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

**e-Meeting, January 25th – February 5th, 2021**

**Source: Moderator (Intel Corporation)**

**Title: Draft of Summary#1 of AI: 8.1.2.4 Enhancements on HST-SFN deployment**

**Agenda item: 8.1.2.4**

**Document for: Discussion and Decision**

# Introduction

In RAN#86 meeting the work item on enhanced MIMO support was agreed for Rel-17 [1]. The objectives of WID include enhancements to multi-TRP transmission scheme in HST-SFN scenario.

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| 2. Enhancement on the support for multi-TRP deployment, targeting both FR1 and FR2:  …  d. Enhancement to support HST-SFN deployment scenario:  i. Identify and specify solution(s) on QCL assumption for DMRS, e.g. multiple QCL assumptions for the same DMRS port(s), targeting DL-only transmission  ii. Evaluate and, if the benefit over Rel.16 HST enhancement baseline is demonstrated, specify QCL/QCL-like relation (including applicable type(s) and the associated requirement) between DL and UL signal by reusing the unified TCI framework |

The document contains summary of the company’s proposal and Moderator’s proposals.

# Possible enhancements for HST-SFN deployment

The section summarizes company proposals regarding enhancements that can be supported for HST-SFN deployment. The proposals are based on the contributions [2]-[21] submitted to RAN1#104-e meeting.

## Support of UE-based solution

## Issue #1-1 (Support of scheme 1)

Regarding support of scheme 1 in Rel-17 for HST-SFN deployment scenario. In RAN1#103-e meeting it was agreed to support two TCI states for the same DM-RS antenna ports. However, formal agreement on support of scheme 1 in Rel-17 is still missing. It is, therefore, proposed to have a conclusion on this issue.

**Issue#1-1:** Whether to support scheme 1

* Scheme 1 is supported in Rel-17
  + **Supported by:** Futurewei, InterDigital, Huawei / HiSilicon, ZTE, LGE, Spreadtrum, Lenovo / Motorola Mobility, Nokia/NSN, CMCC, Ericsson, Qualcomm, …
* Scheme 1 is not supported in Rel-17
  + **Supported by:** vivo?

Based on the company’s view, there is majority that prefers specification of scheme 1 and the following proposal is made:

**Proposal 1-1:**

* *Scheme 1 is supported in Rel-17*
  + *FFS other details*

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| **Company** | **Comment** |
| InterDigital | Support |
| Huawei, HiSilicon | Support the FL’s proposal |
| OPPO | Fine with the proposal. |
| ZTE | Support FL proposal |
| Lenovo/MotM | Support |
| Spreadtrum | Support |
| LG | Support |
| NEC | Support |
| Sony | Support |
| vivo | OK with the proposal.  As SFN PDCCH has been supported in AI 8.1.2.1, it generally needs two TCI states both associated with QCL-Type A. Considering the coordination of SFN PDCCH and SFN PDSCH, we are ok to support scheme 1, though the performance and UE complexity of scheme 1 are suboptimal compared with NW-based solution. |

## Issue #1-2 (QCL types/assumptions when TRS is source)

Regarding support of QCL types/assumptions when TRS is used as source RS in TCI state for scheme 1. Several companies expressed their preference regarding preferred QCL variant for scheme 1 identified in RAN1#103-e meeting. Summary of the company’s views is provided below:

**Issue#1-2:** For scheme 1, when the same DMRS port(s) are associated with two TCI states containing TRS as source reference signal, the following QCL is supported for Rel-17

* Variant E from RAN1#103-e meeting agreement
  + **Supported by**: Futurewei, InterDigital, OPPO, ZTE, LGE, Spreadtrum, Lenovo / Motorola Mobility, Nokia / NSN, CMCC, Apple, Intel, Qualcomm, …

**Proposal 1-2:**

* *For scheme 1 support Variant E for QCL assumption in TCI state when TRS is used as source RS*
* *Extend the above agreement to SFN transmission of PDCCH*

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| **Company** | **Comment** |
| InterDigital | support |
| Huawei, HiSilicon | Support |
| OPPO | Fine with the proposal. |
| ZTE | Support FL proposal |
| Lenovo/MotM | Some companies have provided different variants of Scheme 1. We support Variant E only for the case in which a TRP-specific TRS transmission is assumed, i.e., TRP1 transmits TRS0 only and TRP2 transmits TRS1 only |
| Spreadtrum | Support |
| LG | Support |
| NEC | Support |
| Sony | For scheme 1 only (not combined with Doppler pre-compensation), we are supportive to Variant E. |
| vivo | Support the proposal |

## Issue #1-3 (Indication of scheme 1)

Regarding configuration of scheme 1. Several companies provided their preference regarding switching of scheme 1 with legacy schemes. Summary of the company’s preference is provided below:

**Issue#1-3:** How to support configuration / switching of Rel-17 scheme 1 with legacy Rel-15/Rel-16 schemes?

* **Alt-1**: Dynamic (DCI-based)
  + FFS which legacy schemes should support dynamic switching with scheme 1
  + **Supported by**: ZTE, Samsung, QC, …
* **Alt-2**: Semi-static (RRC-based)
  + **Supported by**: InterDigital, OPPO, NEC, Lenovo/Motorola Mobility, CMCC, …

Companies are encouraged to provide their preference / views regarding the above alternatives.

**Proposal 1-3:**

* *TBD*

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| **Company** | **Comment** |
| InterDigital | Propose to add Alt-3,   * **Alt-3**: Using implicit mechanisms   + **Supported by**: InterDigital |
| Huawei, HiSilicon | More discussion is needed. The benefits on the both side should be clarified. |
| OPPO | Support Alt-2. RRC signaling should be used for switching between scheme 2a/2b/3 and Rel-17 HST-SFN, which are configured via single CDM group and two TCI states. For switching between Rel-17 HST-SFN and single TRP/scheme 1a, dynamic switching can be considered via configuration of TCI state(s) and CDM group(s) |
| ZTE | Have the same view with OPPO. One RRC signaling is needed to enable Rel-17 SFN scheme 1. Then, we can directly discuss issue #1-4. |
| Lenovo/MotM | Support Alt-2. We also believe this should be merged with Proposal 1-4 |
| Spreadtrum | Support Alt-2. Share the same view with OPPO. |
| LG | We prefer Alt-1. This is because there can be various service types also in HST deployment as the same reason as supporting dynamic switching between eMBB and URLLC schemes in Rel-16 multi-TRP transmission. |
| NEC | Support Alt-2. |
| Sony | Support Alt-2. In our view, the DL transmission schemes should be semi-statically configured and changed. |
| vivo | Support Alt-1: Dynamic.  But we suggest discussing this issue after determining the QCL assumption of NW-based solution, since the QCL assumption of NW-based solution is directly associated with how to design the indication of scheme 1 and NW-based solution with a unified design. |

## Issue #1-4 (Legacy schemes for switching with scheme 1)

If dynamic switching of scheme 1 is supported, the following options of the legacy schemes from Rel-15/16 were proposed based on the submitted contribution.

**Issue#1-4:** Dynamic switching of Rel-17 scheme 1 is supported with the following legacy schemes

* **Alt-1**: Switching with 1a/single-TRP
* **Alt-2**: Switching with schemes 1a/4/single-TRP
* **Alt-3**: Switching with schemes 1a/2a/2b/3/single-TRP
* **Alt-4**: Switching with 1a/2a/2b/3/4/single-TRP/Rel-15 SFN scheme
* FFS: Whether all DMRS ports are within one CDM group
* FFS: Detailed signaling solution
* [Extend the alternatives to TRP-based pre-compensation, if supported]

Companies are encouraged to provide their preference / views regarding the above alternatives.

**Proposal 1-4:**

* *TBD*

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| **Company** | **Comment** |
| Huawei, HiSilicon | Based on the discussion in Section 2.1.3. |
| OPPO | Support Alt-1, similar to scheme 2a/2b/3. |
| ZTE | We support Alt-1.  Further, in the typical HST scenarios, all DMRS ports should be within one CDM group. |
| Lenovo/MotM | Support Alt-1 |
| Spreadtrum | Based on the discussion in section 2.1.3. We support Alt-1. |
| LG | One of scheme 2a/2b/3/4 can be configured by RRC. Based on this, it seems that Alt-2/3 can be modified as follows and we support this.  Switching with schemes 1a/one of 2a,2b,3,4/single-TRP |
| NEC | Support Alt-1. |
| vivo | Agree with ZTE, support Alt-1 and all DMRS ports within one CDM group. |

## Issue #1-5 (Number of TCI states in FR2)

Regarding the number of TCI states that should be supported for scheme 1 in FR2. Several companies provided their views on this issue. Summary of the company’s preference is provided below:

**Issue#1-5:** The number of TCI states supported for scheme 1 in FR2

* At most two TCI states can be configured/indicated for the UE
  + **Supported by**: Futurewei, Huawei / HiSilicon, CATT, vivo, Lenovo/Motorola Mobility, Nokia/NSN, Samsung, QC
* Two or more TCI states can be configured/indicated for the UE
  + **Supported by**: Intel
* Further study more than two TCI states
  + **Supported by**: Sony

Based on the company’s preference above, there is majority that prefers support of at most two TCI states for scheme 1 in FR2. Therefore, the following proposal is made:

**Proposal 1-5:**

* *At most two TCI states are supported for scheme 1 in FR2*

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| **Company** | **Comment** |
| Huawei, HiSilicon | Support FL’s proposal. |
| OPPO | Support the proposal. |
| ZTE | Support FL proposal |
| Lenovo/MotM | Support |
| Spreadtrum | Support |
| LG | Support |
| NEC | Support |
| Sony | If the majority view is to support at most 2 TCI states for scheme 1 in FR2, we are fine with FL’s proposal. |
| vivo | Support the proposal |

## Issue #1-6 (Additional source RS for scheme 1)

A few companies have mentioned that in Rel-15 for PDSCH a TCI state may be configured not only with TRS as source RS, but also with other reference signals (e.g., CSI-RS for CSI acquisition) as illustrated below. Therefore, it should be discussed whether to restrict supported source RS configurations in TCI state for HST-SFN scenario.

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| - 'QCL-TypeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'QCL-TypeD' with the same CSI-RS resource*,* or  - 'QCL-TypeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'QCL-TypeD' with a CSI-RS resource in an *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *repetition*,or  - QCL-TypeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured without higher layer parameter *trs-Info* and without higher layer parameter *repetition* and, when applicable, 'QCL-TypeD' with the same CSI-RS resource. |

**Issue#1-6:** Whether to support additional source RS for scheme 1 in addition to TRS, e.g. allowing the same QCL and RS combination as currently supported for PDSCH in Rel-15?

* **Alt-1**: All QCL source RS resource types as defined in TCI state of Rel-16 multi-TRP are supported for scheme 1
  + **Supported by**: CATT, …
* **Alt-2**: Only TRS is supported as QCL source for QCL-TypeA in TCI
  + **Supported by**: …
* It was already agreed that ach TCI state may be additionally associated with {Spatial Rx parameter} (i.e., QCL-TypeD)

Companies are invited to share their preference on support of the additional source RS in TCI state for scheme 1.

**Proposal 1-6:**

* *TBD*

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| **Company** | **Comment** |
| InterDigital | Support Alt-2 |
| Huawei, HiSilicon | Alt.1 can be discussed |
| OPPO | Support Alt-1 as Rel-15. |
| ZTE | We fail to see the necessity to discuss this issue. Proposal 1-5 is enough.  Based on the current Rel-15/16 for a target PDSCH/PDCCH after RRC connection, only QCL-TypeA and TypeD are allowed. Nothing is changed in Rel-17. |
| Lenovo/MotM | Support Alt-2 |
| Spreadtrum | Support Alt.1 |
| Sony | We are open to Alt-1. If DL RS other than TRS cannot provide similar QCL-TypeD performance, NW can only configure TRS in TCI states. But at the moment, we think these alternatives may need to be discussed more. |
| vivo | Support Alt-1 |

## Issue #1-7 (Additional target RS for scheme 1)

A few companies have mentioned that support of multiple QCL reference RS or two TCI states may be also required for reference signals in HST-SFN scenario. It is therefore proposed to discuss necessity of the multiple TCI state agreement to CSI-RS.

**Issue#1-7:** Whether to support multiple QCL reference RS and TCI states for reference signals?

* **Alt 1**: Support two TCI states indication for CSI-RS for CSI acquisition
  + **Supported by**: …
* **Alt 2**: Two TCI states are only supported for PDCCH / PDSCH
  + **Supported by**: …

Companies are invited to share their preference on support of multiple QCL reference RS or TCI states for the reference signals.

**Proposal 1-7:**

* *TBD*

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| **Company** | **Comment** |
| InterDigital | Support Alt 2. We don’t think there would be much use for Alt 1. |
| Huawei, HiSilicon | Support Alt.2. |
| OPPO | Support Alt.2. |
| ZTE | Support Alt.2. |
| Lenovo/MotM | We believe discussion on the alternatives would be pre-mature without agreeing on CSI-RS for CSI transmission scheme for HST-SFN |
| Spreadtrum | Support Alt.2 |
| LG | Support Alt.2. |
| NEC | Support Alt.2. |
| Sony | Support Alt.2, since CSI-RS is not included in scheme 1 or scheme 2. |
| vivo | Support Alt.2. As distributed TRS is configured in HST-SFN, it’s natural that CSI-RS is also distributed, thus we don’t see the necessity to support two TCI states for SFN CSI-RS. |

## Issue #1-8 (Support of scheme 2)

Regarding support of scheme 2. Several companies expressed their preference regarding support of scheme 2 in Rel-17. Some companies have also provided LLS evaluation results comparing performance of scheme 2 with scheme 1 and the baseline scheme. Summary of the company’s views is provided below:

**Issue#1-8:** Whether to support scheme 2 in Rel-17?

* Scheme 2 is supported
  + **Supported by**: InterDigital, Intel, LGE, Lenovo / Motorola Mobility, …
* Scheme 2 is not supported / low priority
  + **Supported by**: OPPO, Samsung, Nokia/NSN, Qualcomm, …

Since there is no clear majority to support scheme 2 in Rel-17, it is recommended to have the following conclusion.

**Proposal 1-8:**

* *Possible conclusion:*
  + *Scheme 2 is not supported in Rel-17*

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| **Company** | **Comment** |
| InterDigital | Don’t support the proposal, both schemes 1and 2 should be supported. |
| Huawei, HiSilicon | Support the FL’s proposal. Scheme-2 is less performance than Scheme-1 (evaluated in our Tdocs in RAN1#103-e meeting) and also have issue on DMRS overhead. |
| OPPO | Support the proposal. |
| ZTE | Support FL proposal. |
| Lenovo/MotM | Multiple companies have provided different alternatives for Scheme 2. At least it should be discussed |
| Spreadtrum | Support |
| Sony | Support FL’s proposal. |
| vivo | Support the proposal |

## Other issues

This section contains other issues that companies want to highlight for discussion regarding support of UE-based schemes.

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| **Company** | **Comment** |
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## Support of TRP-based solution

## Issue #2-1 (Support of TRP-based pre-compensation)

Regarding support of TRP-based pre-compensation scheme in Rel-17. In RAN1#103-e meeting it was agreed to support two TCI states for the DM-RS antenna ports. However, formal conclusion on support / no support of specification based TRP pre-compensation scheme in Rel-17 is still missing. It is, therefore, proposed to have a decision on this issue.

**Issue#2-1:** Whether to support specification based TRP pre-compensations?

* TRP-based frequency offset pre-compensation is supported in Rel-17
  + **Supported by**: Futurewei, Huawei / HiSilicon, vivo, ZTE, CATT, Lenovo/Motorola Mobility, CMCC, Samsung, [OPPO], [Apple], [NEC], Spreadtrum, Docomo, Sony
* TRP-based frequency offset pre-compensation is not supported in Rel-17
  + **Supported by**: LGE, Nokia / NSN, Ericsson

Based on the company’s preference above, there is majority that prefers specification of TRP-based frequency offset compensation in Rel-17 for HST-SFN scenario, which is similar to the RAN1#103-e meeting. Therefore, the following proposal is made:

**Proposal 2-1:**

* *TRP-based pre-compensation is supported in Rel-17*
  + *FFS other details*

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| **Company** | **Comment** |
| Huawei, HiSilicon | Support the FL’s proposal. Interference (ICI) will be reduced with frequency compensation, the evaluation results show the obvious gain in our Tdocs. |
| OPPO | Support the proposal. |
| ZTE | Support FL proposal. We also provided many simulation results to justify the benefit of pre-compensation scheme. |
| Lenovo/MotM | Support |
| Spreadtrum | Support |
| NEC | Support |
| Sony | Support FL proposal. |
| vivo | Support the proposal, since TRP-based pre-compensation outperforms scheme 1 as shown in our simulation results. |

## Issue #2-2 (QCL types/assumptions when TRS is source)

Regarding new QCL types/assumption for TRS, when TRS resource(s) is used as source RS in the TCI state. The following preferences on the QCL Variants (agreed in RAN1#103-e meeting) were provided by companies in their tdocs for TRP-based compensation schemes.

**Issue#2-2:** For TRP-based pre-compensation, when the same DMRS port(s) are associated with two TCI states containing TRS as source reference signal, at least one variant from RAN1#103-e meeting agreement is supported for Rel-17 HST-SFN scenario

* **Variant A**
  + **Supported by**: Futurewei, OPPO, Huawei / HiSilicon, ZTE, CATT, Spreadtrum, Sony, CMCC, …
* **Variant B**
  + **Supported by**: CATT, QC, Intel, …
* **Variant C**
  + **Supported by**: vivo, CMCC, …
* **Variant E**
  + **Supported by**: Futurewei, …

Companies are invited to share their preference on QCL types/assumptions when TRS is used as source in TCI state for TRP-based pre-compensation scheme.

**Proposal 2-2:**

* *TBD*

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| --- | --- |
| **Company** | **Comment** |
| Huawei, HiSilicon | Support Variant A. For Variant-B, the average delay and delay information from one link is missing. |
| OPPO | Support Variant A only. |
| ZTE | The same view as HW and OPPO |
| Lenovo/MotM | Support Variant A |
| Spreadtrum | Support Variant A. |
| LG | Support Variant A |
| NEC | Support Variant A. |
| Sony | Support Variant A. And we are also fine with Variant E when a UE could be indicated to ignore some QCL properties in one out of 2 TCI states. |
| vivo | Support Variant C, as analyzed in our tdoc, the average delay is mainly measured by SSB and TRS and then used for downlink timing. Thus from the perspective of adjusting downlink timing, UE referring to the average delay measured on only one of two TRSs is enough. |

## Issue #2-3 (Signalling of QCL types/assumption)

Regarding signalling of QCL type/assumptions for TRP-based pre-compensation scheme. Two approaches were mentioned by companies:

**Issue#2-3:** For TRP-based pre-compensation QCL assumptions is provided to the UE by using

* **Alt-1**: New QCL type
  + **Supported by**: Intel, …
* **Alt-2**: The existing QCL type(s) with certain QCL parameters dropped from the indicted QCL type
  + FFS rule to determine TCI state with dropped QCL parameters
  + **Supported by**: InterDigital, ZTE, Sony, …

Companies are invited to share their preference on signalling option of QCL types/assumptions for TRP-based pre-compensation scheme.

**Proposal 2-3:**

* *TBD*

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| --- | --- |
| **Company** | **Comment** |
| InterDigital | We believe that in Alt-2, those parameters should not be dropped.  Therfore, we think the proposed alternatives should be combined, by introducing a new QCL type that maintains the so-called “the certain QCL parameter”, and it leaves it to the UE implementation whether to be used or not.  **Proposal 2-3:**   * *Introduce a new QCL type, that maintains all QCL parameters.* |
| Huawei, HiSilicon | Support Alt.1. In our understanding, if we support Variant-A, then it is straightforward to use new QCL type with {average delay, delay spread}. |
| OPPO | Support Alt-2 for less specification impact. |
| ZTE | Support Alt-2 for less specification impact.  We cannot accept Alt.1 since the TCI state with the new QCL type cannot be shared for Rel-17 pre-compensation SFNed PDSCH/PDCCH and other signals including non-Rel-17 MTRP PDSCH/PDCCH, single-TRP PDSCH/PDCCH and CSI-RS. The drawback of Alt.1 is as follows   * + The number of supported beams will be reduced or the required number of support TCI states should be increased.     - Based on the current specification, TCI states can be configured by RRC signaling usually to PDSCH, PDCCH, CSI-RS and also possible to UL signals as being discussed in agenda 8.1.1 for unified TCI framework. However, if the new QCL type E is introduced, one new TCI state can only be configured for SFN mannered PDSCH (possible also for SFN mannered PDCCH), but impossible to be configured for all other signals including CSI-RS, non-SFN mannered PDSCH, e.g. single-TRP based PDSCH, etc. even the same TRS resource is included in the new TCI state and legacy TCI state.       * For example, maximum 128 beams are needed for a UE where the first 64 TCI sates corresponding to 64 beams are for TRP 0, and the other 64 TCI states also corresponding to 64 beams are for TRP1. If all of the second 64 TCI states for TRP 1 are new QCL type which can only be used for SFN mannered PDCCH/PDSCH, another 64 traditional TCI states should be configured for non-SFN mannered PDCCH/PDSCH, CSI-RS for TRP1. So the number of configured TCI states for TRP 1 should be 64+64=128 for 64 beams. The total number of configured TCI states for both TRP0 and TRP1 should be 64+128 = 192 to support 128 beams. It is noted that only 128 TCI states are supported in the current specification.   + The flexibility of activated beams by MACCE will be sacrificed.     - Currently, maximum 8 TCI states can be activated by MACCE for both single-TRP and MTRP. However, if the new TCI state with new QCLtype is introduced, the activate 8 TCI states should be clearly split into two parts, and cannot be shared for single-TRP and MTRP anymore. Thus, 8 activate TCI states can only support maximum 4 beams to support Rel-17 SFN and Rel-15/16 schemes.   In our view, the TCI structure and signalling information can be the same as Rel-15/16. Once gNB schedules Rel-17 pre-compensation SFN transmission, UE can just leverage delay related parameters from the first or second indicated TCI state. The spec impact is very minor, e.g. UE assume only {average delay, delay spread} is used from the second indicated TCI state.  However, if we support new QCL type, RRC impact on TCI structure is needed, the number of configured/activated TCI states should be further discussed. |
| Lenovo/MotM | Support Alt-1. Agree with Huawei, this is clearly related to the outcome of Proposal 2-2. In case Variant A is supported, a new QCL type is needed |
| Spreadtrum | Support Alt.1. Share the same view with Huawei. |
| LG | Support Alt-2. |
| NEC | Support Alt-2. |
| Sony | Same view with OPPO that using existing QCL type would introduce less standard impact, but provide the same function. Support Alt-2. |
| vivo | Support Alt.1. We prefer to specify a new QCL-type, i.e. {delay spreed}. |

## Issue #2-4 (Indication of of the carrier frequency for UL)

Regarding indication of the carrier frequency for UL transmission. Several companies expressed their views regarding this issue, which are summarized below:

**Issue#2-4:** Indication of carrier frequency for TRP-based pre-compensation

* **Option 1** (implicit) from RAN1#102-e agreement
  + **Supported by**: Futurewei, OPPO, CATT, vivo, CMCC, Lenovo / Motorola Mobility, Qualcomm, Intel, NTT DOCOMO, …
* **Option 2** (explicit) from RAN1#102-e agreement
  + **Supported by**: Sony, Intel, Nokia / NSN (if supported), Qualcomm, NTT DOCOMO, …

Companies are invited to share their preference regarding indication option of the carrier frequency for UL.

**Proposal 2-4:**

* *TBD*

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| --- | --- |
| **Company** | **Comment** |
| Huawei, HiSilicon | Option-1 is fine |
| OPPO | Support Option 1. |
| ZTE | Support option 1 |
| Lenovo/MotM | Support Option 1 |
| Spreadtrum | Support Option 1 |
| LG | Support option 1 |
| NEC | Support option 1. |
| Sony | Support Option 2. |
| vivo | Support Option 1. |

## Issue #2-5 (QCL-like association between DL and UL RS)

Regarding support of QCL-like association between DL and UL RS, e.g. for carrier frequency indication in UL. Several companies expressed their views whether it requires specification support or can be up to UE implementation. Companies views on this issue are summarized below:

**Issue#2-5:** Whether to support QCL-like association between DL and UL RS?

* **Option 1**: QCL-like association of the resource(s) received in the 1st step with UL signal transmitted in the 2nd step is supported by specification. FFS between the following alternatives:
  + **Alt-1**: Explicit indication of the DL RS for QCL-like association
  + **Alt-2**: Implicit indication of DL RS for QCL-like association
  + **Supported by**: Futurewei, Sony, CMCC, Ericsson (if supported), Qualcomm, …
* **Option 2**: QCL-like association of the resource(s) received in the 1st step with UL signal transmitted in the 2nd step is supported by implementation without specification impact
  + **Supported by**: CATT, vivo, Samsung, Intel, …

Companies are invited to share their preference on QCL-like association between DL and UL RS.

**Proposal 2-5:**

* *TBD*

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| --- | --- |
| **Company** | **Comment** |
| OPPO | Support Option 2. No specification impact is needed. |
| ZTE | Option 1 is slightly preferred. |
| Lenovo/MotM | We support Option 1 Alt-1. Existing fields in SRS configuration can be used |
| LG | Support option 2 |
| NEC | Support Option 2. |
| Sony | Support Option 1 to reduce additional DL signaling in control channel. In addition, we can leave Alt.1 and Alt.2 under Option 1 FFS. |
| vivo | Support Option 2. Within the ability of frequency offset estimation in the NW side, no matter what the uplink carrier frequency is, the frequency pre-compensation value in the NW side can still be derived by the implementation. |

## Issue #2-6 (Indication of TRP pre-compensation scheme)

Some companies have provided their views regarding configuration of TRP pre-compensation scheme and support of dynamic switching with legacy schemes. Companies views on this issue are summarized below:

**Issue#2-6:** How to support switching/configuration of TRP pre-compensation with legacy Rel-15/Rel-16 schemes?

* **Alt-1**: Dynamic (DCI-based)
  + FFS which legacy schemes should support dynamic switching
  + **Supported by**: ZTE, Qualcomm, …
* **Alt-2**: Semi-static (RRC-based)
  + **Supported by**: InterDigital, OPPO, …

Companies are invited to share their preference on indication of TRP pre-compensation scheme.

**Proposal 2-6:**

* *TBD*

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| --- | --- |
| **Company** | **Comment** |
| Huawei, HiSilicon | Prefer Alt.1 |
| OPPO | Support Alt-2. The same mechanism as Issue#1-3 and Issue#1-4. |
| ZTE | The same solution as Scheme 1.  In addition, we think only one of Scheme 1 and TRP pre-compensation SFN can be configured by RRC signaling at a given time. |
| Lenovo/MotM | Support Alt-2. |
| Spreadtrum | Support Alt-2. |
| LG | We have the same view with ZTE. One of scheme 1 and TRP pre-compensation SFN can be configured by RRC, and the same solution as scheme 1 can be supported for switching with Rel-15/16 schemes. |
| NEC | Support Alt-2. |
| Sony | Support Alt-2. |
| vivo | Support Alt.1 |

## Other issues

This section contains other issues that companies want to highlight for discussion regarding support of TRP-based pre-compensation scheme.

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| **Company** | **Comment** |
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## Support of SFN transmission of PDCCH

## Issue #3-1 (MAC CE indication for CORESET)

Several companies have provided discussion on higher-layer signalling enhancements to support MAC CE activation of two TCI states for PDCCH. Based on the discussion, the following proposal is made:

**Proposal 3-1:**

* *Support MAC CE activation of two TCI states for PDCCH*
  + *FFS other details*

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| **Company** | **Comment** |
| Huawei, HiSilicon | Support FL’s proposal |
| OPPO | Support the proposal. |
| ZTE | Support |
| Lenovo/MotM | Support |
| Spreadtrum | Support |
| LG | Support |
| NEC | Support |
| Sony | Support FL proposal. |
| vivo | Support the proposal. |

## Issue #3-2 (Default TCI for PDSCH and aperiodic CSI-RS)

In the context of supporting two TCI states for PDCCH, several companies have mentioned the issue of the default beam(s) for PDSCH and aperiodic CSI-RS. Based on the companies contributions the following proposal is made.

**Proposal 3-2:**

* *Study UE default beam behavior for the case when two TCI states are configured for a CORESET* 
  + *Consider the following scenarios of PDSCH and aperiodic CSI-RS transmissions*
    - *Scenario-1: For DCI format not having the TCI field*
    - *Scenario-2: For PDSCH scheduling offset less than the threshold timeDurationForQCL*
    - *Scenario-3: For AP CSI-RS scheduling offset less than the threshold beamSwitchTiming / beamSwitchTiming-r16*
  + *Consider at least the following solutions:*
    - *Alt-1: gNB ensures the lowest CORESET ID in the latest slot only configured with one TCI state by implementation*
    - *Alt-2: Modify the definition of the lowest CORESET ID in the latest slot, e.g. the lowest CORESET ID among the CORESETs associated with one TCI state in the latest slot.*
    - *Alt-3: QCL assumption associated with one of TCI states, e.g. always selects the first or the second TCI state*
    - *Alt-4: QCL assumption associated with both of two TCI states*
    - *Alt-5: Select TCI state of PDSCH with a lower ID*
    - *Other alternatives are not precluded*

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| **Company** | **Comment** |
| InterDigital | Support the proposal |
| Huawei, HiSilicon | Not support. We need to discuss and decide first which case need default TCI before list solutions for study. At least we are not convinced Scenario-1 and 3 are necessary. Scenario-2 may be discussed. |
| OPPO | The default TCI state for PDSCH should depend on the transmission scheme of PDSCH.   * If HST-SFN transmission is configured for PDSCH, two TCI states will be activated by MAC CE. Similar to S-DCI based M-TRP transmission, the lowest codepoint corresponding to two TCI states activated by MAC CE should be applied to the PDSCH if PDSCH scheduling offset less than the threshold *timeDurationForQCL*. * If other transmission scheme is configured for PDSCH, and the TCI state of the CORESET with lowest ID is expected to be applied to PDSCH by current specification, predefined one TCI state from the two TCI states can be applied to PDSCH if two TCI states are configured for the CORESET. |
| ZTE | Support the proposal for study |
| Lenovo/MotM | Support the proposal |
| LG | OK to study |
| NEC | Support to study. |
| Sony | We are open to study, but the default beam of PDSCH and Ap-CSI-RS seems not the 1st priority. |
| vivo | Support the proposal  Regarding the comment from OPPO, we agree that Scenario-2 is related to the transmission cases discussed in our contribution. There are four possible options as follows:   * Case1: SFN based PDCCH scheduling PDSCH from STRP in Rel-15 * Case2: SFN based PDCCH scheduling PDSCH from MTRP in Rel-16 (including scheme 1a,2a,2b,3,4), and UE is capable of simultaneous reception of two beams * Case3: SFN based PDCCH scheduling PDSCH from M-TRP in Rel-16 (including scheme 3,4), but UE is not capable of simultaneous reception of two beams * Case4: SFN based PDCCH scheduling SFN based PDSCH from M-TRP, and UE is capable of simultaneous reception of two beams   We think case2 and case4 can reuse the legacy behaviour, e.g. corresponding to the lowest codepoint among the TCI codepoints containing two different TCI states. Only case1 and case3 should be considered here. Thus, we prefer to revise the proposal as follows:  **Proposal 3-2:**   * *Study UE default beam behavior for the case when two TCI states are configured for a CORESET*    + *Consider the following scenarios of PDSCH and aperiodic CSI-RS transmissions*     - *Scenario-1: For DCI format not having the TCI field*     - *Scenario-2: For PDSCH scheduling offset less than the threshold timeDurationForQCL, and the following two cases are considered.*       * *Case1: SFN based PDCCH scheduling PDSCH from STRP*       * *Case2:* *SFN based PDCCH scheduling PDSCH from M-TRP in Rel-16 (e.g. scheme 3/4), but UE is not capable of simultaneous reception of two beams*     - *Scenario-3: For AP CSI-RS scheduling offset less than the threshold beamSwitchTiming / beamSwitchTiming-r16*   [The second sub-bullet in original proposal is not copied here to reduce redundancy] |

## Issue #3-3 (Default spatial relation for PUCCH/SRS/PUSCH)

A few companies have mentioned the issue of the default Tx beam(s) for dedicated-PUCCH/SRS/PUSCH transmission in the context of supporting two TCI states for PDCCH. Based on the company’s contributions the following proposal is made.

**Proposal 3-3:**

* *Study use of TCI state with a lower ID as default spatial relation and PL-RS for dedicated-PUCCH/SRS/PUSCH scheduled by DCI format 0\_0 if the CORESET with the lowest ControlResourceSetId is activated with two TCI states*

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| **Company** | **Comment** |
| Huawei, HiSilicon | OK to study |
| OPPO | Fine with the proposal. |
| ZTE | Support the proposal for study |
| Lenovo/MotM | Support |
| Spreadtrum | We are fine to study. In current stage, we suggest to list all of options to downselect, e.g., the first TCI state, or the second TCI state. |
| NEC | Support to study. |
| Sony | We are open to study, but the UL default beam seems not the 1st priority as well at the moment. |
| vivo | Support to study the default spatial relation for PUCCH/SRS/PUSCH.  And using TCI state with a lower ID is one potential method, other methods such as selecting the first or the second TCI state should also be considered. |

## Issue #3-4 (Issues related to BFR support)

Several companies have mentioned BFR issues that should be addressed for the UE configured with PDCCH monitoring associated with two TCI states. Based on the company’s contributions the following proposal is made.

**Proposal 3-4:**

* *Study support of the BFD for Rel-17 BFR and Rel-15/16 BFR when two TCI states are configured for a CORESET. Consider at least the following aspects:*
  + *Reference signal for BFD* 
    - *E.g. whether to consider only CORESETs with single active TCI state or both CORESETs with single and two TCI states, how to define rules for BFD RS selection, whether to support CSI-RS resource pairs or SSB pairs as BFD RS*
  + *Assumptions for hypothetical BLER calculation for PDCCH*
    - *E.g. whether RS in the two TCI states are directly used as the BFD RS or UE calculates one hypothetical BLER under SFN assumption based on two independent BFR RS*
  + *Configuration of NBI RS*
  + *UE behavior on monitoring the PDCCH candidate after BFD*
  + *Other aspects are not precluded*

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| **Company** | **Comment** |
| InterDigital | Prefer to discuss the topic when we have more stability in M-TRP BM discussion. |
| Huawei, HiSilicon | Not support. Similar view with InterDigital. |
| OPPO | This topic can be discussed later. |
| ZTE | OK to study |
| Lenovo/MotM | Agree with InterDigital |
| Spreadtum | Fine to discuss it later. |
| LG | OK to study |
| NEC | Support to study. |
| Sony | Open to study. |
| vivo | OK to study |

## Issue #3-5 (Identification of SFN-ed PDCCH scheme)

One company has mentioned the issue of identification of the Rel-17 SFN-ed when simultaneously used with Rel-17 non-SFN transmission scheme for PDCCH in HST-SFN scenario. Based on this discussion, the following proposal is made:

**Proposal 3-5:**

* *Study necessity of simultaneous support and identification of the SFN and non-SFN enhanced PDCCH transmission schemes discussed in agenda item 8.1.2.1*

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| **Company** | **Comment** |
| InterDigital | Need further discussion. |
| OPPO | It is not needed to support M-TRP based PDCCH repetition (non-SFN) for PDCCH which is SFNed from different TRP. Simultaneous configuration of the SFN and non-SFN enhanced PDCCH transmission schemes is not supported. |
| ZTE | Could proponent clarify what the use case is , and how to support simultaneous SFN and non-SFN PDCCH. |
| Lenovo/MotM | Should be deferred until more details of SFN and non-SFN enhanced PDCCH transmission schemes are agreed |
| Spreadtrum | Fine to discuss it. |
| NEC | Further discussion later. |
| Sony | In our view, the SFN transmission scheme has better to be as much transparent as possible to UE. Can any concrete benefit be clarified by identifying SFN Tx and non-SFN Tx scheme? This may need more discussion. |
| vivo | We are a little confused about the meaning of the proposal.  Does it mean that SFN PDCCH can be combined with non-SFN PDCCH together, e.g., SFN-ed PDCCH with TDM repetition, or SFN PDCCH and non-SFN PDCCH can be indicated separately for HST-SFN?  If it’s the former meaning, we support the proposal, because in the HST scenario, the PDCCH transmission between gNB and UE would suffer severe path loss due to metal coaches of the train. Therefore, in order to improve the reliability of PDCCH, SFN-ed PDCCH with TDM repetition can be considered. |

## Issue #3-6 SS-specific configuration of one/two TCI states

A few companies have mentioned the issue of search space specific configuration of one or two TCI states for SFN transmission of PDCCH. Based on this discussion, the following proposal is made:

**Proposal 3-6:**

* *Study support of configuration for one or two TCI States for different search spaces of PDCCH*

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| **Company** | **Comment** |
| InterDigital | Support the proposal |
| Huawei, HiSilicon | Not support, concern on the complexity. |
| OPPO | Not support. |
| ZTE | Not support. |
| Lenovo/MotM | Support, this should be studied |
| Spreadtrum | Not support |
| LG | Support the proposal. SS-specific configuration can be useful. For example, both SFNed PDCCH and non-SFNed PDCCH can be supported based on single CORESET with two TCI states. |
| NEC | Not support. |
| Sony | Not support. |
| vivo | Support the proposal.  One use case is to support dynamic switching between STRP and MTRP for PDCCH transmission. When one CORESET is configured with two TCI states, search spaces associated with the CORESET can be configured with one TCI state for STRP or both TCI states for MTRP. |

## Other issues

This section contains other issues the companies want to highlight for discussion regarding support of SFN PDCCH transmission.

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## Issue #4-1 (Other non-categorized proposals)

The proposals supported by one company are provided below for consideration in the next RAN1 meetings.

* *A new definition on QCL association relationship of one antenna port and one antenna port group*
* *Support of small delay CDD with a properly adjusted delay offset between TRPs*
* *Support configuration of combination of SFN and TDM based PDCCH simultaneously*
* *Study additional QCL configuration constraints for TCI, e.g. TCI state shall be associated with the same QCL Type, i.e., QCL-TypeA and/or QCL-TypeD*
* *Introduce new QCL type-E with loose Doppler shift relationship between the target and source RS.*
* *Study zone-based configuration for TCI/QCL information to mitigate potential high signaling overhead.*
* *Support new QCL information indicating opposite polarity of Doppler shift between different transmissions.*
* *Support variable-rate TRS transmission for HST deployment scenario.*
* *TCI states configured in non-serving cell(s) with PCI either explicitly configured or implicitly associated*
* *Support of unified TCI state in DCI to trigger SP/AP-TRS followed by SP/AP-SRS*
* *DMRS adaptation for HST SFN scenario*
* *UE assisted DMRS adaptation for DL, in which UE provides an indication of the most convenient DMRS configuration*
* *Study PTRS design in case of SFN transmission scheme*
* *Dynamic DMRS configuration signaling to enable DMRS adaptation*
* *New SRS pattern for UL Doppler estimation purpose*
* *SRS allocation for Doppler measurements multiplexing with any UL or DL channel for the addressed UE*
* *Support transmitting DMRS REs for one antenna port in FDM fashion from both TRPs*
* *Study UE behavior when CORESET with multiple QCL type-D RSs is overlapped with another CORESET(s).*
* *Study TA issue in HST scenario*

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| **Company** | **Comment** |
| vivo | SFN channel in the UE side would suffer the following problems:   * SFN signals from two TRPs might cancel out with each other at the middle point of two TRPs. * Lager delay between the SFN signals from two TRPs would cause deep and more frequent fading of the SFN channel, leading to performance degradation of SFN transmission.   Therefore, small delay CDD with a properly adjusted delay offset between TRPs can be studied to further enhance the performance of HST-SFN. |
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# Other issues

This section contains other issues the companies want to highlight.

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| **Company** | **Comment** |
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# References

[1] RP-193133, New WID: Further enhancements on MIMO for NR, Samsung 3GPP TSG RAN Meeting #86, Sitges, Spain, December 9-12, 2019.

[2] R1-2100041, Enhancement to support HST-SFN deployment scenario, FUTUREWEI

[3] R1-2100067, Enhancements for M-TRP Transmission to Support HST-SFN in Rel-17, InterDigital, Inc.

[4] R1-2100122, Enhancements on HST-SFN deployment, OPPO

[5] R1-2100212, Enhancements for high speed train for multi-TRP in Rel-17, Huawei, HiSilicon

[6] R1-2100289, Discussion on Multi-TRP HST enhancements, ZTE

[7] R1-2100347, Discussion on enhancements for HST-SFN deployment, CATT

[8] R1-2100425, Further discussion and evaluation on HST-SFN schemes, vivo

[9] R1-2100622, Enhancements on HST-SFN deployment, LG Electronics

[10] R1-2100640, Enhancements to HST-SFN deployments, Intel Corporation

[11] R1-2100787, Discussion on enhancements on HST-SFN deployment, Spreadtrum Communications

[12] R1-2100848, Considerations on HST-SFN operation for multi-TRP, Sony

[13] R1-2100952, Discussion on HST-SFN deployment, NEC

[14] R1-2100988, Enhancements for HST-SFN deployment, Lenovo, Motorola Mobility

[15] R1-2101009, Enhancements for HST-SFN deployment, Nokia, Nokia Shanghai Bell

[16] R1-2101036, Enhancements on HST-SFN deployment, CMCC

[17] R1-2101143, Enhancement on HST-SFN deployment, Ericsson

[18] R1-2101190, Enhancements on HST-SFN, Samsung

[19] R1-2101354, Views on Rel-17 HST enhancement, Apple

[20] R1-2101450, Enhancements on HST-SFN deployment, Qualcomm Incorporated

[21] R1-2101601, Discussion on HST-SFN deployment, NTT DOCOMO, INC.

# Appendix (Summary of the agreements)

The agreements made in RAN1#102e and RAN1#103e meetings are provided below.

**RAN1#102e meeting agreements**

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| **Agreement**  For the discussion purpose consider the following categorization of the enhanced DL transmission schemes   * **Scheme 1**:   + TRS is transmitted in TRP-specific / non-SFN manner   + DM-RS and PDCCH/PDSCH from TRPs are transmitted in SFN manner * **Scheme 2**:   + TRS and DM-RS are transmitted in TRP-specific / non-SFN manner   + PDSCH from TRPs is transmitted in SFN manner   **Agreement**  Study the following aspects of the enhanced transmission schemes:   * **For scheme 1**:   + Target DL physical channels, i.e., PDSCH only or PDSCH + PDCCH   + Whether more than 2 QCL/TCI states are required and corresponding signaling details   + Whether and how to indicate scheme 1 for differentiation with Rel-16 non-SFNed transmission schemes with multiple QCL/TCI states   + QCL relationship between TRS and DMRS ports   + Note: Other schemes/aspects are not precluded * **For scheme 2**:   + Association of each MIMO layer of PDSCH to DM-RS antenna ports   + Whether more than 2 QCL/TCI states are required and corresponding signaling details   + Whether and how to indicate scheme 2 for differentiation with Rel-16 non-SFNed transmission schemes with multiple QCL/TCI states   Note: Other schemes/aspects are not precluded |

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| **Agreement**  Study TRP-based frequency offset pre-compensation including the following aspects:   * Aspects related to indication of the carrier frequency determined based on the received TRS resource(s) in the 1st step   + **Option 1**: Implicit indication of the Doppler shift(s) using uplink signal(s) transmitted on the carrier frequency acquired in the 1st step     - Indication for QCL-like association of the resource(s) received in the 1st step with UL signal transmitted in the 2nd step     - Type of the uplink reference signals / physical channel used in the 2nd step, necessity of new configuration and corresponding signaling details   + **Option 2**: Explicit reporting of the Doppler shift(s) acquired in the 1st step using CSI framework     - FFS: Indication for QCL-like association of the resource(s) received in the 1st step with UL signal transmitted in the 2nd step     - CSI reporting aspects, configuration, quantization, signalling details, etc. * New QCL types/assumption for TRS with other RS (e.g., SS/PBCH), when TRS resource(s) is used as target RS in TCI state * New QCL types/assumptions for TRS with other RS (e.g., DM-RS), when TRS resource(s) is used as source RS in the TCI state * Target physical channels (e.g., PDSCH only or PDSCH/PDCCH) and reference signals that should be supported for pre-compensation * Signalling/procedural details on whether/how the pre-compensation is applied to target channels * Whether multiple sets of TRS and pre-compensation on TRS is needed in 3rd step.   Note: Other aspects/schemes are not precluded |

**RAN1#103e meeting**

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| **Agreement**  Support at least the following configuration for HST scenario in Rel-17   * The same DMRS port(s) can associate with multiple TCI states   + FFS other details   Note: DMRS and PDCCH/PDSCH from different TRPs are transmitted in SFN manner  **Agreement**  At most two TCI states are supported for HST scenario in Rel-17   * FFS: Whether to support more than two TCI states for FR2 * FFS configuration/signalling details of the TCI states   Note: DMRS and PDCCH/PDSCH from different TRPs are transmitted in SFN manner  **Agreement**  When the same DMRS port(s) are associated with two TCI states containing TRS as source reference signal, at least one variant is supported for Rel-17 HST-SFN scenario based on further evaluations   * **Variant A**: One of the TCI state can be associated with {*average delay*, *delay spread*} and another TCI states can be associated with {*average delay, delay spread, Doppler shift, Doppler spread*} (i.e., QCL-TypeA) * **Variant B**: One of the TCI state can be associated with {*average delay, delay spread*} and another TCI state with {*Doppler shift, Doppler spread*} (i.e., QCL-TypeB) * **Variant C**: One of the TCI state can be associated with {*delay spread*}  and another TCI states can be associated with {*average delay, delay spread, Doppler shift, Doppler spread*} (i.e., QCL-TypeA) * **Variant E**: Both TCI states can be associated with {*average delay, delay spread, Doppler shift, Doppler spread*} (i.e., QCL-TypeA) * FFS: Indication method to apply QCL, e.g., via new QCL-type, or reuse existing QCL-type while UE to ignore certain QCL properties * Note: Each TCI state in the above variants may be additionally associated with {Spatial Rx parameter} (i.e., QCL-TypeD) * Note: Companies are encouraged to provide evaluation results for the above variants based on agreed EVM from RAN1#102e meeting * Note: Above variants are applicable to scheme 1 and/or TRP based pre-compensation as a reference for evaluation. * This agreement is for the purpose of evaluation and does not imply the support or lack of support of scheme 1 and/or TRP based pre-compensation |

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| **Agreement**  For PDCCH reliability enhancements, support SFN scheme + Alt 1-1.   * FFS: TCI state activation for CORESET, impact on default beam, BFD resource for BFR   Where the Alt 1-1 is agreed as:  Alt 1-1: One PDCCH candidate (in a given SS set) is associated with both TCI states of the CORESET. |