**3GPP TSG-RAN WG1 Meeting #112bis-e  (tb) R1-2303914**

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

**Agenda Item: 9.7.1**

**Source: Moderator (Huawei)**

**Title: FL summary#2 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.

Please search ‘**FL2**’ for comments and discussion. The feedback is expected by 24h from now on, i.e. **UTC 4:00am on Wed, 19 April**.

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 TDDRel-18 LP-WUS (50min). L1 design. Receiver architectureRel-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. EvaluationRel-18 LP-WUS (45min). L1 design. EvaluationRel-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]
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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, AppleAs 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. |
| CMCC | In general, we are fine with the proposal especially the part of unified design for both spatial and power domain enhancements. But as commented by other companies, the design of the CSI feedback is still under discussion. Different companies may have different understanding about that.  |
| Samsung | Support |
| InterDigital | We support CSI report containing single feedback corresponding to one spatial domain adaptation. This is primarily to alleviate any complexities and latencies for processing multiple CSI at the UE. Also, as indicated by simulations from multiple companies, the benefit of having multiple CSI in single report is not clear. As mentioned by companies, some clarification of multi-CSI feedback will be very useful. Similar to vivo, we are ok with providing multiple CSI in multiple reporting occasions where each report has CSI on one spatial domain adaptation.  |
| Panasonic | We agree with DOCOMO and think it is better to have clearer clarification of single-CSI feedback and multi-CSI feedback before agreeing on supporting both. |
| Ericsson | To enable proper gNB decisions on power/spatial domain adaptation, we support multi-CSI feedback in one reporting instance, where the multiple CSIs correspond to multiple hypotheses on spatial domain adaptation patterns or PDSCH-to-CSI-RS offsets. |
| Qualcomm | We agree that RAN1 should agree on a framework to facilitate discussion and progress. However, we do not support the proposal in the current form due to the below reasons:* It is not clear what “one adaptation” or “more than one adaptation” means.
	+ From our perspective, it is important to discuss the FFS from the last meeting that “FFS: Details on the definition of spatial adaptation patterns” since the spatial adaptation pattern (SAP) is expected to be involved in all discussions from CSI-RS resource/CSI report configuration to CSI reporting.
* It is not clear what multi-CSI feedback means.
	+ We don’t think multi-CSI feedback needs to be called out explicitly. Instead, we can discuss that the UE may provide N CSIs associated with N spatial adaptation patterns where $1\leq N\leq L$ (FFS: value of $L$). Furthermore, we should discuss whether N CSIs are available before spatial domain adaptation of PDSCH (Type 1) and before spatial domain adaptation of CSI-RS/PDSCH (Type 2).

From discussion perspective, backward discussion starting from CSI feedback (in particular from undefined multi-CSI feedback) is very hard since we don’t know how CSI-RS resource/CSI report configuration looks like.Hence, we suggest discussing in the following order:* Definition of spatial adaptation pattern
* CSI-RS resource configuration
* CSI report configuration
* CSI report based on CSI-RS resource configuration and CSI report configuration.
	+ Whether UE provides N CSIs associated with N spatial adaptation patterns where $1\leq N\leq L$ (FFS: value of $L$).
	+ Whether N CSIs are available before spatial domain adaptation
	+ Whether N CSIs are sent in a single CSI report or sent in separate CSI reports

Whether CSI reduction is necessary when N > 1.  |
| LG Electronics | Even though P1 is a high-level proposal, single/multi-CSI feedback itself is not clear to us.For spatial domain adaptation, does ‘multi-CSI feedback’ correspond to A2-2 in the previous agreement (i.e., One CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern)? |
| FL2 | This is to be combined with the discussion in section 3.2. |

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).**

**FL2: The following was agreed on Monday. The above is closed.**

**Agreement**

Define necessary enhancements to support both types of spatial adaptation cases (as defined in RAN1#112) in Rel-18.

* Note: This does not imply explicit definition in specifications for adaptation types.
* Note: This does not imply explicit specification changes are made for both cases

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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. |
| CMCC | We support the proposal. As we commented in the last meeting, both type 1 and type 2 products can be observed for the deployment, then the enhancements applicable to both types should be supported. |
| Samsung | Support |
| InterDigital | Support FL’s proposal |
| Panasonic | We agree. |
| Ericsson | We agree that specifications should enable enhancements for both Type-1 and Type-2 adaptation; however, we do not think that Type-1 and Type-2 should be explicitly defined in specifications (e.g. existing spec enables type 1/2 implementations without referencing such terminology). Rather, the gNB would configure CSI reporting according to which adaptation type is used.We think “CSI enhancements” is too broad. As commented by other companies, we think the specifications impact of Type-2 spatial domain adaptation seems to be quite minimal. We think the only thing missing from current specifications is a mechanism to configure the UE to report multiple-CSIs within a single CSI-ReportConfig (Alt 2-2 from last meeting). We understand that is a separate discussion. So for now, perhaps the following is appropriate wording:**Specifications support ~~CSI~~ enhancements to facilitate ~~for~~ network energy savings for both types of spatial adaptation cases (as defined ~~that agreed~~ in RAN1#112).****FFS: whether/what CSI enhancements are needed.** |
| Qualcomm | As agreed last meeting that both types of adaptation are under discussion, let us further discuss both types to understand necessary specification impact. We don’t see the need of this proposal at this stage. |
| LG Electronics | Support. |

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. |
| CMCC | Support the joint operation of spatial domain adaptation and power domain adaptation, considering the commonality of design and specification impact. And a joint operation could also be used to avoid coverage loss.For the joint operation of cell DTX/DRX and spatial/power domain adaptation, it needs further discussion and clarification of the behavior of cell DTX/DRX. Then we can consider the combination of the two features.  |
| Samsung | * 1st bullet point: Joint operation, e.g., a unified signaling, seems a natural design choice given that both adaptations are regarding CSI-RS resource and CSI report enhancements.

2nd bullet point: We’d better to wait and see how cell DTX/DRX is defined and then assess if a joint operation, e.g., a unified signaling, signaling handling rule, can be considered.  |
| Panasonic | We are supportive on joint operation of spatial domain adaptation and power domain adaptation, which can take a higher priority. |
| **FL2** | As a clarification, the original question is more about to identify possible issues regarding a joint operation, compared to the discussion/design of each on it own. Although at least the first sub-bullet seems to gain majority support, it is not yet clear what needs to be resolved as an issue. Therefore, please continue your input if you have an issue to be discussed. Otherwise, this will not be recommended for conclusion/agreements. |
| **Lenovo2** | @FL: While we can move forward with joint operation of spatial and power domain enhancements, supporting joint spatial/power and Cell DTX/DRX would be challenging since this requires a joint agreement with agenda 9.7.2. Is it possible to coordinate with the FL for 9.7.2, or make a request to the chairman to provide guidance on a way forward? |
| **Nokia/NSB2** | The 2nd-bullet point was also touched upon in the FL summary discussions of AI. 9.7.2. We should avoid the duplicate discussions, and to have the discussions either in 9.7.1 or in 9.7.2.Similar view as Apple, the Type-2 may require the joint considerations between spatial and power domain. And specifically, the 1st-bullet point relates to Q12. Firstly, we should have the Q12 to be clarified, then we could further discuss on what exactly needs to be done with the 1st-bullet point. |

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 $P\geq $1 different (subsets of the available antenna ports in the array) spatial domain patterns at the gNB, it should be configured to report for $K\leq P$ CSI(s), where the value of $K $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. |
| CMCC | We are generally fine with the proposal. Since if multiple CSI feedbacks are contained in one CSI report, the connection or the correlations between different configurations or assumptions can be used for the overhead reduction. Of course the detailed solutions and analysis are needed for making the decision. |
| Samsung | Support |
| InterDigital | As mentioned in Q1, clarification of multi-CSI feedback is needed before discussing further on the related details. We also share similar concern as raised by Apple. From our understanding, “whether gNB can indicate to UE which CSI(s) the UE shall report” can apply for both single CSI feedback and multi-CSI feedback, depending on whether the indication of the CSI associated with a spatial adaptation is done via semi-static or dynamic signaling.  |
| Panasonic | We think P3 should be discussed after P1, considering the P3 has many details still to be clarified. |
| Ericsson | While we agree that multiple CSI(s) should be reported in a one reporting instance, we think it is too early to agree on overhead reduction and/or UE complexity reduction techniques.Regarding overhead, for aperiodic CSI reporting on PUSCH, for example, it may not be motivated to reduce overhead as there are not the same overhead restrictions as on PUCCH. Hence, we think overhead reduction techniques, if needed, should be FFS, taking into account the channel carrying the CSI feedback (PUSCH or PUCCH).Regarding UE complexity, as a baseline we think that if the UE is triggered to report N CSIs, then N CPUs would be consumed as in current spec, hence it is not essential to specify UE complexity reduction approaches. Practically speaking, how would they even be specified? It seems like a detailed UE procedure would be difficult to agree on given that actual CSI computation details could vary for different implementationsWe think overhead reduction and UE complexity reduction should be decoupled and discussed separately. It was already agreed in last (“Note: UE complexity needs to be taken into account.”).Suggested update: **P3****If multi-CSI feedback is supported, ~~also~~ at least support multiple CSI(s) are reported in one report without overhead ~~and/or UE complexity~~ reduction techniques*** **gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report.**
* **FFS: Support of multiple CSI(s) reported in one report with overhead reduction techniques**
* **FFS: whether/how to reduce UE complexity**
 |
| Qualcomm | Please see our reply in P1. We C&P some related suggestion below.From discussion perspective, backward discussion starting from CSI feedback (in particular from undefined multi-CSI feedback) is very hard since we don’t know how CSI-RS resource/CSI report configuration looks like.Hence, we suggest discussing in the following order:* Definition of spatial adaptation pattern
* CSI-RS resource configuration
* CSI report configuration
* CSI report based on CSI-RS resource configuration and CSI report configuration.
	+ Whether UE provides N CSIs associated with N spatial adaptation patterns where $1\leq N\leq L$ (FFS: value of $L$).
	+ Whether N CSIs are available before spatial domain adaptation
	+ Whether N CSIs are sent in a single CSI report or sent in separate CSI reports

Whether CSI reduction is necessary when N > 1. |
| LG Electronics | Support in general, but still the definition of ‘multi-CSI feedback’ is not clear though. From the gNB’ perspective, it is beneficial to support multiple CSI(s) in one report to find the optimal spatial or power adaptation patterns. If the supported number of adaptation patterns is large, a method of reducing the candidate number of spatial or power adaptation patterns is needed in order to reduce the amount of CSI information to be calculated and reported. In this case, it is possible to consider a method in which the gNB indicates the CSI corresponding to the spatial or power adaptation pattern to be calculated and reported directly to the UE.  |
| FL2 | For single-CSI vs multi-CSI, I’m not sure how much benefits can be viewed as sufficient given the discussion so far and companies preference. It is not too early rather a bit late if not to decide this still. For progress, ‘if’ is set to allow more considerations. However, it is encouraged to think about whether it is something RAN1 cannot agree on, or it is one configuration tool that should be allowed in specification and up to network/UE vendors to choose support or not.For single-CSI case, possibly gNB indication can also be used as one company point out.For multi-CSI case, if not to report them in one report, which means UE needs to report the CSI separately for each pattern in multiple occasions. This either consumes more DCI indication/triggering, or overhead, and UE power consumption. It is not clear whether under multi-CSI any benefits can be observed with separate reporting. However there can be more explanations to elaborate this.Considering that overhead reduction and UE complexity are topics with interest and with FFS/Note already from last meeting, there is no need to repeat them if the agreement is not to confirm such FFS nor concrete solutions. We can always discuss those separately.**P3-rev1****Support a framework that enables a UE to provide *N* CSIs associated with *N* spatial adaptation patterns where** $1\leq N\leq L$ **(FFS: value of** $L$**) in one report*** **For discussion purpose, N=1 refers to single-CSI while N>1 refers to multi-CSI.**
* **gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report**
* **FFS whether a UE can also report each CSI in separate CSI report for multi-CSI.**
 |
| **Company** | **Comments** |
| China Telecom | We are generally fine with Pe-rev1. And actually, we don’t think reporting the CSI separately for multi-CSI should be supported since we can’t see the benefits of such mechanism compared with reporting multiple CSIs in one report.  |
| DOCOMO2 | We support the updated proposal. Such framework may also be applied for power adaptation. So, we suggest the update of this and other wordings as follow if I understand the FL’s motivation correctly. **Support a framework that enables a UE to ~~provide~~ report *N* CSIs associated with *N* spatial adaptation patterns where** $1\leq N\leq L$ **(FFS: value of** $L$**) in one report*** **For discussion purpose, N=1 refers to single-CSI while N>1 refers to multi-CSI.**
* **gNB can optionally indicate/trigger to UE which ~~subset of~~ N CSI(s) the UE shall report**
* **FFS whether a UE can also report each CSI in separate CSI report for multi-CSI.**

**FFS how the framework applied for power adaptations** |
| ZTE,Sanechips2 | Support.We don’t see the benefit of report each CSI in separate CSI report for multi-CSI. The UE complexity is same as report multi-CSI in one report, but it costs more signaling overhead, more energy for both gNB and UE.Therefore, we think multi-CSI in one report should be supported. For multi-CSI in separate report, it can be FFS.For the update suggested by DOCOMO, we are okay. |
| Huawei, HiSilicon | **P3-rev1****Support a framework that enables a UE to provide *N* CSIs associated with *N* spatial adaptation patterns where** $1\leq N\leq L$ **(FFS: value of** $L$**[Huawei: L is the maximum of spatial adaptation patterns?]) in one report*** **For discussion purpose, N=1 refers to single-CSI while N>1 refers to multi-CSI.**
* **gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report**

**FFS whether a UE can also report each CSI in separate CSI report for multi-CSI.**We are OK with P3-rev1 for this time. **But we support N>1 at least.**Some companies (VIVO, Inter digital) support multiple CSIs in multiple CSI reporting occasion. In such approach the actual UE complexity and UL payload is equals to the multiple CSIs in one reporting occasion (without any UL payload and complexity reduction enhancement). In addition, for multiple CSIs reporting in multiple CSI reporting occasions, in order to get multiple CSIs, gNB needs to persistently transmit multiple triggering/indicating signaling and then results in large L1/L2 signaling overhead.  |
| InterDigital | The updated proposal is more inclusive, and we are generally ok with the current form, although we support **N=1**. Regarding UE complexity, it is not clear to us how reporting multi-CSI in one report results in the same complexity as reporting one CSI in one report. The amount of CSI processing at UE can increase when reporting multi-CSI in one report (e.g. number of calculated CSI is multiplied for a single report configuration). When reporting multi-CSI in single reporting occasion, if the UE is reporting at least CQI and RI for each spatial adaptation pattern, the overhead is also expected to increase proportionally. Clearly there is a tradeoff between complexity and overhead when considering single-CSI vs. multi-CSI, and we think it is important to strive for a solution that balances the tradeoff.  |
| ITRI | We can support P3-rev1 in principle.At least L=1 (single CSI case) should be supported.For L>1 (multi-CSI case), we should down-select the following options:* Option 1: separate CSI report for multi-CSI
* Option 2: one CSI report for multi-CSI

FFS: If Option 2 is supported, UL payload size for CSI reporting should be discussed. |
| Qualcomm2 | Assume CSI report config has $N$ SAPs, and each pattern has $K\_{p}$ NZP CSI-RS resources for channel measurement. The UE shall need to compute $N×K\_{p}$ CSIs in total. Main question: how should “UE to report N CSIs associated with N spatial adaptation patterns” be interpreted? There could be two different interpretations:* Interpretation 1: UE reports one CSI for each SAP. In particular, UE shall select one CSI to report for an SAP.
* Interpretation 2: UE reports N CSIs out of $N×K\_{p}$ CSIs.

From our perspective, we think Interpretation 1 should be pursued and some clarification is needed in the proposal.We don’t support 2nd bullet of the proposal with the following reasons:* For periodic CSI reporting, the bullet means that gNB may use L1/L2 signaling to request a subset of CSIs. If this is the case, why does not gNB trigger SP or AP CSI reporting?
* For aperiodic CSI reporting or semi-persistent CSI reporting, gNB can trigger a state with CSI report config having N spatial adaptation patterns using existing triggering mechanism. Hence, no new indication is necessary.

Hence, we propose the following **update**:**For an CSI report config with N spatial adaptation patterns, Support a framework that enables a UE to ~~provide~~ report *N* CSIs associated with *N* spatial adaptation patterns where** $1\leq N\leq L$ **(FFS: value of** $L$**) in one report and one CSI for each spatial adaptation pattern.** * **For discussion purpose, N=1 refers to single-CSI while N>1 refers to multi-CSI.**
* **~~gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report~~**
* **FFS whether a UE can also report each CSI in separate CSI report for multi-CSI.**
 |
| Lenovo2 | We support the main paragraph of the proposal as well as the first bullet. For the second bullet, we prefer to include the possibility of UE selection of the N CSIs. Can we consider the following wording?**For a CSI report config with N spatial adaptation patterns, Support a framework that enables a UE to ~~provide~~ report *N* CSIs associated with *N* spatial adaptation patterns where** $1\leq N\leq L$ **(FFS: value of** $L$**) in one report** * **For discussion purpose, N=1 refers to single-CSI while N>1 refers to multi-CSI.**
* **~~gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report~~**
* **FFS: whether the *N* CSIs are indicated by gNB or selected by UE**
* **FFS whether a UE can also report each CSI in separate CSI report for multi-CSI.**
 |
| Intel | We are generally ok with main bullet and 1st sub-bullet.As for the 2nd sub-bullet, we have a question on what would happen if the gNB does not indicate/trigger. The sub-bullet describes the indication/trigger being optional, which we don’t understand well.If the gNB does not indicate/tigger what is the expected UE behavior?(1) UE does not report multiple CSIs and only report 1(2) UE can pick and choose any hypothesis from N CSIs and report any value(3) something elseIt would be good if “optionally indicate/trigger” could be clarified the proponents. Also, it needs to be discussed whether N CPUs would be counted as in current spec for reporting N CSIs or not. |
| Xiaomi | We support the content of main bullet and first sub-bullet. For the second sub-bullet, the motivation of gNB indication/triggering is not clear to us.For the third sub-bullet, we do not see any benefits compared with one CSI report with N CSIs.In addition, the signalling overhead for the third sub-bullet is another issue. |
| Nokia/NSB2 | First, we share similar view as QC that it would be better to first define spatial adaptation pattern, CSI-RS resource configuration, CSI report configuration, and the interaction between those, etc. This would make the discussion clearer, instead of rushing to a conclusion here before having a somewhat clear idea on the overall baseline framework and operation.Regarding multi-CSI case, to our view:* UEs report the CSI separately for each pattern in multiple occasions is a workable solution based on legacy framework. We agree that the overall ES potential may not be good as multiple CSI feedbacks in one UL occasion case. But from specification perspective, it may require much less spec impact.
* Thus, we propose, the UEs report the CSI separately for each pattern in multiple occasions can be considered as a baseline solution. And we may further discuss how it can be operated with Periodic, Semi-periodic, and Aperiodic ways.
* And further enhancement with better ES gain can be pursued with multiple CSI feedbacks in one UL occasion case

We thus suggest the following updates on P3-rev1:**For reporting multiple CSIs associated with multiple spatial adaptation patterns, consider at least one of the following options:*** **Option 1: UE reports each CSI in a separate CSI reporting occasion.**
	+ **FFS: gNB indication/triggering, considering different reporting types (such as aperiodic and semi-persistent).**
* **Option 2: UE reports *N* CSIs in one CSI reporting occasion, where** $1\leq N\leq L$ **(FFS: value of** $L$**)**
	+ **FFS: gNB indicating/triggering the UE to report *N* CSIs in one CSI reporting occasion, considering different reporting types (such as aperiodic and semi-persistent).**
	+ **Note: This doesn’t preclude using more than one reporting occasion, e.g., *N1* CSIs in one CSI reporting occasion and *N2* CSIs in a next CSI reporting occasion.**
* **FFS: whether the UE could be configured to select CSI(s) to report under Option 1 and/or Option 2.**
 |
| ETRI | We support the proposal and prefer Qualcomm’s version which further clarifies the relation between CSIs and spatial adaptation patterns. |
| Fujitsu2 | For the main bullet, the definition of L is not clear. In our understanding, L is the number of configured spatial adaption patterns. For the second sub-bullet, it seems that gNB indicating CSIs to be reported is only considered in multi-CSI. In our opinion, it is applicable to both single-CSI and multi-CSI. Besides, the word ‘optionally’ seems redundant. We propose the following update:**Support a framework that enables a UE to provide *N* CSIs associated with *N* out of *L* configured spatial adaptation patterns in one report where** $1\leq N\leq L$ **(FFS: value of** $L$**) ~~in one report~~*** **For discussion purpose, N=1 refers to single-CSI while N>1 refers to multi-CSI.**
* **gNB can ~~optionally~~ indicate/trigger to UE which CSI or subset of CSI(s) the UE shall report**

**FFS whether a UE can also report each CSI in separate CSI report for multi-CSI.** |
| Apple2 | We share the similar view as QC and Nokia and as stated in our comment to P1, 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.We think Nokia’s proposal to consider UEs report a single CSI separately for each spatial adaptation pattern in multiple reporting instances can be considered as a baseline solution. And the enhancements related P/SP/AP CSI/CSI reporting should be defined clear enough before we rush to support the joint multiple CSI reporting in one reporting instances.  |
| Samsung2 | Agree with FL2 summary and the revised proposal with the following reasons:* Multiple CSI in separate reports vs. single multi-CSI report
	+ Multiple CSI in separate reports can be achieved in the current specification by configuring a UE with multiple separate CSI reports. With this approach, it is assumed that the UE will separately perform CSI-RS measurements for each of the resources linked with multiple separate CSI reports. Also, as pointed out by FL, separate multiple DCI triggering messages need to be sent out by the gNB for the case of A-CSI report. From UE perspective, this approach requires a UE to transmit UCI multiple times in separate occasions, which will consume more power by the UE and the UL resource.
	+ Single multi-CSI report should aim for deriving multiple CSI from a single set of CSI-RS measurements such as for subsets of antenna ports from the given set of antenna ports or for different power control offset values. In contrary to the former approach, this approach requires single triggering message, single CSI-RS resource measurements, and provides opportunities to further reduce UCI overhead in one message as multiple CSI reports are highly correlated as they are derived from a single set of measurements.
	+ Given the majority support and for the progress, it is preferable to first agree in principle to support multi-CSI report rather than keep debating on the sufficiency of the overhead reduction gain. Procedurally, once multi-CSI report is agreed in principle, discussions on the overhead reduction schemes will follow naturally with proper consideration on the CPU counting method.

The following is a revised proposal for the sake of progress and also refinement of wording. **P3-rev1****Support a framework that enables a UE to provide *N* CSIs associated with *N* spatial adaptation patterns from *L* sub-configurations provided to the UE, where** $1\leq N\leq L$**, in one report.** * **FFS: whether/how the gNB indicates to UE the number *N* and the corresponding subset of *N* configurations from *L* sub-configurations.**
* **FFS: UCI overhead reduction scheme and scaling for CPU counting**
* **Note: When *L*=1, it is single CSI report as in the legacy system.**
* **Note:** $L\leq L\_{max}$**, where** $L\_{max}$ **is defined by specification or per UE capability.**
 |
| vivo | We disagree that a decision can be made without clearly justified benefit just because it could be too late for progress. Any enhancement needs to be considered only when sufficient benefits are shown by evaluation. Currently there are limited companies providing evaluation results for multi-CSI. As pointed out by some companies, performance benefit of multi-CSI is small compared to single-CSI, and also according to the TR in SI single-CSI can have remarkable NES gain. Note that multi-CSI would cause the complexity for UE have to be greatly increased. It is highly encouraged the proponent companies who support multi-CSI provide more evaluation results to justify there could be sufficient benefit and why it is necessary.Before the performance benefit is clearly justified, we suggest to focus on the design for adaptation based on N spatial adaptation patterns in different report occasion, i.e., single CSI report for different spatial adaptation patterns in different report occasions.Regarding the proposal, we suggest to clarify how the N CSIs are reported and separate the different options.**P3-rev1-new****For the framework that enables a UE to provide *N* CSIs associated with *N* spatial adaptation patterns where** $1\leq N\leq L$ **(FFS: value of** $L$**) in M report, consider the following options or combination of the options*** **Option 1: UE to provide *N* CSIs associated with *N* spatial adaptation patterns where** $1\leq N\leq L$ **in M report, M = N**
* **For each report, UE provide single CSI associated with one spatial adaptation pattern**
* **Note: this is single CSI in a report**
* **Option 2: UE to provide *N* CSIs associated with *N* spatial adaptation patterns where** $1<N\leq L$ **in M report, M = 1**
* **For each report, UE provide CSI associated with N spatial adaptation pattern**
* **Note: this is multi-CSI in a report**
* **Option 3: UE to provide *N* CSIs associated with *N* spatial adaptation patterns where** $1<N\leq L$ **in M report,** $1<M<N$
* **For each report, UE may provide CSI associated with one or multiple spatial adaptation patterns**
* **Note: this is hybrid single CSI and multi-CSI in different reports**
* **For each option, gNB can indicate/trigger to UE which subset of CSI(s) the UE shall report**
* **FFS how to down-select**
 |
| LG Electronics2 | We are OK with the updated proposal and also think that multi-CSI in one report is beneficial to gNB for finding optimal spatial or power adaptation patterns. However, multiple CSI reporting is not always necessary, and to reduce the signaling overhead and computation complexity of UE, we can consider gNB to indicate/trigger subsets of CSIs to be reported to UE. In that sense, we prefer not to have FFS for the second sub-bullet, but we can accept the version revised by Lenovo2.Regarding the definition of single-CSI and multi-CSI, our view is that the definition is related to how many N CSIs (associated with N spatial adaptation patterns) are actually reported and not related to how my K CSIs (associated with K spatial adaptation patterns) are configured with a CSI report config. With this understanding, we propose the following modification on top of Lenovo2’s version.**For a CSI report config ~~with N spatial adaptation patterns~~, Support a framework that enables a UE to ~~provide~~ report *N* CSIs associated with *N* spatial adaptation patterns where** $1\leq N\leq L$ **(FFS: value of** $L$**) in one report** * **For discussion purpose, N=1 refers to single-CSI while N>1 refers to multi-CSI.**
* **~~gNB can optionally indicate/trigger to UE which subset of CSI(s) the UE shall report~~**
* **FFS: whether the *N* CSIs are indicated by gNB or selected by UE**
* **FFS whether a UE can also report each CSI in separate CSI report for multi-CSI.**

**Note: The CSI report config can be configured with more than N spatial adaptation patterns.** |

**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 aregNB 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.
 |
| CMCC | We share a similar view as Spreadtrum that UE only report the CSI based on gNB’s configuration. Whether a UE selected CSI or which kind of selection the UE can make should be further discussed. |
| Samsung | No.  |
| **FL2**  | Nokia listed two cases that may be used for UE selection for which cases the performance may still be ensured.**PQ2****Further study** * **whether UE can select CSI(s) to report when the spatial patterns in the set of candidate patterns have same number of (active) spatial/antenna elements.**
* **Whether gNB can configure certain rules or conditions for UE selection of CSI(s) when the patterns in the set of patterns have different number of (active) spatial/antenna elements**
 |
| China Telecom | We don’t think the UEs should be supported to select CSI(s) to report. Even the different CSIs have the same number of spatial/antenna elements, the CSI-RS are different, which means gNB wants to know the information with all of such spatial patterns. And since the final decision should be made by gNB, we don’t think there is a need to support selecting CSI(s) to report. We don’t think the mechanism that gNB configuring certain rules for UE to select the CSI is needed, since the gNB can trigger/indicate the UE which CSIs to be reported directly(described in P3), |
| ZTE, Sanechips2 | For the first bullet, legacy spec supports that UE reports one CSI of one resource in multiple resources with the same pattern. The difference between legacy specification and the enhancement should be clarified. For the second bullet, as we commented in 1st round, the benefit is unclear. gNB cannot get enough CSI(s) and UE complexity cannot be reduced. |
| Huawei, HiSilicon | We are OK to further study it. However, from our perspective, UE selecting CSI(s) reporting means gNB’s shutdown decision is affected by UE’s CSI(s) selection criteria. So, UE’s CSI(s) selection criteria should consider the same factors that the DL traffic and actual transmission situation as gNB. However, due to the UE has no knowledge about DL traffic, it is difficult for UE to select the best shutdown pattern(s) for gNB, especially in extreme case that only one CSI is selected by UE. |
| **CEWiT** | No, this may cause lack of CSI information at the BS and also the UE still needs to calculate all the CSIs. Hence the selection should be indicated by the BS. |
| ITRI | In our perspective,• For the 1st bullet, system performance should be simulated if UE selects CSI(s) to report. Moreover, CSI-selection criteria for UE should be discussed. • We can discuss the 2nd bullet if the 1st bullet is agreed to be supported; otherwise, the 2nd bullet should not be discussed. |
| Qualcomm2 | * The 1st bullet is unclear since the spatial adaptation pattern/sub-configuration is not defined yet. We strongly suggest RAN1 discuss/define it. For example, for Type 1 adaptation, if the spatial adaptation pattern/sub-configuration includes a codebook configuration and resources with the same number of CSI-RS ports as that in the codebook, we can focus on discussion/interpretation on CSI reporting as we discussed in P3.
* We don’t support 2nd bullet. For a spatial adaptation pattern (from our perspective), it should be up to UE to select which CSI to report.
 |
| Lenovo2 | We are OK to study. Agree with ZTE, the UE selecting (and reporting) CSIs from multiple CSI corresponding to multiple CSI-RS resources is already supported in legacy behavior, so we don’t see an issue.  |
| Intel | In general, we do not think UE should pick and choose spatial patterns. Not only it puts extra burden at the UE, there needs to be extra specification effort to define CSI feedback fields that allow gNB to figure out which spatial patterns were selected, and if UE does not provide feedback for the spatial patterns that gNB is primarily interested in, the whole CSI report becomes useless.The most straightforward thing would be to have UE simply follow gNB instructions all the time.The alternative to this would be have the UE figure out optimal spatial patterns (which might be difficult since optimality may not be just based on throughput). This also means UE may need to compute more CSI feedback only to report back few of them. Dimensioning the extra UE complexity for such operation is going to be quite difficult.In short, while do not object to having the study, we think there are far more draw backs for allowing the UE to be able to select spatial patterns then the potential benefits it brings. |
| Xiaomi | We share the similar view with Intel. Generally, the CSI of different adaptation patterns are different. Extra spec work may be needed to help gNB to figure out the corresponding adaptation pattern for the reported CSI. It should be determined by gNB configuration. |
| ETRI | For first bullet, we don’t think it is beneficial for UE to select a CSI across spatial patterns when they have same number of spatial/antenna elements.For second bullet, UE-selected CSI can be further studied, but at this moment we think the rule for selection can be predefined in the specification, not to be provided by gNB. |
| Fujitsu2 | Currently, we do not see the benefit of UE selecting CSI(s) to report. First, it can only reduce the UCI overhead but not the UE complexity as UE still needs to calculate all the CSIs. Second, what a UE selects are the optimal ones from its perspective, without the knowledge of traffic load and transmission situation, it is hard to say that what the UE selects can be consistent with what the base station wants in perspective of network energy saving. However, we are open to it if the benefit is confirmed. |
| CATT | We don’t see the need to have UE selection of CSI reports to enable gNB achieving network energy saving.  |
| Apple | Not at the moment, this is an optimization enhancement and potentially increases UE computation complexity. |
| Samsung2 | We disagree to let UEs to select CSI(s) to report in multi-CSI report. First of all, the objective of CRI reporting as described by Nokia and our objective here are two different things. The Case 1 described by Nokia, which is the case of a CSI-RS resource set containing multiple CSI-RS resources with identical number of antenna ports, is mainly for Tx beam selection purpose, e.g., different beam directions or different combinations of TRPs for NC-JT, etc. However, the objective of multi-CSI report is to provide a gNB assistance information to facilitate its SD adaptation decision from multiple candidate adaptation patters with reduced capability. If a UE selects CSIs to report, the gNB do not have a control over the exact set of information that it wants to gather for its SD adaptation decision making. Also, as the gNB’s SD adaptation applies to all the UEs in the cell, the gNB may want to obtain assistance information from a group of UEs. If multiple UEs select CSIs corresponding to arbitrary sets of SD adaptation patterns, which are differ from one to another, such information may not be best utilized by the gNB for its decision making. Defining a rule/condition for a UE selection of CSIs is also not straightforward as different SD adaptation patterns mostly correspond to reduced capability of operations by gNB, e.g., reduced number of antenna ports, reduced transmission power, etc.  |
| LG Electronics2 | We think that there is a risk in terms of the operation of the gNB to have the UE directly select the CSI corresponding to the spatial or power adaptation pattern to be calculated and reported on its own. |

**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. |
| CMCC | Fine with the proposal. |
| Samsung | Support in high-level. The proposal may be formulated in a more directive statement with clear spec impacts.  |
| InterDigital | We think it is early to discuss the details of overhead reduction and the related enhancements, before discussing the benefit of multi-CSI feedback (in single report) compared to single CSI feedback. The discussions related to P4 can be considered at later stage.  |
| Panasonic | Same Comment with that to P3. |
| Ericsson | Firstly, we agree with Nokia that overhead reduction and UE complexity reduction are separate topics and should be decoupled and discussed separately.We think the bullet “Constraint for e.g., differentiation …” is unclear and should be removedWe think the examples in the final bullet “Signaling aspect …” should be removed. As we commented previously, CSI reporting on PUSCH it may not be motivated to reduce overhead as there are not the same overhead restrictions as on PUCCH. So there should be a bullet on “Impact on channel carrying UCI, i.e., PUSCH, PUCCHWe agree with Huawei that L1-RSRP should be removed. In current specifications, the UE computes L1-RSRP for multiple CSI-RS resources and is configured to report top-N L1-RSRP values, where N is configurable.Suggested updates below.**P4****If multi-CSI feedback is supported, for study of techniques for 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**
		- **Impact on channel carrying UCI, i.e., PUSCH, PUCCH**
		- **~~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)~~**
 |
| LG Electronics | We are generally fine with the proposal but it needs to clarify what is the meaning of UCI format. In addition, the priority reporting levels between multiple CSI information and the priority rule for handling collision between the CSI reports in the time-domain can be also considered. |
| FL2 | The following is considered.**P4-rev1****for multi-CSI feedback (if agreed), for techniques for overhead/report payload~~/UE complexity~~ reduction, study 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**
		- **Impact on channel carrying UCI, i.e., PUSCH, PUCCH**
		- **~~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** |
| China Telecom | Fine with the proposal. |
| DOCOMO2 | We support the proposal.  |
| ZTE, Sanechips2 | We are generally okay with the proposal..Details in sub-bullet can be added to make it clearer.* **Enhancement for report of CRI/RI/PMI/CQI**
	+ - **Impact on CSI computation and/or CPU occupation**
		- **Impact on channel carrying UCI, i.e., PUSCH, PUCCH**
		- **Solutions to compressing the CSI overhead, e.g.,common CRI/RI/PMI/CQI or differential RI/CQI**
			* **Other solutions are not excluded.**
 |
| Huawei, HiSilicon | It is agreed last meeting that "UE complexity needs to be taken into account" and the enhancement with reduced payload, looking into how they are achieved according to multiple companies' input in Q3, also help reduce the UE complexity. ’ Therefore, if this is not added in the P4-rev1, we request a separately bullet to capture this, e.g. **for multi-CSI feedback (if agreed), for techniques for UE complexity reduction, study the following aspect*** **Enhancement for CPU occupation reduction.**

As discussed in our contribution, the multiple CSIs calculation complexity can be reduced by the correlation on CSI-RS resources and PMI. For example, there are 2 patterns and each patterns has 4 resources. Due to the CSI-RS resource correlation, after the best CSI-RS resource is determined for one pattern, the UE knows the best CSI-RS resource of another pattern without iteration in all 4 CSI-RS resources. Then, the CPU occupation can be reduced from 8 to 5.  |
| InterDigital | Ok with the updated proposal |
| ITRI | In our perspective, we are fine with P4-rev1 if multi-CSI feedback is agreed. |
| Qualcomm2 | The proposal direction is fine in general. We propose making the following **update**. * **Enhancement for report of CRI/RI/PMI/CQI with following considerations**
	+ - **Impact at least on CSI computation and/or CPU occupation**
		- **Impact on channel carrying ~~UCI~~ CSI, i.e., PUSCH, PUCCH**
		- **Impact on UE complexity**
 |
| Lenovo2 | We believe it is necessary to keep the bullet corresponding to “impact on UCI format”. The mapping order of CSI fields when multiple CSI is reported would be necessary to complete the specification, as done for all CSI reporting types.  |
| Intel | Generally ok with proposal P4-rev1 |
| Futurewei | Is the understanding correct that these enhancements should only be applicable to the multi-CSI feedback case? Or should we also clarify what the ‘multi-CSI feedback’ options are? |
| Xiaomi | Fine with the updated proposal. |
| Nokia/NSB | We cannot work on something in details which has not been agreed.Suggest to clarify and agree on P3 first, then to further discuss the details on P4.Also, as we commented on P3, it would be better to first define spatial adaptation pattern, CSI-RS resource configuration, CSI report configuration, and the interaction between those, etc.In other words, ‘enhancement for report of CRI/RI/PMI/CQI’ should not be our priority now.  |
| ETRI | Fine with the updated proposal. |
| Fujitsu2 | CSI computation and CPU occupation is related to UE complexity. We suggest to remove this sub-bullet as UE complexity reduction is removed in the main bullet.**For multi-CSI feedback (if agreed), for techniques for overhead/report payload reduction, study the following aspects*** **Enhancement for report of CRI/RI/PMI/CQI**
	+ - **~~Impact on CSI computation and/or CPU occupation~~**

**Impact on channel carrying UCI, i.e., PUSCH, PUCCH** |
| CATT  | We are OK with proposal P4-rev1 |
| Apple2 | Focus on the baseline mode first, where UE reports one CSI separately in each reporting instance corresponding to multiple spatial adaptations. When the baseline mode is defined clear enough, we are fine to study necessary enhancement for overhead reduction. |
| Samsung2 | We disagree to remove L1-RSRP. Is the removal because 1) it is considered not relevant to SD adaptation or because 2) an enhancement to current L1-RSRP reporting mechanism is not needed? 1. In the input provided by Huawei, HiSilicon, it was mentioned that ‘Remove L1-RSRP since it not clear how it can help in spatial adaptation or power adaptation’. When Type 2 SD adaptation is performed by gNB and, thereby, gNB’s beam shape and Tx power change, L1-RSRP is necessary to assess the impact of adaptation.

In the input provided by Ericssion, it was mentioned that ‘In current specifications, the UE computes L1-RSRP for multiple CSI-RS resources and is configured to report top-N L1-RSRP values, where N is configurable’. Is the intention of this sentence to note that differential L1-RSRP reporting is already supported? If so, we agree on that specific aspect no additional enhancement is needed. However, there are other aspects that we think an enhancement is needed for L1-RSRP when Type 2 SD adaptation is performed, e.g., UE behavior for calculating L1-RSRP when timeRestrictionForChannelMeasurements is not configured.  |
| vivo | We would like to note that for UE to report CSIs associated with multiple spatial adaptation patterns, study on techniques for overhead/report payload can be considered.Besides, we think CSI computation and/or CPU occupation are not related to overhead reduction. So this sub-bullet needs to be removed.We suggest the following change for the proposal.**P4-rev1****for UE providing N CSIs associated with *N* CSIs associated with *N* spatial adaptation patterns in one or multiple reports where** $1\leq N$ **~~multi-CSI feedback~~** **(if agreed), for techniques for overhead/report payload~~/UE complexity~~ reduction, study 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~~**
		- **Impact on channel carrying UCI, i.e., PUSCH, PUCCH**
		- **~~Constraint for e.g. differentiation of different CSI report content due to same or different number of spatial/antenna elements~~**
 |
| LG Electronics2 | We are generally fine with the proposal. But, as we commented, if multi-CSI feedback is supported, the priority reporting levels between multiple CSI information and the priority rule for handling collision between the single-CSI report and the multi-CSI report in the time domain should be also considered. |

**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 | CommonCRI | 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. |  |  |  |  |  |  |  |
| Samsung |  | - | - | Provide separate configurability on whether PMI is reported for each of the multiple reports. Also, consider reusing DFT basis set between reports.  | Differential report. | Differential report | Indicator for a subset of multiple reports to share PMI/CQI/RI. UE only report shared PMI/CQI/RI for the subset of reports; for the remaining reports, separate PMI/CQI/RI are reported. | Consider providing indication to UE for whether to perform multi-CSI reporting or not for P/SP reports.  |
| Intel | Which | Common CRI | Common RI | Common PMI |  |  |  |  |
| How | While sub-optimal it could be possible to have a common CRI be applied for all spatial patterns. Similarly for rank as well.Use of common PMI require bit more discussion, since PMI for different number of ports can’t be derived directly from one set of PMI feedback. However, it may be possible to sub portion of the precoding matrix to formulate precoding matrix for smaller number of port case. |  |  |  |  |

**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.
 |
| Samsung | Impact on UCI format as described in our response to Q3. Agree in high-level that CPU counting needs to be revised for multi-CSI; details FFS.   |
| FL2 | To be continued. |

**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. |
| FL2 | To be discussed together with other RRC parameters. |
|  |  |
|  |  |

**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. |
| FL2 | To be revisited if more progress is available for L1/L2 singalling. |
|  |  |
|  |  |

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 patternsCase 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 patternsConsidering 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**
 |
| CMCC | We are not sure a unified design can solve both Type 1 and Type 2 spatial adaptation patterns. For Type 1 spatial adaptation pattern, one CSI-RS resource can be configured with different muting pattens. But for the Type 2 spatial adaptation pattern, due to the change of TxRU or the antenna elements, the antenna pattern would be changed and also the TCI states or the CSI would be changed accordingly. Then it is not suitable to reuse one CSI-RS resource for different spatial adaptation pattern. For the A1-2 revised, it is a little bit confusing that, multiple resources should be configured within one resource setting. And if multiple beam or the CRI should be indicated, then a multiple resources should be configured within the resource setting. Could the FL or the proponents further clarify this issue. The A1-2 revised would be more understandable if we change the ***one resource*** to ***resources***, and change ***the resource*** to ***each resource***. If my understanding is not correct, please clarify. Thank you. |
| Samsung | Not sure if a revision to previous agreement is needed. In our understanding A1-1 is legacy while A1-2 is an enhancement that can be applicable to both Type 1 and Type 2 SD adaptations. During the RAN1 112 online discussion, the term ‘spatial adaptation pattern’ was more broadly and inclusively understood, not limited to Type 1 SD adaptation.  |
| InterDigital | We are fine with the proposal, in principle, although we share the same view with Samsung on the need for revision. At least for Type -1, we are supportive of A1-2. This is because the UE could evaluate CSI for multiple spatial adaptation patterns (e.g. corresponding to different subsets of antenna ports) using the same CSI-RS resource.  |
| Panasonic | We think the “one resource setting” in P5 needs clearer explanation. It means a general resource setting for all the configured CSI reports or the CSI-RS resource within a configured CSI report?  |
| Ericsson | We agree that different alternatives are needed depending on Type-1 or Type-2 SD adaptation, hence it makes sense to support both. Regarding some companies’ comments on what is supported in current spec, both A1-1 and A1-2 are already supported. What is new is how the spatial domain adaptation is associated with the resources / resources sets.In current spec, a resource setting (CSI-ResourceConfig) is always configured with CSI-RS resource \*sets\*, and reporting is triggered/configured on sets, not individual resources, even if a set contains only one resource. Hence A1-1 revised and A1-2 revised should be updated to reflect this.Suggest update below. **Support configurability of NZP CSI-RS resource(s) for channel measurement within one resource setting ~~for channel measurement~~ corresponding to more than one spatial adaptation patterns, by the following:*** **A1-1-revised: a resource set with multiple resources ~~are~~ is configured within a resource setting, where each resource is associated with only one spatial adaptation pattern**
	+ **Note: this can facilitate network energy savings for Type-2 spatial adaptation**
* **A1-2-revised: ~~a resource setting with one~~ a resource set with one resource is configured within a resource setting, where the resource is associated with more than one spatial adaptation pattern~~s~~**
	+ **Note: this can facilitate network energy savings for Type-1 spatial adaptation**
 |
| Qualcomm | We think the proposal should be further clarified. * A1-1-revised: unclear on how it works: If we take Type 1 as example, does it mean that the resource set will have resources of different antenna port configurations? Maybe different resources in the set correspond to different spatial adaptation patterns?
* A1-2-revised: is there any limitation on “one resource” e.g., Type 1 adaptation does not seem work if the resource has 4 ports only? How does a resource associated with a SAP is determined for the “one resource”?

Hence, we suggest the following **update**:**On adaptation of spatial elements, for ~~Support~~ configurability of NZP CSI-RS resource(s) within one resource setting for channel measurement ~~corresponding to more than one spatial adaptation patterns,~~ further discuss ~~by~~ the following:*** **A1-1-revised: multiple resources are configured within a resource setting, where ~~each~~ different resources correspond to different ~~is associated with only one~~ spatial adaptation patterns**
* **A1-2-revised: a resource setting with one resource is configured, where the resource is associated with one or more than one spatial adaptation patterns**

**FFS: How to determine a reduced resource for a spatial adaptation pattern from the configured resource.** |
| LG Electronics | In principal, we agree with P5 but suggest some modification as follows.**Support configurability of NZP CSI-RS resource(s) within one resource setting (i.e., *CSI-ResourceConfig*)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 and spatial adaptation patterns associated with two different resources can differ**
* **A1-2-revised: a resource setting with one or more resource is configured, where each resource is associated with more than one spatial adaptation patterns**
 |
| FL2 | The following is agreed on Monday.**Agreement**Support configurability of NZP CSI-RS resource(s) for channel measurement within one resource setting corresponding to more than one spatial adaptation patterns with at least one of the following* A1-1-revised: a resource set with multiple resources is configured within a resource setting, where each resource is associated with only one spatial adaptation pattern
* A1-2-revised: For a resource configured in a resource set within a resource setting, the resource can be associated with more than one spatial adaptation patterns
	+ FFS: Whether one or more than one resource can be configured in the resource set

**Q9-moved*** **~~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?**
* **Do you consider more than one resource can be configured for A1-2?**
 |
| **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. |
| LG Electronics | This issue should be addressed together in Section 3.3. |
| China Telecom | We think this should depends on the spatial patterns of CSI-RS resources. For example, if the nested structure is adopted, we think the number of antenna ports in one resource set configuration can be different since there is no extra cost for CSI-RS mapping. |
| ZTE, Sanechips2 | For the second bullet, we think more than one resource should be supported for A1-2. Even for the current specification, multiple resources within one resource set configured with different QCL information are allowed. We don’t believe a restriction of only one resource within the resource set is needed for A1-2. In this case, if gNB would like to obtain CSI information for different QCL, it has to configure multiple resource settings, and UE has to report all the CSI information for all the resource settings/QCL, the OH and complexity will be increased.So we don’t think such the motivation of the restriction is valid/clear. |
| Huawei, HiSilicon | **To answer the first question in Q9-moved:** We are ok to consider CSI-RS resource set that has resources with different number of antenna ports **To answer the second question in Q9-moved:** For A1-2-revised, gNB can configure the UE with more than one resources in CSI-RS resource set and we do not think that we need to limit this implementation flexibility at the gNB**.** The motivation to limit the number of CSI-RS resource is not clear for us. Especially, for the CSI-RS transmission with port virtualization, one CSI-RS can only cover a limited range of the cell (beam). In this situation, gNB needs to transmit multiple CSI-RS to a UE in order to select a proper CSI-RS beam for a UE.  |
| ITRI | In our perspective,* For the 1st bullet, we think that the number of antenna ports can be different for CSI-RS resource set configuration.

For the 2nd bullet, we think that more than one resource can be configured for A1-2 can be configured. |
| Qualcomm2 | On 1st bullet, for A1-2, the resources in the resource set should have the same number of CSI-RS ports as the number of ports in one codebook configuration in the CSI report config.On 2nd bullet, we are fine with configuration of more than one CSI-RS resource in the resource set as long as there is restriction on the total number of resources in the set and/or the total number of resources the UE measures CSI in a CSI report config.  |
| Intel | Similar comments as Nokia. Changes to existing specification on CSI-RS resources within a CSI-RS resource set has impact to how CRI is determined and how this information is interpreted for multi-CSI feedback. We also think we need to distinguish number of antenna ports for a CSI-RS resource vs. number of hypothetical antenna ports assumed for a CSI report. Assuming we are discussing the former, we are not sure what is the use case for indicating different number of ports within a resource set. We assume the number of hypothetical antenna ports (that correspond to a spatial pattern) is something separately considered from the actual configured number of ports for a CSI-RS resource. |
| Futrurewei | 1Q: No. Our understanding is that the intention of the revised A1-1 is that within the resource set, the different resources CAN be of different number of antenna ports in order to support different spatial patterns.2Q: Yes, because current spec support this and we see no reason to restrict the flexibility of current spec. |
| Xiaomi | For the first bullet, prefer to allow one CSI-RS resource set to have different number of antenna ports. That way is efficient to adapt different spatial patterns.For the second bullet, our answer is yes. Similar view with Futurewei, no motivation to restrict the number of resources to one is observed. |
| ETRI | First bullet: Yes. Since spatial patterns with different number of CSI-RS ports can be configured by A1-2-revised, we don’t see a need to change the specification to allow CSI-RS resources with different number of ports. A1-1-revised may be applicable for FR2.Second bullet: For NES purpose, there seems no need to another CSI-RS resource in the same CSI-RS resource set. At the same time, if we do not make such restriction, more than one resource is allowed by the current specification. Whether there is need for such restriction can be further discussed. |
| Fujitsu2 | For the 1st sub-bullet, we think CSI-RS resources within a resource set can be associated with different number of antenna ports. In this way, only one resource set configuration is needed for multiple type 1 adaptation patterns, the configuration overhead can be reduced accordingly. In addition, it also requires the least amount of specification work to realize this.For the 2nd sub-bullet, we are open to multiple resources considering that current specification has already supported this |
| CATT | **Q9****1st Bullet –No.** there is no restriction on same number of antenna ports in order to support antenna patterns with different number of antenna ports.**2nd bullet – Yes**. It is up to gNB implementation to configure one or more CSI-RS resource. |
| Apple2 | For the first bullet, stick to the current spec that the resources within a resource set should have the same number of port. For type 1 spatial adaptation, UE only needs to measure on the same CSI-RS resource using different number of ports assumptions, there is no need to configure multiple resources with different numbef of ports.For the second bullet, we could be fine to support more as long as the CPU occupation and active CSI-RS and ports are counted accordingly. |
| Samsung2 | For the first bullet point, we think that the restriction on the number of antenna ports to be the same is not needed or may be improper with NES objective. The objective of the current spec having such restriction, i.e., a CSI-RS resource set containing multiple CSI-RS resources to have an identical number of antenna ports, is mainly for beam selection for the same antenna configuration but with different beam directions. Note however that the objective for NES is to probe the impact of adaptation with reduced capability, e.g., subsets of antenna ports from a given CSI-RS resource. Therefore, such restriction is counterintuitive to the objective of NES.For the second bullet point, yes, we think that more than one resources can be configured, which is up to the network. If we limit a resource set to include only one resource, it is an unnecessary restriction to the current specification.  |
| vivo | Q9For A1-1 where a resource set with multiple resources is configured within a resource setting, if each resource is associated with only one spatial adaptation pattern and different resources are associated with different spatial adaptation pattern, there is no need to limit the CSI-RS resource set configuration should only include resources with the same number of antenna ports.For A1-2 where a resource configured in a resource set within a resource setting and the resource can be associated with more than one spatial adaptation patterns, it is natural CSI-RS resource set configuration can include resources with the different number of antenna ports. |
| LG Electronics2 | To support type-1 spatial domain adaptation for A1-1-revised in the agreement above, we think that two CSI-RS resources within the resource set can have different numbers of antenna ports, which is different from the current specification.For the second question, we don’t think the restriction of the number of resources within the resource set as one is necessary for A1-2-revised. |

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. |
| CMCC | The need for introducing new CSI-RS resource mapping should be further justified.  |
| Samsung | No. |
| **FL2** | Given the discussion so far, is it possible to agree on the following?**P-Q7**：**New CSI-RS resource (RE mapping) pattern is not introduced for R18 network energy savings purpose.** |
| China Telecom | We support the P-Q7. |
| DOCOMO2 | Support the proposal considering the potential specification impact and unclear benefits.  |
| ZTE, Sanechips2 | Support |
| Huawei, HiSilicon | Support with P-Q7. |
| ITRI | Support |
| Qualcomm2 | The benefits of having new resource pattern: (1) minimal spec change (i.e., adding some new rows in the mapping pattern table) while achieving most potential NES gain; (2) maximally leveraging existing UE implementation.We are fine with the conclusion. |
| Lenovo2 | Support |
| Intel | Ok with P-Q7 |
| Xiaomi | Support |
| Nokia/NSB2 | Fine with P-Q7. |
| ETRI | Given that majority supports it, we are also okay with the proposal. |
| Fujitsu2 | We support this proposal. New resource mapping pattern should be precluded to save specification effort. |
| CATT | Agree with P-Q7 |
| Apple | Support |
| LG Electronics2 | We are not against P-Q7, but need clarification on CSI-RS resource pattern or RE mapping pattern in this proposal. According to 211 spec, 18 rows are supported to determine CSI-RS locations within a slot (as in Table 7.4.1.5.3-1). Is it correct understanding that P-Q7 implies no new row will be added in Table 7.4.1.5.3-1? |

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.**

|  |  |
| --- | --- |
| **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. |
| CMCC | In general, we are fine with this direction considering the multiple sub-configurations could be used to indicate different assumptions of the spatial/power adaptations. If more details and parameters could be discussed, it could be better.  |
| Samsung | Support in high-level. A few comments on the list: 1) CodebookConfig includes N1-N2 as well as CBSR. Thus, no need to separately list N1-N2, 2) nrofPorts is part of CSI-RS-Resource configuration. Thus, no need to be listed for CSI report configuration. Also, nrofPorts is already known by N1 and N2. 3) subset of antenna ports maybe better to be given as a part of CSI-RS resource configuration. A proper codebook size needs to be set for the indicated subset of antenna ports, not the other way around.Additionally, it is suggested to include reportQuantity. The report quantities can be separately configured for each sub-configuration to reduce overhead, e.g., PMI may not need to be reported for all the sub-configurations.   |
| InterDigital | Generally ok with FL’s proposal. Under the first FFS bullet, we suggest including a group identity as follows:* **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**
		- **Group identity associated with group of NZP CSI-RS resources**
		- **Other (new) parameters, if any**

For overhead reduction, we think a group identity associated with a group of NZP CSI-RS resources can be useful to be included for each sub-configuration. For example, such group of NZP CSI-RS resources may be associated with a spatial adaptation pattern.  |
| Panasonic | We are okay. |
| Ericsson | We support A2-2, at least for Type-1 spatial domain (SD) adaptation. For Type-2, we don’t think sub-configurations are needed since the adaptation is transparent to the UEs (# of ports does not change) – as mentioned earlier, type 2 SD can be supported with minimal spec updates. In this case multiple resources are needed, where each resource corresponds to a different SD pattern. Hence, we think that the proposal should say “At least for Type-1 SD adaptation”Also, we are unclear on what “with overhead reduction” means in the main bullet. This can be removed. We do not think the FFS is relevant since for type 1 SD, there is only one resource needed within a resource set. So the second FFS can be removed. **At least for Type-1 spatial domain adaptation, 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 domain adaptation pattern*** **FFS: the parameters that need to be separately included for each sub-configurations**
	+ - **CodebookConfig, N1 and N2**
		- **~~nrofPorts~~**
		- **number of CSI-RS ports**
		- **Indicator(s) of a subset of antenna CSI-RS ports on which the UE should measure CSI ~~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.~~**
 |
| Qualcomm1 | Both FFSs should be discussed in the context of CSI-RS resource configuration and spatial adaptation pattern. Hence, supporting DCM’s suggestion.While we prefer A2-1, we can live with A2-2 if the CSI processing related parameters are properly scaled. Further, overhead reduction should be discussed later. Hence, we propose the following update:**On adaptation of spatial elements, 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*** **CSI processing related parameters are linearly scaled with the number of spatial adaptation patterns and the number of resources in each spatial adaptation pattern.**
* **FFS: the number of sub-configurations in the CSI report**

**FFS: the number of resources in the CSI report** |
| LG Electronics | We are fine with the main bullet, but it seems more discussion is needed for FFS parts especially about which parameters are necessary depending on type of spatial domain adaptation. |
| FL2 | Regarding**Possible Agreement** **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**There could be certain related issues to be discussed. However as one general configurability, A2-2 seems agreeable to all. **Therefore, comments that concerns this proposal, please elaborate.**There are several related questions in addition to the original FFSs, which are below and separately questioned.• Whether it is only for Type-1 spatial domain adaptation?• Whether CSI processing related parameters are linearly scaled with the number of spatial adaptation patterns and the number of resources in each spatial adaptation pattern.**P6-rev2****At least support ~~configurability of~~ A2-2, i.e. one CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern.** |
| **Company** | **Comments** |
| China Telecom | Support the P6-rev2.  |
| DOCOMO2 | Support the updated proposal.  |
| ZTE, Sanechips2 | Support. |
| Huawei, HiSilicon | We support P6-rev2.**For the first question: Type 2 can also utilize sub-configuration.**For type 2, a sub-configuration corresponding to one pattern can contain/associate with CSI-RS resources corresponding to this pattern, such that the CSIs for these resources can be in one report for UCI payload reduction or UE complexity reduction. From gNB configuration perspective, the benefits hold for both cases and this can be a common framework for both type 1 and type 2.**For the Second question: We do not think the CSI processing related parameters should be linearly scaled with the number of spatial adaptation patterns and the number of resources in each spatial adaptation pattern.**As we discussed in P4 and in our contribution, the CPU occupation for multiple CSI feedback can be further reduced by the correlation on CSI-RS resources and PMIs. So, we think CPU occupation number can be further reduced. For example, there are 2 patterns and each pattern have 4 resources. Due to the CSI-RS resource correlation, after the best CSI-RS resource is determined for one pattern, the UE knows the best CSI-RS resource of another pattern without iteration in all 4 CSI-RS resources. Then, the CPU occupation can be reduced from 8 to 5.  |
| CEWiT | We are fine with the proposal. |
| ITRI | Support |
| Qualcomm2 | We suggest adding the following FFS to the proposal since they need be discussed and agreed in RAN1 to make A2-2 feasible.* **FFS: scaling for CSI processing related parameters**
* **FFS: the number of sub-configurations/resources/resource sets in the CSI report configuration**
 |
| Lenovo2 | * Support. This has been supported in legacy design, e.g., multiple codebook sub-configurations within the same CSI-ReportConfig
 |
| Intel | Ok with P6-rev2 |
| Xiaomi | Support the updated proposal. |
| Nokia/Nsb2 | The question may relate to how exactly the “sub-configuration” is to be defined. (it can be very much related to Q8)* Could the defined IEs in sub-configuration cater for both Type-1 and Type-2?
* The required CSI processing power also depends on how exactly the “sub-configuration” is to be defined.

We suggest the following updates (in green):**At least support ~~configurability of~~ A2-2, i.e. one CSI report configuration contains multiple CSI report sub-configurations where each sub-configuration corresponds to one spatial adaptation pattern.** * **FFS whether there is a need to explicitly introduce/configure a ‘sub-configuration’ IE or not.**
 |
| ETRI | Support the updated proposal. |
| Fujitsu2 | Support |
| CATT | We are OK with P6-rev2 |
| Apple2 | **OK**  |
| Samsung2 | Support |
| vivo | Support the proposal |
| LG Electronics2 | Support the updated proposal. |

**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. |
| Samsung | Not sure how the above listed parameters are related to overhead reduction. If it is related to RRC signaling overhead, it is not a critical problem. As described in our response to P6, the report quantities can be separately configured for each sub-configuration to reduce overhead.  |
| InterDigital | See our response to P6 above |
| FL2 | **P-Q8****For CSI report configuration, at least the following can be included for each sub-configuration*** + **CodebookConfig, n1-n2**
	+ **codebook subset restriction**
	+ **a subset of antenna ports within a codebook**
	+ **rank restriction**
	+ **nrofPorts**
	+ **Indicator(s) of a subset of antenna ports within a codebook**
	+ **report quantity**
 |
| **Company** | **Comments** |
| DOCOMO2 | We have concerns of the updated proposal. Generally speaking, the list is too long and some of them are duplicated, e.g., many of them are related to codebook configurations. We think one of the motivations of sub-configuration is to reduce the indication payloads, it is better to consider whether each of them is really needed for sub-configurations.  |
| ZTE, Sanechips2 | Following update is suggested.* + **a subset of antenna ports ~~within a codebook~~**
	+ **Indicator(s) of a subset of antenna ports ~~within a codebook~~**
 |
| Huawei, HiSilicon | We think P-Q8 need the following modifications, **P-Q8****For CSI report configuration, at least the following can be included for each sub-configuration*** + **Parameters in CodebookConfig~~,~~[Huawei: CodebookConfig contains the following parameters]**
	+ **n1-n2**
	+ **~~codebook subset restriction~~**

**[Huawei: As discussed in our contribution, UE can determine a X port codebook subset restriction based on Y port codebook subset restriction. So, codebook subset restriction does not need to be configured in each sub-configuration.]*** + **rank restriction**
	+ **~~a subset of antenna ports within a codebook~~**
	+ **~~rank restriction~~**
	+ **~~nrofPorts~~**
	+ **~~Indicator(s) of a subset of antenna ports within a codebook~~**
	+ **Port subset indication [Huawei: The above three bullets (green) can be summarized as this.]**
	+ **report quantity**

For type 1 shutdown, the number of CSI-RS port is changed, so different N1 and N2 need to be configured for different spatial adaptation patterns. Nevertheless, the configuration of Codebook subset restriction(s) for different spatial adaptation patterns can be further decreased by utilization of PMI correlation. For example, as shown in following, there is always a 32 port PMI that directs to the same/similar direction as a 16 port PMI. If the codebook subset restriction indicates the 32 port DFT vector $v\_{l,m}$ cannot be used, the corresponding 16 port PMIs will not be used at the same time.  |
| InterDigital | The update to proposal P-Q8 suggested by ZTE is reasonable and is ok with us. For overhead reduction when configuring CSI report configuration, we think it would be useful for configuring a group/set of CSI-RS resources that may be associated with each sub-configuration. As such, we suggest including the following to proposal P-Q8.**Group identity associated with group of NZP CSI-RS resources**  |
| Qualcomm2 | From the current specification, codebook configuration (*CodebookConfig*) includes (n1, n2) for single panel and (ng, n1, n2) for multi-panel, codebook subset restriction, and rank restriction. Hence, having *CodebookConfig* is sufficient to cover info such as (n1, n2) for single panel and (ng, n1, n2) for multi-panel, codebook subset restriction, and rank restriction.On the antenna ports, we don’t think *nrofPorts* is needed since the number of ports can be determined from values of ng, n1 and n2 in the *CodebookConfig.* For “a subset of antenna ports within a codebook” and “Indicator(s) of a subset of antenna ports within a codebook”, we think they are talking about the same thing. Hence, only one of them should be kept. Furthermore, there is no such subset of ports within a codebook since port is indexed in the CSI-RS resource, not codebook.Hence, we propose the following **update**:**For CSI report configuration, at least the following can be included for each sub-configuration*** + **CodebookConfig, ~~n1-n2~~**
	+ **~~codebook subset restriction~~**
	+ **~~a subset of antenna ports within a codebook~~**
	+ **~~rank restriction~~**
	+ **~~nrofPorts~~**
	+ **Indicator(s) of a subset of antenna ports ~~within a codebook~~**
	+ **report quantity**
 |
| Lenovo2 | We agree with QC’s updates, codebook config already includes most bullets listed. We also believe it is important to identify the supported codebook types for PMI, e.g., Type-I or Type-II  |
| Intel | Could someone clarify the distinction between “a subset of antenna ports within a codebook” and “Indicator(s) of a subset of antenna ports within a codebook”?Its not clear to us what we are agreeing to for the following two sub-bullets. |
| Nokia/NSB2 | We don’t see a strong need to include ‘report quantity’ for now. We would be fine with it, but sub-band configuration needs to be added as we previously suggested (given that different spatial patterns would have different channel characteristics in terms of frequency selectivity).We thus suggest the following updates (in red):**P-Q8****For CSI report configuration, at least the following can be ~~included~~ considered for each sub-configuration*** + **CodebookConfig, n1-n2**
	+ **codebook subset restriction**
	+ **a subset of antenna ports within a codebook**
	+ **rank restriction**
	+ **nrofPorts**
	+ **Indicator(s) of a subset of antenna ports within a codebook**
	+ **Sub-band configuration (of frequency related configuration)**
	+ **report quantity**
 |
| ETRI | We think Qualcomm’s version is more agreeable at this stage. We prefer to make one more change as:**For CSI report configuration, at least the following can be included for each sub-configuration*** + **CodebookConfig, ~~n1-n2~~**
	+ **~~codebook subset restriction~~**
	+ **~~a subset of antenna ports within a codebook~~**
	+ **~~rank restriction~~**
	+ **~~nrofPorts~~**
	+ **FFS: Information ~~Indicator(s)~~ of a subset of antenna ports ~~within a codebook~~**
	+ **report quantity**

The reason is that in our understanding, a subset of antenna ports may or may not be explicitly indicated as part of the CSI report sub-configuration. For example, it may be derived by CodebookConfig n1-n2, or may be indicated as part of CSI-RS resource configuration. In the latter case, each sub-configuration may include association information with a spatial element pattern. |
| Fujitsu2 | Most of the above elements are reauired to be separately configured in type 1 adaptation case. More specifically, for type 1 adaptation, different CodebookConfig and nrofPorts are required for different spatial adaptation patterns, while for type 2 adaptation, common CodebookConfig and nrofPorts can be considered. We think that separate lists for type 1 adaptation and type 2 adaptation are needed to facilitate the discussion about which element is required for sub-configuration.  |
| CATT | We support Qualcomm’s proposed update |
| Apple | We think only codebookConfig can be seen for current as needed, where codebook subset restriction is configured in the same IE with N1,N2 in codebookConfig.For nrofPort, we think this should be included in the resource configuration.For indicators of a subset of antenna ports, we think this may also not be needed if a predetermined rule is defined to determined the ports.For rank restriction and report quantity, we think this depends on the overhead reduction discussion, and can be FFS for now**P-Q8****For CSI report configuration, at least the following can be included for each sub-configuration*** + **CodebookConfig~~, n1-n2~~**
	+ **~~codebook subset restriction~~**
	+ **~~a subset of antenna ports within a codebook~~**
	+ **FFS: rank restriction**
	+ **~~nrofPorts~~**
	+ **~~Indicator(s) of a subset of antenna ports within a codebook~~**
	+ **FFS: report quantity**
 |
| Samsung2 | Support in high-level along with a few revisions for elaboration. The reasons for revisions is* n1-n2, CBSR, and RI-restriction are part of CodebookConfig. Thus, listing them in the same level with CodebookConfig is inappropriate.
* nrofPorts is part of CSI resource configuration, not CodebookConfig. Also, it is implicitly included in the CodebookConfig via n1-n2 indication.
* Do not understand having both ‘a subset of antenna ports within a codebook’ and ‘Indicator(s) of a subset of antenna ports within a codebook’. Indicators may be included in the triggering DCI for indication of which sub-configurations.

**P-Q8****For CSI report configuration, at least the following can be included for each sub-configuration*** + **CodebookConfig**
		- **n1-n2, codebook subset restriction, rank restriction**
		- **a subset of antenna ports within a codebook**
	+ **report quantity**
 |
| vivo | At least consider the following. FFS others* + **CodebookConfig, n1-n2**
	+ **nrofPorts**
	+ **report quantity**
 |
| LG Electronics2 | There seem to be some sub-bullet that are unclear or duplicated on the list. Regarding codebook config, we share the view with Qualcomm. Regarding indicator of a subset of antenna ports, it might be needed for A1-2-revised but we haven’t decided yet A1-2-revised will be supported. Regarding report quantity, could you please explain why this report quantity can be different for each sub-configuration? |

**~~Q9~~ (FL2: moved to section 3.3)**

**~~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.~~ |
| ~~LG Electronics~~ | ~~This issue should be addressed together in Section 3.3.~~ |

**FL2 QP6**

**For A2-2 approach,**

**• do you consider whether it can be applied to Type-2 spatial domain adaptation?**

**• do you consider whether CSI processing related parameters are linearly scaled with the number of spatial adaptation patterns and the number of resources in each spatial adaptation pattern.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| China Telecom | * Though may not be needed, we think The A2-2 can stilled be used for Type-2 SD adaptations.
* Basically , the parameters are linearly scaled with the number of patterns and resources, but it can be influenced by the details for overhead and UE complexity reduction methods.
 |
| DOCOMO2 | To reply above two questions: For 1st question: yes, A2-2 can be applied to Type-2 spatial domain adaptation. For example, one sub-configuration is associated with one CSI resource or CSI resource set, each CSI resource or resource set is associated with one Type 2 pattern. Considering multiple sub-configuration associated with multiple Type patterns, Type 2 can be supported. For 2nd question: it depends on how the measurement is done. If the UE can measure once and obtain multiple CSIs with different spatial/power assumption, e.g., measuring once on 8 port CSI-RS and obtain CSIs with 2/4/8 ports, the linearly scaling could not reflect actual complexity.  |
| ZTE, Sanechips2 | Support.For the first question, we think we don’t need to limit A2-2 to Type 1 adaptation, it should be considered for both types.For the second question, we think further discussion is needed. We agree that the CSI processing related parameters will be increased for multi-CSI report. However, the CSI calculation complexity can be reduced considering the high correlation of the precoding matrices of different port numbers. Direct scaling up the CSI processing parameters seems too conservative . |
| Huawei, HiSilicon | As discussed in P6-rev2. |
| Qualcomm2 | Yes for 1st question.For 2nd question, we propose to add “• FFS: scaling for CSI processing related parameters” to P6-rev2. |
| Intel | Q1: yesQ2: depending on what we agree for the multi-CSI case, and whether reduced complexity CSI feedback mechanisms are supported. |
| Xiaomi | Yes for Q1. |
| Nokia/NSB2 | Depending on its design, A2-2 could still accommodate for Type 2 spatial adaptation: if two spatial patterns are based on Type 2 adaptation, they could still be evaluated using different CSI-RS resource occasions in time. Otherwise, using different CSI-RS resources would also allow to evaluate these spatial patterns.Overall, the CPU count would need to scale up with either the number of CSI-RS resources and/or the number of spatial patterns being evaluated. How to exactly scale up the CSI processing related parameters could be discussed later once the baseline framework is clearer, e.g., on defining spatial adaptation pattern, CSI-RS resource configuration, CSI report configuration, and the interaction between those.  |
| ETRI | Yes for Q1. |
| Fujitsu2 | For the 1st question, we think that A2-2 can be applied to type 2 adaptation. As explained by DOCOMO, each sub-configuration can be associated with one CSI-RS resource, where each CSI-RS resource is associated with one type 2 spatial adaptation pattern.For the 2nd question, when CSIs corresponding to different spatial adaptation patterns are calculated independently, it is straightforward that CPU occupancy are linearly scaled with the number of spatial adaptation patterns and the number of resources in each spatial adaptation pattern. In the case of utilizing correlation between PMIs, further study is required. In addition, the simplest way is to calculate of CPU occupancy based on the highest case to accommodate different situations.  |
| CATT | We don’t think A2-2 would work for Type 2 spatial domain adaptation |
| Samsung2 | 1st point: Yes, it can be applied to Type 2 SD adaptation. 2nd point: We agree the need to revise the current CPU counting method. However, we disagree ‘linearly’ scaling as multi-CSI reports can be derived from a single set of measurements. For instance, it may be just two different power offset values assumed for calculation. Details on how to scale can be further studied.  |
| LG Electronics2 | Yes, for the Q1.For Q2, it can depend on the overhead reduction scheme and how the contents of multi-CSI reports are organized. |

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. |
| CMCC | We are fine with the proposal. As commented by other companies, the AP CSI-RS has enough flexibility. And the periodic and semi-persistent CSI-RS can provide a relative long period measurement, and consequently more valid CSI measurement and performance. Then both semi-persistent and periodic CSI-RS should be supported.  |
| Samsung | Support. We think all types of reporting need to be supported to provide a flexibility to the network. |
| Panasonic | We are okay. |
| Ericsson | While we are open to consider periodic and semi-persistent reporting, we think aperiodic CSI reporting is best suited for requesting of multiple CSIs from the UE in an “on demand fashion” for making decisions at the gNB for energy saving purposes. Hence, we think that aperiodic should be treated with priority. We disagree with comments from some companies that aperiodic reporting already supports spatial/power domain adaptation. Given that there is strong support for A2-2 where a report configuration contains multiple sub-configurations, it still needs to be discussed how to trigger various sub-configurations. This also applies to triggering CSI reports on multiple PDSCH-to-CSI-RS power offsets.Overall, we support the revised proposal from Oppo. 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** |
| Qualcomm1 | Aperiodic CSI reporting is better fit for the adaptation. We think focusing only on aperiodic CSI reporting makes sense.* We don’t see the need to support semi-persistent CSI report procedure. It should be noted that this procedure is triggered by MAC-CE and having this triggering often for NES is expected to significantly NES gain.

It may be possible to support the adaptation with periodic CSI reporting. However, such adaptation may be slow due to reporting periodicity. In addition, if L1/2 signalling is introduced to change the CSI reporting, it works just like aperiodic CSI reporting (L1 signalling) or semi-persistent CSI reporting (L2 signalling). |
| LG Electronics | We support the proposal. |
| FL2 | **P7-rev1****Specifications does not preclude that CSI enhancements for network energy savings can be used for any of aperiodic CSI report procedure, periodic CSI report procedure, semi-persistent CSI report procedure.** |
| **Company** | **Comments** |
| China Telecom | Support the proposal. |
| DOCOMO2 | Support the updated proposal to ensure the feasibility CSI reporting configuration. |
| ZTE, Sanechips2 | Support.  |
| Huawei, HiSilicon | We are OK. |
| CEWiT | Support the proposal |
| InterDigital | Support |
| ITRI | Support |
| Qualcomm2 | We are fine with the proposal although aperiodic CSI reporting is most efficient way for adaptation. |
| Lenovo2 | Agree with QC. Prefer to limit discussion to CSI reporting over PUSCH, which includes aperiodic reporting and semi-persistent reporting over PUSCH. The CSI feedback overhead and NCPU corresponding to NES spatial adaptation mode is expected to be higher than conventional CSI feedback, it is not preferred to support for reporting on PUCCH or with periodic reporting  |
| Intel | ok |
| Xiaomi | Support the proposal |
| Nokia/NSB2 | Fine with the proposal.Overall, we see benefits to consider semi-persistent CSI reporting, in addition to aperiodic CSI reporting. Actually, semi-persistent reporting could be seen as a multi-shot aperiodic CSI report as the gNB can trigger a semi-persistent report on PUSCH instead of triggering multiple aperiodic CSI reports on PUSCH in order to reduce the PDCCH overhead (only one DCI needs to be transmitted for activation instead of a separate DCI for each CSI report). We are also fine to consider periodic CSI reporting. |
| ETRI | Support the proposal. |
| Fujitsu2 | Support |
| CATT | Ok with the proposal |
| Samsung2 | Support |
| vivo | We support the proposal. But we think we suggest to focus on core features of enhancement for spatial adaptation first. |
| LG Electronics2 | Support 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.  |
| Samsung | Agree in high-level. The list will naturally become clear as the WI progresses. |
| FL2 | With the agreements on CSI-RS resource configuration, the question is modified as below**Q10-rev1****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 (for a subset of antenna ports within a codebook, FFS active or non-active)**
		- **Codebook configuration n1-n2**
		- **codebook subset restriction**
		- **Antenna panel number Ng (for multi-Panel)**
		- **Common antenna array dimension parameter**
		- **Common antenna panel number Ng**
		- **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 (already agreed)**
	+ - **A1-1-revised: a resource set with multiple resources is configured within a resource setting, where each resource is associated with only one spatial adaptation pattern**
		- **A1-2-revised: For a resource configured in a resource set within a resource setting, the resource can be associated with more than one spatial adaptation patterns**
* **Note: TCI-State can be separately discussed in other sections**
 |
| **Company** | **Comments** |
| DOCOMO2 | Thank you for the update. But it can be discussed later. |
| Huawei, HiSilicon | If A1-1-revised is enabled, there is no need to define spatial adaptation. One resource implicitly represents a spatial adaptation pattern.If A1-2-revised is enabled, due to this approach cannot support for type 2 shutdown, RRC configuration should only consider type 1 shutdown. So, **Q10-rev1****For spatial domain adaptation,** * **the following parameters are proposed for RRC configuration**
	+ - **~~indicator used for supporting spatial domain adaptation based CSI report enhancement~~**

[Huawei: Not clear for us. What does it mean?]* + - **nrofPorts**
		- **Antenna port indexes (for a subset of antenna ports within a codebook, FFS active or non-active)**
		- **Codebook configuration n1-n2**
		- **~~codebook subset restriction~~**

[Huawei: As discussed in our contribution, UE can determine a X port codebook subset restriction based on Y port codebook subset restriction. So, only one codebook subset restriction need to be configure.]* + - **Antenna panel number Ng (for multi-Panel)**
		- **~~Common antenna array dimension parameter~~**
		- **~~Common antenna panel number Ng~~**

[Huawei: For type 1 shutdown, they cannot be common.]* + - **ResourceMapping**
		- **~~powercontroloffset~~**

[Huawei: For type 1 shutdown, the EPRE of the CSI-RS remains the same. There is no need to configured this parameter in type 1 shutdown case]* + - **~~PowerControlOffsetSS~~**

[Huawei: For type 1 shutdown, the EPRE of the CSI-RS remains the same. There is no need to configured this parameter in type 1 shutdown case. In addition, PowerControlOffsetSS is used for pathloss calculation, it is no need for CSI calculation.]* + - **~~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 (already agreed)**
	+ - **A1-1-revised: a resource set with multiple resources is configured within a resource setting, where each resource is associated with only one spatial adaptation pattern**
		- **A1-2-revised: For a resource configured in a resource set within a resource setting, the resource can be associated with more than one spatial adaptation patterns**

**Note: TCI-State can be separately discussed in other sections** |
| Qualcomm2 | We should focus on P-Q8 where we define sub-configuration/spatial adaptation pattern. This question can be discussed after we have good understanding on P-Q8. |
| Lenovo2 | Prefer to defer the discussion until the framework is agreed |
| Intel | In general, these details can be discussed after high level solutions/configuration are more concrete.  |
| Nokia/NSB2 | As we also indicated on Q8, we think that sub-band configuration (or frequency relate configuration) needs to be added as we previously suggested (given that different spatial patterns would have different channel characteristics in terms of frequency selectivity). |
| ETRI | We prefer to discuss necessary parameters together with relevant functionality/usage as was done in P6. |
| CATT | We are OK with Q10-rev1 but should be aligned after the agreements in P-Q8 |
| Apple | Thanks for the list, however we think this list mixes resource configurations and reporting configuration parameters together. We think this could be separately discussed with Q8, while Q8 focuses on the reporting parameters and Q10 focuses on resource configuration parameters.  |
| Samsung2 | We think it would better to be discussed later once features are stable. |
| vivo | Can be discussed later |
| LG Electronics2 | Depending on which one or both between A1-1-revised and A1-2-revised will be supported, or depending on type-1 or type-2 spatial domain adaptation, we may need different set of necessary RRC configurations. |

**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. |
| CMCC | This can be discussed later. |
| Samsung | Same view as Lenovo and it can be discussed later. |
| FL2 | Majority seems to prefer to discuss this later. For reminder, the below is considered**PQ11****FFS: the number of patterns/CSI-RS resources/resource sets/resource setting/sub-configurations in reportConfig/report config(s).** |
| **Company** | **Comments** |
| ZTE, Sanechips2 | OK |
| Huawei, HiSilicon | Seems OK. This also relates to the discussion of *L* in **P3-rev1**. |
| ITRI | OK |
| Qualcomm2 | This FFS should be added to P6-rev2 for further discussion later e.g., next meeting. |
| Lenovo2 | Agree with Huawei, should be part of P3-rev1 |
| Xiaomi | Support  |
| ETRI | OK |
| CATT | OK |
| Apple | OK. The exact number can not be discussed before the whole framework is defined clear enough. |
| Samsung2 | Agree to postpone the discussion.  |
| vivo | Can be discussed later |

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.  |
| CMCC | We do not see any difficulties in supporting type 2 adaptation for the symbols configured with CSI-RS. If the transmit power is reduced due to the type 2 adaptation, power boosting could be used to maintain the coverage. |
| Samsung | Not supporting Type-2 SD in symbols configured with CSI-RS does not make sense. This implies that the network needs to adapt its spatial elements back and forth multiple times even within one slot, if it includes CSI-RS. Therefore, it needs to be supported and the CSI-RS transmission power also needs further enhancement as it is not just assumed by gNB but the UE also needs to know the CSI-RS power for correct calculation of CSI.  |
| Panasonic | After some of the TxRUs are shut down, it naturally applies and impact all the slots/symbols no matter configured with CSI-RS or not. In deployments configured with precoded CSI-RS by multiple TxRUs, to adapt the CSI-RS power is necessary. |
| FL2 | Three companies consider overall no enhancement is needed even if type 2 adaptation is supported in symbols configured with CSI-RS. Five companies consider it needs enhancements. Please continue the discussion.  |
| Qualcomm2 | CSI-RS is used for various use cases. What is CSI-RS for in the proposal? Is it for CSI reporting only? We think this should be clarified first before detail discussion. |
| Intel | Not entirely sure what it means to be left to gNB implementation. Some form of power offset information should be conveyed to the UE, otherwise how would the UE be able to compute CSI feedback?Here we assume question is asking whether some additional enhancements need to be made on top of the existing power offset signaling supported for CSI feedback for type 2 adaptation. For this question, we think not likely needed. However, this requires some further discussion on how the CSI report configuration is set for not only type 2 but also for type 1, as we would prefer to have some unified CSI report signaling framework for this approach. Therefore, we think this question may need to be revisited once, RAN1 has more conclusion on the CSI report framework for multi-CSI feedback cases. |
| CATT | It should be transparent to UEs when the CSI-RS has different characteristic due to network energy saving. Thus, no specification impact.  |
| Apple | Slighly prefer not to support Type 2 for CSI-RS, since this complicates UE measurement procedure due to the potential change of CSI-RS transmission power. |
| Samsung2 | Not supporting Type-2 SD in symbols configured with CSI-RS does not make sense. To avoid frequent adaptations by gNB, the applicability of Type-2 SD adaptation needs to be assumed in the specification work regardless of symbols configured with CSI-RS or not.  |
| vivo | We think Type-2 spatial element adaptation enhancement can be supported in symbols configured with CSI-RS. The impact can be up to gNB handling. |
| LG Electronics2 | We think both type-1 and type-2 spatial domain adaptations should be supported in symbols configured with CSI-RS, and necessary enhancements to support it can be discussed. |

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 $N'<N\_{Panel}$ 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.  |
| Samsung | Issues related to single panel should be the priority. Issues and solutions related to the treatment of multi-panel as co-located TRPs would fall under m-TRP operation and therefore should be kept out of the scope.  |
| FL2 | This discussion can be revisited later. |

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.  |
| CMCC | From our understanding, both types of spatial adaptation should be supported. Both spatial adaptation types should be considered for the beam management and or TCI frameworks should be considered, if any. |
| Samsung | In our view, type-1 and type-2 both adaptations should be supported for TCI framework. |
| CATT | BM enhancement for different number of antenna ports (Type 1) and beam width (Type 2) should be supported for spatial adaptation  |

**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 |
| CMCC | Fine to study. |
| Samsung | Support |
| Panasonic | Agree. |
| Ericsson | We do not support the proposalWe agree with the comments from ZTE and vivo.Furthermore, even if Type-2 adaptation results in wider CSI-RS beams, it is not expected that L1-RSRP measurements at the UE will result in a different UE Rx beam selection that would require a different TCI state to be indicated to the UE for PDSCH/PDCCH reception. Furthermore, Type-2 adaptation of SSB is not in scope, hence if SSB is the QCL reference for PDCCH/PDSCH reception, no enhancements are needed. |
| LG Electronics | Support in general. However, we think enhancement of beam management and TCI framework can be needed also for type-1 spatial domain adaptation. For instance, as in **A1-2-revised** of P5, if 16 antenna ports out of 32 antenna ports within the same NZP CSI-RS resource are turned off, QCL property can be affected even for type-1 spatial domain adaptation. |
| FL2 | Clarification is that support of Type 2 adaptation naturally applies to PDSCH, however whether it also applies to CSI-RS is the question here. For the timing being, the following seems agreeable to majority. Please show your concern if any; otherwise no need for input.**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** |
| ZTE, Sanechips2 | We don’t think the spatial domain adaptation has to impact the RS for beam management and/or TCI framework. So we don’t think the proposal is needed. |
| Qualcomm2 | Similar comment to Q12 C&P below:CSI-RS is used for various use cases. What is CSI-RS for in the proposal? Is it for CSI reporting only? We think this should be clarified first before detail discussion. |
| CATT | OK with the proposal |
| Samsung2 | Support the proposal.In our view, both Type 1 and Type 2 adaptation of spatial elements will have associated impact on TCI framework. In Type 1, switching off CSI-RS ports configured within a CSI-RS resource will impact QCL property and thus, change TCI state. In Type 2 adaptation of spatial elements, muting of antenna elements associated with a CSI-RS port will also impact QCL and TCI state.In summary, we support proposal of enhancing TCI framework, at least for Type 2. However, Type 1 is not precluded.  |
| vivo | As commented before, adaptation for the CSI-RS Resources for beam management would have impact on the L1-RSRP/L3-RSRP measurement, thus may affecting the legacy behavior based on the RSRP measurement.  |

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)**
 |
| CMCC | Fine for further study. |
| Samsung | Support in high-level to further study those aspects.  |
| Panasonic | Agree. |
| Ericsson | We think that these can be handled by gNB implementation and scheduling. |
| LG Electronics | Basically we think transition time or application delay can be introduced in case gNB indicates/triggers spatial/power domain adaptation pattern via DCI or MAC-CE. However, we can discuss P9 further once such kind of indicator is agreed. |
| FL2 | Considering the majority preference, the following is made. Note that the indication for notifying the adaptation to UE is not the same indication for gNB indicating/triggering e.g. multi-CSI.**P9-rev1****Further study the potential impact of spatial and power domain adaptation, considering:*** **whether data interruption time/transition time needs to be 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**
* **whether explicit indication for PDSCH (and CSI-RS) power change timing and value(s)**
 |
| **Company** | **Comments** |
| China Telecom | Support for further study. |
| DOCOMO2 | Support the proposal. |
| ZTE,Sanechips2 | We don’t think the proposal is needed. The timing issue can be handled by gNB. Moreover, even with the current spec, the PDSCH transmission power can be dynamically adjusted without any indication. |
| CEWiT | we are fine with the proposal |
| InterDigital | Support |
| Qualcomm2 | Support the proposal |
| Lenovo2 | Support |
| Intel | Ok with study. |
| Xiaomi | Support |
| Nokia/NSB2 | **First, we think that ‘transition time’ and ‘power or spatial change’ should be under separate proposals.**In addition, we don’t understand what “power change timing’ exactly mean in P9-rev1. 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 ‘change’ indication could also be considered in the discussions.  |
| Fujitsu2 | Support for further study |
| CATT | We are OK to further study but don’t see this is an essential issue |
| LG Electronics2 | OK for the further study, but we have an editorial comment as below.**P9-rev1****Further study the potential impact of spatial and power domain adaptation, considering:*** **whether data interruption time/transition time needs to be 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**
* **whether explicit indication for PDSCH (and CSI-RS) power change timing and value(s) is needed**
 |

**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. |
| FL2 | Please continue to elaborate the details. |
| Huawei, HiSilicon | We are OK with further study. However, from our perspective,1. gNB can schedule PDSCH transmission by considering the transition time per spatial/power adaptation. In addition, the TxRUs/spatial elements shut-down/turn-on and DL transmission power increase/decrease can be implemented in extreme short duration, e.g. in one OFDM symbol. So, we think that, transition time is unnecessary.
2. Current specification does not restrict that transmission power of PDSCH and DMRS. However, the UE needs to handle the PDSCH and DMRS reception power changes which is not a problem and can be overcome by the AGC tracking. Actually, we can further check this issue.
 |

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 |
| Samsung | Support |
| InterDigital | While we support L1/L2 dynamic signaling, we think the contents of the dynamic signaling is to be further discussed. In principle, dynamic signaling should effectively convey the update to the spatial adaptation pattern while incurring low overhead. For example, if multiple CSI-RS resources are associated with a spatial adaptation pattern, indicating each of the CSI-RS resource in L1/L2 signaling may not be effective. In such scenarios, indicating the sub-configuration corresponding to a group of CSI-RS resources can be more effective than indicating each CSI-RS resources.  |
| Panasonic | We are okay. Also we support revision from Apple, which we think that should additionally apply to multi-CSI feedback.**If single-CSI feedback is supported, support L1/L2 signaling to indicate/trigger a CSI-RS resource/report 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/report corresponding to one or multiple spatial adaptation patterns.**  |
| Ericsson | We don’t support the proposal in its current form.While we agree that that for the purposes of CSI reporting, it is necessary to inform the UE what PDSCH-to-CSI-RS offset(s) to assume (for power domain adaptation) and what codebook info(s) to assume (for Type-1 spatial domain adaptation), we don’t think the proposal about triggering resource(s) is meaningful. The proposal should be written in terms of triggering CSI reports, not resources.Furthermore, for the 2nd bullet, it is not clear why a “subset” of CSI-RS resources needs to be triggered/indicated. |
| LG Electronics | In general we are fine with the intention of P10, but suggest some modifications as follows.**Support L1/L2 signaling to indicate/trigger a subset of CSI report sub-configurations corresponding to one or multiple spatial or power adaptation patterns out of those configured in a CSI report configuration.** **FFS: Signaling details** |
| FL2 | This is already in a previous 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. |
| Samsung | It can be DCI and/or MAC-CE depending on the reporting types. |
| InterDigital | We prefer DCI for dynamic signaling |
| CEWiT | We also prefer DCI for dynamic signaling |
| Intel | If signaling are to be supported, it should be DCI.MAC-CE does not allow configuration to multiple UEs, and MAC CE must be sent to each UE individually, which defeats the purpose of introducing signaling to reduce latency and overhead. |
| CATT | DCI |

**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. |
| Samsung | UE-specific signaling can be baseline. Additionally, UE group-common signaling can be considered.  |
| InterDigital | We prefer cell or group common signaling for lower overhead |
| Intel | Group-common is preferred for the obvious reasons. |
| CATT  | UE-specific |

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. |
| Samsung | Our understanding is that at least the following Rel-15 UE capabilities (TR38.822) are related with the note in WID:- FG 2-33, CSI-RS and CSI-IM reception for CSI feedback- FG 2-35, CSI report framework |
|  |  |
| FL2 | In any case, it seems potential impact can be studied on at least some of the existing UE capabilities. Note due to NBC, new capabilities will be developed. **PQ18****Study the potential enhancements/extension to at least****- FG 2-33, CSI-RS [and CSI-IM reception] for CSI feedback****- FG 2-35, CSI report framework** |
| **Company** | **Comments** |
| ZTE, Sanechips2 | okay |
| Huawei, HiSilicon | We don’t think discussion of relationship with UE capability is necessary at this stage. It is too early to define and actually anything new is an extension/enhancement – the discussion for any exact impact can be carried out during the discussion. |
| Qualcomm2 | We share the same view as Samsung on the interpretation of UE capability Note in WID.We do not support PQ18. Since the Note already says “Note: Legacy UE CSI/CSI-RS capabilities applies when considering total number of CSI reports and requirements”, the PQ18 goes against the Note.BTW, the intention of the question is just to understand what capabilities are related to the Note in WID.  |
| Intel | Ok with study. |
| Nokia/NSB | On PQ18, our understanding is that the Note restrict us from introducing new capabilities, but we are open to further discuss this. |
| Fujitsu2 | In our understanding, the enhancement/extension of UE capabilities is conflict with the statement of the note in the WID. But we are open for further study. |
| CATT | OK to study |
| Apple | The “Note” in the TR restricts the increase of UE total number of CSI reports and requirement. How to count the number of CSI reports and requirement should be based on the enhancements to be made for NES. |

# 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. |
| CMCC | Support the proposal.  |
| Samsung | Support |
| InterDigital | Support |
| Panasonic | We are okay. |
| Ericsson | We suggest below updates. **For power domain adaptation, for CSI reporting, support configuration of more than one power offset values for PDSCH relative to CSI-RS** * **FFS: impact on CSI processing requirement**
* **FFS : Triggering/indication of power offset value(s)**
 |
| LG Electronics | We are fine with the proposal but it would be better what FFS bullet (i.e., impact on CSI processing requirement) implies can be clarified. |
| FL2 | **P11-rev1****For power domain adaptation, for CSI reporting, support configuration of more than one power offset values for PDSCH relative to CSI-RS** * **FFS: impact on CSI processing requirement**
* **FFS : Triggering/indication of power offset value(s)**
 |
| **Company** | **Comments** |
| China Telecom | Support. |
| ZTE, Sanechips2 | Support. |
| Huawei, HiSilicon | **P11-rev1****For power domain adaptation, for CSI(s) reporting, support configuration of more than one power offset values for PDSCH relative to CSI-RS** * **FFS: impact on CSI processing requirement**
* **FFS : Triggering/indication of power offset value(s)**
 |
| CEWiT | Support |
| InterDigital | Support |
| ITRI | Support |
| Qualcomm2 | We suggest to add an FFS:FFS: details on configuration of the power offset values. |
| Lenovo2 | Support |
| Intel | Ok with P11-rev1 (also Huawei’s update). |
| Xiaomi | Support |
| Nokia/NSB2 | We support the proposal but prefer to remove the 2nd FFS or use the wording from the previous meeting: “Whether/how one or more power offset values are dynamically indicated to UE” |
| ETRI | Support |
| Fujitsu2 | Support |
| CATT | We do not support the proposal since the power adaptation would be transparent to the UE reception of PDSCH/DMRS after radio channel |
| Samsung2 | SupportIn our view, difference in power offset between CSI-RS and PDSCH would impact CSI measurements to be used for PDSCH link adaptation. |
| vivo | Ok in principleFor next step, we think more details on how to configure more than one power offset should be discussed. The similar framework for power domain adaptation as spatial domain adaptation can be used. E.g., * A1-1: a resource set with multiple resources is configured within a resource setting, where each resource is associated with only one power offset values
* A1-2: For a resource configured in a resource set within a resource setting, the resource can be associated with more than power offset values
 |
| LG Electronics2 | Support |

**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** |
| 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. |
| CMCC | At least the L1/L2 signaling can be introduce for the power domain adaptation. A unified mechanism could be strived for both power and spatial domain adaptation. |
| Samsung | Yes. Likewise, CSI-RS transmission power. powerControlOffset/powerConrolOffsetSS values are needed to be known by UE for correct calculation of CSI.  |
| InterDigital | We share similar views with Fujitsu in that L1/L2 dynamic signalling can be considered for indicating the adjustment to the power offset value between PDSCH and CSI-RS.  |
| LG Electronics | Similar to the spatial domain adaptation, L1/L2 signaling can be used to request the report of CSI information corresponding to specific power offset values or to indicate adaptation.  |
| FL2 | To be revisited. |

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. |
| CMCC | Whether an update of the ***PowerControlOffsetSS*** is needed depends on the mechanism related to the CSI-RS enhancements. If the transmit power of the CSI-RS is changed, e.g. due to type 2 spatial adaptation, the ***PowerControlOffsetSS*** will be changed. We are open for the discussion of this issue until the enhancements related to the CSI-RS is more clear.  |
| Samsung | For PD adaptation, no. For Type 2 SD adaptation, yes.  |
| InterDigital | Given the adverse impact to legacy UEs, we do not think updating PowerControlOffsetSS is needed |
| Panasonic | Yes, as this would be a consequence of Type 2 adaptation. |
| LG Electronics | If Type 2 spatial element adaptation is adopted, the CSI-RS power may be changed because the number of TxRUs per port is changed while the number of ports is maintained. |
| FL2 | The view is a bit split and may also be related to a previous discussion for spatial adaptation. It can be revisited later. |
| CATT | Yes |

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.**

|  |  |
| --- | --- |
| **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)  |
| Samsung | No. The current proposal is ambiguous; Calculating PDSCH power backoff is not that straightforward. It depends on numerous factors such as MCS, rank, HARQ retransmission, and more.  |
| Ericsson | While we agree that PDSCH-to-CSI-RS offset needs to be indicated to the UE for the purposes of CSI reporting, we don’t think that indication of PDSCH power is needed. Also it is not clear what “backoff” means in this context. Backoff from what? Moreover, there is no signaling of DL power (or power backoff) in today’s spec. DL power control for PDSCH is up to gNB implementation. |
| LG Electronics | We are fine with the proposal. |
| FL2 | A slight majority seems not prefer to support this direction. Can be revisited later. |

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.

|  |
| --- |
| **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.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
|  |  |
|  |  |
|  |  |
|  |  |

# 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.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **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. |

**FL2 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)**?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Huawei, HiSilicon | It is needed since SA5 asked RAN/RAN1 and relevant WGs to correct the table if needed and inform them. RAN1 as the leading WG for this WI can take the responsibility for a response LS, since the latest RAN plenary did not take care of it and left it up to WGs. |
| Apple | Although we concur with necessity for LS relply, with the current detailed wording including schemes that are not RAN1 agreement yet is not acceptable, “e.g. joint report of multiple CSIs with overhead reduction, for spatial and power domain techniques..”We suggest either sending the LS providing only current WI scopes or wait until the last RAN1 meeting for a detailed reply. |
|  |  |
|  |  |
|  |  |

# 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]
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## 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.
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