**3GPP TSG-RAN WG1 Meeting #112bis-e  (tb) R1-2303913**

**e-Meeting, 17-26 April, 2023**

**Agenda Item: 9.7.1**

**Source: Moderator (Huawei)**

**Title: FL summary#1 for spatial and power domain techniques for R18 NES**

**Document for: Discussion and decision**

# Introduction

This summary contains background, proposals based on contributions and discussion points/proposals from moderator, according to the following:

[112bis-e-R18-NES-01] Email discussion on techniques in spatial and power domains by April 26 – Yi (Huawei)

* Check points: April 21, April 26

When preparing your input, please read the instructions in “Additional Guidelines for RAN1#112b-e Meeting Management” document in [R1-2302259](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302259.zip), about check points, input timing etc. Also the naming for uploaded document is as usual.

Given that we will have one online session on Monday, initial collection of comments before that is expected. The time left prior to the first call is less than 24h, therefore, input for at least proposals (start with ‘Px, instead of ‘Qy’) can be considered to reduce your input time, since open ‘Q(uestions)’ would need more time to be converged. However, it is still encouraged to have input for ‘Q(uestions)’ for example when you firstly uploaded once for ‘P(roposals)’, before the first session call. It helps to generalize the next round of questions/proposals for further discussions. The feedback is expected by at least 100 min before the session for NES start, i.e. UTC 20:30 on Monday.

For information, the current online schedule for GTW1 for Week 1 is as follows (while if there is offline schedule per Chair’s further update, it will be added once decided):

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|  | **Week 1** | | | | |
| **Monday**  UTC 20:30~23:30 | **Tuesday**  UTC 20:30~23:30 | **Wednesday**  UTC 20:30~23:30 | **Thursday**  UTC 20:30~23:30 | **Friday**  UTC 20:30~23:30 |
| **GTW1** | R18 MIMO (100min) . CSI . Unified TCI . SRI/TPMI for  8TX  **R18 NES (80min) . Spatial/power  domain . Cell DTX/DRX** | R18 Duplex (80min) . SBFD . Dynamic TDD  Rel-18 LP-WUS (50min) . L1 design . Receiver  architecture  Rel-18 XR (50min) | R18 MIMO (100min) . Two TA . DMRS . SRS . UL precoding for  multi-panel  **R18 NES (80min) . Spatial/power  domain . Cell DTX/DRX** | R18 Duplex (60min) . SBFD . Evaluation  Rel-18 LP-WUS (45min) . L1 design . Evaluation  Rel-18 XR (45min)  Rel-18 TEI (30min) | R18 MIMO (120min)  **R18 NES (60min)** |

# Recommendations for GTW/offline

Tbd.

# Spatial element adaptation including beam management

The objective for spatial element adaptation is as below.

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| * Specify necessary enhancements on CSI and beam management related procedures including measurement and report, and signaling to enable efficient adaptation of spatial elements (e.g. antenna ports, active transceiver chains) [RAN1, RAN2] |

The relevant agreements are excerpted as below.

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| **Agreement**  For the purpose of further discussions in RAN1 on NES spatial domain adaptations, consider the following cases   * Type 1: all antenna elements associated to a logical antenna port is disabled/enabled * Type 2: part/subset of antenna elements associated to a logical antenna port is disabled/enabled   **Agreement**  For spatial element adaptation, further study the following   * A1-1) Each CSI-RS resource/resource set/resource setting can be associated with only one spatial adaptation pattern   + FFS: Details on how the association is done * A1-2) Each CSI-RS resource/resource set/resource setting can be associated with one or more spatial adaptation patterns   + FFS: Details on how the association is done * FFS: Details on the definition of “spatial adaptation patterns” |

By dividing the issues into separate subsections, companies’ proposals are excerpted for each and followed by FL questions/proposals.

3.1 Framework

**Company proposals**

[Huawei, HiSilicon]: Support MFTA as an efficient dynamic adaptation without UPT performance loss, where CSIs corresponding to multiple candidate spatial adaptation patterns and/or multiple power back-off values need to be available at gNB before gNB taking the adaption decision.

[vivo]: Design a unified framework for spatial elements adaptation and power offset adaptation.

[ZTE]: Same framework can be used for the enhancement on power domain and the enhancement on spatial domain.

[China Telecom]: Support the mechanism of UE dynamically measuring the CSI first then gNB making the decision for the spatial/power domain adaptation.

[Samsung]: Support joint operation of cell DTX/DRX and spatial/power domain adaptation techniques.

[ERTI]:

* For the purpose of discussion, consider the following use cases for Type 1 spatial element adaptation.
  + - Use case 1: Multi-CSI report based on virtual CSI-RS muting
    - Use case 2: CSI report based on actual CSI-RS muting
* Aim for a joint design for CSI enhancements considering both spatial element adaptation and transmit power adaptation.

[CMCC]: Joint adaptation of spatial domain and power domain configurations can be considered to avoid coverage loss.

[MediaTek]: Aim for a unified CSI enhancement for NES adaptations in spatial and power domains.

[LGe]: Both of the following two types are supported for NES spatial domain adaptation.

* + - Type 1: All antenna elements associated to a logical antenna port are disabled/enabled
    - Type 2: Part/subset of antenna elements associated to a logical antenna port are disabled/enabled

[AT&T]: Corresponding CSI is available at gNB before adaptation.

Also, regarding different implementations, some particular considerations are provided.

[FW]: no additional indication or signaling of the different implementations of the spatial adaptation is needed.

[vivo]: Enhancements on spatial elements adaptation and poweroffset adaptation need to be applicable to both type-1 shutdown and type-2 shutdown.

[Spreadtrum]: Type 2 is down-prioritized.

[Fujitsu]: The CSI related enhancement(s) for the support of type 1 spatial element adaptation and type 2 spatial element adaptation are considered and discussed separately.

**FL summary**

According the discussion and contributions, in order to identify necessary configuration for CSI-RS resource and CSI reporting, understanding what is expected by gNB from UE feedback and how efficiently it is reported, is the essential aspect. The choice between whether multi-CSI feedback is needed or single-CSI feedback is sufficient would lead to completely different framework and designs.

To determine whether multi-CSI needed, three companies (Huawei/HiSi, ZTE, vivo) bring simulation results for spatial domain adaptation and one company (OPPO) bring results for power domain adaptation, showing that there is benefit to do that, although (vivo/OPPO) consider the benefits of multi-CSI for spatial domain or power domain adaptation respectively is small compared to single-CSI feedback thus it is not justified for specification enhancements. One company (Apple) also quoted the TR results showing that single-CSI can have remarkable NES gain.

On one hand, in addition to the NES gain, the decision may also depend on whether performance loss (e.g. UPT) can be acceptable for one solution. On the other hand, whether UE complexity/overhead can be reasonably reduced or not may also be essential.

Regarding the former, as can be seen in the framework section as well as CSI feedback section, majority (15 companies) seems to consider that to enable multiple CSI(s) corresponding to multiple spatial adaptions available is critical for gNB proper decision. Regarding the UE complexity and overhead reduction, also a large number of contributions is discussing how to mitigate the impact.

Although more evaluations and views may be helpful, considering the timeline, decision is expected within this meeting and parallel discussion for other aspects including UE complexity/overhead reduction, necessary enhancements for configuration and reporting procedures should be continued along with possible branches. From specification perspective, the framework to be generalized should have the flexibility to allow both single-CSI and multi-CSI feedback operations. A first proposal is made as below, with proposals in later sections set to continue relevant discussion (e.g. whether it is based on a common CSI-RS resource etc.).

**P1**

**Enhancements for spatial and power domain adaptation support both single-CSI feedback corresponding to one adaptation and multi-CSI feedback corresponding to more than one adaptation.**

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| **Company** | **Comments** |
| Lenovo | Support. We believe this would be a good tradeoff to support different NES techniques with different CPU requirements |
| vivo | We agree to support single CSI feedback for one spatial or power adaptation pattern.  For multi-CSI feedback, it should be first clarified whether multi-CSI feedback is in one CSI report or in multiple CSI report occasion.  We are fine to consider multi-CSI feedback in multiple CSI report occasions corresponding to more than one adaptation.  For multi-CSI feedback in one CSI report occasion, we still have concerns and it is too premature to support before addressing these concerns. Performance benefits on multi-CSI feedback regarding how many throughput and power saving gain can be achieved, how much UE complexity/overhead are increased should be carefully evaluated and clarified.  First, the NW ES gain from multi-CSI feedback in one occasion is limited. However, the complexity for UE and the overhead for a single report have to be greatly increased, compared to single-CSI feedback in one occasion. Instead, CSI report for different adaptation in different report occasions would not increase the complexity for UE and also be helpful for gNB to perform adaptation.  Second, the only benefit of multi-CSI feedback in one occasion is to improve the CSI accuracy, since gNB can acquire more than one CSI report in one reporting. However, in case of NW ES, the CSI accuracy would not be an issue since there could be low traffic load or low mobility UEs. Besides, gNB can also configure shorter CSI report periodicity for CSI feedback. |
| DOCOMO | We understand that multiple CSIs with different spatial/power assumptions could help gNB to take better adaptation decision.  But the definition of “single -CSI feedback” and “multi-CSI feedback” is not clear here. It should be further clarified before saying support or not. |
| OPPO | We are fine in principle for spatial domain, but as we stressed in our contribution, it would be good to make it clear by ‘one adaptation’.  On the other hand, for power domain, we still hold a conservative view. From our simulation results, it does not bring benefits. |
| Apple | We think it is necessary to define more clearly of what is single-CSI feedback and what is multi-CSI feedback and the implication behind. Does this only refer to gNB obtaining single or multiple CSI results before it makes final adaptation decisions, where these CSI results can be obtained in multiple reporting instances or does this specifically refers to reporting all the CSI results in one single reporting instance?  If it is the latter, we are not fully convinced by the necessity of the multi-CSI feedback in one reporting instance yet. As stated in our contribution, the single CSI feedback can already provide remarkable NES gain and the multi-CSI result was only provided by 3 sources in the TR and the same 2 sources in this meeting, while increases UE CSI computation load. Although some complexity reduction mechanisms are provided for the multi-CSI in one reporting instance to lower UE CSI computation complexity, however, according to the evaluation results provided, there will still be UPT loss compared with complete CSI feedback schemes, so it is hard to identify which is better, single CSI with complete CSI feedback or multi-CSI with compressed CSI feedback. Not to mention the various schemes to be determined on which of the quantities can be omitted and corresponding impact on UE complexity.  We consider it logical to start with the single adaptive case, which is to support CSI adaptation feedback with only single CSI in one reporting instance, while the multiple CSIs corresponding to multiple spatial adaptation patterns can still be feedback in a sequential way for gNB to make final adaptation. |
| FL | To vivo, Apple  As for the benefits of multi-CSI, perhaps more evaluations can help as said. But as also said in the summary part, decision is expected within this meeting considering the overall timeline, especially as I concern that relevant discussion may be suspended due to a pending decision on this – which seems already the case from your response to other relevant sub-topics. Noting that the potential schemes were present during SI and evaluations, if expected, should have been performed since the first WI meeting.  As for the clarification on the wording of multi-CSI, I will try to improve it after more views are received. |
| Spreadtrum | Dynamic adaptation on the current CSI framework may be sufficient. Current spec already support multi-CSI feedback. Enhancement on the current multi-CSI feedback needs to be justified. |
| ETRI | We support the proposal. It may be good to further clarify the meaning of single CSI feedback and multi-CSI feedback as DOCOMO commented. |
| Fujitsu | We are fine with the proposal in principle.  In our opinion, both single CSI feedback and multi-CSI feedback have pros and cons considering the benefits in terms of energy saving/throughput performance and the UE complexity/UCI overhead. Thus, we need to consider and discuss the necessary enhancement(s) for both feedback approaches. |
| ZTE, Sanechips | Support.  It will be beneficial if UE report CSIs for different numbers of CSI-RS ports in advance so that gNB has more information about channel state of different number of ports. According to our results, multi-CSI report provides additional 17.36% ESG and less UPT loss compared with single CSI report. Hence, at least multi-CSI should be considered.  For single CSI feedback, it can be regarded as one special case of multi-CSI feedback, common frame can be considered.  Replies to other companies’ comments:  We are not convinced by the comments that UE complexity will be increased by multi-CSI reporting since it is already allowed by the spec to configure UE with multiple CSI for different purposes. On the contrary, we think the CSI computation can be reduced by exploit the high correlation of the precoding matrices of different spatial patterns.  High CSI accuracy is always needed for better scheduling, high resource efficiency, and NES, regardless of traffic load.  For the evaluation results in TR, it is clear that the cost of single CSI is significant degradation of system performance. However, when it comes to real implementation, system performance is also an important KPI. Unignorable performance loss will make the NES technique less attractive. Therefore, multi-CSI is needed to achieve a better tradeoff. |
| Huawei, HiSilicon | Clearly having multi-CSI feedback corresponding to more than one adaptation pattern enables the gNB to take better adaptation decision. However, we agree with DOCOMO that the definition of “single -CSI feedback” and “multi-CSI feedback” should be clarified before support or not support decision. And For that we propose:  **P1**  **Enhancements for spatial and/or power domain adaptation pattern, where each pattern correspond to one** TxRUs shutdown/non-shutdown pattern and/or one power back-off value(s),  **support ~~both single-CSI feedback corresponding to one adaptation and~~ multi-CSI ~~feedback~~ report(s) corresponding to more than one adaptation pattern. [ to enable the gNB to take efficient TxRUs and/or power adaptation decision(s).]**  We proposed to delete “**~~single-CSI feedback corresponding to one adaptation~~**” because our simulation, confirm the advantage of having multi-CSIs feedback. gNB decision using the availability of multi-CSI report(s) before the adaptation decision (named MFTA in our paper) ***can obtain 18.5% and 13.9% energy saving gain compared with AFTM (single CSI is for one spatial and/or power pattern is available before the shutdown decision), @30%RU without UPT loss in TDD and FDD cases, respectively.*** |
| Nokia/NSB | We are fine with P1 to support both single-CSI feedback corresponding to one adaptation and multi-CSI feedback corresponding to more than one adaptation. |
| MediaTek | **It is suggested to define spatial/power adaptation (pattern) before deciding this proposal.**  The relation between CSI report and the adaptation configuration is related to how we define a spatial/power adaptation (pattern). From companies’ contribution, it looks the association with CSI-RS resource configuration is commonly accepted (either one or multiple adaptation patterns can be associated to one CSI-RS resource configuration). When the association is defined, the relation between CSI report and spatial/power adaptation (pattern) can follow the principle between CSI report and CSI-RS resource configuration. |
| Futurewei | We support P1 but there are clarifications needed to understand what and how many of these spatial and power adaptation patterns before agreeing on this proposal right away. |
| Xiaomi | We share the similar view that the definition of “single-CSI feedback” and “multi-CSI feedback” should be clarified.  If it goes to the multi-CSI feedback in one CSI report, we are fine to support it. Nevertheless, efficient mechanisms should be studied to reduce the processing and reporting overhead. |

Also, it seems to be the majority preference that both types as gNB implementations should be allowed for a network to enjoy the NES. What needs to be considered could be: whether the design has to be a common solution, which could be left to the discussion along with each type of shutdown as needed.

**P2**

**Specifications support CSI enhancements for network energy savings applicable for both types of spatial adaptation cases (as that agreed in RAN1#112).**

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| **Company** | **Comments** |
| Lenovo | We are fine to continue discussing both types, however it is not yet clear to us whether Type 2 spatial adaptation would require specification impact. To be constructive, we are fine with either removing the word “Specifications”, or otherwise add an FFS on “Whether Type-2 spatial adaptation requires further specification support” |
| vivo | Agree |
| DOCOMO | As we see the necessity of both spatial adaptation types, the CSI enhancement of both of them is needed.  We support FL’s proposal. |
| OPPO | We agree that both types need to be considered. However, the current specification does not seem to differentiate these two types. Whether the proposal suggests to do so? |
| Apple | We are fine to support both types, although we think type 1 is more friendly to both gNB and UE in terms of resource transmission and measurement. We also consider it necessary to support a common framework to support both types. |
| FL to Lenovo/OPPO | This proposal does not necessarily lead to specification definition of a type. It is to say that the enhancement should be workable for both types of implementations.  To clarify this point, ‘applicable’ is added. |
| Spreadtrum | Type-2 has too large spec impact, since analog beam shape is changed. |
| ETRI | We are generally fine with the proposal, but it may be better to study what is expected specification impact for Type 2 spatial element adaptation (seems not much discussed compared to Type 1) before agreeing this. |
| Fujitsu | We are fine with the proposal.  Since type 1 and type 2 have different properties, the CSI enhancements for type 1 spatial adaptation and type 2 spatial adaptation can be discussed separately. |
| ZTE, Sanechips | For the Type 1 port muting, one CSI-RS resource can be configured to associated with multiple spatial adaptation patterns (i.e., A1-2). It provides some benefits with less OH, more NES gain, etc. And these benefits should be considered in the resource configuration.  Therefore, if both types are supported, at least the measurement resource configuration should be separately discussed along with each type of shutdown. |
| Huawei, HiSilicon | We support FL’s proposal. |
| Nokia/NSB | We are fine with the proposal.  It would be good to aim at a common solution to cover both adaptation types (i.e., Type 1 and Type 2), meaning that the common solution with specification work covers the practical gNB implementation needs for both types. |
| MediaTek | Support the proposal.  Given different gNB implementation may apply a corresponding type of adaptation for NES, **a unified CSI enhancement ensures a unified implementation for UE to support both types of NES adaptations.** |
| Futurewei | Support the proposal. |
| Xiaomi | Fine to continue studying the specification impact of type 1 and type 2. However, we are wondering if a common framework is possible. At least the number of antenna ports changes for type 1, while keeps unchanged for type 2 with spatial adaptation. |

The following is set for digging more about joint operation of spatial domain adaptation and power domain adaptation, and these two with Cell DTX/DRX.

**Q1**

**What may need further consideration for**

* **joint operation of spatial domain adaptation and power domain adaptation**
* **joint operation of cell DTX/DRX and spatial/power domain adaptation?**

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| **Company** | **Comments** |
| Lenovo | We prefer to defer this discussion due to lack of clarity of NES solutions on spatial, power domains as well as cell DTX/DRX |
| vivo | We support joint operation of spatial domain adaptation and power domain adaptation.  For joint operation of cell DTX/DRX and spatial/power domain adaptation, it should be discussed later after design of Cell DTX/DRX is more clear. |
| DOCOMO | The unified framework for joint operation of spatial and power adaptation is expected.  Regarding joint operation of cell DTX/DRX and spatial/power domain adaptation, it should be discussed after details of both enhancements are made. |
| Apple | Yes to the first bullet if type 2 is supported.  No to the second bullet, since these two do not need to be jointly operated, it will be clearer if the behaviors could be defined separately. |
| ETRI | We support the first bullet. Second bullet point can be discussed later after more progress is achieved in the two AIs. |
| Fujitsu | We support joint operation of spatial domain adaptation and power domain adaptation as they have commonality. Power domain adaptation can be seen as a special case of type 2 spatial element adaptation without the change of mapping relationship between spatial elements and logical antenna ports.  Regarding joint operation of cell DTX/DRX and spatial/power domain adaptation, it can be postponed after clear definition of cell DTX/DRX mechanism is made. |
| ZTE, Sanechips | Support the first bullet. Since both spatial domain adaptation and power domain adaptation are related to CSI enhancement, we prefer a joint operation of spatial domain adaptation and power domain adaptation.  For the second bullet, we think it can be considered when the mechanism of cell DTX/DRX is clear in RAN1/RAN2. |
| Huawei, HiSilicon | For spatial domain and power domain, design of CSI framework can be in a unified way.  For cell DTX/DRX and spatial/power domain adaptation, the two features can be used by gNB independently. Thus, there seems no need to joint operation of these to avoid importing additional effort. |
| Nokia/NSB | We are fine with both bullet points.  At current stage, we should first focus on the ‘spatial adaptation operation’ alone without necessarily considering joint operations, so that we are able to progress on defining the baseline operation.  NOTE: The question mark at the end of the 2nd-bullet point should be removed. |
| Futurewei | These are open issues for further discussions and hence there is no need to explicitly agree on this. |
| Xiaomi | We also support the first bullet. For the second bullet, it is premature to discuss that. Besides, we notice that the second bullet is also discussed in Session 9.7.2. Maybe redundant work should be avoided. |

3.2 CSI feedback

The relevant agreements are excerpted as below.

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| **Agreement**  For spatial domain adaptation, further study necessary enhancements for multiple CSI(s) where each CSI corresponds to a spatial adaptation pattern, e.g.   * FFS: gNB indicates to UE which CSI(s) the UE shall report * FFS: the UE selects which CSI(s) are reported * FFS: multiple CSI(s) are reported in a joint CSI report * FFS: Overhead reduction for multiple CSI(s)   Note: UE complexity needs to be taken into account. |

**Company proposals**

[Huawei, HiSilicon]:

* For both Type 1 and Type 2, study and specify how the high correlation on CSI-RS beam can be exploited to reduce multiple CSIs calculation complexity and reporting overhead.
* For both Type 1 and Type 2, study and specify how the high correlation on PMI can be exploited to reduce multiple CSIs calculation complexity and reporting overhead.
* Support gNB configuring, and triggering if needed, multiple CSIs reporting.
* Support multiple CSIs reporting in one report with overhead reduction techniques based on shared CRI, shared PMI and differential CQIs. FFS details of the one report content.

[Nokia, NSB]:

* To minimize the CSI feedback overhead, discuss on the CSI report content, i.e., whether/how this report would be based on a subset selection from multiple spatial patterns by the UE.
* Discuss whether there is a need to differentiate the CSI report content depending on whether the spatial patterns have same or different number of spatial/antenna elements.
* Discuss CSI report feedback size reduction considering sub-band configuration adaptation to each spatial pattern.
* In the case where the UE is required to provide CSI report based on multiple (indicated) candidate spatial patterns, to reduce the burden at the UE, discuss whether/how the UE is allowed to skip evaluating some of the candidate spatial patterns based on some rules.
* Discuss how the CSI computation/derivation operation is impacted due to switching to a new spatial pattern, considering channel and interference measurements.

[vivo]: Support single-CSI report in one CSI reporting occasion. When CSI report configuration includes multiple sub-configurations, only one sub-configuration from the multiple sub-configurations is activated at one time.

[OPPO]: When UE is allowed to report part of the configured CSI reports, the rules for CSI selection need to be discussed and specified.

[Spreadtrum]:

* The adaptation of PMI/RI/CQI calculation and reporting is prioritized, and the adaptation of CRI/RSRP/SINR is down-prioritized or discussed separately.
* Multiple CSIs without compression can be supported as baseline, and multiple CSIs with compression needs to consider UE complexity reduction.

[CATT]:

* UE should be configured to perform multiple CSI measurements from each NZP CSI-RS resource for type-1 spatial domain adaptation.
* Multiple CSI reports associated with one NZP CSI-RS resource should be supported in Rel-18.
* gNB indication to UE on the selected CSI report (s) should be supported.

[Intel]:

* Consider supporting CSI feedback report(s) based on a hypothetical CSI-RS resource set, which may be a subset of the configured CSI-RS resource set and with a different power offset between CSI-RS and PDSCH.
* To reduce UE computational complexity burden, consider multi-CSI feedback enhancements that can leverage precoding matrix for one of the CSI feedback for another CSI feedback that correspond to a different subset of CSI-RS ports.

[Fujitsu]:

* For single CSI feedback, group-common L1 signaling should be considered to efficiently indicate the UEs of the CSI-RS resource/report update.
* For multiple CSIs feedback, UCI overhead and CSI processing complexity reduction is required. To achieve this, gNB selects the CSIs to be reported and indicates them to UE.
  + - Dynamic signaling is used for indicating UE of the CSIs need to be measured and reported

[ZTE]:

* Multi-CSI report should be considered for network spatial adaptation for energy saving.
* Reporting only one PMI with the largest number of ports for multiple CSIs report should be considered to reduce the UCI overhead.
* gNB can configure multiple bitmap candidates by RRC signaling, and use L1 signaling to select one or more from the multiple candidates.
* To reduce signaling overhead and guarantee performance, each bit in a bitmap corresponds to two ports with different polarization directions but in same position.
* Differential RI/CQI can be considered to reduce UCI overhead.

[InterDigital]: A CSI report contains CSI information associated with at most one spatial adaptation pattern. Support reporting of CSI based on dynamically indicated subset of antenna ports.

[Google]:

* The CSI feedback enhancement for spatial domain NES should be based on CSI measurement from one or more than one CSI-RS resources configured with the same number of antenna ports.
* Support the UE reports at least one CSI including the CRI(s) and corresponding CQI/RI/PMI measured based on the CSI-RS resource(s) indicated by the CRI(s).
* Support the CSI feedback enhancement for NES based on Rel-15 Type1 codebook, Rel-16 eType2 codebook and Rel-18 eType2 codebook refinement for CSI feedback for high/medium UE velocity and coherent joint transmission.

[Samsung]:

* Multi-CSI report is supported in which a UE derives multiple CSI reports from a single set of CSI-RS measurements for different hypotheses of CSI-RS mapping patterns, CSI-RS transmission powers, and PDSCH transmission powers.
* For multi-CSI reporting, a UE can be provided multiple CSI-RS resource mapping sub-configurations from a single set of CSI-RS measurement via CDM group level antenna port subset indication.
* For multi-CSI reporting, a UE can be provided multiple CSI-RS resource mapping sub-configurations from a single set of CSI-RS measurements via two-step indication: first in the CDM group level and then in the antenna port level within the indicated CDM groups.
* For multi-CSI reporting, a UE can be provided one or more of CSI report sub-configurations for a number of CSI-RS resource sub-configurations including parameters related to codebook configurations and/or CSI report quantities.
* For multi-CSI reporting, a UE is indicated by the serving gNB a set of CSI-RS resource sub-configurations for which the UE reports CSI.
* For multi-CSI reporting, further study the following payload size reduction schemes
  + - Differential/threshold-based reporting of CSI quantities such as CQI, L1-RSRP.
    - Reuse DFT basis set and differential/thresholding-based amplitude/phase coefficient reporting for multiple PMI reports of the same size or similar size.
* For multi-CSI reporting, support a mechanism for a UE to perform CSI measurement and reporting following UE-group-specific DCI indication. Otherwise, the UE skips multi-CSI reporting.

[CMCC]:

* Enhancements on adaptation of CQI, RI, or PMI calculation with spatial elements on/off.
* UE reports multiple CSIs with different antenna muting pattern assumptions in one CSI reporting.
* The multiple CSIs within the CSI reporting could be used for the recommendation of muting pattern to gNB.

[CEWiT]: gNB indicating to UE which CSI(s) the UE shall report is supported.

[MediaTek]: The CSI report for a spatial adaptation pattern contains common PMI and RI values but different CQI values corresponding to different candidate power offset values.

* + - FFS: Extension on UCI format
    - FFS: How to specify CPU occupation for generating the CSI report for a spatial adaptation pattern.

[LGe]:

* The following options can be considered to reduce the UE's CSI computational complexity and to find the optimal spatial or power adaptation patterns from the gNB perspective.
  + - Option 1: gNB indicates the spatial or power adaptation pattern(s) to be calculated and reported, and UE calculates and reports CSI information corresponding to indicated spatial or power adaptation pattern(s).
    - Option 2: gNB configures a specific condition/threshold (e.g., target CQI) to the UE in advance and UE calculates and reports only multiple CSI information corresponding to multiple spatial or power adaptation patterns only when the condition/threshold is satisfied.
* When multiple CSIs corresponding to multiple spatial or power adaptation patterns are reported as one CSI report, the following options can be considered to reduce feedback overhead.
  + - Option A: If there is a CSI content (e.g., RI) that remains unchanged across adaptation patterns, the CSI content (e.g. RI) may be included only once without including the CSI content for each adaptation pattern, and the remaining CSI contents for each adaptation pattern can be contained.
    - Option B: Based on the condition/threshold (e.g., CQI index) configured by the gNB, both wideband CSI and sub-band CSI information are included in the CSI report for the best performance (e.g., highest CQI) spatial or power adaptation pattern(s), and only wideband CSI information are included in the CSI report for other adaptation patterns.

[Apple]: For multiple CSI, support NW activation/triggering a single CSI report for one report instance under the multiple spatial adaptation pattern assumptions or power adaptation values.

[Qualcomm]: RAN1 only specifies joint CSI report for multiple CSIs if its CSI report overhead reduction is high compared to separate CSI reports.

* + - A separate CSI report for each CSI corresponding to a spatial adaptation pattern as baseline.
    - (in a separate proposal) Support CSI report based on a subset of CSI-RS resources configured in an CSI report setting

[AT&T]:

* Define different CSI reporting hypotheses for different levels of spatial dimensions which rely on the same RRC configuration
  + - For CSI resource configuration, a common CSI-RS resource/resource set is associated with multiple spatial adaptation patterns
    - For CSI reporting, support joint reporting of multiple CSIs
      * Further study the need/benefit of overhead reduction
* Different CSI reporting hypotheses for different levels of spatial dimensions are defined by reusing the ZP-CSI-RS framework avoiding fundamental changes to the codebook structure and/or CSI-RS patterns
* Consider enhancements to the CSI reporting procedures for efficient reporting of different hypotheses for different levels of spatial dimensions

[Docomo]:

* The mechanism of multiple CSI(s) reported in a joint CSI report should be supported.
* The overhead reduction mechanism of following can be considered to reduce the CSI report payload.
  + - Reporting once if CSI contents are the same across reported CSIs.
      * E.g., reporting one CRI for CSIs with Type 1 adaptation.
    - Reporting a joint coded field
      * E.g., reporting a joint coded RI for CSIs with reduced number of CSI-RS ports.
    - Reporting the difference between CSIs.
      * E.g., reporting CQI difference across CSIs with power adaptation.
* The benefits of the mechanism of UE selecting CSI(s) to be reported should be further clarified.

[Ericsson]:

* When a UE receives DCI indicating a trigger state with multiple sub-configuration indicators, the UE transmits one CSI report including CSI results corresponding to each of indicated sub-configurations.
* When a UE receives DCI indicating a trigger state including only one sub-config indicator, the UE measures and reports CSI according to the indicated sub-configuration only.

[Fraunhofer]:

* With a UE set to measure CSI corresponding to 1 different (subsets of the available antenna ports in the array) spatial domain patterns at the gNB, it should be configured to report for CSI(s), where the value of can be either configured by the network or can be fixed in the specifications.
* Regarding the option for letting the UE select which CSI(s) are reported, in order to enable the UE to make such selection effectively, the UE should be configured with sufficient information from the gNB so as to take certain NES requirements into account, in addition to the UE performance.
* RAN1 to discuss mechanisms to enable UEs to perform beam measurement and efficient reporting to meet NES requirements while maintaining sufficient link gains.

**FL summary part 1**

If single-CSI feedback only is supported, as preferred by [vivo, Spreadtrum, Apple, Fujitsu, InterDigital], the possible enhancement is to determine which exact CSI-RS resource for UE channel measurement and report. There seems no enhancement needed from CSI feedback perspective.

If multi-CSI feedback is supported, following up questions could be

* whether gNB can indicate to UE which CSI(s) the UE shall report. From UE complexity/report overhead reduction perspective, there are benefits to do so and gNB has the responsibility to decide which ones to use. In case the supported number of adaptation patterns is not large, a gNB may also not use such indication. Around 9 companies (including CATT, LG, Fujitsu, FW, ZTE, SS, E//, CEWiT and Panasonic) support this approach.
* whether the UE is allowed to select which CSI(s) to report. Impact on UE complexity/report overhead can be minimized. However, it can be questionable on whether gNB would have sufficient information to perform adaptation. Around 2 companies (including LG, CATT) support this approach while 2 companies (including OPPO, Fraunhofer) also want to discuss further along this direction, if certain rules can be conditioned for ensuring the performance.
* whether multiple CSI(s) are reported in a joint CSI report. Similar benefits as the first approach, particular with the motivation to further reduce the overhead/UE complexity as in a joint CSI report. Around 10 companies (including Huawei/HiSi, Intel, ZTE, MTK, LGe, AT&T, Docomo, Samsung, Fraunhofer, E//) support this approach while few companies consider this only if benefits are sufficient (Qualcomm (only if overhead reduction is significant)).

Based on the above, it seems at least the first and third approach can be combined with flexibility of gNB to use.

**P3**

**If multi-CSI feedback is supported, also support multiple CSI(s) are reported in one report with overhead and/or UE complexity reduction techniques**

* **gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | Support. Can we add another note on whether the UE can select the subset of CSI(s) it shall report? |
| vivo | Similar comment as P1. It should be clarified that whether multi-CSI feedback is reported in one or different occasions.  Performance benefits on multi-CSI feedback regarding how many throughput and power saving gain, how much UE complexity and overhead reduction can be achieved should be carefully evaluated and clarified first. After there are more evaluation results and analyzes to show clear benefit, whether and how to support overhead reduction/UE complexity reduction can be discussed later. |
| DOCOMO | As multiple CSI reports needs large payload size for CSI reporting, the multiple CSIs reported in one joint CSI report with further overhead reduction methods is an efficient way for NES operation from operators’ point of view.  For the mechanism of UE selects CSI(s) to be reported, from our consideration, the complexity of UE measurement is not reduced as the UE may need to measure all the configured CSIs before selecting the CSI to be report. How the UE to select the reported CSI(s) to help the gNB to take the adaptation decision should be further clarified.  We support FL’s proposal with following slight update.  **~~If multi-CSI feedback is supported, also s~~Support multiple CSI(s) are reported in one report with overhead and/or UE complexity reduction techniques**  **gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report.** |
| OPPO | UE complexity is fairly important to be considered. The netowrk may configure multiple patterns and if the UE is required report all, the UE complexity will not be affordable. From our viewpoint, we should also discuss the maximum number of CSI to be reported in one CSI reporting. The suggested P3 does not set a maximum limit and leave gNB to optionally allow UE to report subset of CSI. This is risky from UE point of view.  For the overhead reduction, we think that this can be discussed later after the maximum number of CSI to be reported in one CSI reporting is concluded. |
| Apple | We need to understand the intention clearly, we think this has the implication that single CPU will be counted for the multiple CSIs, which is unacceptable for us even with the overhead and/or UE complexity reduction. As we have stated in P1, it is unclear which is better, single CSI with complete CSI feedback or multi-CSI with compressed CSI feedback, so it is too early to discuss on this part yet. We could focus on the single CSI or multiple CSI in multiple reporting instances first. |
| FL to vivo/Apple | The ‘if’ condition is added particularly for continuing the discussion.  From FL perspective, a decision within this meeting is needed or at least other relevant work should not be suspended. |
| Spreadtrum | Multi-CSI feedback is supported in current spec. whether we need to reduce UL resource overhead and UE complexity is to be justified. MIMO topic has done many things to reduce UL resource overhead and UE complexity. What can we do further should be asked at first? |
| ETRI | Okay to support overhead reduction techniques assuming that CSI overhead will be problematic in multi-CSI feedback. For the complexity reduction part, it may or may not be achievable depending on detailed feedback schemes. So we prefer to put FFS for the complexity reduction. |
| Fujitsu | We share the same view as vivo that the benefit of multiple CSI(s) in one report needs to be well evaluated first. |
| ZTE, Sanechips | Support.  Based on our evaluation, it can be observed that providing sufficient CSI information corresponding to different spatial patterns/power offset values at the same time is beneficial to assist NW dynamic adaptation without sacrificing the UPT performance. Therefore, multi-CSI feedback in one report should be supported for spatial/power domain adaptation. And OH/UE complexity reduction is also helpful for this enhancement to make it more useful.  According to our evaluation, since there is high correlation between the precoding matrices of different ports, the CSI OH can be compressed. Based on the evaluation results in Table 5 in our contribution, it can be seen that reporting a common PMI can reduce about 65% OH of PMI.  Table 5 Payload of PMI reporting   |  |  |  |  | | --- | --- | --- | --- | | Scheme | Payload of wideband PMI reporting | Payload of subband PMI reporting | Total payload | | Report one PMI | 10(bits) | 18(bits) | 28(bits) | | Report multi-PMI | 10+10+8=28(bits) | 18\*3=54(bits) | 82(bits) |   In addition to that, dynamic indication of CSI report subsets can be optionally considered. In this case, the dynamic indication should not be limited to select only one subset. Indication of multiple subsets of CSIs should be also considered to exploit the benefits of multi-CSI feedback in one report. |
| Huawei, HiSilicon | Support the main part.  For the bullet, the motivation of gNB indicating subset of CSI(s) to report is not very clear for us. Why gNB needs some CSIs at some point and needs some other CSIs at another point? From our perspective, gNB needs all CSIs to do the shutdown decision and scheduling decision. If only a subset of CSI(s) is reported by UE, gNB cannot do proper shutdown (due to the lack of all CSIs) which resulting in performance loss and less energy saving gain. Hence, we propose the following modification  **P3**  **If multi-CSI ~~feedback~~ report(s) is supported for NES adaptation before the adaptation decision, ~~also~~ support multiple CSI(s) are reported in one report with overhead and/or UE complexity reduction techniques**   * **~~gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report.~~** |
| Nokia/NSB | We don’t support proposal 3 in its current form.  In our view, there are two main approaches that should be considered:   * Approach 1: UE is configured to select X (such as 1 or 2, etc.) spatial patterns, from a set of indicated candidate spatial patterns, for which the UE reports the corresponding CSI(s) to the gNB e.g., in an UL reporting occasion. * Approach 2: UE only reports CSI for one spatial adaptation in an UL reporting occasion from a set of indicated candidate spatial patterns.   P3 seems to condition the support the above approaches to the support of multi-CSI feedback in one UL reporting occasion.  In addition, in our view Approach 1 provides enough knowledge for the gNB to make suitable spatial adaptation decision, without the need to have CSI for every single candidate pattern.  Furthermore, we think, Approach 1 and/or Approach 2 could be further considered as both would allow reduced UL overhead (up to gNB decision). And the approach where the UE is always required to report CSI for all indicated candidate patterns would result in high UL overhead.  The aspect on UE complexity reduction could be discussed, if still needed, after discussing and concluding whether to support Approaches 1 and/or 2. |
| MediaTek | Support and think overhead and UE complexity reduction is best based on the same design. For example, sharing RI and PMI for spatial adaptation patterns also allows UE to reduce CSI calculation complexity. On the other hand, due to the dependency of PMI on RI, sharing PMI while requiring re-evaluation of RI may bring limited UE complexity reduction, which is less preferred. In this regard, joint design consideration is suggested:  **If multi-CSI feedback is supported, also support multiple CSI(s) are reported in one report with joint overhead and~~/or~~ UE complexity reduction techniques**  **gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report.** |
| Futurewei | We consider this agreement can be deferred once we have clarification what these multi-CSI correspond to. |
| Xiaomi | We share the similar comment as P1. Efficient mechanisms should be studied to reduce the processing and reporting overhead. |

**Q2**

**If multi-CSI feedback is supported, do you consider**

* **whether certain rules or conditions can be used for UE to select CSI(s)**
* **if so, please elaborate what rules or conditions.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | UE can select CSI(s) to report based on performance, e.g., CQI. The selection criteria can also be left for UE implementation |
| Spreadtrum | According to current CSI feedback framework, UE just calculates CSI and feeds back to gNB. The autonomous selection of CSI to report is new UE behavior. |
| ZTE, Sanechips | The benefits of selecting one or more CSI(s) report by UE are unclear. Some comments are  gNB cannot get enough CSI(s) and may not be able to dynamically adapt antennas with a tradeoff between NES gain and UPT performance.  UE still needs to calculate CSI(s) for all spatial adaptation pattern(s), UE complexity cannot be reduced.  UE has no clue about the gNB implementation for NES. |
| Nokia/NSB | Yes, this falls under the Approach 1 we listed in our input on P3 above.  For the selection approach from a set of candidate spatial patterns, we foresee two main cases (to be considered separately and/or jointly):   * Case 1: When the spatial patterns in the set of candidate patterns have same number of (active) spatial/antenna elements. In this case, there is practically no difference in power/energy saving level (from network Tx perspective) between the different spatial patterns. One way for pattern selection would be to follow similar logic as for CRI (*CSI-RS resource indicator*) down-selection in Rel-15, by basically letting the UE select one preferrable pattern based on UE implementation.   + Other than UE implementation, it’s also possible to let the gNB configure criteria for the selection, such as ones related to rank, RSRP or CQI, etc. * Case 2: When the patterns in the set of patterns have different number of (active) spatial/antenna elements. In this case, different spatial patterns may have different power/energy saving levels. Hence, UE would need to report a pattern(s) with best power/energy saving while fulfilling one or more criteria related with performance constraint, such as minimum rank. |

**FL summary part 2**

If multi-CSI feedback is supported, for overhead and UE complexity reduction, CSI content and CSI computation operation needs to be broken down. At least the following are discussed in companies’ contributions:

* CRI: considered enhancement may be possible, by Huawei/HiSi, Google.
* RI: considered enhancement may be possible, by ZTE, Spreadtrum, CMCC, MediaTek, LGe (if unchanged)
* PMI: considered enhancement may be possible, by Huawei/HiSi, Spreadtrum, Intel, ZTE, Samsung, CMCC, MediaTek
* CQI: considered enhancement may be possible, by Huawei/HiSi, Spreadtrum, ZTE, Samsung, CMCC, LGe(target CQI)
* L1-RSRP: considered enhancement may be possible, by Samsung
* General: Docomo (by reporting once for shared content, joint coded field, or difference part only)

As consequence, the potential impact would be on UCI format, CSI computational requirements.

Therefore, a first proposal could be below for guiding further discussion while some following up proposals are also given for possible down-selection. Note, regarding the potential impact on CSI processing requirements, this may be common for power domain adaptation techniques and can be discussed together along with section 3.13 – ‘UE complexity/capability’.

**P4**

**If multi-CSI feedback is supported, for techniques for overhead/report payload/UE complexity reduction, considering the following aspects**

* **Enhancement for report of CRI/RI/PMI/CQI/L1-RSRP**
  + - **Impact on UCI format**
    - **Impact on CSI computation and/or CPU occupation**
    - **Constraint for e.g. differentiation of different CSI report content due to same or different number of spatial/antenna elements**
* **Signalling aspect including RRC configuration (e.g. wide-band or sub-band, ReportQuantity, power offset) and L1/L2 signalling (e.g. group common signalling, bitmap indication)**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | We are fine with the proposal. We propose adding an FFS on the possibility of reporting shared report quantities for different CSI corresponding to two spatial adaptation patterns, e.g., common RI/PMI for two spatial patterns but different CQI values for each spatial pattern |
| vivo | Similar comment as P3. Performance benefits on multi-CSI feedback regarding how many throughput and power saving gain, how much UE complexity and overhead reduction can be achieved should be carefully evaluated and clarified first. After there are more evaluation results and analyzes to show clear benefit, whether and how to consider enhancement for overhead reduction/UE complexity reduction can be discussed later. |
| DOCOMO | We support the proposal with following update.  **~~If multi-CSI feedback is supported, f~~For techniques for overhead/report payload/UE complexity reduction, considering the following aspects**   * **Enhancement for report of CRI/RI/PMI/CQI/L1-RSRP**   + - **Impact on UCI format**     - **Impact on CSI computation and/or CPU occupation**     - **Constraint for e.g. differentiation of different CSI report content due to same or different number of spatial/antenna elements**   **Signalling aspect including RRC configuration (e.g. wide-band or sub-band, ReportQuantity, power offset) and L1/L2 signalling (e.g. group common signalling, bitmap indication)** |
| Apple | As we have stated in P1, it is unclear which is better, single CSI with complete CSI feedback or multi-CSI with compressed CSI feedback, so it is too early to discuss on this part yet. We could focus on the single CSI or multiple CSI in multiple reporting instances first. |
| Spreadtrum | Analog beam is related to coverage and mobility. They are not adapted so dynamically. |
| ETRI | It seems premature to agree on these details at this stage. “Study” instead of “consider” may be fine for us. |
| Fujitsu | For the first sub-bullet, the feasibility of shared CSI reporting (especially for RI and PMI) corresponding to different spatial adaptation patterns needs to be verified first. |
| ZTE, Sanechips | Support in general.  In our understanding, the multi-CSI has impact on CSI report content, but no impact on UCI format. We think same UCI format determination (like format 1,2,3,) can be applied to this CSI enhancement. |
| Huawei, HiSilicon | We agree with the proposal. However, we have the following proposals:   1. Remove L1-RSRP since it not clear how it can help in spatial adaptation or power adaptation 2. Remove the sub-bullet “**Constraint for e.g. differentiation of different CSI report content due to same or different number of spatial/antenna elements**” because the advantage of having such differentiation in the reporting is not clear. 3. L1/L2 signaling is not agreed yet and we do not expect that it will be needed for **configuration** **overhead/report payload/UE complexity reduction**   Hence, we propose the following modifications:  **If multi-CSI feedback is supported, for techniques for configuration overhead/report payload/UE complexity reduction, consider~~ing~~ the following aspects**   * **Enhancement for report of CRI/RI/PMI/CQI~~/L1-RSRP~~**   + - **Impact on UCI format**     - **Impact on CSI computation and/or CPU occupation**     - **~~Constraint for e.g. differentiation of different CSI report content due to same or different number of spatial/antenna elements~~** * **Signalling aspect including RRC configuration (e.g. wide-band or sub-band, ReportQuantity, power offset) and L1/L2 signalling (e.g. the need of L1/L2 signalling, if L1/L2 is needed whether it is group common signalling, if L1/L2 signalling is needed whether there is a need for bitmap indication)** |
| Nokia/NSB | First, we think it would be better to decouple the ‘UL overhead/report payload’ and ‘UE complexity reduction’ aspects at a first stage.  On the ‘UL overhead/report payload’ aspect, we think that Approaches 1 and 2 that we listed in our input on P3 could be a good starting point, as these approaches would somewhat result in low UL overhead by design (and up to gNB decision).   * Approach 1: UE is configured to select X (such as 1 or 2, etc.) spatial patterns, from a set of indicated candidate spatial patterns, for which the UE reports the corresponding CSI(s) to the gNB. * Approach 2: UE only reports CSI for one spatial adaptation in an UL reporting occasion.   In general, we should aim at reusing the existing CSI framework whenever possible. Also, optimizations on the CSI report content/quantities could be discussed at a later stage once the baseline operation is defined. We should avoid spending time on optimizations if the baseline operation is still not fully clear/defined.  On the second bullet point, although it’s generic, we are generally fine with considering the signalling aspects. |
| MediaTek | Support.  The proposal is inclusive and also provides good directions for companies’ further investigations and discussions. |
| Xiaomi | Prefer to deprioritize this proposal. The detailed techniques can be discussed after multi-CSI feedback is agreed. |

**Q3**

**For multi-CSI feedback (if supported), do you consider whether/which/how of the following can be enhanced for CSI report content reduction?**

* **CRI**
* **RI**
* **PMI**
* **CQI**
* **L1-RSRP**
* **Other (new) CSI content, if any**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Company and comments** | | **CRI** | **RI** | **PMI** | **CQI** | **L1-RSRP** | **Other content** | **Other comments** |
| e.g. Company A | Which |  |  |  |  |  |  |  |
| How |  |  |  |  |  |  |  |
| DOCOMO | Which | Common CRI | Common CRI,  Joint coded RI | Common PMI | Differentiate CQI |  |  |  |
| How | Feasibility of reporting common or different CRI according to gNB configuration | For Type 1 adaptation, joint coded RI can be considered.  For Type 2 and power adaptation, common RI can be expected. | For power adaptation, common PMI can be expected. | Wideband Differentiate CQI can be expected. |  |  |  |
| ZTE, Sanechips | Which | Yes | Yes | Yes | Yes |  |  |  |
| How | Common  CRI | Differential RI | Common PMI | Differential CQI |  |  |  |
|  |  |  |  |  |  |  |  |  |
| Huawei, HiSilicon | Which | Y | Y | Y | Y | N | N |  |
|  | How | Based on the correlation on CSI-RS resources corresponding to different spatial patterns, one CRI can represents multiple best CSI-RS resources. The correlated CSI-RS resources can be pre-configured by gNB or predefined. | For spatial adaptation, the rank may be fall-back, multiple RIs may be needed. Whether multiple RIs can be further compressed, we are open to it. | Based on the correlation on PMIs in the best CSI-RS resource, only one PMI is sufficient in some cases. For example, if the RI remains the same, one PMI can be reported by UE. If the RI is fall-back, the precoding matrix with low rank can be determined/selected from the precoding matrix with highest rank. | Differential CQIs can be reported by UE. | L1-RSRP is used for beam management. it not clears how it can help in spatial adaptation or power adaptation |  |  |
| Nokia/NSB | Please see our input to Q2.  Also, we don’t think discussing such optimizations is essential now, as we should first focus on defining the baseline operation. |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |

**Q4**

**For multi-CSI feedback (if supported), for the parameters you indicated possible for enhancement, what could be the potential impact on, including but not limited to**

* **Impact on UCI format**
* **Impact on CSI computation and/or CPU occupation**
* **Constraint for e.g. differentiation of different CSI report content due to same or different number of spatial/antenna elements**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | For UCI format, CPU occupation as well as mapping order of CSI fields, we prefer to reuse the Rel-17 CSI framework for multi-TRP (Section 6.3.1.1.2 of TS38.212), which also supported reporting multi-CSI feedback corresponding to up to three transmission hypotheses. We do not believe supporting a new design for UCI mapping is feasible given the limited time available before the end of the Rel-18 discussions |
| DOCOMO | For UCI mapping, we think that R17 multi-TRP CSI mapping cannot be directly used by R18 NES due to the following reasons:  - In R17 multi-TRP, it may contain CSIs of single-point CSI(s) and muti-point CSI. The feedback contents of muti-point CSI is different compared to single-point CSI. As R18 NES only contains single-point CSIs, the UCI mapping of R17 multi-TRP could not be directly reused by R18 NES.  - In R17 multi-TRP, there is no relationship between CSIs, thus payload reduction cannot be performed. But for R18 NES, obvious relations can be observed between CSIs, payload reduction approaches ca be reused. Then the UCI mapping enhancement for R18 NES is needed. |
| Fujitsu | For CSI computation and CPU occupation, it depends on which alternatives for CSI-RS resource configuration and CSI report configuration are adopted. It should be discussed after the agreements w.r.t. configuration is made. |
| ZTE, Sanechips | If UE can report some common information for multi-CSI, the CSI computation and/or CPU occupation will be impacted considering that the UE does not need to exhaustively search all the CSI combination (like, CRI, RI, PMI, CQI) for other patterns.  The motivation of the last bullet should be clarified, does it mean “the restriction of codebook”? |
| Nokia/NSB | As we indicated above, impact on UCI format could be considered only after a ‘workable’ baseline operation is defined.  Impact on CSI computation and CPU occupation could be further considered with multi-CSI feedback.   * For CSI computation, we could discuss whether there would be need to consider ways for the UE e.g., to skip the evaluations of some spatial patterns to reduce the burden at the UE. * For CPU occupation, evaluating multiple spatial patterns and providing a corresponding CSI report(s) using one UL reporting occasion would increase the consumption of CSI processing units (CPU) at the UE, given that a CPU is only released after the CSI report is transmitted. And thus, the required number of additional CPUs would potentially need to scale up with the number of spatial patterns to evaluate before the CSI report transmissions. Hence, considering CSI report(s) through different UL reporting occasions would allow to reduce the need to consume many CSI processing units at a time in this case.   CSI report content due to same or different number of spatial elements would need to be discussed as there could be two cases:   * Case 1: When the spatial patterns in the set of candidate patterns have same number of (active) spatial/antenna elements. In this case, there is practically no difference in power/energy saving level (from network Tx perspective) between the different spatial patterns. One way for pattern selection would be to follow similar logic as for CRI (*CSI-RS resource indicator*) down-selection in Rel-15, by basically letting the UE select one preferrable pattern based on UE implementation.   + Other than UE implementation, it’s also possible to let the gNB configure criteria for the selection, such as ones related to rank, RSRP or CQI, etc. * Case 2: When the patterns in the set of patterns have different number of (active) spatial/antenna elements. In this case, different spatial patterns may have different power/energy saving levels. Hence, UE would need to report a pattern(s) with best power/energy saving while fulfilling one or more criteria related with performance constraint, such as minimum rank. |

**Q5**

**For multi-CSI feedback (if supported), what need to be RRC configured, in addition to those covered by proposal(s)/discussions in the sections of 3.3 - ‘CSI-RS resource configuration’, 3.5 - ‘CSI report configuration’ and 3.7 - ‘Definition of spatial adaptation pattern’?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia/NSB | Since baseline operation for multi-CSI feedback is still not really defined, we think Q5 could be considered at a later stage. |
|  |  |
|  |  |
|  |  |

**Q6**

**For multi-CSI feedback (if supported), what can be additionally indicated by L1/L2 signaling, in addition to those covered by proposal(s)/discussions in the sections of 3.12 - ‘Need of signalling to UE due to adaptation’?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia/NSB | Since baseline operation for multi-CSI feedback is still not really defined, we think Q5 could be considered at a later stage. |
|  |  |
|  |  |
|  |  |

3.3 CSI-RS resource configuration

**Company proposals**

[FW]: Multiple CSI-RS resources, each corresponding to a spatial element configuration, should be specified in one CSI-RS resource setting (Alternative A1-2) with the following supports/enhancements:

* + - The different CSI-RS resources within a resource set, each with different number of antenna port mapping that corresponding a unique ‘spatial pattern’ (as in A1-1), and/or
    - Increasing the number of resource sets that can be configured, each with different number of antenna port, at least for Semi-persistent and periodic resources configuration and CSI reporting.

[Huawei, HiSilicon]:

* Support A1-1) for both type 1 and type 2 shutdown. Each CSI-RS resource/resource set/resource setting implicitly represent one “spatial adaptation pattern”.
* Further study and identify the scenarios and proper CSI-RS transmission patterns that can be beneficial before adopting A1-2).

[Panasonic]: It is important to check both network side regarding realistic flexibilities to support for this feature and the UE side complexity and capability, before concluding on which alternative to adopt.

[Nokia, NSB]:

* If a large number of spatial patterns is considered, an option along the lines of A2-2 could be considered where one CSI report configuration is used to evaluate multiple spatial adaptation patterns.
* To enable CSI assistance information for spatial adaptation, further consider Option 1-2 and Option 2-2:
  + - Option 1-2: one CSI-RS resource is associated to / used to evaluate multiple spatial patterns.
    - Option 2-2: one CSI-RS resource set is associated to / used to evaluate multiple spatial patterns.
    - FFS: whether these options can be used for all cases and scenarios of interest, and if not, which other option(s) should be adopted.
    - FFS: how to indicate the UE with the antenna port subsets which represents different spatial patterns for evaluation/reporting under these options.
      * FFS: whether other information should be indicated/updated to the UE.
* To enable CSI assistance information for spatial adaptation, further consider Option 3-2:
  + - Option 3-2: one resource setting is associated to /used to evaluate multiple spatial patterns.
    - FFS: whether this option can be used for all cases and scenarios of interest.

[vivo]: Support Alt. 1-1 + Alt. 2-2 for spatial element adaptation

* One resource configuration for channel measurement includes multiple CSI-RS resource sets, where each resource set can be associated with only one spatial adaptation pattern
  + - CSI-RS resource in different CSI-RS resource sets may have different resourceMapping (e.g., nrofports) that corresponds to different spatial adaptation pattern
* One CSI report configuration includes multiple sub-configurations, where each sub-configuration corresponds to one of the configured CSI-RS resource sets
  + - Sub-configuration at least includes codebookConfig

[OPPO]: If the spatial adaptation pattern includes one spatial element before adaptation and another spatial element after adaptation, A1-1 may be considered as a subset of A1-2.

[Spreadtrum]:

* Dynamic switching between CSI-RS resources or spatial adaptation patterns for a CSI-RS resource can be considered.
* A1-2) is not supported.

[CATT]: Precoded CSI-RS to emulate different antenna ports could be applied to CSI enhancement for both type-1 and type-2 spatial domain adaptations.

[Fujitsu]: Support CSI-RS configuration

* + - A1-2-1) Each CSI-RS resource (*NZP-CSI-RS-Resource*) is associated with multiple spatial adaptation patterns
      * The common parameters are FFS
    - A1-2-2) Each CSI-RS resource set (*NZP-CSI-RS-ResourceSet*) is associated with multiple spatial adaptation patterns

[ZTE]: For spatial element adaptation with multi-CSI report, each CSI-RS resource/resource set/resource setting can be associated with more than one spatial adaptation patterns.

[xiaomi]: support A1-2 that each CSI-RS resource can be associated with one or more spatial adaptation patterns.

[InterDigital]: Support association of one CSI-RS resource with more than one spatial adaptation pattern, where each pattern corresponds to a different subset of antenna ports.

[China Telecom]: Support to adopt A1-1) for the association between CSI-RS resource and spatial adaptation pattern, i.e., each CSI-RS resource/resource set/resource setting can be associated with only one spatial adaptation pattern. Support to associate one CSI-RS resource with one spatial adaptation pattern.

[Google]: Study the rank-specific codebook configuration, where different (N1, N2) can be configured for different ranks.

[CMCC]: Each CSI-RS resource/resource set/resource setting can be associated with one or more spatial adaptation patterns, i.e. A1-2, should be supported.

[CEWiT]: Each CSI-RS resource set associated with one or more spatial element adaptations is supported.

* + - Each CSI-RS within the resource set is associated with individual spatial elements adaptation.

[Transsion]:

* Each CSI-RS resource setting is associated with one spatial adaptation patterns should be excluded.
* Each CSI-RS resource or each CSI-RS resource set setting is associated with one spatial adaptation patterns can be supported.
* Each CSI-RS resource is associated with more spatial adaptation patterns can be supported.

[Apple]: For resource configuration,

* consider the following options to configure the spatial adaptation pattern due to reduction of logical antenna ports (where which value is to be used for CSI report can be further indicated):
  + - Opt 1: one CSI-RS resource associated with multiple *nrofPorts*, same across all CSI-RS resources in a resource set.
    - Opt 2: one CSI-RS resource set with multiple *nrofPort* values, where each CSI-RS resource within the set is associated with a single *nrofPort* value, the additional *nrofPort* values are configured per resource set level.
* consider the following options to configure the spatial adaptation pattern due to change of spatial element mapping or transmission power:
  + - Opt 1: one CSI-RS resource associated with multiple TCI-stats/*powerControlOffsetSS*/ *powerControlOffset* values
    - Opt 2: one CSI-RS resource associated with one TCI-state/*powerControlOffsetSS*/ *powerControlOffset*, and the multiple CSI-RS resources are within one CSI-RS resource set
    - Opt 3: one CSI-RS resource associated with one TCI-state/*powerControlOffsetSS*/ *powerControlOffset*, and the multiple CSI-RS resources are in multiple resource sets

[Lenovo]: Two CSI resource configurations, corresponding to whether the NES mode is activated or deactivated, are supported.

[Qualcomm]:

* A spatial adaptation pattern includes a codebook configuration and reduced NZP CSI-RS resource(s) for channel measurement with the same number of antenna ports as that in the configured codebook.
  + - An antenna array corresponding to the spatial adaptation pattern is a uniform linear array with a supported configuration provided in Table 5.2.2.2.1-2 and Table 5.2.2.2.2-1 of TS 38.214 for Type-I single panel and Type-I multi-panel, respectively.
    - FFS: how to determine the reduced NZP CSI-RS resource(s).
* If RAN1 adopts A2-2 for CSI report configuration and A1-2 for NZP CSI-RS resource set configuration, the following aspects are included for an CSI report configuration.
  + - NZP CSI-RS resource set configuration for channel measurement includes CSI-RS resources with the same number of antenna ports.
    - Reduced NZP CSI-RS resource(s) for channel measurement corresponding to a spatial adaptation pattern are determined from the resource(s) in the configured CSI-RS resource set.
    - The CSI processing requirements (e.g., CPU counting, counting of simultaneous active CSI-RS resources, etc.) are scaled linearly by the number of codebook configurations and the number of CSI-RS resources for each configured codebook in the CSI report configuration.
* To determine a reduced NZP CSI-RS resource for a spatial adaptation pattern, one subset of CSI-RS antenna ports associated with a CSI-RS resource in the configured CSI-RS resource set is indicated.
  + - FFS: details on CSI-RS antenna port subset indication.

[AT&T]: Define different CSI reporting hypotheses for different levels of spatial dimensions which rely on the same RRC configuration

* + - For CSI resource configuration, a common CSI-RS resource/resource set is associated with multiple spatial adaptation patterns
    - For CSI reporting, support joint reporting of multiple CSIs
      * Further study the need/benefit of overhead reduction

[Docomo]:

* For association between CSI resource and spatial pattern, A1-2) should be supported. Furthermore, to achieve both Type 1 and Type 2 spatial adaptation, Opt.2 or Opt.3 of following can be supported.
  + - Opt.1: Each CSI-RS resource associated with one or more spatial adaptation patterns.
    - Opt.2: Each CSI-RS resource set associated with one or more spatial adaptation patterns.
    - Opt.3: Each CSI-RS resource setting associated with one or more spatial adaptation patterns.
* Codebook configuration should be enhanced by configuring common or separated codebooks for multiple spatial assumptions to achieve Type 1 or Type 2 adaptation.

[Ericsson]:

* For Type-1 spatial element adaptation, each CSI-RS resource/resource set/resource setting can be associated with one or more spatial adaptation patterns (i.e. A1-2 in the RAN1#112 agreement).
* For Type-1 spatial element adaptation, a CSI-RS resource set is configured within a CSI Resource Setting (CSI-ResourceConfig) wherein the set contains a single CSI-RS resource associated with one or more spatial element adaptation patterns.
* For Type-2 spatial element adaptation, each CSI-RS resource/resource set/resource setting can be associated with only one spatial adaptation pattern (i.e. A1-1 in the RAN1#112 agreement).
* For Type-2 spatial element adaptation, a CSI-RS resource set is configured within a CSI Resource Setting (CSI-ResourceConfig) wherein the set contains multiple CSI-RS resources each one associated with a spatial element adaptation pattern.

[Fraunhofer]:

* Regarding A1-1, for details on the association, multiple spatial adaptation patterns can be associated with individual CSI-RS resource so that UEs can be enabled to provide report(s) with respect to one or more of the CSI-RS resources.
* Regarding A1-2, for details on the association, multiple spatial adaptation patterns can be associated with a single CSI-RS resource while different subsets of the CSI-RS resource can be configured corresponding to each spatial adaptation pattern so that UEs can be enabled to provide report(s) with respect to one or more of the configured subsets of the CSI-RS resource.

[ETRI]:

* For enhancements on CSI-RS resource configuration, further consider the following two options:
  + - Option 1: Each CSI-RS resource can be associated with one or more spatial adaptation patterns (A1-2)
    - Option 2: Each CSI-RS resource can be associated with only one spatial adaptation pattern (A1-1)

**FL summary**

Regarding the CSI-RS resource configuration approaches (i.e., A1-1 and A1-2 as agreed in RAN1#112) and association with spatial adaptation pattern, it is observed that solutions could be different between Type 1 and Type 2 and it is possible that a specific gNB may only implement one of the two shutdown types. On the other hand, from UE perspective, a generalized solution applicable to both types (as much as possible) is desirable in order to minimize the implementation work.

A1-1 (supported by 7 companies including Huawei, vivo, CATT, E/// etc.) can be applicable to both types of shutdown cases while A1-2 does not work for Type 2. A slightly larger number of supporters is observed for A1-2 (supported by 13 companies including Nokia, SS, MTK, QC, E///, etc). Also, it seems a few companies (FW, Nokia, Fujitsu, Docomo) mentioning support of A1-2 also support A1-1 as a sub-case of A1-2 by utilizing resource set or resource setting of CSI-RS configurations, in order to allow one CSI-RS resource associated to only on spatial adaptation pattern for type 2.

FL consider specifications can support both approaches for gNB configuration flexibility. How to minimize the specification work for different types of spatial adaptation can be kept in mind in future discussion. Furthermore, in order to not mix the two configuration approaches, at least for ensuring both types of shutdown can be properly considered during the work, a proposal is made below with modified texts for each approach.

Additionally, it seems the discussion so far is to focus on NZP-CSI-RS resource configuration. This makes sense since we are developing enhancement for channel measurement and reporting. Thus it is reflected.

**P5**

**Support configurability of NZP CSI-RS resource(s) within one resource setting for channel measurement corresponding to more than one spatial adaptation patterns, by the following:**

* **A1-1-revised: multiple resources are configured within a resource setting, where each resource is associated with only one spatial adaptation pattern**
* **A1-2-revised: a resource setting with one resource is configured, where the resource is associated with more than one spatial adaptation patterns**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | We are fine with the proposal, however we believe the answer is different for each spatial adaptation type, for instance, Type-2 cannot be supported with Alt A1-2. |
| vivo | We think the main bullet does not need to limit one resource setting for channel measurement is configured corresponding to more than one spatial adaptation patterns. In fact, multiple resource settings can also be configured for channel measurement corresponding to more than one spatial adaptation patterns. In this case, different resource settings are corresponding to different spatial adaptation patterns, and the resources configured within a resource setting are associated with only one spatial adaptation pattern.  We suggest the following modification for P5  **Support configurability of NZP CSI-RS resource(s) within one or multiple resource setting(s) for channel measurement corresponding to more than one spatial adaptation patterns, by the following:**   * **A1-1-revised: multiple resources are configured within a resource setting, where each resource is associated with only one spatial adaptation pattern** * **A1-1-revised-2: multiple resource sets are configured within one resource setting, where each resource set is associated with only one spatial adaptation pattern.** * **A1-2-revised: a resource setting with one resource is configured, where the resource is associated with more than one spatial adaptation patterns**   The difference between A1-1-revised and A1-1-revised-2 is whether the resources within a resource setting can be associated with one or multiple spatial adaptation pattern. In our view, spatial adaptation for NW ES needs to be operated in single or multiple TRPs cases. For m-TRP, multiple resources for channel measurement for different TPRs can be configured as a group. In order to support spatial adaptation for m-TRP, it is simpler to configure different spatial adaptation pattern for different resource settings, where each resource setting including multiple resources corresponding to different TRPs. |
| DOCOMO | A unified indication/configuration approach to support both Type 1 and Type 2 adaptation is expected to minimize the work of specification and improve the configuration flexibility of realistic NES operation.  Although we think that the contents of the proposal do not have much difference compared to A1-1) and A1-2) which we agreed in last meeting but just with re-organized wording, if it can help for the further discussion in the future, we can support the proposals. |
| OPPO | We are fine with the original proposal P5.  Regarding vivo’s modification, it seems to change the principle of P5. We understand the intention of P5 is to configure only one resource setting instead of multiple resource settings. |
| Apple | Are we listing only the resource configuration enhancements here or any configuration that can be considered for spatial adaptation are to be listed? It is noted that A1-1-revised is already supported by current spec, while A1-2-revised needs enhancements.  Another clarification comment is that does this mean that both alternatives will be supported or if only one alternative is enough, we can focus on only one of them? |
| FL to Apple | Any configuration can be considered and the above two are the possible ones that FL see, as different configuration approaches to achieve the purpose of the main bullet. |
| Spreadtrum | A1-1-revised is already supported in current spec. The proposal could be whether A1-2-revised should be introduced in R18 for NES purpose? |
| ETRI | We prefer to have a single solution to reduce the workload. Our preference is A1-2. In our view, A1-2 can support both Type 1 and Type 2 adaptation. |
| Fujitsu | The first sub-bullet only describes the association relationship between resource setting/resource and spatial adaptation patterns, while that for resource set is missing. Depending on the configuration at the resource set level, A1-1-revised can be further divided into the following two sub-alternatives:  Case 1. one resource set is configured within a resource setting, where multiple resources are configured within one resource set and each resource is associated with one spatial adaptation patterns  Case 2. multiple resource sets are configured within a resource setting, where multiple resources are configured within each resource set and each resource is associated with one spatial adaptation patterns  Considering that the case 1 has lower configuration overhead than case 2, case 1 should be supported. Thus, we suggest the following modification:  **P5**  **Support configurability of NZP CSI-RS resource(s) within one resource setting for channel measurement corresponding to more than one spatial adaptation patterns, by the following:**   * **A1-1-revised: ~~multiple resources are configured within a resource setting, where each resource is associated with only one spatial adaptation pattern~~**   **one resource set is configured within a resource setting, where multiple resources are configured within one resource set and each resource is associated with one spatial adaptation patterns**   * **A1-2-revised: a resource setting with one resource is configured, where the resource is associated with more than one spatial adaptation patterns** |
| ZTE, Sanechips | A1-2-revised.  One CSI measurement resource corresponding to different spatial domain patterns has less overhead of both RRC signaling and CSI-RS transmission, more network energy saving. Moreover, it results in high correlation among multiple CSIs, and the correlation can be used to reduce UL overhead.  However, the restriction of one resource in a resource setting is not needed since different resources can be configured with different QCL information. We prefer the following modification:  **A1-2-revised: a resource setting with one or more resources is configured, where the resource is associated with more than one spatial adaptation patterns** |
| Huawei, HiSilicon | We support both options. However, we suggest the following modifications:  **P5**  **Support configurability of NZP CSI-RS resource(s) within one resource setting for channel measurement corresponding to more than one spatial adaptation patterns, by the following:**   * **A1-1-revised: multiple resources are configured within a resource setting, where each resource is associated with only one spatial adaptation pattern** * **A1-2-revised: a resource setting with one or more resource(s) is configured, where ~~the~~ each resource is associated with more than one spatial adaptation patterns** |
| Nokia/NSB | Fine with the intention of the proposal. However, better to first further discuss and clarify whether to consider CSI-RS resource/ resource set/ resource setting level. It seems the proposal already concludes that resource level is considered.  Also, the discussion should also account for interference measurements as well.  Further, we could discuss whether the existing ZP-CSI-RS framework could be leveraged and improved for the objective here. |
| MediaTek | Support A1-2.  From UE computation point of view, association of a common CSI-RS resource setting implies the possibility of shared CSI computations. In this regard, we are more supportive of A1-2. |
| Futurewei | Support A1-2 and also with the understanding that A1-2 covers the case of A1-1 as well. |
| Xiaomi | The intention of the second sub-bullet. In our understanding, it depends on the gNB configuration for the number of configured resources. In this case, we suggest the following modification:  **P5**  **Support configurability of NZP CSI-RS resource(s) within one resource setting for channel measurement corresponding to more than one spatial adaptation patterns, by the following:**   * **A1-1-revised: multiple resources are configured within a resource setting, where each resource is associated with only one spatial adaptation pattern** * **A1-2-revised: a resource setting with one or multiple resources is configured, where the resource is associated with more than one spatial adaptation patterns** |

3.4 CSI-RS resource mapping pattern

**Company proposals**

Other than CSI-RS resource configuration, the CSI-RS resource mapping (RE mapping) patterns are also mentioned. Views are captured below.

[Nokia, NSB]: Do not introduce additional CSI-RS resource patterns for the purpose of spatial adaptation.

[NEC]: Reduced CSI-RS density for frequency domain network energy saving should be considered.

[xiaomi]: How to enable efficient adaptation of resource mapping for the reception of one CSI-RS resource should be further studied.

[Samsung]: For Type 1 SD adaptation, each NZP CSI-RS resource/resource set/resource setting can include one or more of CSI-RS to RE mapping patterns.

[Qualcomm]: (Observation) It is necessary to enhance CSI-RS patterns so that additional reduced CSI-RS patterns associated with subsets of CSI-RS antenna ports are nested inside the CSI-RS pattern with all CSI-RS antenna ports being active.

* + - Option 1: Introduce additional CSI-RS resource patterns
    - Option 2: Support CSI report based on a subset of CSI-RS resources configured in an CSI report setting

**FL summary**

The need of new CSI-RS resource mapping pattern is not sufficient enough at the moment. However for further digging the potential benefit under the configuration of a common CSI-RS resource for type 1 adaptation/shutdown case, it is suggested to share your views with details for this below question.

**Q7**

**Do you consider there is benefit for introduction of new CSI-RS resource (RE mapping) pattern, and if so, what patterns you think can be introduced?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| DOCOMO | The necessity of new CSI-RS resource (RE mapping) pattern should be further studied. |
| ETRI | The necessity of new CSI-RS resource pattern may depend on applied CSI schemes.  When full-port CSI-RS resource is transmitted (e.g., MFTA in Huawei’s tdoc), legacy CSI-RS resource pattern is sufficient. Even if UE uses a subset of CSI-RS antenna ports to derive CSI, the mapping pattern can be maintained.  Meanwhile, when CSI-RS antenna ports of a CSI-RS resource is partially muted, it may be efficient to change the mapping pattern to transmit unmuted CSI-RS antenna ports. |
| ZTE, Sanechips | We think new CSI-RS resource pattern is not needed. Using signaling to indicates indexes of a subset of ports is easier and has less specification impact. |
| Huawei, HiSilicon | We do not think that there is a need to introduce new patterns. It is a lot of specification effort without clear advantages. |
| Nokia/NSB | We still don’t see any strong reason to introduce new CSI-RS resource patterns. Also, for this issue, lots of discussions and efforts are expected. |
| Xiaomi | Prefer not. Multiple additional CSI-RS resource patterns may be needed to configure different situations of spatial adaptations. In this case, the spec influence is huge. |

3.5 CSI reporting configuration

The relevant agreements are excerpted as below.

|  |
| --- |
| **Agreement**  For spatial element adaptation, further study the following   * A2-1) Independent/separate CSI report configurations where each CSI report configuration corresponds to one spatial adaptation pattern * A2-2) One CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern   + FFS: Details of sub-configuration |

**Company proposals**

[Huawei, HiSilicon]:

Support A2-2) one CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern. Sub-configuration contains:

* For type 1:
* N1 and N2
* FFS：CSI resource setting related parameters
* For type 2:
* FFS: CSI resource setting related parameters

[Nokia, NSB]: Discuss how to configure CSI measurements and reports for different spatial patterns in time, considering different reporting types (semi-persistent, periodic, aperiodic).

[Spreadtrum]: Dynamic switching between CSI report configurations or spatial adaptation patterns for a CSI report configuration can be considered.

[CATT]: One or more sub-CSI reports could be included in CSI report configuration for type-1 spatial domain adaptation with each CSI-RS resource associated with one or more spatial adaptation patterns or type-2 spatial domain adaptation with each CSI-RS resource associated with only one spatial adaptation pattern.

[Intel]: (Observation) CSI report setting for multiple CSI feedback corresponding to multiple CSI-RS resource set hypothesis cannot be separated into independent CSI report settings as the multiple CSI feedback may be coupled with each other.

[Fujitsu]: Support CSI report configuration

* + - A2-1) Each *CSI-ReportConfig* corresponds to one spatial adaptation pattern
    - A2-2) Each *CSI-ReportConfig* corresponds to multiple spatial adaptation patterns
      * The common parameters are FFS

[xiaomi] support A2-2 with one CSI report configuration containing multiple spatial adaptation patterns.

[InterDigital]: RRC configures a set of antenna ports subsets for each NZP CSI-RS resource. RRC configures a group identity for the purpose of indicating a subset of antenna ports for each NZP CSI-RS resource.

[China Telecom]: Support to adopt A2-2) for CSI report, i.e., one CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern, so that the calculation and report complexity of UE can be reduced.

[Samsung]: For Type 1 SD adaptation, each CSI report configuration can include one or more of codebook configurations.

[ETRI]: For enhancements on CSI reporting configuration, adopt A2-2) One CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern.

[CMCC]: One CSI report configuration containing multiple CSI report sub-configuration where each sub-configuration corresponds to one spatial adaptation pattern, i.e. Alt 2-2, should be supported.

[CEWiT]: One CSI report configuration corresponding to one or more spatial element adaptations is supported.

[MediaTek]: One CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern

* + - Note: Legacy CSI report configuration can already be associated to multiple NZP-CSI-RS resource configurations.

[Transsion]: One CSI report configuration that includes multiple CSI report sub-configurations can be supported.

[LGe]:

* the following approaches can be taken into account for CSI framework enhancement.
  + - Approach 1: One CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration is associated with one CSI-RS resource set (for CMR) and corresponds to one spatial or power adaptation pattern. Each CSI-RS resource/resource set can be associated with only one spatial or power adaptation pattern (e.g., for a CSI reporting setting, CSI-RS resource set #1 with 32-APs NZP CSI-RS resource(s) and CSI-RS resource set #2 with 16-APs NZP CSI-RS resource(s), as CMR).
    - Approach 2: One CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration is associated with a subset of CSI-RS resources within a CSI-RS resource set and corresponds to one spatial or power adaptation pattern. CSI-RS resource set can be associated with more than one spatial or power adaptation patterns but each CSI-RS resource within the CSI-RS resource set can be associated with only one spatial or power adaptation pattern (e.g., for a configured CSI-RS resource set in a CSI reporting setting, CSI-RS resources #1/#2 with 32 APs and CSI-RS resources #3/#4 with 16 APs).
    - Approach 3: One CSI report configuration contains multiple CSI report sub-configurations where multiple sub-configurations are associated with a same CSI-RS resource but correspond to different spatial or power adaptation patterns. Each CSI-RS resource can be associated with one or more spatial or power adaptation patterns (e.g., a CSI-RS resource within a configured CSI-RS resource set for a CSI reporting setting, is configured with multiple power offset values of {-3, 3} dB, or with 32 and 16 APs).
* For a CSI report configuration that contains multiple CSI report sub-configurations where each sub-configuration corresponds to a different number of antenna ports, independent/separate *CodebookConfig* higher layer parameters are configured for each sub-configuration.
* For a CSI report configuration that contains multiple CSI report sub-configurations where multiple sub-configurations are associated with a same CSI-RS resource but correspond to different number of antenna ports, discuss at least following issues.
  + - How to signal ON/OFF status for each antenna port
    - How to adjust antenna port mapping considering codebook construction based on antenna ports with ON status

[Apple]:

* For reporting configuration, whether using separate CSI configuration or a single report configuration with multiple sub-configurations, depends on the clarification on UE CSI/CSI-RS capability and CPU counting, that is, the number of supported CPUs for CSI measurement and counting remains the same as current UE capability and
  + - If independent/separate CSI report configurations are supported, CPU occupation is based on per configuration as current.
    - If a single report configuration with multiple sub-configurations is supported, the CPU occupation should be based on per sub-configuration.
* If independent/separate CSI report configurations are supported, consider enhancement on multiple report grouping with resource and reporting parameter redundancy reduction.
* If a single report configuration with multiple sub-configurations is supported, consider at least codebookConfig and associated CSI-RS resource/resource set in the sub-config.

[Lenovo]:

* Support a single CSI reporting setting corresponding to multiple higher-layer configured spatial domain adaptation patterns.
* For a CSI reporting setting corresponding to multiple higher-layer configured spatial domain adaptation patterns, support one of the following alternatives
  + - Alt1. Multiple CSI resource settings for channel measurement corresponding to the multiple spatial domain adaptation patterns
    - Alt2. A single CSI resource setting for channel measurement associated with one NZP CSI-RS resource set, where the NZP CSI-RS resource set further comprises multiple NZP CSI-RS resources for channel measurement corresponding to the multiple spatial domain adaptation patterns
* A single CSI report is supported for reporting CSI corresponding to multiple spatial domain adaptation patterns

[Qualcomm]:

* A spatial adaptation pattern includes a codebook configuration and reduced NZP CSI-RS resource(s) for channel measurement with the same number of antenna ports as that in the configured codebook.
  + - An antenna array corresponding to the spatial adaptation pattern is a uniform linear array with a supported configuration provided in Table 5.2.2.2.1-2 and Table 5.2.2.2.2-1 of TS 38.214 for Type-I single panel and Type-I multi-panel, respectively.
    - FFS: how to determine the reduced NZP CSI-RS resource(s).
* If RAN1 adopts A2-2 for CSI report configuration and A1-2 for NZP CSI-RS resource set configuration, the following aspects are included for an CSI report configuration.
  + - NZP CSI-RS resource set configuration for channel measurement includes CSI-RS resources with the same number of antenna ports.
    - Reduced NZP CSI-RS resource(s) for channel measurement corresponding to a spatial adaptation pattern are determined from the resource(s) in the configured CSI-RS resource set.
    - The CSI processing requirements (e.g., CPU counting, counting of simultaneous active CSI-RS resources, etc.) are scaled linearly by the number of codebook configurations and the number of CSI-RS resources for each configured codebook in the CSI report configuration.

[AT&T]:

* Define different CSI reporting hypotheses for different levels of spatial dimensions which rely on the same RRC configuration
  + - For CSI resource configuration, a common CSI-RS resource/resource set is associated with multiple spatial adaptation patterns
    - For CSI reporting, support joint reporting of multiple CSIs
      * Further study the need/benefit of overhead reduction
* Different CSI reporting hypotheses for different levels of spatial dimensions are defined by reusing the ZP-CSI-RS framework avoiding fundamental changes to the codebook structure and/or CSI-RS patterns
* Consider enhancements to the CSI reporting procedures for efficient reporting of different hypotheses for different levels of spatial dimensions

[Docomo]: For association between CSI report configuration and spatial pattern, A2-2) should be supported. On top of that, A2-2) can be used together with A1-2), e.g., one CSI report configuration with multiple sub-configurations can be configured to measure one CSI resource set/resource setting associated with one or more spatial adaptation patterns.

[Ericsson]:

* For Type-1 spatial element adaptation, one CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern (i.e. A2-2 in the RAN1#112 agreement).
* For Type-1 spatial domain adaptation, for aperiodic CSI reporting, support configuration of one or more indicators within a trigger state, where an indicator points to a sub-configuration within a CSI-ReportConfig.
* For Type 1 spatial domain adaptation, a CSI-Report sub-configuration includes the following information for CSI measurement and reporting
  + - A number of antenna ports
    - Indicator(s) of a subset of antenna ports within a codebook
* For Type-2 spatial element adaptation, support a variant of A2-2 in the RAN1#112 agreement in which one CSI report configuration is associated with multiple spatial adaptation patterns, but sub-configurations are not used. The association can be based on current specifications by configuration of a CSI-RS resource set in CSI-ResourceConfig with multiple CSI-RS resources.
* For Type-2 spatial element adaptation, support a new RRC parameter within CSI-ReportConfig that indicates to the UE that it should report multiple CSIs in case a trigger state points to a CSI-RS resource set within CSI-ResourceConfig that contains multiple CSI-RS resources. For example, the new parameter could be named reportConfig2 with new value ‘multi-RI-PMI-CQI.’ The UE uses the legacy parameter reportConfig if the trigger state points to a CSI-RS resource set with only a single CSI-RS resource.

**FL summary**

There is vast support (13 companies) of A2-2 where one CSI report configuration contains multiple CSI report sub-configurations with each sub-configuration corresponding to one spatial adaptation pattern. Two companies have different opinion, of whom one considers RRC overhead and complexity will not be reduced by A2-2 but could be supportive if the overhead reduction is significant, and another company concerns UE complexity increase. Also UE capability discussion is triggered by two companies, as detailed in another section (section 3.13).

With one of the major motivations to have A2-2 is to enable CSI feedback with reduced reporting payload and/or UE complexity, the potential of that has been demonstrated in many contributions. Note support of a reporting configuration does not mean support of multi-CSI feedback performed by UE. From gNB perspective, it may also reduce the RRC overhead by sharing many IEs in current specification, e.g. *reportConfigType* however may also require additional new parameters. Therefore, it would be desirable to

**P6**

**Support configurability of A2-2 with overhead reduction, i.e. one CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern**

* **FFS: the parameters that need to be separately included for each sub-configurations**
  + - **CodebookConfig, N1 and N2**
    - **nrofPorts**
    - **Indicator(s) of a subset of antenna ports within a codebook**
    - **Other (new) parameters, if any**
* **FFS: whether the resource set configuration only includes CSI-RS resource(s) with the same number of antenna ports.**

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| **Company** | **Comments** |
| Lenovo | Support. A common codebook config can be supported for different spatial adaptation patterns, with different groups of sub-configurations including different configurations of N1 and N2, as well as different CBSR.  We also prefer to add codebook subset restriction (CBSR) for parameters to be included separately for each sub-configuration |
| vivo | We are Ok |
| DOCOMO | We support the proposal.  We think the motivation of the proposal is minimize the duplicated RRC indication when configuring multiple CSIs for reporting. Firstly, we should carefully consider what kind of parameters are essential for each sub-configuration. Secondly, it also depends on the discussion progress of other issues.  Based on above, we suggest removing sub-bullets as the details may depends on the discussion progress of other issues.  **Support configurability of A2-2 with overhead reduction, i.e. one CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern**   * **~~FFS: the parameters that need to be separately included for each sub-configurations~~**   + - **~~CodebookConfig, N1 and N2~~**     - **~~nrofPorts~~**     - **~~Indicator(s) of a subset of antenna ports within a codebook~~**     - **~~Other (new) parameters, if any~~** * **~~FFS: whether the resource set configuration only includes CSI-RS resource(s) with the same number of antenna ports.~~** |
| OPPO | We are fine with P6 |
| Apple | We think it needs to be clarified on what is the overhead reduction here referring to. Configuration overhead, or reporting overhead reduction?  It needs to be discussed together with the CPU occupation. If the CPU occupation is based on per sub-configuration, we could support this enhancement. |
| FL to Apple | It is for RRC configuration overhead reduction. |
| Spreadtrum | Multiple CSI report sub-configurations should be defined at first. |
| ETRI | Support the main sentence. “with overhead reduction” may be deleted, which is being addressed in P3 and Q8 and not much related to this proposal.  For first FFS bullet, some of the parameters may not belong to CSI report configuration but belong to CSI-RS resource configuration. So we prefer to discuss this aspect as a separate proposal. We feel the second FFS bullet is more related to P5, and suggest to also remove it here. |
| Fujitsu | We are fine with the main bullet. For the 1st sub-bullet, the listed parameters are for type 1 adaptation, which need to be described clearly. For the 2nd sub-bullet, it should be discussed in the CSI-RS resource configuration in section 3.3. As we stated for P5, a resource set containing CSI-RS resource(s) associated with multiple numbers of antenna ports has the benefit of reduced configuration overhead, so it should be considered.  We suggest the following modifications:  **P6**  **Support configurability of A2-2 with overhead reduction, i.e. one CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern**   * **FFS: the parameters that need to be separately included for each sub-configurations if type 1 spatial element adaptation is enabled**   + - **CodebookConfig, N1 and N2**     - **nrofPorts**     - **Indicator(s) of a subset of antenna ports within a codebook**     - **Other (new) parameters, if any**   + **~~FFS: whether the resource set configuration only includes CSI-RS resource(s) with the same number of antenna ports.~~** |
| ZTE, Sanechips | For the last FFS, it should be discussed in resource configuration, instead of report configuration. Furthermore, whether the resources within the resource set configuration needs to be with the same number of antenna ports is determined by whether/how one resource to be associated with multiple spatial adaptation patterns |
| Huawei, HiSilicon | We support this proposal and we propose the following modifications:  **P6**  **Support configurability of A2-2 with overhead reduction, i.e. one CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern**   * **FFS: the parameters that need to be separately included for each sub-configurations**   + - **Parameters in CodebookConfig,**     - **N1 and N2**     - **FFS: Codebook subset restriction does not include in sub-configuration.**   **[**Huawei: For type 1 shutdown, multiple N1 and N2 are necessary. **Only one Codebook subset restriction is sufficient for type 1 shutdown case, due to correlation of PMI.]**   * + - **~~nrofPorts~~**   [Huawei: merge with the next sub-bullets below]   * + - **Indicator(s) of a subset of antenna ports, if A1-2-revised is supported ~~within a codebook~~**     - **Other (new) parameters, if any** * **FFS: whether the resource set configuration only includes CSI-RS resource(s) with the same number of antenna ports.** |
| Nokia/NSB | The main bullet is OK in general. We think that sub-band configuration should be also listed to be discussed as part of the sub-configuration (given that different spatial patterns would have different channel characteristics in terms of frequency selectivity).  Further, we could discuss whether the existing ZP-CSI-RS framework could be leveraged and improved, from configuration perspective, for the objective here, or whether this would introduce more overhead / or would be more complicated compared to other approaches. |
| MediaTek | Support the proposal for providing the essential parameters that UE requires to generate CSI outcome for one spatial adaptation pattern. |
| Xiaomi | Fine with the main bullet. As for the second FFS, we share the similar view with Fujitsu that it should be discussed separately. |

**Q8**

**For overhead reduction for A2-2 (if agreed), what parameters do you consider need to be separately included for each sub-configuration, including but not limited to**

* + - **CodebookConfig, N1 and N2**
    - **nrofPorts**
    - **Indicator(s) of a subset of antenna ports within a codebook**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | We prefer to add codebook subset restriction (CBSR) for parameters to be included separately for each sub-configuration |
| DOCOMO | We think that “**a subset of antenna ports within a codebook**” can be predefined as the indication needs much bits and the performance of a predefined pattern is similar as a dynamic indicated pattern if the port number is the same. |
| Nokia/NSB | These parameters could be considered as a starting point. Ng may also be considered for the multi-panel case if seen necessary.  We think that it would be better to mention: CodebookConfig, such as N1-N2 and rank restriction etc.  As we indicated above, we think that sub-band configuration should be also considered to be discussed. |
|  |  |

**Q9**

**For overhead reduction for A2-2 (if agreed), do you consider the CSI-RS resource set configuration should only include resources with the same number of antenna ports? Any other restrictions you may consider as needed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | Yes. CSI-RS resources within the same set should contain the same number of ports and configured with the same density to avoid violating legacy behavior |
| Fujitsu | As we discussed above, the discussion related to CSI-RS resource set configuration should be moved to section 3.3. |
| Nokia/NSB | This would depend on the exact option(s) that will be considered for A2-2, i.e., resource setting level, resource set level, or resource level etc. |
|  |  |

3.6 CSI reporting types

**Company proposals**

There are three type of CSI-RS transmission and CSI reporting types. Relevant proposals are given below.

[FW]: At least aperiodic CSI-RS configurations and aperiodic CSI reporting triggered by DCI would support the adaptation of the spatial patterns at the gNB.

[Panasonic]: Further study below L1 signaling enhancement:

- Enhancement based on aperiodic CSI report procedure,

- Enhancement based on semi-persistent CSI report procedure,

- Enhancement based on adaptation of periodic CSI report procedure.

[Nokia, NSB]: Discuss how to configure CSI measurements and reports for different spatial patterns in time, considering different reporting types (semi-persistent, periodic, aperiodic).

[CMCC]: Dynamic adaptation for CSI-RS should be supported for semi-persistent and periodic CSI-RS.

**FL summary**

Most contributions do not seem to specifically differentiate different types of CSI-RS except for two companies as listed above (wherein one company leans more on A-CSI-RS and A-CSI report while one prefers SP/P CSI-RS). FL considers from resource/reporting configuration and UE CSI feedback perspective, the design may be generally common for three CSI-RS types except for the potential need of DCI triggering for A-CSI-RS and A-CSI feedback. Therefore, from specification point of view, it would be desirable that all types of CSI-RS transmission and CSI reporting could be workable based on the enhancements. This does not mandate an exactly common design for all types of reporting procedures.

**P7**

**Specifications support CSI enhancements for network energy savings applicable for periodic CSI report procedure, semi-persistent CSI report procedure and aperiodic CSI report procedure.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | We believe at least aperiodic CSI reporting and semi-persistent reporting on PUSCH should be supported for NES, due to the large CSI feedback overhead corresponding to multiple CSI, which may not be suitable for PUCCH reporting. |
| vivo | Agree |
| DOCOMO | Support the proposal to ensure the feasibility of NES configuration and operation. |
| OPPO | We think aperiodic CSI reporting should be treated with high priority. We still hold conservative view on the periodic CSI reporting. We suggest the following revision:  P7-revision  **Specifications support CSI enhancements for network energy savings applicable at least for aperiodic CSI report procedure.**  **FFS: for periodic CSI report procedure, semi-persistent CSI report procedure** |
| Apple | We think current AP CSI report procedures can already provide enough adaptation flexibility, so the enhancement can be applied to periodic and semi-persistent report first. |
| Spreadtrum | Only periodic CSI reporting. AP and SPS CSI reporting is dynamic already. |
| ETRI | We are fine with the proposal. |
| Fujitsu | We are fine with the proposal. |
| ZTE, Sanechips | Support. We think all of these three types of CSI reporting are important for NES, especially for period CSI report, which is commonly used due to the benefits of less OH. |
| Huawei, HiSilicon | Support |
| Nokia/NSB | Although we are fine with the intention of the proposal, we think the current formulation is already concluding that there are enhancements needed. We think that could be one potential direction, but that would need to be discussed first. Also, whether all reporting types would be needed or not. |
| MediaTek | Support at least the use cases of periodic and/or semi-persistent CSI report.  PUSCH for aperiodic CSI report can carry more information so that existing multiple CSI framework without overhead enhancement may still fit in the volume. Also aperiodic nature also implies infrequently triggered. In this regard, CSI enhancement (overhead and UE computation complexity) reduction would be more beneficial for periodic and/or semi-persistent CSI report. In this regard, we support current version or a minimum version (somehow opposite from OPPO proposal):  **Specifications support CSI enhancements for network energy savings applicable at least for periodic CSI report procedure~~,~~ and semi-persistent CSI report procedure; ~~and~~ FFS aperiodic CSI report procedure.** |
| Xiaomi | Fine with the proposal. |

3.7 Definition of adaptation pattern/information for association

At least for discussion purpose, to identify what is an adaptation pattern would be useful and may also be necessary for configuration purpose. The following are expressed from contributions.

**Company proposals**

[Nokia, NSB]:

* For evaluating a spatial pattern, discuss how to enable the UE to determine the spatial configuration, such as codebook configuration (including codebook subset restriction), corresponding to a spatial pattern.
* Discuss the implications of different spatial patterns potentially having different channel characteristics in terms of frequency selectivity on the design of CSI report configuration, specifically from sub-band configuration perspective.

[OPPO]: RAN1 needs to clarify the definition of ‘spatial adaptation pattern’. Whether a such pattern already includes one spatial element before adaptation and another spatial element after adaptation?

[Spreadtrum]: Spatial adaptation pattern is not defined. (Observation: For Type 1, spatial adaptation pattern means the number of ports in a CSI-RS resource; for Type 2, spatial adaptation pattern means the number of antenna elements in a CSI-RS port.)

[CATT]:

* The dynamic selected number of adaptation of TxRUs should be specified selectively with consideration of the network energy gain and the overhead of the CSI reports in achieving the link adaptation gain.
* For spatial domain adaptation with type-1 antenna element mapping, the pattern of CSI-RS antenna ports should be configured to UE based on the mapping of the row/column of antenna array to the antenna ports.
* For type-2 spatial domain adaptation, each CSI-RS resource/resource set/resource setting is configured and associated with only one spatial adaptation pattern.
* For type-1 spatial domain adaptation, at least the following parameter should be considered in configuration of spatial domain adaptation pattern,
  + - Spatial adaptation indicator used for supporting spatial domain adaptation based CSI report enhancement;
    - Antenna array dimension parameter n1-n2 used for determination of the subset of the MIMO Codebook;
    - Antenna panel number Ng used for assistance in multi-Panel MIMO Codebook determination;
    - Active antenna port indexes corresponding to the spatial adaptation pattern;
    - CSI-RS power offset relative to the SSB based on spatial elements adaptation patterns which will be discussed in section 3.
* For type-2 spatial domain adaptation, at least the following parameter should be considered in configuration of spatial domain adaptation pattern,
  + - Common antenna array dimension parameter;
    - Common antenna panel number Ng;
    - ResourceMapping;
    - PeriodicityAndOffset;
    - PowerControlOffsetSS.
* The codebook subset restriction parameters need to be configured for each antenna pattern for dynamic spatial domain adaptation.

[NEC]: Consider using an associated TRX pool index to address the spatial domain configuration whenever the network enters into the energy saving mode.

[ZTE]: The following can be considered to define “spatial adaptation pattern”

* + - Codebook configuration,
    - Port indication for CSI with different number of ports.

[China Telecom]:

* The spatial patterns of CSI-RS should be defined and configured for UE in advance to achieve the spatial domain adaptation mechanism.
* The number of switched off spatial elements should be specified and restricted to several certain numbers.

[ETRI]:

* For the purpose of discussion, a “spatial adaptation pattern” is defined as a combination of 1) a subset of CSI-RS antenna ports from the total set of CSI-RS antenna ports and 2) virtualization of the subset of CSI-RS antenna ports.
* To improve signalling efficiency, a subset of CSI-RS antenna ports can be represented by (unmuted rows, unmuted columns) based on 2D CSI codebook structure.

[MediaTek]: A 'spatial adaptation pattern' is an augmented configuration based on an NZP-CSI-RS resource configuration that include the associated NZP-CSI-RS-ResourceId, a target value of 'nrofPorts' and a list of candidate values of 'powerControlOffset' or 'powerControlOffsetSS'.

* + - Selection of 'powerControlOffsetSS' or 'powerControlOffset' can depend on whether or not the power of CSI-RS is to be adjusted per spatial and power domain adaptation.
    - Note: There can be multiple spatial adaptation patterns associated to an an NZP-CSI-RS resource configuration, each of which contains different target value of 'nrofPorts' and potentially different candidate value(s) of 'powerControlOffset' or 'powerControlOffsetSS'.

[LGe]: Spatial adaptation pattern represents a number of antenna ports for type 1 or a number of enabled antenna elements associated to a logical antenna port for type 2.

[Apple]: A spatial adaptation pattern can be determined by one of the following CSI-RS resource parameters nrofPorts, TCI-State and/or powerControlOffsetSS.

[Qualcomm]:

* A spatial adaptation pattern includes a codebook configuration and reduced NZP CSI-RS resource(s) for channel measurement with the same number of antenna ports as that in the configured codebook.
  + - An antenna array corresponding to the spatial adaptation pattern is a uniform linear array with a supported configuration provided in Table 5.2.2.2.1-2 and Table 5.2.2.2.2-1 of TS 38.214 for Type-I single panel and Type-I multi-panel, respectively.
    - FFS: how to determine the reduced NZP CSI-RS resource(s).
* If RAN1 adopts A2-2 for CSI report configuration and A1-2 for NZP CSI-RS resource set configuration, the following aspects are included for an CSI report configuration.
  + - NZP CSI-RS resource set configuration for channel measurement includes CSI-RS resources with the same number of antenna ports.
    - Reduced NZP CSI-RS resource(s) for channel measurement corresponding to a spatial adaptation pattern are determined from the resource(s) in the configured CSI-RS resource set.
    - The CSI processing requirements (e.g., CPU counting, counting of simultaneous active CSI-RS resources, etc.) are scaled linearly by the number of codebook configurations and the number of CSI-RS resources for each configured codebook in the CSI report configuration.

[Fraunhofer]: define a spatial adaptation pattern as a configured subset of all available ports in an array of antenna ports at the gNB.

[KT]:

* (Observation) spatial adaptation pattern can be interpreted as CMR partitioning pattern for CSI acquisition from a UE perspective.
* for CSI reporting, we can define spatial adaptation pattern group that comprises the spatial adaptation patterns which achieve identical network energy saving gain.
* best CSI reporting can be configured with the spatial adaptation pattern ID per spatial adaptation pattern group.

**FL summary**

One raised question is that whether such a pattern already includes one spatial element before adaptation and another spatial element after adaptation. Although according to the views provided that CSIs should be available before adaptation, the pattern definition may be different depending on the solutions and signalling, e.g. whether the consideration is for RRC parameters, and for DCI indication if introduced. The pattern here at least should be able to provide certain information related to how spatial elements may be shut down and those information needs to be known by a UE for its measurement and CSI feedback. They can be existing parameters or new parameters, if necessary.

To avoid the impression that an explicit definition of spatial adaptation pattern is needed, suggest to directly discuss the necessary information for RRC (noting that, any need of L1/L2 indication would be firstly based on RRC configuration, so relation to the content of L1/L2 indication can be deferred).

**Q10**

**For spatial domain adaptation,**

* **the following parameters are proposed for RRC configuration**
  + - **indicator used for supporting spatial domain adaptation based CSI report enhancement**
    - **nrofPorts**
    - **Antenna port indexes (FFS active or non-active)**
    - **Codebook configuration n1-n2**
    - **Antenna panel number Ng (for multi-Panel)**
    - **Common antenna array dimension parameter**
    - **Common antenna panel number Ng**
    - **Codebook configuration n1-n2**
    - **Antenna panel number Ng (for multi-Panel)**
    - **ResourceMapping**
    - **powercontroloffset**
    - **PowerControlOffsetSS**
    - **Index to a spatial adaptation pattern**
    - **Index to spatial adaptation pattern group**
* **Which do you consider are needed or shared, considering the following respective configuration approaches**
  + - **A1-1-revised: multiple resources are configured within a resource setting, where each resource is associated with only one spatial adaptation pattern**
    - **A1-2-revised: a resource setting with one resource is configured, where the resource is associated with more than one spatial adaptation patterns**
* **Note: TCI-State can be separately discussed in other sections**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| DOCOMO | The priority of the issue is low. It can be discussed later. |
| Spreadtrum | Multiple CSI-RS resource is supported in current spec, so all above parameters can be changed as a whole set. No need to discuss them separately. |
| ETRI | Agree with direction. We can further discuss what is necessary parameters for CSI-RS resource configuration and CSI reporting configuration to express 'spatial adaptation pattern'. |
| Fujitsu | It should be discussed after the agreement w.r.t. CSI-RS resource configuration is reached. |
| Nokia/NSB | The above question is covering several aspects, and this may not be efficient from discussion perspective. Also, some of the aspects are covered in other previous questions.  At least some of the listed aspects could be discussed after the baseline operation is agreed. |

**Q11**

**How many patterns/CSI-RS resources/resource sets/resource setting/sub-configurations in reportConfig/report config(s) do you consider are needed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | This depends on UE capability. Prefer to discuss 2,4 corresponding to different capability levels |
| DOCOMO | The priority of the issue is low. It can be discussed later. |
| ETRI | This issue can be discussed later. |
| ZTE, Sanechips | If gNB has more information about channel state of different number of ports, it has more choices to adapt the antenna patterns to fit into traffic arrival and channel condition without sacrificing system performance. However, UE complexity will be increased if the number of antenna patterns increases. The CSI enhancement should not exceed the legacy UE capability. Hence, we think at least 2,3,4 patterns should be supported. |
| Nokia/NSB | In our view, defining an exact (max) number of spatial patterns to consider in a report configuration is not essential. We could discuss this at a later stage, also considering UE capability etc. |

3.8 Need of adaptation of spatial/transmission power of CSI-RS

There are many discussion regarding the adaptation of CSI-RS, in addition to PDSCH.

**Company proposals**

[FW]: It should be left to network implementations to ensure that the coverage of SSB and/or the CSI-RS are not negatively impacted due to spatial patterns adaptation.

[Huawei, HiSilicon]: reducing the transmission power of CSI-RS is unnecessary.

[Nokia, NSB]: (Observation) If spatial adaptation is not allowed to impact at least some of the CSI-RSs (other than the ones used for spatial patterns evaluation), less network energy savings will be achieved and the gNB wouldn’t be able to e.g., multiplex CSI-RS and PDSCH in the frequency domain (at least in some cases).

[vivo]: Spatial element adaptation and power offset adaptation are not applicable to the CSI-RS Resources for L1-RSRP/L3-RSRP measurement/ beam management.

[CATT]: Coverage of common control channels/signals with spatial domain adaptation should remain the same.

[ZTE]:

* (Observation) The spatial element adaptation with type 1 mapping method does not impact the antenna port configuration of CSI-RS resources for beam management.
* (Observation) The impact on beam management with type 2 mapping method can be avoided by NW implementation.

[Samsung]:

* RAN1 should specify necessary enhancements to support the case when CSI-RS transmission power changes per Type 2 SD adaptation.
* For Type 2 SD adaptation, each NZP CSI-RS resource/resource set/resource setting can include one or more of CSI-RS transmission powers.
* Introduce a signaling mechanism for indicating CSI-RS transmission power change for CSI calculation.

[CMCC]:

* Dynamic adaptation for CSI-RS should be supported for semi-persistent and periodic CSI-RS.
* Uplink power control enhancement is needed for separate uplink and downlink spatial adaption case.

[Transsion]: It is suggested that spatial element adaptation of CSI-RS may be not supported.

[AT&T]: Further study whether adaptation of the number of antenna ports is limited to UE-specific PDSCH transmissions or also extends to cell-wide CSI-RS transmissions

* + - In the latter case, group re-configuration should be specified for efficient signaling of the spatial network energy savings state to all UEs.

[Ericsson]: Type-2 spatial element adaptation enhancement is not supported in symbols configured with periodic CSI-RS. I.e., updates to *powerControlOffsetSS* are not supported for periodic CSI-RS.

**FL summary**

Views for support of adaptation on CSI-RS are split. 6 companies (Nokia/NSB, Samsung, CMCC, and InterDigital, Fujitsu, LGe as they mentioned in the section of ‘Beam management and/or measurement related CSI enh.’) consider it is necessary to support enhancements for compensation of the potential power change for type 2 shut down. 7 (FW, Huawei/HiSi, vivo, CATT, ZTE, Transsion, E//) consider such enhancement is not needed, either because the WID said adaptation is only applied to PDSCH, or consider such power change to PDSCH can be handled by gNB implementation. 3 companies (NEC, Lenovo, AT&T) propose to continue study. For the moment, the following is made.

**Q12**

**Do you consider Type-2 spatial element adaptation enhancement is not supported in symbols configured with CSI-RS?**

**If it is supported, do you consider the impact on CSI-RS transmission power/coverage needs further enhancement or can be up to gNB handling?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| DOCOMO | Same behavior is expected for Type 1 and Type 2 adaptation. Then enhancement of Type 2 spatial adaptation enhancement can be supported in symbols configured with CSI-RS. The coverage issue can be up to gNB handling. |
| Fujitsu | Both type 1 adaptation and type 2 adaptation can be supported in symbols configured with CSI-RS. If adaptation is also performed for 1-port or 2-port CSI-RS, enhancements on BFD and RLM are necessary to avoid false alarm of beam failure and radio link failure. |
| ZTE, Sanechips | If the number of antennas for CSI-RS transmission is reduced, the transmission power and coverage will be degraded. In this case, the cell-edged UEs cannot detect CSI-RS and will seriously affect the user experience. Hence, we prefer that Type-2 spatial element adaptation enhancement is not supported in symbols configured with CSI-RS. |
| Huawei, HiSilicon | For type 2 shutdown, no need to do some enhancement for CSI-RS, e.g. boost the transmission power of CSI-RS.   1. In type 2 shutdown case, if a weak transmission CSI-RS is received by a UE, it is used for the UE to measure the corresponding RS and report the CSI, thus with multiple measurement and report corresponding to different patterns with potentially weak CSI-RS transmission, gNB can essentially take use of that for better adaptation decision. 2. Even if the gNB decides to boost the CSI-RS transmission power to get a better CSI measurement, independent IE *nzp-CSI-RSresource* can be used to configure the CSI-RS resource in type 2 shutdown case as supported in current mechanism already. gNB can configure IE *nzp-CSI-RSresource* by considering the increased transmission power of CSI-RS, potentially for multiple patterns, and choose better CSI. So, static RRC informing CSI-RS transmission power for type 2 shutdown is sufficient. |
| Nokia/NSB | In general, we support considering the impact of spatial adaptation on at least some of the CSI-RS (we could discuss if this includes CSI-RS for beam failure detection or not, …). This would be beneficial e.g., to allow multiplexing PDSCH and CSI-RS in the frequency domain, and more generally to achieve more NES gains/opportunities.  If the above is agreed, we could further discuss whether there is need to indicate the UE a change of power or, equivalently, change of number of antenna elements; and this could be even considered from an antenna port perspective. |

3.9 Need of adaptation of Panel

Also, panel-wise adaptation and relevant issues/procedures are analysed by below.

[Lenovo]:

* Dynamic switching between single-panel operation and multi-panel operation supported in legacy design can be used for NES purposes
* Dynamic switching between single-panel operation and Rel-17 SFN operation supported in legacy design as an optional feature can be used for NES purposes
* If the NES mode is activated for DL CJT with NPanel panels, only a subset of the panels are activated. FFS: the value of N’
* Support enhanced beam reporting, which allows a UE to report the best N beams for each antenna panel independently in one CSI report for NES purposes

**FL summary**

It reads a bit too broad in order to propose anything for potential agreements, e.g. what needs to be switched between single-panel operation and multi-panel operation/R17 SFN operation, and what parameters represent for N beam (e.g. CRI). It is suggested that the proponent to specifically indicate what RRC parameters/L1 indication are needed as well as other necessary specification enhancement for the panel adaptation for NES, in respective sections e.g. CSI-RS resource configuration, definition of adaptation pattern (although note that multi-TRP is out of the scope).

**Q13**

**Companies are also invited to share your views about the proposals from the proponent.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | In Rel-18, CSI reporting enhancements for CJT are supported with two modes, where in Mode 2 the different nodes correspond to co-located panels with the same average delay. We understand that multi-TRP scenarios, e.g., NCJT are out of scope of NES enhancements, however for CJT, where some modes support co-located panels, the answer is not clear to us. We are OK to defer discussion on this question if the moderator (and other delegates) believes this is out of scope as well |
| DOCOMO | The priority of the issue is low. It can be discussed later. |
| Nokia/NSB | Multi-panel case could be explicitly considered in the discussion, but we prefer to first focus on defining the baseline operation for the single panel case.  Also, the use of multi-panel may be transparent to the UE where the gNB could represent a panel by a subset of antenna ports. |
|  |  |

3.10 Beam management and/or measurement related CSI enh.

For bean management, and also other L1/L3 measurement, there are following proposals.

**Company proposals**

[Nokia, NSB]:

* Discuss whether the existing TCI state indication procedures should be enhanced when considering spatial pattern adaptation.
* Discuss how/whether spatial adaption impacts beam failure detection and beam recovery procedures.

[vivo]: Spatial element adaptation and power offset adaptation are not applicable to the CSI-RS Resources for L1-RSRP/L3-RSRP measurement/ beam management.

[CATT]: Multiple beam management functions could be performed with each BM function associated with one TxRU set.

[NEC]:

* Study the impact of spatial elements adaption if the CSI-RS resource is configured as reference RS in TCI state, QCL info, spatial relation, and pathloss reference signal.
* Support scaling the threshold of beam failure detection and threshold of candidate beam identification for power domain network energy saving.

[ZTE]: The enhancement on beam management should be deprioritized.

[InterDigital] RAN1 to consider solutions reducing signaling overhead from changes of TCI states when Type 2 adaptation is used.

[Google]: The enhancement on beam measurement and report for NES should only focus on CSI-RS based beam measurement and report.

[Fujitsu]: Enhancements on RLM and RRM measurement on CSI-RS are necessary considering the potential transmission power fluctuation of 1-port CSI-RS due to adaptation of spatial element.

[Samsung]:

* Specify a solution for preventing beam failure and/or RLF due to potential SD/PD adaptation, e.g., hypothetical beam failure and/or RLF reports for the indicated hypothetical power offset values.
* Specify a solution to enhance beam failure recovery procedure, e.g., switch/update of RS set for beam failure detection and that for candidate beam identification according to the network adaptation.

[CMCC]:

* Enhancements can be studied to enable UE to jointly measure CSI-RS or PL RS transmitted before and after spatial elements on/off.
* Threshold for beam failure recovery or radio link monitoring may be needed to update together with spatial elements on/off.
* TCI states may be needed to update simultaneously with the adaptation of spatial elements.

[LGe]:

* Consider at least the following issues for beam management enhancement.
  + - How to inform UE to adjust the RX beam when receiving a specific CSI-RS for beam management
    - How to handle the case where CSI-RS configured for beam management, radio link monitoring or link recovery procedures is affected by gNB’s adaptation of spatial elements
    - How to adjust the number of repetitions for a CSI-RS resource with the higher layer parameter repetition set to 'on' or 'off'
* Consider the following methods for TCI configuration enhancement.
  + - Method 1: Configure multiple candidate CSI-RS resources as reference signal for QCL information or for spatial relation information, and switch one of them based on L1/L2 signaling
    - Method 2: Configure multiple candidate sets of TCI state(s) associated with DL/UL signal/channel and switch one of them based on L1/L2 signaling
    - Method 3: Invalidate DL/UL signal/channel related to a CSI-RS resource that is deactivated or affected due to gNB’s adaptation of spatial elements

[Lenovo]: For Type2 spatial domain adaptation, evaluate whether the antenna element per port adaptation impacts the accuracy of the QCL relationships between DL/UL RSs.

[AT&T]: If RAN1 agrees to support type 2 spatial adaptation, study the need for beam management and beam failure enhancements.

[Docomo]: Configured TCI may be invalid due to dynamic spatial and power adaptation. An enhanced TCI switch mechanism corresponding to dynamic adaptation should be supported.

[Fraunhofer]: RAN1 to discuss mechanisms to enable UEs to perform beam measurement and efficient reporting to meet NES requirements while maintaining sufficient link gains.

**FL summary**

A number of companies mentioned the need of enhancement for beam management and TCI framework. A first question is whether such enhancement is only motivated due to support of type 2 spatial adaptation.

**Q14**

**If Type-2 spatial element adaptation is not applied in symbols configured with CSI-RS, do you consider what enhancement is needed for beam management and/or TCI framework?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| DOCOMO | We already agree that both types of spatial adaptation should be supported. If Type-2 adaptation is not applied to symbols with CSI-RS, can we consider that Type-2 adaptation is not supported? |
| ZTE, Sanechips | No enhancement is needed. |
| Nokia/NSB | We don’t think this is only motivated by Type 2 adaptation, but generally by any spatial adaptation type. |
|  |  |

**P8**

**At least if Type-2 spatial element adaptation can be applied in symbols configured with CSI-RS, further study the enhancement of beam management and/or TCI framework.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | Support |
| vivo | We don’t see the need to adopt spatial element adaptation for the CSI-RS Resources for L1-RSRP/L3-RSRP measurement/ beam management. So there is no need to consider enhancement of beam management and TCI framework. |
| DOCOMO | Support the proposal. |
| OPPO | More discussion is needed. |
| Apple | Fine for study. |
| ETRI | Fine to study further. |
| Fujitsu | We are fine with the proposal. |
| ZTE, Sanechips | Even if the Type-2 spatial element adaptation can be applied in symbols configured with CSI-RS, the impact on beam management brought by the spatial element adaptation can be avoided by NW implementation. The gNB does not need to perform spatial element adaptation for the CSI-RS resources configured for beam management, and a small amount of energy saving gain is sacrificed to avoid the impact. |
| Huawei, HiSilicon | Support |
| Nokia/NSB | Fine to consider this proposal. |
| MediaTek | Support and think indication of the corresponding power level changing will be useful to minimize impact to potential channel averaging utilized in beam measurements. |
| Xiaomi | Support |

3.11 Need of transition time due to adaptation

There is study point related to transition time.

|  |
| --- |
| **Agreement**  Discuss the signalling aspects for spatial/power domain adaptation for Rel-18 NES-capable UEs considering that   * Whether there is a need for transition time per adaptation (for UE) * Whether/How to inform UE on spatial adaptation pattern update and/or PDSCH/CSI-RS transmission power change due to adaptation. |

Views from companies are given below.

**Company proposals**

[Huawei, HiSilicon]: Transition time per adaptation (for UE) is unnecessary.

[Nokia, NSB]:

* The impact of transition time for spatial adaptation should be accounted for when deciding on the option(s) (regarding resource configuration discussed above) to adopt to enable the evaluation of multiple spatial patterns.
* Discuss the need to specify transition time for spatial adaptation taking into account the different (sleep) states the gNB could be transitioning from/into.

[CATT]: From the UE perspective, there is no transition time for the antenna pattern change in the spatial domain adaptation.

[MediaTek]: RAN1 to further discuss and decision which of the following restrictions is adopted for spatial and power domain NES adaptation:

* + - Alt 1: A data interruption time is introduced
      * FFS: Interruption time duration(s), which may depend on UE capability report
    - Alt 2: Restriction in the range of change of number of CSI-RS ports and PDSCH (and CSI-RS) power offset(s), w.r.t. the setting before NES adaptation.

**FL summary**

2 companies consider that transition time is not needed and can be handled by gNB scheduling. One company consider this transition time also relates to gNB sleep states. Further one company consider such impact may lead to data interruption and/or require restriction to adaptation in terms of range of ports/power change.

The possible causality of such an impact on UE and whether it requires restrictions to gNB is not sufficiently elaborated yet. At least from gNB perspective, it may be up to gNB control how to utilize the different sleep states for scheduling. For UE, some companies mention AGC while some companies also consider AGC is not an issue. This needs more discussion.

**P9**

**Further study the impact of spatial and power domain adaptation, considering:**

* **whether data interruption time/transition time is introduced**
* **whether restriction in the range of change of number of CSI-RS ports and/or PDSCH (and CSI-RS) power offset(s) is needed**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | We are fine with the proposal |
| vivo | We don’t think transition time or time restriction for UE is needed. It can be handled by gNB scheduling. However, we are open to discuss. |
| DOCOMO | Support the proposal. |
| OPPO | Support |
| Apple | Support. We think the transition time per adaptation is important for UE to accommodate for the CSI computation or CSI-RS measurement. |
| Fujitsu | We are fine with the proposal |
| ZTE, Sanechips | We don’t think the transition time for UE is needed. It is adaptation at gNB side. |
| Huawei, HiSilicon | We support further study. |
| Nokia/NSB | We understand the views saying that accommodating ‘transition time’ could be left up to gNB implementation. However, we think we should discuss this aspect so that a common understanding between companies is reached in that regard. To this end, we suggest considering our following observations (copied from our Tdoc R1-2302393) as a starting point for the discussions:  **Observation 28:** **There would be no transmissions of (DL) signal/channels possible during a NW transition time for spatial adaptation, at least considering the spatial elements being impacted by the adaptation.**  **Observation 29: The transition time range for spatial adaptation would depend on the sleep state the gNB is transitioning from/into, and it might also depend on whether analog or hybrid beamforming is considered.**  **Observation 30: Even for the cases where a somewhat large transition time is required for spatial adaptation, the gNB should be able to reduce the impact of such transition time as much as possible still based on implementation. Also, introducing and specifying a transition time would potentially require noticeable specifications efforts.**  On the second bullet-point, we think that the power related aspect for PDSCH could be more discussed under the power domain adaptation. Overall, we see need to indicate the UE a ‘change’ of power adaptation and/or number spatial elements (where this latter one could be considered from antenna port perspective, e.g., for Type 2 adaptation). The need for a restriction in the range reading ‘change’ indication should also be considered in the discussions. |
| MediaTek | While restriction is useful for UE to accommodate the impact due to spatial and power domains adaptation, explicit indication for PDSCH (and CSI-RS) power change timing and value(s) can potentially help UE to deal with the power change more smartly. In this regard, one additional bullet is suggested for the proposal:  **Further study the impact of spatial and power domain adaptation, considering:**   * **whether data interruption time/transition time is introduced** * **whether restriction in the range of change of number of CSI-RS ports and/or PDSCH (and CSI-RS) power offset(s) is needed** * **Explicit indication for PDSCH (and CSI-RS) power change timing and value(s)** |

**Q15**

**For further discussion, please elaborate the aspects/reasons that may lead to**

* **data interruption time/transition time, and/or**
* **restriction in the range of change of number of CSI-RS ports and/or PDSCH (and CSI-RS, if agreed) power offset(s)**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | If different spatial adaptation patterns correspond to different CSI-RS resources of the same CSI-RS resource set, the number of CSI-RS ports corresponding to the different spatial adaptation patterns should remain the same, otherwise further spec enhancement is needed |
| Nokia/NSB | To further discuss the transition time aspect, we copy the following from our Tdoc (R1-2302393):  Regarding the transition time for spatial pattern change, there are two main cases to consider:   * Case 1 – CSI-RS transmissions to enable spatial adaptation: depending on which option(s) among the various options discussed earlier in this contribution, there may be a need for a transition time between two (consecutive) CSI-RS resources transmitted using different spatial patterns. * Case 2 – spatial adaptation for PDSCH: when the gNB decides to adapt the spatial pattern for PDSCH transmissions, there would be a need for a transition time to switch from one spatial pattern to another.   One aspect to discuss is the assumption to make regarding the impact on gNB transmissions during the transition time. In our view, there would be no transmissions possible during this time, at least considering the spatial elements being impacted by the adaptation.  Another important aspect, be it for Case 1 or Case 2 above, is whether the gNB could accommodate the transition time for spatial adaptation based on gNB implementation. This could be feasible potentially depending on the range/values to assume for the required transition time. The transition time range would depend on the sleep state the gNB is transitioning from/into, and it might also depend on whether analog or hybrid beamforming is considered etc. |
|  |  |
|  |  |

3.12 Need of signalling to UE due to adaptation

The relevant agreements are excerpted as below.

|  |
| --- |
| **Agreement**  Discuss the signalling aspects for spatial/power domain adaptation for Rel-18 NES-capable UEs considering that   * Whether there is a need for transition time per adaptation (for UE) * Whether/How to inform UE on spatial adaptation pattern update and/or PDSCH/CSI-RS transmission power change due to adaptation. |

**Company proposals**

[FW]: The association based on layer 1 signaling should be introduced to dynamically signal the following to the UE the CSI-RS resources to use for its CSI reporting:

* + - The CSI-RS resource or subset of CSI-RS resources that corresponds to different number of antenna ports, and/or
    - The CSI-RS resource set that corresponds to different number of antenna ports.

[Huawei, HiSilicon]:

* Informing the UE on spatial adaptation pattern update and/or PDSCH transmission power change is unnecessary.
* There seems no need for gNB to indicate which exact CSI-RS resources for UE to measure and report, unless there are a large amount of CSI-RS resources configured.

[Panasonic]:

* Further study below L1 signaling enhancement:
  + - Enhancement based on aperiodic CSI report procedure,
    - Enhancement based on semi-persistent CSI report procedure,
    - Enhancement based on adaptation of periodic CSI report procedure.
* Enhancement of L1/L2 signal can be designed with unified structure to support dynamic spatial element and power domain adaptation.

[Nokia, NSB]:

* Support signalling of spatial pattern change to the UE. Discuss signalling content of spatial adaptation, considering that different spatial patterns may differ in at least one of the following spatial elements:
  + - Set of antenna ports,
    - Set/number of active (or muted) antenna elements or TxRUs for one or more antenna ports.
* Discuss signalling ways for spatial adaptation, considering the following options as a baseline:
  + - Option 1: Use DCI, including group common DCI if seen beneficial, to indicate the UE(s) a spatial pattern change/adaptation.
      * This option could include leveraging signaling for existing operation(s) if feasible/possible.
    - Option 2: Use MAC CE to indicate the UE(s) a spatial pattern change/adaptation.
    - Option 3: Use semi-static or even semi-dynamic configuration and operation, i.e., via RRC or MAC CE, for switching between various spatial patterns over different period of times, i.e., spatial partitions in time. And use dynamic signaling, via DCI or MAC CE, to update such configuration.

[vivo]: Support group common DCI to indicate the active sub-configuration corresponding to a spatial adaptation pattern that UE shall report. For each CSI reporting occasion corresponding to one report configuration, only one sub-configuration can be indicated as active.

[CATT]: The L1-signaling indication of antenna pattern is essential to be included in the DCI format when spatial domain adaptation is performed with the number of Tx antenna changes with different antenna pattern.

[NEC]:

* Consider the activation of different network energy saving techniques (e.g., time, frequency, spatial, power) via semi-static network energy saving configuration.
* Support both accumulative value indication and absolute value indication for efficient adaption of power and spatial elements for network energy saving.

[Intel]: Consider supporting L1 based signaling, such as DCI based signaling, that enables re-configuration of CSI-RS resources and CSI report for a group of UEs.

[Fujitsu]:

* For single CSI feedback, group-common L1 signaling should be considered to efficiently indicate the UEs of the CSI-RS resource/report update.
* For multiple CSIs feedback, UCI overhead and CSI processing complexity reduction is required. To achieve this, gNB selects the CSIs to be reported and indicates them to UE.
  + - Dynamic signaling is used for indicating UE of the CSIs need to be measured and reported

[ZTE]: To better adapt to CSI reporting requirements, dynamic indication of one or more CSIs can be considered, where the dynamic indication should convey information for one or multiple spatial adaptation patterns to support multi-CSIs.

[InterDigital]:

* A DCI can indicate subset of antenna ports applicable to a group of NZP CSI-RS resources for CSI reporting.
* The DCI indicating subset of antenna ports is received in a UE-group common search space.

[China Telecom]: The indication should be transmitted to UE to trigger the corresponding CSI measurement and reporting when the spatial adaptation happens. The new measurement is not for gNB to make the decision of adaptation but just to secure the network performance.

[Google]: Support dynamic activation/deactivation for a CSI report configuration.

[Samsung]:

* Introduce L1/L2 signaling for updating a given NZP CSI-RS resource/resource set/resource setting by indicating an index from the set of configured CSI-RS mapping patterns, CSI-RS transmission powers, and PDSCH transmission powers per Type 1 SD, Type 2 SD, and PD adaptations, respectively.
* Consider UE-group-specific L1 signaling for updating a given NZP CSI-RS resource/resource set/resource setting per SD/PD adaptation.
* If a L1/L2 signaling for updating a given NZP CSI-RS resource/resource set/resource setting is introduced, the number of active CSI-RS ports in a given active BWP should be derived based on the L1/L2 signaling indication.
* Extend the current TCI state indication DCI to additionally indicate a CSI-RS resource sub-configuration ID per SD/PD adaptation.
* Introduce L1/L2 signaling for updating a given CSI report configuration by indicating an index to a CSI report sub-configuration from the set of configurations per Type 1 SD adaptations.
* For multi-CSI reporting, a UE is indicated by the serving gNB a set of CSI-RS resource sub-configurations for which the UE reports CSI.
* Introduce a signaling mechanism for indicating CSI-RS transmission power change for CSI calculation.

[ETRI]:

* For use case 2, a spatial adaptation pattern that UE receives for CSI measurement can be dynamically indicated (switched) by a DCI.
* When the CSI-RS antenna port virtualization (or, beam pattern) is expected to change due to TX chain activation or deactivation, UE can be indicated to reset its CSI measurement or reporting behaviour.

[CEWiT]: gNB dynamically signalling information about the adaptation of spatial elements to the UE is supported. gNB adapting the spatial elements and indicating UE to report CSI corresponding to the adapted configuration is supported.

[MediaTek]:

* Specify cell-wise indication of spatial and power domain adaptation for NES, including
  + - Indication of change in maximum number of ports utilized for CSI (Type-1 disabling/enabling)
    - Indication of change in PDSCH and/or CSI-RS power offsets (Type-2 disabling/enabling)
    - Indication of (partial) reset to CSI and beam management procedures
* For cell-wise indication, utilize SIB for broadcasting the candidate settings of spatial and power domain adaptation for NES and some bit(s) in paging indications for activating one candidate setting for the NES adaptation.

[Lenovo]:

* Evaluate whether dynamic switching between two P/SP CSI reporting configurations corresponding to activated and deactivated NES modes is needed
* For Type1 spatial domain adaptation, evaluate the following sub-types for determining the selected antenna ports when the NES mode is activated
  + - Type1-A. Antenna port group indication via port-selection parameter in Type-II PS codebook type
    - Type1-B. Antenna port group indication via CRI field, where different CRI codepoints correspond to different antenna port groups of the same CMR

[AT&T]: Further study whether the actual number of spatial dimensions for which the UE shall report CSI uses L1 or MAC procedures

[Ericsson]:

* When a UE receives DCI indicating a trigger state with multiple sub-configuration indicators, the UE transmits one CSI report including CSI results corresponding to each of indicated sub-configurations.
* When a UE receives DCI indicating a trigger state including only one sub-config indicator, the UE measures and reports CSI according to the indicated sub-configuration only.

[ITRI]: For NES spatial domain adaptations, at least the following signal mechanisms for spatial element adaption should be discussed:

* + - UE specific DCI
    - Group common DCI
    - Cell-wise indication

**FL summary**

Apart from the purpose to mitigate/address the issue due to adaptation as discussed in the section of ‘Need of transition time due to adaptation’, there are other purposes for dynamic signalling, including switching/reconfiguration of CSI-RS resource(s), activation or deactivation of adaptation operation. A large number of companies support introduction of L1/L2 signalling to UE. For single-CSI feedback, it can be used for indication of the exact CSI-RS resource for UE to measure and report CSI as supported by [vivo, Apple], while for multi-CSI feedback, a subset of CSI-RS resources is indicated to reduce the UE burden while achieve fast adaptation, as proposed by 8 companies [FW, Nokia/NSB, CATT, Intel, Samsung, ZTE, ETRI, E//].

The signalling may be carried via DCI or MAC-CE. It may be carried in a UE specific, UE-group-common or cell-wise manner.

Considering the proposal in section of ‘CSI feedback’ where the gNB is assumed to be able to further indicate/trigger a subset of CSI(s),

**P10**

**If single-CSI feedback is supported, support L1/L2 signaling to indicate/trigger a CSI-RS resource corresponding to a spatial adaptation pattern.**

**If multi-CSI feedback is supported, support L1/L2 signaling to indicate/trigger a subset of CSI-RS resources corresponding to one or multiple spatial adaptation patterns.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | Support |
| DOCOMO | For indication of CSI-RS resource, we could discuss issues of section 3.3 and 3.4 firstly. After that we can come back here. |
| Apple | **We are supportive of L1/L2 signalling to activate/trigger the CSI-RS resource/report. For certain scenarios, e.g. Type 1 spatial adaption and power domain adaptation, no new resources are needed to be activated/triggered, only the report corresponding to a different spatial adaptation patter or power assumption needs to be triggered. Therefore, we propose the following modification:**  **If single-CSI feedback is supported, support L1/L2 signaling to indicate/trigger a CSI-RS resource/report corresponding to a spatial adaptation pattern.** |
| Spreadtrum | Both single and multi-CSI feedback is supported in current spec. We don’t know why to discuss them separately? |
| ETRI | We support the proposal. |
| Fujitsu | We are fine with the proposal. |
| ZTE, sanechips | Okay.  As we commented in P1, the indication/triggering of a single CSI feedback/one spatial adaptation pattern is a special case of multi-CSI feedback/multiple adaptation pattern, it can be considered together with multi-CSI feedback/multiple adaptation patterns. |
| Huawei, HiSilicon | We do not support L1/L2 dynamic signaling.  The motivation of gNB indicating subset of CSI(s) or one to report is not very clear for us. Why gNB needs some CSIs/one at some point and needs some other CSIs/ another one CSI at another point? From our perspective, gNB needs all CSIs to do the shutdown decision and scheduling decision. If only a subset of CSI(s) is reported by UE, gNB cannot do proper shutdown (due to the lack of all CSIs) which resulting in performance loss and less energy saving gain. |
| Nokia/NSB | It is a bit early to discuss this aspect. We should first discuss and agree on other (baseline) aspect. |
| MediaTek | Support and fine with Apple revision suggested. |
| Xiaomi | Fine with the proposal |

**Q16**

**Do you consider such signaling should be via DCI or MAC-CE?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| DOCOMO | It can be discussed later. |
| ZTE, Sanechips | Spatial/power domain adaptation will impact all UEs in a cell, MAC-CE is UE-specific signaling and may cost more signaling overhead. Hence, we prefer the signaling to be DCI, if dynamic indication is supported. |
| Nokia/NSB | This could be considered at a later stage, after some other important aspects are clarified. |
| Xiaomi | Also prefer to discuss it later. |

**Q17**

**Do you consider such signaling should be via UE-specific, UE group-common or cell-wise?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| DOCOMO | It can be discussed later. |
| ZTE, Sanechips | Similar with Q16, UE group-common DCI is preferred, if dynamic indication is supported.  For cell wise indication, it can be implemented via group common DCI by configuring the same RNTI for all the NES-capable UEs in the cell. |
| Nokia/NSB | This could be considered at a later stage, after some other important aspects are clarified. |
|  |  |

3.13 UE complexity/capability

UE complexity and relevant capabilities are one aspect that needs to be clarified/discussed as mentioned in WID.

|  |
| --- |
| * Note: Legacy UE CSI/CSI-RS capabilities applies when considering total number of CSI reports and requirements |

**Company proposals**

[Nokia, NSB]: Clarify the exact UE CSI/CSI-RS capabilities covered in the following Note (captured in the WI description):

* + - “Note: Legacy UE CSI/CSI-RS capabilities applies when considering total number of CSI reports and requirements.”
    - Without further clarifications on this Note, all the legacy capabilities related to total number of CSI reports and requirements would need to be assumed.

[Intel]:

* Discuss further whether legacy UE CSI capability related to total number of CSI reports and requirements can be utilized to only indicate to network energy saving enhancement of multi-CSI feedback for multiple CSI-RS resource set hypothesis (if agreed to be introduced) but not for general legacy UE CSI capabilities when UE is indicating more than 1 concurrent CSI report processing in a CC.
* From UE capability perspective, treat a CSI report setting for multiple CSI feedback corresponding to multiple CSI-RS resource set hypothesis as one CSI report setting per BWP.
* (Observation) The UE complexity for handling multi-CSI feedback in a CSI report for multiple CSI-RS resource set hypothesis may not be equivalent to multiple legacy CSI report for multiple legacy CSI-RS resource sets.
* (Observation) For type 2 port selection codebook, legacy capability for maximum number of port can be applied to infer support for any hypothetical CSI-RS port subset configuration that is strictly smaller than the maximum number of ports for NES enhanced multi-CSI feedback.

[Qualcomm]: UE reports a set of supported candidate values for the total number of CSI-RS resources per set for an CSI-RS resource set configured with repetition set to ‘on’.

**FL summary**

Although UE capability might be also discussed in a later stage, two companies noted that it is important to understand how the enhanced/developed UE capabilities are related to the legacy UE capabilities, and which.

Literally, total number of CSI reports and requirements is concerned and thus the directly relevant capabilities at least include the *csi-ReportFramework*. On the other hand, if all legacy capabilities and their general use also include the count for NES purpose, there can be other interpretation such that one joint report of CSI(s) can be treated as one report as proposed by Intel.

The total ‘requirement’ in the text could be vague about where it applies to (measured ports, report, CSI calculation or resource etc.). At least there is preference from one or two companies (Spreadtrum, Qualcomm) to consider CSI processing requirement as linearly scaled with e.g. number of CSI-RS resources as baseline, without compression. However this consequently leads to linearly scaled up UE complexity, thus FL consider whether it is really beneficial or not needs some more discussion. Nevertheless, the intention of such text in WID should be kept in mind such that UE vendors can afford the enhancements to be developed from this feature.

**Q18**

**Which legacy UE capability(ies) do you consider should apply, regarding the note in WID?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| DOCOMO | From our understanding, supporting R18 NES is one kind of new UE capability, so with the new capability, the extension of the UE capability defined in *csi-ReportFramework* can be considered if necessary. |
| Nokia/NSB | We think it’s important to reach common understanding between companies on the Note. As we indicated in our Tdoc, without further clarifications on the Note, all the legacy capabilities related to total number of CSI reports and requirements would need to be assumed. |
|  |  |
|  |  |

# DL transmission power adaptation

The objective for transmission power adaptation is as below.

|  |
| --- |
| * Specify necessary enhancements on CSI related procedures including measurement and report, and signaling to enable efficient adaptation of power offset values between PDSCH and CSI-RS [RAN1, RAN2] |

The relevant agreements are excerpted as below.

|  |
| --- |
| **Agreement**  For adaptation of power offset values between PDSCH and CSI-RS, further study the following   * Where/how to configure multiple power offset values   + Whether/how one or more power offset values are dynamically indicated to UE for CSI measurement/reporting, and PDSCH reception   + Overhead reduction for CSI reports associated with multiple power offset values between PDSCH and CSI-RS   + Whether other UE report content can be included |

By dividing companies’ proposals into different subsections, they can be summarized as below.

4.1 Adaptation of transmission power of PDSCH

**Company proposals**

[Nokia, NSB]: Configuration of multiple powerControlOffset values within a single NZP-CSI-RS resource is supported.

[OPPO]: RAN1 does not support CSI reporting based on multiple power offset configuration.

[Spreadtrum]: Dynamic switching among multiple power offsets between PDSCH and CSI-RS can be considered.

[Fujitsu]: Support each CSI-RS resource/resource set to be associated with multiple power offsets between CSI-RS and PDSCH.

[ZTE]: Each CSI-RS resource/resource set/resource setting can be associated with one or more power offset values.

[Samsung]: each NZP CSI-RS resource/resource set/resource setting can include one or more of PDSCH transmission powers.

[CMCC]: Multiple power offset values can be configured and dynamically indicated and/or activated.

[Transsion]: RRC signaling plus L1/L2 signaling can be used to configure the multiple power offset values between PDSCH and CSI-RS.

[LGe]: Power adaptation pattern represents a power offset value between PDSCH and CSI-RS.

[Qualcomm]: If RAN1 adopts a framework where UE performs CSI for more than one power offset value for a CSI report config, the following aspects are included.

* + - The CSI processing requirements (e.g., CPU counting, counting of simultaneous active CSI-RS resources, etc.) are scaled linearly by the number of power offset values and the number of CSI-RS resources in the CSI report configuration that gNB requests CSI report.

[Ericsson]:

* For power domain adaptation, for aperiodic CSI reporting, support configuration of one or more *powerControlOffsets* within a trigger state.
* When a UE receives DCI with a trigger state indicating multiple *powerControlOffsets*, the UE transmits one CSI report including CSI results corresponding to each of the *powerControlOffsets*.
* When a UE receives DCI indicating a trigger state including only one *powerControlOffset*, the UE measures and reports CSI according to that *powerControlOffset*.

**FL summary**

Many support of configuring multiple poweroffset between CSI-RS and PDSCH is observed. 4 companies also support the introduction of L1/L2 signalling for further indication/triggering a subset of power offset value(s). One company consider it shout not be supported while one company can be conditional supportive. Since there is still uncertainty on whether RRC configured multiple power offsets can be agreeable or not, the introduction of L1/L2 signalling on top of that is separately discussed. Note there is an FFS on the impact on CSI processing requirements set for power domain adaptation, while this can actually be discussed together with that for spatial domain adaptation techniques.

**P11**

**For power domain adaptation, support configuration of more than one power offset values for PDSCH relative to CSI-RS**

* **FFS: impact on CSI processing requirement**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | Support. Different power offset values may impact RI, PMI and CQI, e.g., lower PDSCH power implies lower rank would be supported and vice versa, leading to impacting PMI and CQI in turn. |
| vivo | Ok in principle.  We prefer to use the same framework for multiple power offset configuration as for spatial adaptation pattern. |
| DOCOMO | Support the proposal. |
| OPPO | Based on our simulation results, we don’t see the benefits. Thus, we don’t support this proposal. |
| Apple | We are fine with the proposal, and we think a common configuration framework should be strived for both spatial and power adaptation. |
| ETRI | Support the proposal. |
| Fujitsu | We are fine with the proposal. |
| ZTE, Sanechips | Agree.  UE performs CSI measurement with more than one power offset values and report multi-CSI can guarantee the network obtain the proper/accurate CSI measurement results and assist the network for the dynamic transmission power adjustment. |
| Huawei, HiSilicon | Support  Similar to spatial domain, gNB can do proper shutdown and scheduling decision based on the multiple CSIs. |
| Nokia/NSB | We support the proposal |
| MediaTek | Support and think the power offset(s) can also be used for UE to estimate the CQI with reduced/increased beam power level due to Type-2 adaptation. |
| Xiaomi | Support the proposal. Besides, a unified framework for spatial and power adaption is preferred. |

**Q19**

**For power domain adaptation, do you consider there is need to introduce L1/L2 signalling, for e.g. indicating/switching the adaptation(s) corresponding to a (subset of) power offset values?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo |  |
| vivo | We prefer to use the same framework for multiple power offset configuration as for spatial adaptation pattern. To be specific, we prefer to indicate only one power offset value as that for spatial domain adaptation |
| DOCOMO | RAN1 should provide the gNB the feasibility to configurate power offsets. We consider above is necessary. |
| ETRI | If a unified design for spatial and power domain adaptations is taken, Q19 may correspond to P10. |
| Fujitsu | Similar as spatial element adaptation, L1/L2 signaling can be considered for indicating the hypothesis power offset or a subset of hypothesis power offset. |
| ZTE, Sanechips | If the dynamic indication is considered for spatial domain adaptation, similar framework can be applied to power domain. |
| Huawei, HiSilicon | Seems not necessary. The same reason as we discuss in spatial domain. |
| Nokia/NSB | We think that there is no need for L1/L2 signalling to indicate which power offset value is used for CSI reporting. However, indication of actual PDSCH power change using L1/L2 signalling should be considered. |
| Xiaomi | Signaling to indicate the power offset adaptation is beneficial for improving the CSI accuracy. Thus, it should be supported. |

4.2 Need of adaptation of transmission power of CSI-RS

**Company proposals**

[Huawei, HiSilicon]: reducing the transmission power of CSI-RS is unnecessary.

[CATT]:

* Each CSI-RS resource should be configured with one or more power offset relative to the SSB based on spatial elements adaptation patterns.
* With configuration of multiple *powerControlOffsetSS* values associated with different spatial element adaptation patterns, additional enhancement on *powerControlOffset* value is not needed for feedback overhead reduction purpose.

[Transsion]: It is recommended to change only the power of PDSCH.

[Ericsson]: For power domain adaptation techniques, dynamic updates for *powerControlOffsetSS* are not supported.

**FL summary**

Only small number of companies contribute on this with split views.

**Q20**

**Do you consider there is need to support dynamic update of *PowerControlOffsetSS*, at least for power domain adaptation?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Lenovo | No. Dynamic update of PowerControlOffsetSS is not needed, so far the proponents have not provided evidence on whether energy savings corresponding to power adaptation of CSI-RS has considerable gains compared to PDSCH power adaptation |
| vivo | No need to consider. |
| DOCOMO | From our understanding, the adaptation of the power offset between CSI-RS and SSB is out of the scope of R18 NES WI. |
| ZTE, Sanechips | There is no need to dynamic update of *PowerControlOffsetSS*. |
| Nokia/NSB | This question seems to be related to Q12 above. RAN1 should wait for Q12 to progress before discussing this. |

4.3 CSI report configuration and reporting

**Company proposals**

[Nokia, NSB]:

* CSI report based on NZP-CSI-RS resource containing multiple power offset values is specified
  + FFS how the size of the report is reduced
* CSI reporting is enhanced by adding information about how much PDSCH power can be reduced and still maintain the same rank and/or MCS that is achievable with the powerControlOffset value included in the NZP-CSI-RS configuration.

[CATT]: With configuration of periodic CSI report setting, multiple sub-CSI associated with different powerControlOffset values should be reported to gNB.

[NEC]: Support UE to report its tolerance of potential PDSCH power reduction.

[Fujitsu]: Both single CSI feedback and multiple CSIs feedback can be considered for CSI tracking when dynamic adaptation of PDSCH transmission power is adopted.

* + - For single CSI feedback, group common L1 signaling to update of power offset between CSI-RS and PDSCH should be considered
    - For multiple CSIs feedback, gNB could indicate to UE the hypothesis power offsets for CSI measurement and report to reduce UCI overhead.

[ZTE]: Multi-CSI report with multiple power offset values between PDSCH and CSI-RS should be supported. Differential CQI should be can be adopted for multi-CSI in one reporting with multiple power offset values.

[xiaomi]: Enhancement to enable CSI reporting with multiple power offsets should be introduced.

[InterDigital]:

* A CSI report contains CSI information associated with at most one power offset value.
* CSI report contains indication of assumed power offset adjustment.

[China Telecom]: Support one CSI report contains multiple CSIs corresponding to different power control offsets. FFS: mechanism to reduce the reporting complexity.

[Google]:

* Support the UE to report a power backoff indicator (PBI) in a CSI report indicating the potential transmission power backoff for PDSCH.
* Support to introduce a CQI subset restriction to reduce the CQI feedback overhead and identify a better transmission power backoff.

[CMCC]: Multiple CSI reports within one CSI reporting should be supported at least for the power domain enhancements.

[Lenovo]:

* Evaluate the following UE-assisted power control offset selection techniques for possible down selection for Rel-18 NES-capable UEs:
  + - Alt1. Reporting a power control offset value based on a target WB CQI configured by the network
    - Alt2. Reporting two CQI values associated with two power control offset values corresponding to whether NES mode is deactivated or activated, respectively
      * FFS: Whether the second CQI value is a differential CQI value with respect to the first CQI value
* If the UE is configured to report two CQI values associated with two power control offset values corresponding to whether NES mode is deactivated or activated, respectively, the subband differential CQI values corresponding to the second power control offset are reported via one bit each

[Qualcomm]: RAN1 only specifies joint CSI report for multiple CSIs in power adaptation if its CSI report overhead reduction is high compared to separate CSI reports.

* + - A separate CSI report for each CSI corresponding to a power offset value that gNB requests as baseline.

**FL summary**

There are many aspects similar to the discussion for spatial domain adaptation that. Apart from those, the UE reported content may include something new as proposed by [Nokia/NSB, NEC, Google]. As the views are not yet sufficient, further study is proposed.

**P12**

**Further study the need of UE report of power back off of PDSCH, e.g. a maximum value of PDSCH power back off.**

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| **Company** | **Comments** |
| Lenovo | OK to study, however the maximum PDSCH power back off should be constrained by another QoS, e.g., a minimum CQI value that needs to be achieved under the maximum PDSCH power back-off value |
| vivo | For different power offset, legacy CSI report is sufficient. |
| DOCOMO | If UE can report CSIs related to different PDSCH power assumptions, above report may be not necessary. |
| OPPO | Based on our simulation results, we don’t see the benefits. Thus, we don’t support this proposal. |
| ZTE, Sanechips | We don’t think UE report of power back off of PDSCH is necessary since UE may not have clear information about traffic arrival and scheduling strategies at NW side. Meanwhile, it is more beneficial for UE to report CSI with multiple power offset between CSI-RS and PDSCH, and gNB can performs the dynamic transmission power adjustment according to the report. |
| Huawei, HiSilicon | OK to study, but seems no need for this.  Multiple CSIs corresponding to multiple powercontroloffset(s) (configured or indicated by gNB) has been reported from UE. gNB can derive the proper power back off value based on the multiple CSIs. Hence, there is no need to additionally report power back off of PDSCH. |
| Nokia/NSB | We support the proposal. |
| MediaTek | No support. We prefer specification directly capture the largest PDSCH power increment/reduction (i.e., no need of additional UE report) |

4.4 Need of signalling to UE due to adaptation

The relevant agreements are excerpted as below, same one as that for spatial adaptation while a need for that for different domains could be different.

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| **Agreement**  Discuss the signalling aspects for spatial/power domain adaptation for Rel-18 NES-capable UEs considering that   * Whether there is a need for transition time per adaptation (for UE) * Whether/How to inform UE on spatial adaptation pattern update and/or PDSCH/CSI-RS transmission power change due to adaptation. |

**Company proposals**

[FW] support adaptive power adaptation dynamic signaling to the UE of the multiple *powerControlOffse*t values to be used in CSI can be introduced.

[Huawei, HiSilicon]: Informing the UE on spatial adaptation pattern update and/or PDSCH transmission power change is unnecessary.

[Panasonic]: For efficient and effective power domain adaptation, the power offset between CSI-RS and PDSCH and the power offset between CSI-RS and SSS should be adapted with enhanced L1/L2 signaling for CSI report.

[Nokia, NSB]: Define PDSCH transmission change indication limited to cases where it is beneficial for the UE.

* FFS Discuss in which cases the indication is beneficial to the UE (e.g., if power change rate is high and/or power change is large)
* FFS Discuss whether the UE should provide information related to when it benefits from the indication (e.g., by indicating its need, or by indicating a power change rate or range which the UE can/cannot cope with).

[CATT]: Dynamic signalling could be used to activate/deactivate semi-persistent CSI report for subset of powerControlOffset values but could not be used for dynamic change of powerControlOffset value/subset associated with periodic CSI report configuration.

[Fujitsu]: Both single CSI feedback and multiple CSIs feedback can be considered for CSI tracking when dynamic adaptation of PDSCH transmission power is adopted.

* + - For single CSI feedback, group common L1 signaling to update of power offset between CSI-RS and PDSCH should be considered
    - For multiple CSIs feedback, gNB could indicate to UE the hypothesis power offsets for CSI measurement and report to reduce UCI overhead.

[ZTE]: Dynamic indication can be considered for power domain enhancement.

[xiaomi]: Signaling to enable efficient adaptation of power offset values between PDSCH and CSI-RS needs further study.

[InterDigital]:

* Support reporting of CSI based on dynamically indicated power offset.
* Power offset assumed for a NZP CSI-RS resource is determined by its RRC-configured power offset value and a dynamically signaled power offset adjustment.
* RRC configures a group identity for the purpose of power offset adjustment for each NZP CSI-RS resource.
* A DCI can indicate an adjustment of power offset between PDSCH and CSI-RS applicable to a group of NZP CSI-RS resources for CSI reporting.
* The DCI indicating adjustment of power offset is received in a UE-group common search space.

[China Telecom]: Not support to indicate the power offset values to UE for CSI measurement/reporting.

[Google]: With regard to the AGC, support to indicate the transmission power backoff ratio for the scheduled PDSCH by DCI.

[Samsung]:

* Introduce L1/L2 signaling for updating a given NZP CSI-RS resource/resource set/resource setting by indicating an index from the set of configured CSI-RS mapping patterns, CSI-RS transmission powers, and PDSCH transmission powers per Type 1 SD, Type 2 SD, and PD adaptations, respectively.
* Consider UE-group-specific L1 signaling for updating a given NZP CSI-RS resource/resource set/resource setting per SD/PD adaptation.
* If a L1/L2 signaling for updating a given NZP CSI-RS resource/resource set/resource setting is introduced, the number of active CSI-RS ports in a given active BWP should be derived based on the L1/L2 signaling indication.
* Extend the current TCI state indication DCI to additionally indicate a CSI-RS resource sub-configuration ID per SD/PD adaptation.

[CMCC]: Multiple power offset values can be configured and dynamically indicated and/or activated.

[CEWiT]: Dynamically adapting the DL transmit power of signals/channels at gNB in specific set of frequency and time resources is supported. Dynamically indicating about the adaptation of DL transmit power to the UE is supported.

[Transsion]: RRC signaling plus L1/L2 signaling can be used to configure the multiple power offset values between PDSCH and CSI-RS.

[Lenovo]: For power control offset indication for Rel-18 NES-capable UEs, evaluate the following alternatives for down selection:

* + - Alt1. Configuring two power control offset values per CSI-RS resource, along with dynamic indication of whether the NES mode is activated or deactivated
    - Alt2. Dynamic indication of the power control offset, e.g., via DCI indication
    - Alt3. MAC-CE based power control offset indication

[Qualcomm]: The UE is provided with an indication on the PDSCH transmission power change.

* + - FFS: Details on PDSCH transmission change indication

**FL summary**

The discussion on the need of dynamic signalling for power adaptation is very similar to that discussed for spatial adaptation. It is suggested to discuss this after more progress available for spatial domain adaptation.

**Q21**

**Discussion can be requested if you have different view. Otherwise there is no need for input.**

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| **Company** | **Comments** |
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# Others

5.1 LS discussion

The following LS is received, and relevant tdoc as well as guidance from Chair is copied as below.

[R1-2302288](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_112b-e/Docs/R1-2302288.zip) LS on 3GPP work on Energy Efficiency SA5, Huawei

To be taken into account in agenda item 9.7. If response to SA5 is needed, handle it under [112bis-e-R18-NES-01].

Relevant tdoc:

[R1-2303799](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_112b-e/Docs/R1-2303799.zip) Draft Reply LS on 3GPP work on energy efficiency Huawei, HiSilicon

Main content in the draft is copied here for reference.

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| **1. Overall Description:**  RAN1 thanks SA5 for providing their view of the ongoing work on Energy Efficiency (EE) and the questions.  RAN1 would like to note that the Rel-18 WID for network energy savings for NR has been updated to RP‑230566. Also, although this is a RAN1-led work item, as also quoted in Note 13 in S5-231149, the work for this item includes objectives led by RAN2, RAN3 and RAN4 respectively.  Furthermore, in addition to energy savings that the WID RP-230566 is to directly address, the candidate solutions discussed therein can also address digital sobriety by requiring a smaller volume of data to be processed, stored, and transported, e.g. joint report of multiple CSIs with overhead reduction, for spatial and power domain techniques. This can be noted in your future work.  To be accurate and comprehensive, the following revised texts are provided for the table of 3GPP Release 18 work on EE.   |  |  |  |  | | --- | --- | --- | --- | | RAN WG1 |  | * Rel-18 SID in RP-221443 [8]. Expected completion date: RAN#98 (Dec. 2022). Completed. See objectives in NOTE 11. * TR 38.864 [9]. See evaluated techniques for energy saving in NOTE 12. * Rel-18 WID in RP-230566 [x]. Expected completion date: RAN#104 (June 2024). See objectives in NOTE 13. |  | | RAN WG2 |  | Objectives led by RAN2 in RP-230566. See objectives in NOTE 13. |  | | RAN WG3 |  | Objectives led by RAN3 in RP-230566. See objectives in NOTE 13. |  | | RAN WG4 |  | Objectives led by RAN4 in RP-230566. See objectives in NOTE 13. |  |     **2. Actions:**  **To 3GPP SA5:**  **ACTION:** RAN1 respectfully ask SA5 to take the above into account in their future work on Energy Efficiency. |

**Q22**

**Do you consider a reply LS is needed? And if so, any modification to the draft reply LS in** [**R1-2303799**](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_112b-e/Docs/R1-2303799.zip)**?**

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| **Company** | **Comments** |
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# Conclusion

Tbd.

# Reference

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| [**R1-2302333**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302333.zip) | Spatial and Power Adaptations for Network Energy Savings | FUTUREWEI |
| [**R1-2302337**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302337.zip)**=>**  [**(/R1-2303955)**](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_112b-e/Inbox/R1-2303955.zip) | CSI enhancements for network energy saving | Huawei, HiSilicon |
| [**R1-2302389**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302389.zip) | Spatial and power domain adaptation for network energy saving | Panasonic |
| [**R1-2302393**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302393.zip) | Techniques in spatial and power domains | Nokia, Nokia Shanghai Bell |
| [**R1-2302498**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302498.zip)**=>**  **(/**[**R1-2303910**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303910.zip)**)** | Discussions on NES techniques in spatial and power domain | vivo |
| [**R1-2302561**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302561.zip) | Discussion on techniques in spatial and power domains | OPPO |
| [**R1-2302613**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302613.zip) | Discussion on NES techniques in spatial and power domains | Spreadtrum Communications |
| [**R1-2302716**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302716.zip) | Network Energy Saving techniques in spatial and power domain | CATT |
| [**R1-2302751**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302751.zip) | Discussion on network energy saving techniques in spatial and power domains | NEC |
| [**R1-2302809**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302809.zip) | Discussion on NWES techniques in spatial and power domain | Intel Corporation |
| [**R1-2302912**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302912.zip) | Discussion on NW energy saving techniques in spatial and power domains | Fujitsu |
| [**R1-2302944**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302944.zip) | Discussion on NES techniques in spatial and power domains | ZTE, Sanechips |
| [**R1-2302995**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2302995.zip) | Discussion on techniques in spatial and power domains | Xiaomi |
| [**R1-2303024**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303024.zip) | Discussion on techniques in spatial and power domains | InterDigital, Inc. |
| [**R1-2303030**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303030.zip) | Discussion on spatial/power domain adaptation for network energy saving | China Telecom |
| [**R1-2303056**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303056.zip) | Network Energy Saving in Spatial and Power Domain | Google |
| [**R1-2303141**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303141.zip) | Techniques in spatial and power domains | Samsung |
| [**R1-2303202**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303202.zip) | Network energy saving techniques in spatial and power domains | ETRI |
| [**R1-2303247**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303247.zip) | Discussion on network energy saving techniques in spatial and power domains | CMCC |
| [**R1-2303309**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303309.zip) | Discussion on spatial and power adaptations for network energy savings | CEWiT |
| [**R1-2303344**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303344.zip) | On NW energy saving techniques in spatial and power domains | MediaTek Inc. |
| [**R1-2303379**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303379.zip) | Discussion of NES techniques in spatial domain and power domain | Transsion Holdings |
| [**R1-2303426**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303426.zip) | Discussion on NES techniques in spatial and power domains | LG Electronics |
| [**R1-2303496**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303496.zip) | Discussion on spatial and power domain enhancements to support network energy saving | Apple |
| [**R1-2303531**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303531.zip) | Network energy saving techniques in spatial and power domains | Lenovo |
| [**R1-2303603**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303603.zip) | Techniques in spatial and power domains | Qualcomm Incorporated |
| [**R1-2303651**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303651.zip) | Network energy savings techniques in spatial and power domains | AT&T |
| [**R1-2303722**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303722.zip) | Discussion on spatial and power domain enhancements for NW energy savings | NTT DOCOMO, INC. |
| [**R1-2303757**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303757.zip) | NW energy saving techniques in spatial and power domains | Ericsson |
| [**R1-2303780**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303780.zip) | Discussion on techniques in spatial and power domains | ITRI |
| [**R1-2303813**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303813.zip) | Spatial Domain Adaptation for NES | Fraunhofer IIS, Fraunhofer HHI |
| [**R1-2303850**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112b-e/Docs/R1-2303850.zip) | Discussion on spatial domain adaptation for NES | KT Corp. |

# Appendix

## A. Objectives

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| The objectives of the work item are the following:   1. Specify SSB-less SCell operation for inter-band CA for FR1 and co-located cells, if found feasible by RAN4 study, where a UE measures SSB transmitted on PCell or another SCell for an SCell’s time/frequency synchronization (including downlink AGC), and L1/L3 measurements, including potential enhancement on SCell activation procedures if necessary [RAN4, RAN2] 2. Specify enhancement on cell DTX/DRX mechanism including the alignment of cell DTX/DRX and UE DRX in RRC\_CONNECTED mode, and inter-node information exchange on cell DTX/DRX [RAN2, RAN1, RAN3]  * Note: No change for SSB transmission due to cell DTX/DRX. * Note: The impact to IDLE/INACTIVE UEs due to the above enhancement should be avoided.  1. Specify the following techniques in spatial and power domains  * Specify necessary enhancements on CSI and beam management related procedures including measurement and report, and signaling to enable efficient adaptation of spatial elements (e.g. antenna ports, active transceiver chains) [RAN1, RAN2] * Specify necessary enhancements on CSI related procedures including measurement and report, and signaling to enable efficient adaptation of power offset values between PDSCH and CSI-RS [RAN1, RAN2] * Note: Above objectives are only for UE specific channels/signals * Note: Legacy UE CSI/CSI-RS capabilities applies when considering total number of CSI reports and requirements  1. Specify mechanism(s) to prevent legacy UEs camping on cells adopting the Rel-18 NES techniques, if necessary [RAN2] 2. Specify CHO procedure enhancement(s) in case source/target cell is in NES mode [RAN2] 3. Specify inter-node beam activation and enhancements on restricting paging in a limited area [RAN3]. 4. Specify the corresponding RRM/RF core requirements, if necessary, for the above features [RAN4] |

## B. RAN1#112 agreements for 9.7.1

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| **R1-2301964** FL summary#1 for spatial and power domain techniques for R18 NES Moderator (Huawei)  **Agreement**  For the purpose of further discussions in RAN1 on NES spatial domain adaptations, consider the following cases   * Type 1: all antenna elements associated to a logical antenna port is disabled/enabled * Type 2: part/subset of antenna elements associated to a logical antenna port is disabled/enabled     **R1-2301965** FL summary#2 for spatial and power domain techniques for R18 NES Moderator (Huawei)  **Agreement**  For spatial element adaptation, further study the following   * A1-1) Each CSI-RS resource/resource set/resource setting can be associated with only one spatial adaptation pattern   + FFS: Details on how the association is done * A1-2) Each CSI-RS resource/resource set/resource setting can be associated with one or more spatial adaptation patterns   + FFS: Details on how the association is done * FFS: Details on the definition of “spatial adaptation patterns”   **Agreement**  For spatial element adaptation, further study the following   * A2-1) Independent/separate CSI report configurations where each CSI report configuration corresponds to one spatial adaptation pattern * A2-2) One CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern   + FFS: Details of sub-configuration   **R1-2301966** FL summary#3 for spatial and power domain techniques for R18 NES Moderator (Huawei)  **Agreement**  For spatial domain adaptation, further study necessary enhancements for multiple CSI(s) where each CSI corresponds to a spatial adaptation pattern, e.g.   * FFS: gNB indicates to UE which CSI(s) the UE shall report * FFS: the UE selects which CSI(s) are reported * FFS: multiple CSI(s) are reported in a joint CSI report * FFS: Overhead reduction for multiple CSI(s)   Note: UE complexity needs to be taken into account.  **Agreement**  For adaptation of power offset values between PDSCH and CSI-RS, further study the following   * Where/how to configure multiple power offset values   + Whether/how one or more power offset values are dynamically indicated to UE for CSI measurement/reporting, and PDSCH reception   + Overhead reduction for CSI reports associated with multiple power offset values between PDSCH and CSI-RS   + Whether other UE report content can be included   **Agreement**  For spatial and power domain adaptation, solution(s) based on adaptation within an active BWP is considered as baseline  **Agreement**  Discuss the signalling aspects for spatial/power domain adaptation for Rel-18 NES-capable UEs considering that   * Whether there is a need for transition time per adaptation (for UE) * Whether/How to inform UE on spatial adaptation pattern update and/or PDSCH/CSI-RS transmission power change due to adaptation. |