain can be achieved when an additional DMRS symbol is inserted in the special slot for PUSCH repetition.*

**Observation 4*** *For PUSCH with 4 repetitions and joint channel estimation with bundling size of 2 slots, performance difference is negligible between existing DMRS pattern as defined in Rel-15 and equally spaced DMRS pattern.*

**Observation 5*** *For PUSCH with 4 repetitions, when employing joint channel estimation with bundling 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*** *UE needs to keep same Tx power, precoder and frequency resource within a window for joint channel estimation over multiple PUSCHs.*

**Proposal 2*** *Higher DMRS density in time domain is not supported for PUSCH enhancement.*

**Proposal 3*** *Lower DMRS density in time domain is not supported for PUSCH enhancement.*

**Proposal 4*** *Additional DMRS symbols located in the special slot may not be supported for PUSCH enhancement.*

**Proposal 5*** *Equally spaced DMRS pattern may not be supported for PUSCH enhancement.*

**Proposal 6*** *For inter-slot frequency hopping with inter-slot bundling, the bundle size may be configured by higher layers, or implicitly determined based on the number of repetitions for PUSCH.*
 |
| Apple/ R1-2103118 | **Proposal 1: Joint channel estimation for back-to-back PUSCH transmissions within one slot is not supported.****Proposal 2 : Confirm the following 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**

**Proposal 3: Specify the inter-slot frequency hopping pattern to enable the conjunction operation of repetition, frequency hopping and cross-slot channel estimation.** |
| Qualcomm/ R1-2103180 | **Proposal 1:** Deprioritize joint channel estimation for the following cases:* 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:** RAN1 waits for further RAN4 input on feasibility of the following cases:* Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.
* Use case 5: PUSCH transmissions across non-consecutive slots.

**Proposal 3:** RAN1 specifies time domain window(s) during which UE may maintain phase continuity among PUSCH transmissions subject to phase continuity requirements.* The UE is not required to maintain phase continuity of the PUSCH transmissions scheduled outside of the window.
* FFS: how to indicate the window configuration.

**Proposal 4:** Support multiple non-overlapping time domain windows for joint channel estimation over PUSCH repetitions. * Windows are determined based on semi-static slot format configuration.
* FFS: determine start of a window.

**Proposal 5:** For each PUSCH transmission, the UE signals a bundling indication in the PUSCH transmission.**Proposal 6:** Only support non-interleaving case where the bundled PUSCHs in a hop are consecutively transmitted when inter-slot frequency hopping is configured. **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. |
| Samsung/ R1-2103253 | ***Observation 1: The time domain window is defined as the duration in which the power consistency and phase continuity are preserved for joint channel estimation.*** ***Proposal 1: Support a same power, precoding, RV, and frequency position for a number of repetitions of a PUSCH transmission.*** ***Proposal 2: A UE updates the CLPC adjustment state per number of repetitions corresponding to the DM-RS interpolation window.******Proposal 3: 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.*** ***Observation 3: DM-RS interpolation in absence of CFO provides a gain of ~0.7 dB for PUSCH repetition type A and of ~1.3 dB for PUSCH repetition type B.******Proposal 4: Support DM-RS interpolation for both PUSCH repetition Type A and Type B.*** ***Proposal 5: A UE performs PUSCH frequency hopping per number of M>1 PUSCH repetitions. The number M can be predetermined, such as M=4 or M=N/2 where N is the number of repetitions, or be configured by RRC (a selection may also depend on the approach for the determination of the time window).*** ***Proposal 6: Support a same power, precoding and frequency position for a number of repetitions of a PUCCH transmission.***  |
| Sony/ R1-2103312 | Observation 1: For UL dominated traffic, a UE can be configured to ignore DL symbols to maintain UL phase continuity and amplitude consistency. Observation 2: For UEs with cross switch (1-Tx-z-Rx, where z≥2), or in general terms, UEs that have multiple Rx/Tx chains, it is possible to use different antennas for UL and DL traffic during the JCE window.Observation 3: For FR2 a UE needs to be able to request an alternative beam for DL.Proposal 1: Enable JCE by configuring DL blanking to UEs.Proposal 2: Companies are encouraged to investigate the additional power needed to keep the PA biased during the DL periods. Proposal 3: Companies are encouraged to investigate the required isolation between the antenna ports to avoid desensitization from PA noise leakage.Proposal 4: Companies are encouraged to investigate the probability of having too weak signal at the second antenna. Proposal 5: UE capability of supporting JCE and signaling that JCE is not applicable is needed.Proposal 6: Companies are encouraged to estimate the required tolerance of the phase and the amplitude consistency needed for JCE. |
| Nokia/ R1-2103382 | **Proposal 1. 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 the following additional scenarios:*** **back-to-back PUSCH transmissions within one slot;**
* **back-to-back PUSCH transmissions across consecutive slots including:**
	+ - * **one TB processed over multiple slots, PUSCH transmissions of different TB, and PUSCH repetition type B.**

**Proposal 2. 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:**
	+ - * **non-back-to-back PUSCH transmissions across consecutive slots.**
			* **PUSCH transmissions across non-consecutive slots.**
* **gNB to dynamically indicate whether and which DL reception occasion should be monitored by the UE.**

**Proposal 3. RAN1 to specify a time-domain window at least for non-back-to-back PUSCH transmissions with non-zero gap in-between adjacent transmissions. The window size may be reported as UE capability and/or configured via higher-layer signalling.****Proposal 4. For inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation:*** **RAN1 to specify at least the following frequency hopping modes:**
	+ - * **UE switches frequency hop for the repetitions after a DL reception occasion that the UE is expected/configured to monitor/receive.**
			* **UE switches frequency hop for the repetitions after a DL reception occasion that the UE is expected/configured to monitor/receive; and applies a time-domain window starting from the switching slot. The UE also switches frequency hop for the repetitions after the time-domain window expires.**
 |
| Ericsson/ R1-2103446 | **Observations:**1. Multiple PUSCH transmissions within a slot will have at least some loss in coverage as compared to a single PUSCH transmission within a slot, especially if there is also one or more x-symbol gaps in the slot. Therefore, multiple PUSCH transmission does not seem to be a use case within the scope of the coverage enhancement work item.
2. Back to back transmission across slots is the most straightforward use case to support, and the case where there is a multi-symbol gap also appears promising.
3. Support for different numbers of symbols in a slot is more complicated, and likely to have less gain than the same number of symbols in a slot.
4. From a RAN1 perspective, we should strive to support non-consecutive transmission over slots.
	* This may be challenging from a RAN4 perspective, but heavy DL:UL TDD ratios are common in real networks.
5. Sub-slot repetition of PUCCH is to be specified in Rel-17
6. Sub-slot repetition of PUCCH can provide coverage enhancement for URLLC applications
7. The specification impact, net gains, and use cases of TBoMS support for special slot should be carefully studied prior to specifying it.
8. Configurations where the number of symbols is the same in all slots of a TBoMS transmission is a logical starting point for RAN4 studies
	* According to RAN1#104 agreements, at least these configurations will be specified.
	* RAN1 can update RAN4 on supported TBoMS configurations as RAN1 discussions progress.
9. 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.
10. 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.
11. For a fair assessment of the gains from joint channel estimation, the carrier frequency offset (CFO) should be modeled in simulations.
	* The loss from an uncompensated CFO is found to be about 0.5 dB, which is significant in comparison to the overall gains of 1.3 dB observed for joint channel estimation.
12. 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.
13. 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.
	* The simulations were performed using 4 PRBs and assuming a single phase offset over that bandwidth; wider bandwidths are for further study.
14. 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).
15. 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).
16. 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.
17. The benefit of defining a time domain window beyond the slots occupied by a PUSCH is not yet clear
	* A potential use case is where the window is smaller than the number of repetitions, but the performance and need for such a case requires further study.

**Proposals:**1. Respond to RAN4 on specific scenarios that RAN4 should focus in their study according to the proposed LS response in [5].
2. 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.
3. Identify which mechanisms should be specified and which can be gNB implementation to support phase coherence across slots with multiple repetitions.
4. The time domain window during which the UE is expected to maintain power consistency and phase continuity among PUSCH transmissions is according to slots occupied by the same PUSCH content
	* When joint channel estimation is configured, power consistency and phase continuity is required over all repetitions of a PUSCH or over all slots of one TBoMS transmission that meet power consistency and phase continuity requirements
		+ Power consistency and phase continuity requirements are defined according to R1-2102298 as a starting point, and can be revised according to further updates from RAN4.
		+ Further study the need for a time domain window spanning a portion of the PUSCH repetitions or TBoMS transmission**.**
 |
| Panasonic/ R1-2103458 | **Proposals:****Proposal 1: For back-to-back PUSCH transmissions, support necessary design aspects to enable joint channel estimation for the following cases*** **Over back-to-back PUSCH transmissions (of the same TB) for repetition type B across consecutive slots and within a slot where scheduled by dynamic grant or configured grant**
* **Over back-to-back PUSCH transmissions of a single TB over multi-slots**

**Proposal 2: For non-back-to-back PUSCH transmissions with non-zero gap in-between adjacent transmissions, where there is no DL reception and X un-scheduled OFDM symbols in-between the PUSCH or PUCCH repetition, support necessary design aspects to enable joint channel estimation. X is decided by RAN4.****Proposal 3: It is not necessary to enable joint channel estimation for multi-TB scheduling by multiple DCIs and by single DCI at least for NR-U. It is FFS for multi-TB scheduling by a single DCI.** **Proposal 4: The length of time domain window is indicated by scheduled DCI for dynamic grant and by activated DCI for CG type 2. The length of time domain window is RRC configuration for CG type 1.****Proposal 5: TDRA table is used to indicate the length of time domain window.****Proposal 6: Optimization of DMRS location/granularity should be specified only if the significant gain is identified*** **If specified, different number of DMRSs can be set for different PUSCH transmissions within a time domain window.**

**Proposal 7: One or more lengths of time domain windows are configured to be jointly used with inter-slot FH*** **Each of the one or more lengths of time domain windows is used for the same frequency allocation in inter-slot FH procedure.**

**Proposal 8: Each of the one or more lengths of time domain windows and a length of inter-slot FH can be the same or different.****Observations:** **Observation 1: Joint channel estimation with inter-slot frequency hopping provides an improvement of gain of 1.0 ~1.5 dB compared to joint channel estimation without inter-slot frequency hopping and doubling a length of time domain window.****Observation 2: The performance loss due to frequency offset/error of +/- 0.1 ppm can be negligible at least when performing 4 and 8 repetitions with joint channel estimation and inter-slot frequency hopping.** |
| Sierra Wireless/ R1-2103460 | **Proposal 1:** RAN1 should agree on a common residual frequency error for JCE LLS**Observation 1:** The RAN4 UE frequency error requirement of +/- 0.1ppm should NOT be used as a JCE LLS assumption since it does not consider gNB frequency offset compensation. The residual frequency error should be in the range of +/- 50Hz but more input is needed. **Observation 2:** JCE LLS simulation assumptions should focus on indoor low doppler scenarios (e.g. 2Hz)since it is most likely to experience coverage issues due toinbuilding penetration loss.**Observation 3:** For the FDD eMBB scenario, joint channel estimation can provide ~1.5 dB of coverage gain.**Observation 4:** For the FDD VoIP scenario, joint channel estimation can provide ~3.5 dB of coverage gain.**Observation 5:** For the FDD eMBB scenario, the coverage gain for joint channel estimation with frequency hopping and inter-slot bundling is ~1.25dB.**Observation 6:** For the FDD eMBB scenario, joint channel estimation with FH and inter-slot bundling limits frequency diversity.**Observation 7:** For TDD, joint channel estimation can only be used with UEs which can maintain phase continuity across TDD frames. **Proposal 2:** Study resource allocation and procedural changes which could increase the likelihood that a UE could maintain phase continuity across TDD frames.**Observation 8:** For the TDD DDDSU eMBB scenario, joint channel estimation across TDD frames can provide >1 dB coverage gain.**Observation 9:** For the TDD DDDSU VoIP scenario, joint channel estimation across frames can provide ~2 dB coverage gain.**Proposal 3:** The gNB may signal to the UE a required phase continuity time window which the UE shall maintain phase continuity over.* FFS whether signalling is semi-static (e.g. RRC) or dynamic (e.g. DCI)
* FFS whether the time window is a sliding window across the transmission or whether a transmission is segmented into several serial non-overlapping time windows

**Proposal 4:** The UE shall signal a maximum phase continuity time window capability to the gNB which is the maximum time the UE is capable to maintain phase continuity.**Proposal 5:** RAN1’s answer to RAN4’s LS should be for RAN4 to focus on the TDD frame structure DDDSU with multiple slots scenario. |
| Sharp/ R1-2103481 | ***Proposal 1: For non-back-to-back PUSCH transmissions across consecutive slots with X symbol gap (X=1~14) where no other uplink transmission is performed on the X symbol gap, 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 non-back-to-back transmissions of the same TB for repetition type A scheduled by dynamic grant or configured grant***

***Proposal 2: A time domain window is specified such that the phase continuity is ensured.**** ***The specification should ensure that the UE transmission for PUSCH repetitions shall be such that the channel over which a symbol on the antenna port used for uplink transmission is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only if the two symbols corresponds to the same time domain window.***

***Proposal 3: Time domain window configuration should support implicit determination which enables a time domain window to include a set of continuous UL slots.*** |
| NTT DOCOMO/ R1-2103589 | **Proposal 1: Ask RAN4 the amount of tolerable phase change between repetitions in back-to-back transmissions with zero gap in-between adjacent transmissions over multiple slots.** **Proposal 2: A time domain window should be specified per UE, if DMRS transmissions for joint channel estimation over long time require the processing load.****Proposal 3: Support inter-slot frequency hopping with inter-slot bundling when applying joint channel estimation.** **Proposal 4: The duration per hop should be a time domain window. If a time domain window is not specified, duration per hop should be decided based on the specification or indicated by signalling.****Proposal 5: Support joint channel estimation of PUSCH repetition type B as well for back-to-back PUSCH transmission across consecutive slots of the same TB.****Observation 1: Applying joint channel estimation over 2 slots and 4 slots brings a gain of 0.72 dB and 1.02 dB, respectively.**  |
| Lenovo/ R1-2103617 | ***Proposal 1: For specifying joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, use cases with back-to-back PUSCH transmission within one slot in addition to across multiple slots (****repetition type A)* ***are supported.**** ***Support of joint channel estimation for non-back-to-back PUSCH transmissions is dependent up on RAN4’s input***

***Proposal 2: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, additional DM-RS time-domain pattern should be enhanced with following consideration:**** ***to support equally spaced DM-RS symbols across multiple PUSCHs (new design for additional DMRS symbols)***
* ***to avoid extrapolation for large number of symbols for the last PUSCH (similar design aspect as supported in NR)***

***Proposal 3: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, UE should be configured with an additional new configuration for additional DM-RS patterns (for up to 14 symbols) to apply to all PUSCH transmissions, but last**** ***For the last PUSCH transmission, the current additional DM-RS configuration should be applied***

***Proposal 4: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, support multi-slot frequency hopping and multi-slot DM-RS bundling for joint channel estimation for entire hop:**** ***Association between frequency hop duration and DM-RS bundle duration should be supported***
* ***At least hop duration of 2 slots should be supported with DM-RS bundling***

***Proposal 5: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, time domain window for the purpose of joint channel estimation DM-RS bundling should be specified with following details:**** ***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***
* ***For the case of joint channel estimation with frequency hopping, explicit indication/configuration for time domain window can be avoided and implied by the duration of the hop***
* ***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, 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** |
| LG/ R1-2103626 | ***Proposal 1: For non-back-to-back PUSCH transmissions across consecutive slots, and PUSCH transmission across non-consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for repetition type A scheduled by dynamic grant or configured grant******Proposal 2: It should be adopted that received TA command is not applied within time-domain window for joint channel estimation when TA command is indicated to the UE.******Proposal 3: The time domain window for joint channel estimation is specified.******Proposal 4: Time-domain window for joint channel estimation is consecutive slots.******Proposal 5: Multiple time windows in the same transmission channel of the same grant should not be considered.******Proposal 6: The frequency hopping boundary length can be equal to or larger than the time-domain window for joint channel estimation.******Proposal 7: Inter-slot frequency hopping boundary with inter-slot bundling follows cell-specific time-domain resource grid.******Proposal 8: Deprioritize the optimization of DMRS granularity.******Proposal 9: If necessary, the additional DMRS in special slot or orphan symbol can only be considered for optimization of DMRS location in time domain.*** |
| WILUS/ R1-2103701 | ***Proposal 1: For back-to-back PUSCH transmissions, prioritize PUSCH repetition type A and PUSCH repetition type B for joint channel estimation.**** + ***For non-back-to-back PUSCH transmissions, it can be further discussed after RAN4’s conclusion.***

***Proposal 2: For back-to-back PUSCH transmissions with repetition case, specify the time domain window. The length 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, it should be further discussed to determine frequency hopping index by taking into account UE multiplexing, frequency hop balancing and availability of joint channel estimation.*** |