**3GPP TSG RAN WG1 #110 R1-2206812**

**Toulouse, France, August 22nd – 26th, 2022**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary on Rel-18 CSI enhancements

**Document for:** Discussion and Decision

## Introduction

The scope given in the Rel-19 NR Evolved MIMO WID pertaining to CSI enhancement is as follows:

|  |
| --- |
| 1. Study, and if justified, specify CSI reporting enhancement for high/medium UE velocities by exploiting time-domain correlation/Doppler-domain information to assist DL precoding, targeting FR1, as follows:
	* Rel-16/17 Type-II codebook refinement, without modification to the spatial and frequency domain basis
	* UE reporting of time-domain channel properties measured via CSI-RS for tracking
2. Study, and if justified, specify enhancements of CSI acquisition for Coherent-JT targeting FR1 and up to 4 TRPs, assuming ideal backhaul and synchronization as well as the same number of antenna ports across TRPs, as follows:
	1. Rel-16/17 Type-II codebook refinement for CJT mTRP targeting FDD and its associated CSI reporting, taking into account throughput-overhead trade-off
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## Summary of companies’ views

### Issue 1: Type-II codebook refinement for CJT

Table 1A Summary: issue 1

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 1.1 | [109-e] **Agreement**The work scope of Type-II codebook refinement for CJT mTRP includes the following NZP CSI-RS (CMR) setups in Resource Setting associated with Rel-18 Type-II codebook for CJT* Opt1: 1 NZP CSI-RS resource, max # ports = 32
	+ FFS: whether/how to associate TCI states and CSI-RS ports
* Opt2: *K*>1 NZP CSI-RS resources with the same number of ports (representing *K* TRPs)
	+ FFS: The maximum number of ports per resource, and the total number of ports across all resources

FFS: Whether to prioritize/down-select from the two options[109-e] **Agreement**For the Type-II codebook refinement for CJT mTRP, further study the following issues:* …
* Specification entity corresponding to a TRP (e.g. port-group, NZP CSI-RS resource)
* …

**Proposal 1.A**: For the Rel-18 Type-II codebook refinement for CJT mTRP, the NZP CSI-RS resource(s)/port(s) configured as CMR in Resource Setting and the *NTRP* TRPs/TRP-groups are related as follows:* When the CMR comprises 1 NZP CSI-RS resource (if supported), the associated CSI-RS ports are equally partitioned into *NTRP* port-groups
* When the CMR comprises *K*>1 NZP CSI-RS resources (if supported), one resource corresponds to one TRP/TRP-group (i.e. *K*=*NTRP*)
* Note: The terms TRP and TRP-group are used for discussion purposes only (no spec impact is implied).

**FL Note 1**: This topic and proposals have been discussed OFFLINE [1].  | **Proposal 1.A:*** **Support/fine**: Ericsson, IDC, Spreadtrum, vivo, Lenovo, OPPO, CATT, Intel, Xiaomi, LG, CMCC, Apple, AT&T, DOCOMO, Sharp, Nokia/NSB, Sony, Huawei/HiSi, Samsung, MediaTek, Google
* **Not support**: ZTE
 |
| 1.2 | [109-e] **Agreement**The work scope of Type-II codebook refinement for CJT mTRP includes the following NZP CSI-RS (CMR) setups in Resource Setting associated with Rel-18 Type-II codebook for CJT* Opt1: 1 NZP CSI-RS resource, max # ports = 32
	+ FFS: whether/how to associate TCI states and CSI-RS ports
* Opt2: *K*>1 NZP CSI-RS resources with the same number of ports (representing *K* TRPs)
	+ FFS: The maximum number of ports per resource, and the total number of ports across all resources

FFS: Whether to prioritize/down-select from the two options**Proposal 1.B**: For the Rel-18 Type-II codebook refinement for CJT mTRP with *NTRP*>1 TRP/TRP-groups, the following is supported:* The CMR comprises *K*>1 NZP CSI-RS resources, where one resource corresponds to one TRP/TRP-group (i.e. *K*=*NTRP*)
	+ Each of the CSI-RS resources has a same number of CSI-RS ports
* Note: The terms TRP and TRP-group are used for discussion purposes only (no spec impact is implied).

**FL Note**: This topic and proposals have been discussed OFFLINE [1]. Below is the current situation for CMR, Opt1 (CMR 1 resource) vs Opt2 (CMR K>1 resources): * Support (equal priority for) both Opt1 and Opt2: Samsung, DOCOMO, ZTE, AT&T
* Down-select to only (prioritize) Opt1: Qualcomm
* Down-select to only (prioritize) Opt2: MediaTek, Apple, vivo, LG, OPPO, NEC, CMCC, Xiaomi, CATT, Huawei, HiSi, Ericsson, Intel, Fraunhofer IIS/HHI, Lenovo, Google, Spreadtrum, DOCOMO (ok), IDC, AT&T
* Some discussion points:
	+ QCL: If >1 QCLs are needed, Opt2 is more natural and requires no spec changes
	+ Opt1 can be more suitable for intra-site CJT, while Opt2 inter-site CJT
 | **Proposal 1.B:*** **Support/fine**: MediaTek, Apple, vivo, LG, OPPO, NEC, CMCC, Xiaomi, CATT, Huawei/HiSi, Ericsson, Intel, Fraunhofer IIS/HHI, Lenovo (down-select either one), Google, Spreadtrum, DOCOMO (ok), IDC, Xiaomi, AT&T, Nokia/NSB (ok), Sony (ok although prefer Opt1)
* **Not support**: Samsung (both Opt1&2), ZTE (both Opt1&2), Sharp (both Opt1&2)
 |
| 1.3 | [109-e] **Agreement**The work scope of Type-II codebook refinement for CJT mTRP includes refinement of the following codebooks:* Rel-16 eType-II regular codebook
* Rel-17 FeType-II port selection (PS) codebook

FFS: Whether to prioritize/down-select from the two | **Support (equal priority for) both Rel-16 eType-II and Rel-17 FeType-II:** Huawei/HiSi, Sharp**Down-select to only (prioritize) Rel-16 eType-II:** Apple, AT&T, Google, DOCOMO, MediaTek, NEC, CATT, Samsung, IDC, Spreadtrum, vivo, Lenovo, Intel, Xiaomi, Fraunhofer, Qualcomm, Ericsson, Sony, LG, ZTE (involving R16 port-selection CSI)**Down-select to only (prioritize)Rel-17 FeType-II:**  |
| 1.4 | [109-e] **Agreement**The work scope of Type-II codebook refinement for CJT mTRP includes the support of NTRP={1, 2, 3, 4} cooperating TRPs for CJT CSI report* FFS: Signaling of NTRP, e.g. higher-layer (RRC) vs. dynamic
* FFS: Determination of NTRP, e.g. NW-configured vs UE-selected
* FFS: Whether to prioritize or only support NTRP={1, 2}

**Proposal 1.D**: For the Rel-18 Type-II codebook refinement for CJT mTRP with *NTRP*>1 TRP/TRP-groups, support *NTRP*={1, 2, 3, 4} with equal priority. | **Proposal 1.D:*** **Support/fine:** Apple, CATT, AT&T, Google, DOCOMO, MediaTek, ZTE, NEC, Samsung, Huawei/HiSi, IDC, Intel, Sony, Ericsson, Nokia/NSB, Qualcomm, Fraunhofer IIS/HHI, Xiaomi, OPPO, vivo, CMCC
* **Not support:** Lenovo
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| 1.5 | [109-e] **Agreement**The work scope of Type-II codebook refinement for CJT mTRP includes down-selecting at least one or merging from the following codebook structures:* Alt1A. Per-TRP/TRP group (port-group or resource) SD/FD basis selection + relative co-phasing/amplitude (including WB and/or SB). Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}(a\_{1}p\_{1})×W\_{1,1}\tilde{W}\_{2,1}W\_{f,1}^{H}\\\vdots \\(a\_{N}p\_{N})×W\_{1,N}\tilde{W}\_{2,N}W\_{f,N}^{H}\end{matrix}\right]$$* + $a\_{r}$ = co-amplitude and
	+ $p\_{r}$ = co-phase
	+ Including special case of $a\_{r}=p\_{r}=1$ (no co-scaling) or $a\_{r}=0$
* Alt1B. Per-TRP/TRP group (port-group or resource) joint SD-FD basis selection + relative co-phasing/amplitude (including WB and/or SB). Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}(a\_{1}p\_{1})×W\_{SF,1}\tilde{W}\_{2,1}\\\vdots \\(a\_{N}p\_{N})×W\_{SF,N}\tilde{W}\_{2,N}\end{matrix}\right]$$* + $a\_{r}$ = co-amplitude and
	+ $p\_{r}$ = co-phase
	+ Including special case of $a\_{r}=p\_{r}=1$ (no co-scaling) or $a\_{r}=0$
* Alt2. Per-TRP/TRP group (port-group or resource) SD basis selection and joint (across *N* TRPs) FD basis selection. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}\begin{matrix}W\_{1,1}&0\\0&\ddots \end{matrix}&\begin{matrix}0&0\\0&0\end{matrix}\\\begin{matrix}0&0\\0&0\end{matrix}&W\_{1,N}\end{matrix}\right]\tilde{W}\_{2}W\_{f}^{H}$$**Proposal 1.E**: For the Rel-18 Type-II codebook for CJT mTRP, support the following two modes:* Mode 1: Per-TRP/TRP-group SD/FD basis selection which allows independent FD basis selection across N TRPs. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f,1}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f,N}^{H}\end{matrix}\right]$$* Mode 2: Per-TRP/TRP group (port-group or resource) SD basis selection and common (across *N* TRPs) FD basis selection. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f}^{H}\end{matrix}\right]=\left[\begin{matrix}\begin{matrix}W\_{1,1}&0\\0&\ddots \end{matrix}&\begin{matrix}0&0\\0&0\end{matrix}\\\begin{matrix}0&0\\0&0\end{matrix}&W\_{1,N}\end{matrix}\right]\tilde{W}\_{2}W\_{f}^{H}$$* Striving for the two modes to share commonality in detailed designs such as parameter combinations, basis selection, TRP (group) selection, reference amplitude, W2 quantization schemes.
* FFS: Depending on the decision on SCI design, whether additional per-TRP/TRP-group amplitude scaling and/or co-phase is needed or not, and whether they are a part of W2s
 | **Alt1A (16):** ZTE (co-scaling), Apple, LG, CMCC, Xiaomi, CATT, AT&T, Intel, Lenovo, Google, Spreadtrum, NEC, Samsung, Intel, DOCOMO (low priority), Sharp**Alt1B:** Huawei/HiSi **Alt2 (18):** Qualcomm (study per-TRP FD basis selection), MediaTek, vivo, LG, OPPO, CMCC, Xiaomi, AT&T, Fraunhofer IIS/HHI, DOCOMO, Spreadtrum, IDC, Nokia/NSB, Samsung, NEC, Ericsson**Proposal 1.E:*** **Support/fine:** Samsung (w/ FFS on co-amplitude), Lenovo, Intel, DOCOMO (Mode 1 low priority), LG (w/ FFS on co-amplitude), NEC, ZTE, [Ericsson], Xiaomi, vivo (unified design), AT&T (w/ FFS on co-amplitude), Nokia/NSB (ok, Mode 2 only 1st pref), Sony, Qualcomm (allow separate optimization), CMCC (unified design),
* **Not support:** IDC (mode 2 only), OPPO (mode 2 only), MediaTek (mode 2 only), Fraunhofer IIS/HHI (mode 2 only), Huawei/HiSi (mode 1 only), CATT (mode 1 only)

**FL Note:** Alt1A and Alt2 have almost equal # supporters, with the main difference of per-TRP vs. TRP-common FD basis selection. Proponents have argued that while Alt2 is more efficient (better performance and lower overhead), Alt1A can offer benefit for inter-site CJT (where the cooperating TRPs can come from different sites and be separated far apart). In addition, it has also been argued that the co-scaling in Alt1A is not needed (e.g. Huawei). Therefore, it is reasonable (as a compromise) to support both Alt1A and Alt2 as “one codebook” with two modes.* To minimize spec impact, the two modes will share the same detailed designs such as parameter combinations, basis selection, TRP (group) selection, W2 quantization schemes
 |
| 1.6 | [109-e] **Agreement** On the spatial-domain (SD) and frequency-domain (FD) basis design for the Rel-16 Type-II codebook refinement for CJT mTRP, down-select from the following alternatives:* Alt1 (separate, legacy DFT): SD basis and FD basis are separate, each fully reusing the legacy Rel-16 DFT-based design
* Alt2 (joint, DFT): joint SD-FD DFT-based basis
	+ FFS: Details on DFT parameters, e.g. length, oversampling (if any), rotation (if any)
* Alt3 (joint, eigenvector): joint SD-FD eigenvector-based basis
	+ FFS: eigenvector codebook design, parametrization
* Alt4 (separate, eigenvector): SD basis and FD basis are separate, using eigenvector-based basis
	+ FFS: eigenvector codebook design, parameterization

**Proposal 1.F**: For the Rel-18 Type-II codebook for CJT mTRP based on the Rel-16 Type-II codebook, SD basis and FD basis are separate, each fully reusing the legacy Rel-16 DFT-based design | **Alt1:** Apple, AT&T, DOCOMO, ZTE, NEC, CATT, Samsung, IDC, Spreadtrum, vivo, Lenovo, OPPO, Xiaomi, CMCC, MediaTek, Ericsson, Nokia/NSB**Alt2:** **Alt3:** Huawei/HiSi**Alt4:** **Proposal 1.F:*** **Support/fine:** Apple, AT&T, DOCOMO, ZTE, NEC, CATT, Samsung, IDC, Spreadtrum, vivo, Lenovo, OPPO, Xiaomi, CMCC, MediaTek, Ericsson, Nokia/NSB, Intel, Google, Qualcomm, LG, Fraunhofer IIS/HHI
* **Not support:** Huawei/HiSi
 |
| 1.7 | [109-e] **Agreement**On the Type-II codebook refinement for CJT mTRP, down-select from the following TRP selection/determination schemes (where N is the number of cooperating TRPs assumed in PMI reporting):* Alt1. N is gNB-configured via higher-layer (RRC) signaling
	+ The N configured TRPs are gNB-configured via higher-layer (RRC) signaling
	+ Note: only one transmission hypothesis is reported
* Alt2. N is UE-selected and reported as a part of CSI report where N$\in ${1,..., NTRP}
	+ N is the number of cooperating TRPs, while NTRP is the maximum number of cooperating TRPs configured by gNB
	+ In this case, the selection of N out of NTRP TRPs is also reported (FFS: exact reporting scheme)
	+ FFS: Configuration of NTRP TRPs and the value of NTRP, whether explicit or implicit
	+ FFS: In addition to one transmission hypothesis, whether reporting multiple transmission hypotheses (with the same N value or possibly different N values) is supported
* Alt3. The UE reports CSI corresponding to K transmission hypotheses
	+ The N configured TRPs are gNB-configured via higher-layer (RRC) signaling
	+ FFS: supported value(s) of K, and whether the K transmission hypotheses are gNB-configured or UE-reported
 | **Alt1:** Samsung, Huawei/HiSi, Xiaomi, CMCC, AT&T, Nokia/NSB, DOCOMO, Google**Alt2:** ZTE, Spreadtrum, vivo (one hypothesis), NEC, Xiaomi, CEWiT, Ericsson (one hypothesis), Sony, MediaTek, LG, CATT**Alt3:** IDC, Lenovo, Xiaomi |
| 1.8 | The need for new UCI/PMI-related parameters:[109-e] **Agreement**For the Type-II codebook refinement for CJT mTRP, further study the following issues:* The need for the following additional parameters:
	+ Receiver side information by per RX reporting or per layer, e.g. information related to the left singular matrix U of the channel
	+ Indication of relative offset of reference FD basis per TRP with respect to a reference TRP
	+ Information related to the windows for FD basis
	+ Delay/frequency difference(s) across TRPs

… | **RX side info:** Huawei, HiSi, ZTE, Sony**Per-TRP FD basis offset:** ZTE, Nokia/NSB, Sony**FD basis window info:** ZTE, Xiaomi, LG**Per-TRP delay/frequency offset:** Fraunhofer IIS/HHI (N-1 relative delay offsets), Ericsson (in a phase form) |
| 1.9 | [109-e] **Agreement** On the W2 coefficient quantization scheme for the Type-II codebook refinement for CJT mTRP:* At least for N=2, reuse *the following components* of the legacy Rel-16/17 per-coefficient quantization scheme:
	+ Alphabets for amplitude and phase
	+ Quantization of phase and quantization of differential amplitude relative to a reference, reference amplitude (with SCI determining the location of one reference amplitude), where the reference is defined for each layer and each “group” of coefficients
* Further study the following:
	+ For larger N values, if supported, whether/how to improve throughput-overhead trade-off using, e.g. lower-resolution alphabets for amplitude and/or phase than legacy, or higher/same resolution alphabets but smaller number of coefficients than legacy
	+ What constitutes a “group” (e.g. per polarization across TRPs/TRP-groups, per polarization per TRP/TRP-group, per TRP/TRP-group), the number of “groups” per layer for phase and amplitude (1 ≤*C*group,phase ≤ N, 1 ≤ *C*group,amp ≤ 2N), and how to indicate/configure “grouping”
 | **What constitutes one “group”:*** **Per polarization, per TRP/TRP-group (natural extension of legacy:** *C*group,phase **=N,** *C*group,amp **=2N):** Xiaomi, Nokia/NSB, DOCOMO (for codebook structure Alt1A), LG, ZTE, CATT, AT&T
* **Per polarization, across all TRPs/TRP-groups (***C*group,phase **=1,** *C*group,amp **=2):** Samsung, DOCOMO (for codebook structure Alt2), MediaTek (Codebook structure Alt 2), Nokia/NSB, AT&T, vivo, CMCC (at least mode 2)
* *C*group,phase **=1,** *C*group,amp **=2N:** Ericsson
 |
| 1.10 | Supported RI values**Proposal 1.J**: For the Rel-18 Type-II codebook for CJT mTRP, support RI={1,2,3,4}. | **{1,2} only:** Lenovo (prioritize {1,2}, discuss {3,4} later)**{1,2,3,4} (same as legacy):** Huawei/HiSi, Nokia/NSB, Samsung, DOCOMO, Google, MediaTek, Ericsson, ZTE, CATT, AT&T**Proposal 1.J:** * **Support/fine**: Huawei/HiSi, Nokia/NSB, Samsung, DOCOMO, Google, MediaTek, Ericsson, ZTE, CATT, AT&T, CMCC, vivo
* **Not support**: Lenovo
 |
| 1.11 | CJT extension of per-layer Strongest Coefficient Indicator (SCI):* Alt1. One per TRP/TRP-group
* Alt2. One (common) across all TRPs/TRP groups
 | **Alt1:** Lenovo, DOCOMO (for codebook structure Alt1A), CATT (for codebook structure Alt1A, for both per-layer and layer-common)**Alt2:** Samsung, DOCOMO (for codebook structure Alt2), MediaTek, Ericsson, ZTE, Nokia/NSB, AT&T, vivo, CMCC (at least mode 2) |
| 1.12 | The need for explicit/implicit strongest TRP/TRP-group indicator in addition to SCI(s), cf. issue 1.11 | **Yes:** Samsung, NEC, LG, Fraunhofer IIS/HHI, Lenovo, DOCOMO (FFS explicit or implicit), MediaTek, ZTE, CATT**No:** Nokia/NSB (may not be needed at least for single SCI) |
|  |  |  |

Table 1B Type II CJT: summary of observation from SLS

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| --- | --- | --- |
| **Company** | **Metric** | **Key observation** |
| Huawei, HiSi | Mean UPT,5% UPT | * The CJT codebook with joint space-frequency eigenvectors basis achieves 8~14% gain for mean UPT and 5~7% gain for 5%-tile UE UPT, compared with DFT basis.
* There is a significant performance improvement at both mean UPT and 5% UPT when the number of measured/cooperated TRPs increase from 2 to 3 and 4. Four TRPs CJT leads to 20% and 30~40% performance gain improvements for mean UPT and 5% UPT respectively, compared to two cooperating TRPs.
* The full channel feedback for CJT codebook can provide about 12% gain for mean UPT and 13~22% gain for mean UPT and 5% UPT respectively.
* Compared to TRP independent selection of coefficients for W2, joint selection among TRPs can provide about 5~7% and 3~6% performance gains for mean UPT and 5% UPT, respectively, when each TRP has 32 CSI-RS ports.
* There is a significant performance gain at both mean UPT and 5% UPT when the frequency domain granularity changes from 4RB to 2RB, especially at 5% UPT (more than 28%).
 |
| ZTE | Mean UPT,5% UPT,50% UPT,95% UPT | * For SU-MIMO, compared with sTRP and NC-JT, C-JT can bring performance gains in terms of both cell-edge and mean UPT.
* For MU-MIMO, compared with sTRP, C-JT can also bring performance gains in terms of both cell-edge and mean UPT, and then performance gain introducing by CJT increases as SU-MIMO is changed to MU-MIMO
* It can be observed that, based on the receiving side information, there may be a significant performance gain, especially for CJT case.
 |
| vivo | Mean SE (spectral efficiency),5% SE,50% SE,95% SE | * Observation 3: TRP recommendation causes marginal performance loss, but it reduces feedback overhead and UE complexity significantly because more than 50% of UEs do not need to measure CSI of all TRPs based on simple TRP selection rules and do not need to report CSI for all TRPs in the measurement set.
* Observation 4: For some potential schemes of codebook structure
	+ Compared to Alt1A, Alt2 has performance gain.
	+ Searching for the TRP-specific amplitude/phase in Alt1A may cause a significant computation complexity.
* At least for Indoor Hotspot and Intra-site CoMP(Outdoor2), for FD selection, there is almost no performance difference between per-TRP FD selection and joint FD selection at the same parameter pv. And, introducing TRP level reference amplitude has a negligible performance gain in some configurations.
* A limited performance gain is obtained for a larger R for Indoor Hotspot and Intra-site CoMP(Outdoor2).
* The TRP-specific beta may reduce the feedback of the coefficients corresponding to the strongest TRP, which leads to a decrease in performance.
 |
| CATT | Cell-average UPT,Cell-Edge UPT | It can be observed from the simulation results that compared with S-TRP transmission scheme, obvious performance gain can be achieved by the different layout coherent-JT for both cell average and cell edge. Moreover, as the number of TRP increases, both co-located and distributed layouts have significant gain for cell average and cell edge. |
| Intel | SE vs SNR (LLS) | As it can be observed from the above results, subband reporting of co-phasing coefficient outperforms wideband reporting. Also, performance improvement is observed for larger number of bits for the co-phasing coefficient. |
| Fraunhofer | UPT gain, feedback overhead | * Considering the drastic increase in the feedback overhead, the gain achieved using CJT mTRP is marginal compared to single TRP case.
* A better performance-overhead tradeoff can be achieved using a large value of $N\_{3}$.
 |
| Samsung | Mean UPT gain vs overhead | * significant gain in performance vs overhead trade-off can be achieved with $N\_{TRP}=X>N\_{TRP}=Y$ for $X>Y$ in both Outdoor1 and Outdoor2-OptA scenarios.
* Alt2 CB yields the best throughput vs overhead trade-off and Alt1A CB yields slightly better performance vs overhead trade-off than that of Alt1B in both Outdoor1 and Outdoor2-OptA scenarios.
* a sufficient performance gain (70% - 100%) can be obtained in a low-overhead regime that is comparable to the overhead of sTRP case, when $L=1$ and/or low values of $p\_{v}$ (e.g., 1/8) are allowed.
 |
| MediaTek | Mean UPT gain, overhead | * Alt 2 codebook structure shows a significantly better performance-overhead tradeoff compared to codebook Alt 1A.
* Alt 1A codebook structure with wideband co-phasing suffers a substantial performance loss compared to that with subband co-phasing.
* Alt 1A codebook structure suffers the problem of combining potentially different layer precoders via co-amplitude and co-phasing, which causes performance degradation.
 |
| Qualcomm | UPT loss over uncompressed upperbound | It can be observed that under this typical config for Rel-16 eType-II sTRP (just with some straight-forward small extension to mTRP), compression loss is not very tolerable, and some mTRP-specific optimization is needed to study. |
| Ericsson  | Mean/cell-edge SE gain | It can be seen that Alt.2 has a much better performance that Alt.1A. |
| Nokia/NSB | Mean/cell-edge SE gain | Very significant throughput gains in Outdoor 1 scenario at 700 MHz, in the order of 40% for mean UE throughput and 116% for cell-edge throughput. Gains are also significant, although smaller, for Outdoor 2A scenario at 2GHz, with increase in throughput of about 8% and 34% for mean UE and cell-edge throughput, respectively. |
| **Summary**: In general, almost all companies show significant gain in throughput over single-TRP scenarios in all the scenarios agreed in the EVM, with various feedback overhead depending on the simulated codebook structures and optimizations. * Sufficient gain is observed with 3 and 4 cooperating TRPs over 2, suggesting that N\_TRP=3,4 should be treated with equal priority
* In terms of codebook structures, Alt2 generally shows better UPT vs. PMI overhead trade-off over Alt1A, with Alt1A potentially offering some benefit when cooperating TRPs are far apart, e.g. inter-site CJT
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**General observation**:

* Table 1.A:
	+ [1.1]
* Table 1.B:

Table 2 Additional inputs: issue 1

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | 1. **Check and, if needed, update your view in Table 1A/1B, especially on the moderator proposals**
2. **Share additional inputs here, if needed**
3. **More moderator proposals may be added in the next revision**
 |
| Samsung | Proposal 1.A, 1.D, 1.F: supportProposal 1.B: do not support. We think both 1 and >1 CMRs should be supported since they are needed for different scenarios and use cases. In particular, * Co-located or intra-site mTRP scenarios:
	+ it is similar to the legacy Rel.15 Type I multi-panel codebook which works with 1 CMR. So, for Type II CJT in these scenarios, 1 CMR is sufficient.
	+ >1 CMRs are over-design. Why multiple CMRs if antenna ports (across TRPs) are co-located?
* Inter-site scenarios: >1 CMRs are needed due to different QCL (>1 QCL) assumptions across TRPs in these scenarios.

In short, we support both 1 and >1 CMRs since they are needed for two different NW deployment scenarios. We should not impose a solution for one scenario on to another scenario.[Mod: In terms of functionality, either option works for CJT, either will need some additional spec enhancement for CSI, and having both seems redundant. Given the super-majority view, proposal 1.B is the best the group can do.]Proposal 1.E: support in principle. Re mode 1, we think co-amplitude across TRPs are needed since the TRPs are expected to far from each other. So, suggest to add an FFS. * FFS: co-amplitude ($a\_{r})$ in mode 1.

[Mod: Whether this is needed depends on the final SCI design (e.g. if one SCI is used across all TRPs, this doesn’t seem needed and relative scaling across TRPs can be handled in W2). I clarified this in the FFS.]Issue 1.11: support Alt2 |
| Lenovo | Support Proposal 1.A, 1.B, 1.F- Re Proposal 1.D, we have an issue with supporting N={1,2,3,4} with equal priority. Our preference is to support N={1,2} for now, and further study the need to support N={3,4}, until we have further clarity on whether CJT with N>2 is helpful, i.e., >2 TRPs transmit the same set of layers. [Mod: Super-majority view suggests to support 2,3,4 with equal priority to ensure a common CB design. The benefit of having 3,4 has been demonstrated (check SLS submitted by other companies). Proceeding as you suggested would actually cause more issue down the road since it facilitates having specialized designs for 3,4. Your concern can be handled during UE feature discussion, e.g. making 2 basic over 3,4.].- Re. Proposal 1.E, we agree with Samsung that at least co-amplitude scaling for mode 1 is needed[Mod: Added FFS] |
| DOCOMO | Proposal 1.A: support.Proposal 1.B: supportProposal 1.D: supportProposal 1.E: Not support. First, we have similar comment as SS/Lenovo on co-amplitude for Mode 1. [Mod: Added FFS]Second, considering different applicable scenarios of the two alternatives, the reference amplitude, the SCI indication, etc. may need to have different designs. [Mod: Soften the wording, “strive for .. commonality ..” instead if “same”]Third, we have some concerns on workload if both are supported with the same priority. Can we support one Alt with higher priority (e.g., Alt2) and the other Alt with lower priority (e.g., Alt1A)? In that sense, we can focus on/finish high priority scenario and alternative first.[Mod: As the FL, me too ☺ I prefer to support only 1 CB. Unfortunately, Alt1A and Alt2 are almost equally supported. Delaying this to future meetings will not change the outcome since many results have been presented. Proposal 1.E is the best we can do to progress. Re priority for Alt2, I tend to sympathize with you. We can perhaps check online if it is possible (I don’t believe so).]Proposal 1.F: support |
| Google | Proposal 1.A: Support. But it seems proposal 1.B partially covers proposal 1.A? [Mod: True. Proposal 1.A is to establish a common understanding in case proposal 1.B cannot be agreed. If proposal 1.B is agreed, we may not need 1.A.] Proposal 1.B: Support. But we think there should be some further restrictions for the N CMRs, e.g. the CMRs should be transmitted within one slot with regard to AGC impact.[Mod: This can be discussed next, along with, e.g. FFS on total max number of ports. We don’t need to list all the issues now].Proposal 1.D: Support. Proposal 1.E: We have one question on mode 2. If this is for intra-site only, is it used for the sites with the same orientation or not? [Mod: No. Sharing the same FD basis doesn’t imply that all the TRPs have the same antenna (beam ☺) orientation. As long as they are not too far separated, the large-scale delay/FD profiles should be quite close – as partly demonstrated by SLS results showing Alt2 superior to Alt1A in such scenarios.]Proposal 1.F: Support. |
| Intel | **Proposal 1.A**: Support**Proposal 1.B**: Support **Proposal 1.D**: OK**Proposal 1.E**: We are OK with the proposal in principle since it covers two different scenarios (inter-site and intra-site). Regarding the co-amplitude coefficient for mode 1, in our view this can be discussed further as part of W2 design since different amplitude per TRP may be considered in W2.[Mod: Fully agree. Added that in the FFS]Also, we prefer to change the description for mode 2 to make it similar to mode 1 as follows. It will help to simplify discussion related to W2 details (e.g. SCI, quantization, etc.).$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f}^{H}\end{matrix}\right]$$[Mod: Good suggestion. Done] **Proposal 1.F**: Support |
| MediaTek | Regarding issue 1.7 we believe both RRC and UE based TRP selection should be considered, however, if only one option was to be chosen we prefer UE based selection. Regarding Proposal 1E, our preference would be to have a single codebook structure to cover both inter and intra cell scenarios and for that we prefer Alt 2.[Mod: Understood, but please check my response to DOCOMO and I hope you understand the situation.] |
| Qualcomm | **Re proposal 1.E codebook structure**Strongly recommend to take a serious re-consideration for keeping Alt1.A FD-separate codebook as one of the two configurable modes. For brevity, we want to give the following 2 reasons (of course there are more reasons):* Alt1.A v.s. Alt2 is basically wideband co-phase v.s. subband co-phase, under similar overhead. A lot of companies’ evaluation results also show that Alt2 has better performance;
* If both supported, it may be difficult to have shared same “detailed designs” (as FL suggests) b/w the 2 codebooks, and the 2 CBs may need to be designed in parallel separately
	+ Example 1, for “TRP selection” (if supported), Alt1.A CB may need hypothesis configured, while Alt2 CB not
	+ Example 2, for SD “basis selection,” Alt1.A CB may only support per-TRP L, while Alt2 CB can support either per-TRP L or total L
	+ Example 3, for FD “basis selection,” Alt1.A CB may only support per-TRP selection, while Alt2 CB can support either TRP-common or per-TRP selection.

[Mod: Plese check the revised version which should, at least partially, address our comments above.]**Re proposal 1.A/1.B**Clarifications for TRP-group is needed: For K=NTRP TRP-groups, how does a TRP group differentiate from a single TRP?**Re TRP-group**Consider another possible definition for TRP-group: Shared FD and/or SD basis selection[Mod: Re TRP vs TRP-group terms, these are used only for discussion referring to possible NW implementation. Basically a TRP-group (ZTE proposed this term) is a collection of physical TRPs which can be lumped into one “TRP” for specification purposes. But in specification this is irrelevant since we never discuss TRP (let alone TRP-group). The definition you suggested is an implication (not definition), and can cause further confusion depending on the agreed codebook structures.Once we converge more on the CMR definition and CB structures, we may not need to use the terms “TRP” or TRP group” in our discussion since this is related to NW implementation. ] **Support proposal 1.D and 1.F** |
| Mod V11 | **Revised proposal 1.E per inputs** |
| InterDigital | Proposal 1.E: Not supportWe think that having a codebook with dual modes will complicate the specification work due to the co-phasing/co-amplitude required for Alt1A, and we prefer that only Alt2 is supported. [Mod: I fully share your sentiment. The issue is that the number of supporters for 1A and 2 are almost equal – with 2 only having slight majority ☹] |
| NEC | **Proposal 1.A:** Support.**Proposal 1.B:** Fine with the proposal if only one option needs to be down selected**Proposal 1.D:** Support**Proposal 1.E:** Fine with the proposal, while we think the FFS part should be common for both two modes.**Update**: For the Type-II codebook for CJT mTRP, support the following two modes:* Mode 1: Per-TRP/TRP-group SD/FD basis selection. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f,1}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f,N}^{H}\end{matrix}\right]$$* Mode 2: Per-TRP/TRP group (port-group or resource) SD basis selection and joint (across *N* TRPs) FD basis selection. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f}^{H}\end{matrix}\right]$$* FFS: Depending on the decision on SCI design, whether additional per-TRP/TRP-group amplitude scaling is needed or not, and whether it is a part of W2s
* Striving for the two modes to share commonality in detailed designs such as parameter combinations, basis selection, TRP (group) selection, reference amplitude, W2 quantization schemes.

[Mod: Done]**Proposal 1.F:** Support |
| ~~Qualcomm2~~ | ~~The revised Alt2 FD-joint codebook is not equivalent to the original one~~$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f}^{H}\end{matrix}\right]\ne \left[\begin{matrix}\begin{matrix}W\_{1,1}&0\\0&\ddots \end{matrix}&\begin{matrix}0&0\\0&0\end{matrix}\\\begin{matrix}0&0\\0&0\end{matrix}&W\_{1,N}\end{matrix}\right]\tilde{W}\_{2}W\_{f}^{H}$$~~Actually the revised precoder is just~~ **~~another version of Alt1.A FD-separate codebook~~**~~, having restriction that each TRP’s FD basis selection to be the same.~~ |
| OPPO | Proposal 1.E: We agree with some companies that supporting two modes for CJT codebook may be over-designed. We think Alt2 can work well in both inter-site and intra-site scenarios with better performance-overhead tradeoff. We should avoid two parallel codebook design to ensure that the WID scope can be finished on time. We are fine with other proposals. For proposal 1A, we think K CMRs can work in both inter-site and intra-site scenarios and we don’t need two types of configuration.  |
| Ericsson | Regarding **Proposal 1.E**, for Mode 1, is SCI common for all TRPs or will we have SCI per TRP? We assume Alt 2 will have a single SCI common over all TRPs and all polarizations per layer. So if the goal is to strive to have commonality in detailed designs between the two modes, could we make a clarification that SCI is common for all TRPs and all polarizations per layer for both modes?[Mod: This would be good, but (at least) one company (cf. DOCOMO comment) thinks that this is suitable only for mode 2. The baseline is to have the same SCI design (cf. ther “strive … commonality” bullet. The SCI issue is denoted as 1.11 and will be discussed in later rounds.) Regarding **Issue 1.7**, we support Alt 2 and one hypothesis.For **Issue 1.9**, we support single SCI across all TRPs and all polarizations per each layer. For wideband amplitude, we prefer per TRP per polarization. So we support Cgroup\_phase=1 and Cgroup\_amplitude=2N.For **Issue 1.10**, we support RI values of {1,2,3,4} (same as legacy).For **Issue 1.11**, we support Alt 2. |
| MediaTek | We agree with Qualcomm’s comment on:$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f}^{H}\end{matrix}\right]\ne \left[\begin{matrix}\begin{matrix}W\_{1,1}&0\\0&\ddots \end{matrix}&\begin{matrix}0&0\\0&0\end{matrix}\\\begin{matrix}0&0\\0&0\end{matrix}&W\_{1,N}\end{matrix}\right]\tilde{W}\_{2}W\_{f}^{H}$$We prefer the original formulation of Alt2 codebook structure, i.e., joint $W\_{f} $and $W\_{2}$ across TRPs, as we believe the benefits of sharing only the FD basis ($W\_{f} )$ across TRPs are limited.[Mod: No, they are mathematically equivalent (see Qualcomm’s rectification below). Note that they are example formulations which will not be in the spec anyway. But to avoid further debate on this, I included both example formulations.]  |
| Qualcomm | Whether the updated Alt2 equation is equivalent, depends on how to define $\tilde{W}\_{2}$If defined as $\tilde{W}\_{2}=\left[\begin{array}{c}\tilde{W}\_{2,1}\\\vdots \\\tilde{W}\_{2,N}\end{array}\right]$ (not in a diagonal way), we agree that they are equivalent. Then, we agree with E// that, the essential issue becomes: Whether the normalization is per-TRP, which may depend on how we assume power allocation across TRPs – if cross-TRP power allocation not allowed, per-TRP SCI becomes a natural choice – otherwise $\tilde{W}\_{2}=\left[\begin{array}{c}\tilde{W}\_{2,1}\\\vdots \\\tilde{W}\_{2,N}\end{array}\right]$ would not necessarily result in a same power for all TRPs[Mod: Please see the FFS in proposal 1.E – the per-TRP scaling issue is mentioned for further discussion] |
| LG | Issue 1.3: we support to down select Rel-16 eType-II codebook only.Proposal 1.E: we suggest to put FFS on co-phase per TRP as well. If SCI per TRP is introduced, phase of strongest coefficient per TRP is fixed as 0 degree. In this case, in order to represent relative phase among the strongest coefficient per TRP, co-phase per TRP can be considered.[Mod: Done]Proposal 1.F: support.Issue 1.7: support Alt 2 |
| Spreadtrum | Proposal 1.E: We also prefer to adopt only one CB structure. We can support only Alt2 considering that Alt2 is supported by most companies. Two modes in proposal 1.E seems redundant, and it will bring unnecessary spec effect.[Mod: Yes the FL agrees, please check my comment to IDC] |
| Fraunhofer IIS/ Fraunhofer HHI | Support Proposal 1.DProposal 1.E: Some companies mentioned that Mode 1 performs better in inter-site CJT scenarios. However, it is the complete opposite. Mode 1 performs worse in inter-site CJT scenarios due to the large delay differences between the cooperating TRPs. Even for a small delay difference between the TRPs, the coefficients across different TRPs cannot be properly aligned in phase and amplitude. On the other hand, Mode 2 works for both inter-site and intra-site CJT scenarios and outperforms Mode 1 as shown by the simulation results. Therefore, for the sake of simplicity, we prefer supporting only one mode i.e., Mode 2 for Rel. 18 CJT. [Mod: Yes the FL agrees, but please check my comment to IDC]For mode 2, our understanding is that the precoders are jointly calculated across all TRP/TRP groups. If this is the common understanding, we don’t see any problem with the new formulation. Proposal 1.F: Support |
| ZTE | Proposal 1.A/Issue-1.1: In our views, for a CSI-RS resource (regardless of being configured with 1 or K>1 resources), the port groups in the CSI-RS resource can be configurable (i.e., relevant to Ng parameter). Then, we have the following suggestions:**Proposal 1.A**: For the Type-II codebook refinement for CJT mTRP, the NZP CSI-RS resource(s)/port(s) configured as CMR in Resource Setting and the *NTRP* TRPs/TRP-groups are related as follows:* When the CMR comprises 1 NZP CSI-RS resource (if supported), the associated CSI-RS ports are equally partitioned into *NTRP* port-groups
* When the CMR comprises *K*>1 NZP CSI-RS resources (if supported), one resource corresponds to one TRP/TRP-group (i.e. *K*=*NTRP*)
	+ The number of port-groups in a CSI-RS resource can be additionally indicated (e.g., Ng for MultiPanel-TypeI)

[Mod: The proposed new bullet will blur the difference between the two options and goes beyond the intention of Opt2 – which wouldn’t be acceptable for the Opt2-only proponents (representing super-majority) who shared concern during the offline discussion on the notion of port-group. Sorry I cannot add this bullet.]Proposal 1.B/Issue-1.2: For facilitating configuration for TRP/TRP-group, we prefer to have the port-group level indication (intra-site). Then, for intra-&inter-site CJT, it becomes natural that there may be 2 CSI-RS resources, each of which has 2 CSI-RS port groups. Besides for higher signaling overhead, we fail to identify why some TCI/RRC parameters need to be duplicated (e.g., have to use 4 CSI-RS resources as in the above examples).Regarding proposal 1.B, as a basic principle, TRP/TRP-group indices should be specified, and so what's the motivation of the following FFS:* FFS: Whether/how to signal the mapping between NZP CSI-RS resource indices and TRP/TRP group indices

[Mod: This was added because of some comment from Samsung during offline regarding whether this needs to be signaled or not. I removed it since it can create further confusion whether TRP/TRP-group index is needed or not.]Proposal 1.D: SupportProposal 1.E: For Mode-1, we think that Mode-1 can be much flexible, and have individual FD-bases indication over Mode-2. Then, for formula, it seems that co-phasing parameter is missing. * Mode 1: Per-TRP/TRP-group SD/FD basis selection. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f,1}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f,N}^{H}\end{matrix}\right]$$* + FFS: Depending on the decision on SCI design, whether additional per-TRP/TRP-group amplitude/phase co-scaling is needed or not, and whether it is a part of W2s

[Mod: Done] Issue 1.8: In our views, these candidate additional parameters are essential for CJT enhancement and may be considered together for codebook structure selection. Especially, for Rx side info, receiver side information per layer, e.g. information related to the left singular matrix U of the channel, in order to maximize performance gains of MU-MIMO (e.g., for determining optimal Tx precoding and post-SINR/CQI) in C-JT.* In our simulation, it can be observed that in MU-MIMO, due to path-loss/received power difference for each of TRP in CJT, this issue of CQI/MCS estimation for updating DL precoding in CJT becomes much severe compared with STRP.

[Mod: We will discuss this only after the prioritized issues (CMR, CB structures, etc.) are concluded.] |
| Xiaomi  | Proposal 1A, 1B, 1D, 1F, supportProposal 1E, we share same view as Ericsson and Qualcomm the one difference between Alt 1A and Alt 2 is the normalization is per-TRP or across all TRPs. With the updated Alt 2, the Alt 1A can cover the Alt 2 if same $W\_{f}$ is selected in Alt 1A. [Mod: Please check the FFS on per-TRP amplitude scaling, to be discussed later]For issue 1.9: we would like to further discuss these two definitions of “group”.For issue 1.11: for codebook structure Alt 1A, Alt 1 is preferred. For codebook structure Alt 2, Alt 2 is preferred.For issue 1.12: yes. We support the TRP/TRP group indicator. |
| Huawei, HiSilicon | We support proposals 1.A, 1.B, 1.D.For issue#1.3, we support both Rel-16/17 type II codebooks. As simulated, for CJT, Rel-17 PS codebook can achieve a better performance than Rel-16. As with Rel-17 PS codebook, gNB can optimize towards CJT by implementation, it can reuse most of legacy except the codebook structure, which will need little spec effort. With explicitly stated by WID, we don’t see the reason to preclude Rel-17 codebook.We don’t support proposal 1.E and 1.F. We support a joint SD/FD basis, and an eigenvector basis. With eigenvector basis, the basis is more aligned with the beams or spatial paths of the user channel, which could improve the accuracy of CSI feedback. On concerns of feedback overhead, the eigenvector basis can be feedback with a much longer periodicity (e.g., 200ms), and a short term feedback (e,g., with a periodicity of 10ms), much less coefficients (W2) is needed to combine the eigenvector basis. In this way, the feedback overhead can be reduced significantly. An obvious gain can be achieved with joint SD/FD basis and eigenvector basis, as shown in our contribution.For the current proposal 1.E, we don’t see the need to support two modes either. The difference between the modes is just whether a common Wf is used. With the same UE implementation (SVD over concatenated channel matrix of all cooperating TRPs) for all alternatives, Alt 1A could be more flexible with different Wf, not sure the reason that Alt 2 has better performance Alt 1A.[Mod: FL agrees only one is needed, but please check my comment to IDC. And 1.A doesn’t seem to be the majority view (2 is ☺). 1.E is the best compromise the group can do. I hope you can understand] |
| vivo | **Proposal 1.A and 1.B**1. We’d like to confirm the understanding on 1.A doesn’t mean both two options will be supported.

[Mod: Your understanding is correct]1. On TRP group: we think in 1.B, the intention is to use CMRs as the unit for CSI calculation and reporting. It is confusing to associate each CSI-RS resource with a TRP group. TRP group can be something built on multiple CMRs if needed. Hence we suggest to remove “TRP-group” in the proposal, otherwise there will cause too diverse interpretations and misunderstandings in future discussion.

Further, we suggest to have a sub-bullet clarifying that each CSI-RS resource has a same number of ports, as the WID clearly limits “the same number of antenna ports across TRPs”.**Proposal 1.B**: For the Type-II codebook refinement for CJT mTRP with *NTRP*>1 TRPs~~/TRP-groups~~, the following is supported:* The CMR comprises *K*>1 NZP CSI-RS resources, where one resource corresponds to one TRP~~/TRP-group~~ (i.e. *K*=*NTRP*)
	+ Each of the CSI-RS resources has a same number of CSI-RS ports
* FFS: Whether/how to signal the mapping between NZP CSI-RS resource indices and TRP~~/TRP group~~ indices

[Mod: Added the sub-bullet. Re TRP-group, please see my previous comment to Qualcomm. Since this term is used only for discussion and has no spec impact, and it has been used since the last meeting, we can keep it for now. Later as we progress more, the term TRP or TRP group may not even be needed. I added a note on proposal 1.A about this.]**Proposal 1.D**OK**Proposal 1.E**We think a clear line should be drawn to distinguish Mode 1 and Mode 2, which is important for future discussion.Based on the current formulation, Mode 2 means to have a same set of FD basis (i.e., Wf) for multiple TRPs, whereas Mode 1 allows different FD basis selection for different TRPs. Mode 2 basically uses a joint coefficient matrix (W2) to choose different delays for different TRPs if needed. Hence the size and the meaning of the W2 matrix can be different from Mode 1. It’s better to clarify this in the proposal, for example like following,“Mode 1: Per-TRP/TRP-group SD/FD basis selection which allows different FD basis across N TRPs.”“Mode 2: Per-TRP/TRP group (port-group or resource) SD basis selection and ~~joint~~ same (across *N* TRPs) FD basis selection.”* Other details, such as coefficient design, UCI design, etc., will be discussed later. How to calculate the coefficients or FD basis (jointly, separately, etc..) is actually UE implementation.

Further, we agree that we should try to select one option for CJT codebook. If we cannot do so, a unified design for the two modes should be strived for.[Mod: Done, and fully agree on unified design] |
| Nokia/NSB | **Issue 1.5/Proposal 1.E**: Regarding the change of description for Mode 2 to “help to simplify discussion related to W2 details (e.g. SCI, quantization, etc.)”, the implications of this separation are not clear. We would like to clarify that separating out W2,i in Mode 2 should not imply that the format of indicators such as bitmap, SCI, etc. is per TRP. For example, we may define a single bitmap instead of N separate bitmaps, and in case of single SCI (Alt 2 in issue 1.11) we may not need to indicate the strongest TRP separately (issue 1.12), if the SCI index runs across the rows of the joint W2.We suggest adding a note, valid for both Modes:Note: indicators such as bitmap, SCI, etc. may be defined on a joint matrix $W\_{2}=\left[\begin{matrix}\tilde{W}\_{2,1}\\\vdots \\\tilde{W}\_{2,N}\end{matrix}\right]$[Mod: I agree with your analysis. But the note may be misunderstood as giving a bias to a certain design for bitmap and SCI which are still under discussion. We will discuss this in the next rounds with more details. I hope it’s ok.]**Issue 1.9**: we support $C\_{group, phase}=1$ and $C\_{group,amp}=2N$. The phase of combination coefficients in a layer can be normalised across TRPs with respect to the strongest coefficient for that layer as per legacy Rel-16 quantisation scheme. The amplitude references, instead, are defined per TRP per polarisation to address the power imbalance between TRPs due to different RSRP levels.Issue 1.12: for clarification, should “yes” be interpreted as a separate/explicit indicator is needed. The strongest TRP may be identified implicitly through the SCI in case of a single SCI. [Mod: Correct. Yes means explicit (since implicit has no additional spec impact anyway)]  |
| CATT | Add our additional views in the above Table.**Proposal 1.A:** Support.**Proposal 1.B:** Fine with the proposal if only one option needs to be down selected**Proposal 1.D:** Support**Proposal 1.E:** For less specs impact and UE computational complexity, we prefer to prioritize only one codebook structure (one mode in Proposal 1.E) for CJT. We think mode 1(Alt 1A) is a unified framework for both co-located and distributed deployment, which can contain mode 2(Alt 2). For the inter-site or distributed layouts, since the delay paths have large differences across all the TRPs, independent FD basis selection per TRP is necessary; For the intra-site or co-located layouts, if the measurement shows that the delay paths of different TRPs are relatively close, the UE can also report the same FD basis based Alt 1.A to reduce the computational complexity. **Proposal 1.F:** Support |
| Mod V31 | **Minor revisions on proposals 1.A (clarifying note), 1.B (added equal # ports per resource constraint), 1.E (added editorial from vivo, co-phase in FFS from ZTE/LG/NEC). Added proposal 1.J** |
| AT&T | Proposal 1.A: SupportProposal 1.B/ Down-select to only (prioritize) Opt2: Support Proposal 1.D: SupportProposal 1.E: Support (w/ FFS on co-amplitude in mode1)Proposal 1.F: SupportProposal 1.J: SupportIssue1.9: Support both options (Per polarization, per TRP/TRP-group & Per polarization, across all TRPs/TRP-groups)Issue1.10: Support {1,2,3,4} (same as legacy)Issue1.11: Support Alt2 |
| MediaTek | We support the following proposal: 1A, 1B, 1D, 1F, 1J For Issue 1.9 and 1.11we would like to make further comments, we think that the outcomes of these are related to how the gNB normalizes the CJT precoder for transmission of PDSCH. For conventional single TRP transmission, the precoder is normalized to unit norm. For mTRP CJT, since there are different power sources for the geographically separated TRPs, there are potentially three ways in which the precoder could be normalized:* Alt1: mTRP precoder normalized to have unit norm (baseline)
* Alt2: mTRP precoder normalized such that per TRP precoder has unit norm (overall $N\_{TRP}$ TRP precoder has norm = $N\_{TRP}$)
* Alt3: mTRP precoder normalized with respect to the norm of the strongest TRP

For better power utilization of per TRP power sources, Alt 2 is better, however, it introduces inter-layer interference since orthogonality among layers is lost. Alt 3 utilizes the stronger TRP power better while retaining orthogonality among precoder layers. From our preliminary simulation results, we observe different performance for these three alternatives in different deployment/traffic loading conditions. Therefore, we would like to further study these issues before making a decision on the coefficient quantization and normalization schemes.[Mod: Yes, this is a next-level discussion once the prioritized issues are finalized]  |
| Samsung | Proposal 1.B: Do not support. As mentioned earlier, this proposal is OK for inter-site scenarios. For intra-site (co-located) scenarios, we would like to understand the need for multiple CMRs.[Mod: From FL perspective, given the temperature, a more fitting question would be why do we need to support a new scheme Opt1 for intra-site/co-located if Opt2 can work for that scenario? ☺]Proposal 1.E, mode 1: to be precise, from the reporting perspective, the Wf can be the same or different. So, suggest rewording as “which allows independent ~~different~~ FD basis across N TRPs.” [Mod: OK] |
| Qualcomm | For proposal 1.E the two codebooks, we want to use the following formula **form2** (who reveal more details) for discussion, see if incremental insights can be observed by companies

|  |  |  |
| --- | --- | --- |
|  | Alt1A | Alt2 |
| Formula form1 | $$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f,1}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f,N}^{H}\end{matrix}\right]$$ | $$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f}^{H}\end{matrix}\right]$$ |
| Formula form2 | $$\left[\begin{matrix}\begin{matrix}W\_{1,1}&0\\0&\ddots \end{matrix}&\begin{matrix}0&0\\0&0\end{matrix}\\\begin{matrix}0&0\\0&0\end{matrix}&W\_{1,N}\end{matrix}\right]\left[\begin{matrix}\begin{matrix}\tilde{W}\_{2,1}&0\\0&\ddots \end{matrix}&\begin{matrix}0&0\\0&0\end{matrix}\\\begin{matrix}0&0\\0&0\end{matrix}&\tilde{W}\_{2,N}\end{matrix}\right]\left[\begin{array}{c}W\_{f,1}^{H}\\\vdots \\W\_{f,N}^{H}\end{array}\right]$$ | $$\left[\begin{matrix}\begin{matrix}W\_{1,1}&0\\0&\ddots \end{matrix}&\begin{matrix}0&0\\0&0\end{matrix}\\\begin{matrix}0&0\\0&0\end{matrix}&W\_{1,N}\end{matrix}\right]\left[\begin{array}{c}\tilde{W}\_{2,1}\\\vdots \\\tilde{W}\_{2,N}\end{array}\right]W\_{f}^{H}$$ |

For simplicity, we base on: (1) Despite the algorithm, literally from the form2 formulas themselves; (2) Assuming a same overall $\tilde{W}\_{2}$ size: $2L\_{tot}M\_{tot}$, it can be observed that * Alt1A has smaller number of FD bases for each TRP’s PDP: $M\_{tot}/N$ v.s. $M\_{tot}$;
* Alt1A restrict the off-diagonal coefficient as 0

In the above two senses, Alt1A is a restricted version of Alt2.[Mod: I am not sure if your observation is fully correct (see comments below from other companies). Keep in mind that the formulas are EXAMPLES which may not be in the spec – as I mentioned. The current formulation suffices for our current purposes.]As for **another essential issue** of power normalization, it does not differentiate b/w Alt1A and Alt2, but only seems to differentiate b/w formula form1 (looks like per-TRP normalized) and form2 (looks like jointly normalized)[Mod: As I mentioned before power normalization is a next-level detail which may depend on SCI, co-amplitude, strongest TRP indicator if any, etc. It is not needed at this stage.]Hope this helps, and suggest to have formula form2 also captured into FL proposal |
| CMCC | **Proposal 1.A and 1.B**: Support.**Proposal 1.D**: Support.**Proposal 1.E**: Support.The current wording is clear for us, the main difference b/w them is just that the FD basis cross different TRPs is different or common. Although we prefer to have one codebook model to minimize the spec efforts later, with current situation, a unified design for the other details is what we could strive for.[Mod: Thanks for the good observation. I fully agree.]**Proposal 1.F**: Support.**Proposal 1.J**: Support.Issue1.9: We prefer Per polarization, across all TRPs/TRP-groups **(***C*group,phase **=1,** *C*group,amp **=2**), at least for codebook mode 2.Issue1.11: We prefer Alt 2, at least for codebook mode 2. |
| CATT | Revise our views for proposal 1.E. |
| DOCOMO | **Proposal 1.E:** We have a question for clarification. For Mode 2, based on this common FD basis across TRPs, no further TRP-specific FD basis offset indication is allowed, is that correct understanding?**Proposal 1.J:** SupportFor the updated 1.12, we think whether explicit strongest TRP/TRP-group indicator needed or not is also related to codebook structure and/or SCI design. For example, for codebook structure of Alt2 with one SCI for all TRPs, we donot think explicit strongest TRP/TRP-group indicator is needed. However, for codebook structure of Alt1A with one SCI per TRP, we think explicit strongest TRP/TRP-group indicator is needed.[Mod: This is a good observation. I added “implicit” on 1.12 description.] |
| Huawei, HiSilicon | On two formula forms mentioned by QC, I’m not sure whether the following are reasonable assumptions. As from our understanding, Alt 1A and Alt 2 should have the same size of $\tilde{W}\_{2,n}$, therefore, there’s the same information for W2 matrix between two alternatives.  *(Quoted from QC’s comments)**(2) Assuming a same overall* $\tilde{W}\_{2}$ *size:* $2L\_{tot}M\_{tot}$*, it can be observed that* * *Alt1A has smaller number of FD bases for each TRP’s PDP:* $M\_{tot}/N$ *v.s.* $M\_{tot}$*;*

For proposals 1.E and 1.F, we think the decision should be made based on comparison of feedback overhead and performance. To align the understanding of companies and to have a fair comparison between alternatives, it will be much appreciated if the information of following aspects can be provided, so that we can based on the same understanding to compare the feedback and performance gain. Our understanding of the alternatives is provided as below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Per TRP or TRP common basis for W1 and Wf | PMI obtained by SVD over separate TRP channel or over concatenated channel | W2 coefficients separately selected per-TRP or jointly selected across TRPs | Feedback overhead | Performance |
| Alt 1A/1B: per-TRP basis for W1, Wf, or Ws-fAlt 2: per-TRP basis for W1, and TRP common Wf | Alt 1A/1B/2: SVD over concatenated channel | Alt 1A/1B/2: can be jointly selected across TRPs | Alt 1A: per-TRP W1, W2, Wf feedback;Alt 1B: per-TRP W1, Ws-f feedback; long-term eigenvector basis feedback;Alt 2: per-TRP W1, W2, and TRP-common Wf feedback.The same feedback overhead for W1, W2 between alternatives. | Eigenvector basis > DFT basis;Alt 1B>Alt 1A>W2. |

 |
| Samsung | Re QCM’s comment on different #FD bases (hence different W2), we have the same view as HW, i.e., for a given parameter combination (L, M, beta), the size of W2 or Wf matrices are the same for both modes.Re HW’s questions, in our view, the two modes are different (especially the FD bases part). So, the UE implementation for PMI calculation can also be different. In particular, in mode 1, the FD basis can be selected based on per TRP channel, whereas in mode 2, it can be selected based on aggregated (across TRPs) channel.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Per TRP or TRP common basis for W1 and Wf | PMI obtained by SVD over separate TRP channel or over concatenated channel | W2 coefficients separately selected per-TRP or jointly selected across TRPs | Feedback overhead | Performance |
| Same as HW | Alt 1A/1B: SVD over per TRP channelAlt2: SVD over concatenated channel | W2 design can be the same or different for all alts | The same feedback overhead for W1. If W2 design is the same for mode 1 and mode2, then the feedback overhead for W2 will also be the same. | (Assuming DFT based Alt2B) Alt2 >Alt1A~Alt2B The perf. Of Alt2B can be improved (E.g. per element quantization of eigenvector), but @ cost of increased overhead |

 |
| Qualcomm | @ **Huawei** and **Samsung**:Thanks for the response.Firstly for comparable overhead, since the main overhead is for coefficient quantization, a same K0tot (# NZCs per layer for all TRPs) would be most essential. – We assume $K0\_{tot}=β2L\_{tot}M\_{tot}$, it is reasonable to have a same $\tilde{W}\_{2}$ size ($2L\_{tot}M\_{tot}$) for comparison. (BTW, I feel Samsung’s saying is aligned with my understanding “*size of W2 or Wf matrices are the same for both modes*”)For more **designs details** (e.g. if you think the assumption of $K0\_{tot}=β2L\_{tot}M\_{tot}$ is not appropriate for Atl1 separate codebook), it is hard to just tell with a few words, but should rely on further study. – Actually, this is the reason why I doubt the feasibility of “Striving for the two modes to share commonality in detailed designs” (as kindly and ideally suggested by FL).Lastly, a few words to sum up my view: We don’t think Alt1 separate CB necessary; But, **if two modes are supported, they should be studied separately in parallel, e.g. don’t let purpose1 design to drag down purpose2 design (or vise versa)**[Mod: This is why I use “strive for”, which means “try our best”, i.e. baseline is common design for details (this is what we usually do in standardization, i.e. minimizing spec impact as much as we can), but if it has serious impact on performance/overhead, mode-specific solutions can be entertained. Please keep in mind what “strive” means (we use this term all the time in RAN1 and know the implication).] |
| Nokia/NSB | **Proposal 1.E**: we are ok with the current compromise proposal. Our preference was Alt2 only because it has better performance than Alt 1 and different propagation delays between TRPs can be accounted for with TRP-specific FD basis offset (see issue 1.9). So Alt2 with FD basis offset indication provides TRP-specific FD bases like Alt1, but they are shifted versions of one another.Regarding DCM’s question, in our understanding, TRP-specific FD basis offset indication is allowed for both Modes, but it makes sense only for Mode 2.Regarding Huawei’s comments on P1.E/1.F: eigenvector-based $W\_{1}$-$W\_{f}$ assumes UE-specific basis vectors, which requires a redesign of $W\_{1}$ and $W\_{2}$ codebooks, for which companies may have very different proposals. We observe significant performance gains of CJT with the legacy DFT codebooks, so we don’t see the need for this laboursome redesign. Regarding feedback overhead, the difference between Mode 1 and Mode 2 depends on the design of W2 and how Wf is reported in Mode 1. But, in general, we think Mode 2 needs less overhead than Mode 1. Regarding performance, we have same assessment as Samsung in that Alt 2 shows better performance than Alt 1.  |
| vivo | **On Proposal 1.E and 1.F**We think from standard perspective, the difference between Mode 1 and Mode 2 is a same set of FD basis is selected for multiple TRPs in Mode2, while Mode 1 can allow same or different sets of FD basis for multiple TRPs. Considering this, we don’t agree with the statement that a common size of W2 is always used for both Mode 1 and Mode 2. To maintain a same number of NZ coefficients, the size of W2 can be different for the two modes considering different location distribution of the coordinated TRPs, i.e., the delay range and relative delay difference of different TRPs. Also, different total numbers of FD basis may be observed for the two TRPs. Therefore these two are actually different modes. However, we should strive to have a common design on the mechanism for the UCI reporting details.Regarding Alt 1B and joint FD/SD basis, we feel like the difference between Alt 1B and Alt 1A includes only UCI design details, which Alt 1B just uses a joint coding for FD basis and SD basis. We don’t see the need of discussing such micro-optimization of UCI signaling at this stage.**On Proposal 1.J**We are okay to support rank 1-4.**Issue 1.7**We think to support N<=NTRP is beneficial not just for UE complexity and report overhead, but also for NW performance.* UE can select N TRPs based on some metrics which are simple to compute, e.g., RSRP, overall beam-domain quality, etc. Then the complexity to search PMIs and reporting overhead can be saved due to weak TRPs are filtered out. Based on our evaluation, it does not bring much performance loss. We’d like to clarify that how these N TRPs (e.g., based on what criterion) are selected is UE implementation.
* If we look at this issue from a different angle, this can be beneficial to NW side as well. For a given UE capability and reporting overhead, NW can acquire more information. For example, if a UE can only support PMI search for a given number of TRPs or a given number of ports, e.g., 2 TRPs, to have N<=NTRP can enable gNB to configure 3 or 4 TRPs to UE, and UE can search the best precoder from 2 TRPs selected from the configured ones. This can let gNB acquire more information compared with always configuring 2 TRPs.

[Mod: Thanks, this is an important issue we will discuss right after the fundamental issues are resolved]**Issue 1.8**We think these are further details. More discussion and study are needed to understanding these new parameters after we agree on the supported CB structure.**Issue 1.9**We support to have reference amplitude across all TRPs per polarization, i.e., *C*group,phase =1, *C*group,amp =2. We evaluate per-TRP reference amplitude for both Alt 1A and Alt 2 comparing with a reference amplitude across all TRPs per pol. The performance gain of per-TRP reference amplitude is very marginal. Theoretically, per-TRP reference amplitude will bring marginal performance gain as the CSI of a TRP with weaker channel condition contributes less to the overall performance. Thus, we don’t see the need to have it considering it costs more overhead. **Issue 1.11**We support a common SCI across all TRPs, which is same as legacy codebook. |
| Intel (2) | We share similar understanding with Samsung on the different modes (proposal 1E). In our understanding different UE implementation may be assumed for different alternatives. Also, W2 design might be different for different alternatives. So, we support this proposals, other details can be considered further. |
| MediaTek | Re Proposal 1.F1. Per WID, Rel-16/17 codebook would be enhanced for CJT. Although it is up to interpretation, we believe that redesigning SD and FD bases would be much more than enhancement/refinement of these codebooks.
2. Although we agree with HW that long term feedback of eigen bases may reduce overhead, such form of long term feedback is not specified for current Rel-16/17 codebooks. For the ongoing work item on CSI enhancement for high velocities, it is mandated that SD and FD bases would not be modified, even if long term feedback is eventually agreed.

Considering these aspects, the case for joint SD-FD bases (DFT/eigen) and joint or separate eigen bases stands weak.Re codebook structures, we agree with QC at a high level that Alt 2 includes Alt 1A as a special case, but may need further evaluation with a fixed overhead for both modes, and also the fact that eventually there may not be fully common design for the two modes. |
| Mod V48 | **Thanks for the comments from companies that respond to Huawei’s inquiries re proposals 1.E and 1.F. Overall the concern on joint eigenvector basis for Rel-16-based (hence Alt1B codebook) includes unclear throughput-overhead trade-off benefit (optimization), spec impact, the amount of works involved (vs. scope/TU, time/efforts).*** **Other companies are encouraged to comment as well**

**Minor revision on proposals 1.B (including the bullet from 1.A) and 1.E (different 🡪 independent)** |
| Sharp | Proposal 1.A: SupportProposal 1.B: Our preference is to take both options but Opt 2 is OK for progressProposal 1.D: SupportProposal 1.E: We are OK Proposal 1.F: SupportProposal 1.J: Support |

### Issue 2: Type-II codebook refinement for high/medium UE velocities (with time/Doppler-domain compression)

Table 3A Summary: issue 2

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 2.1 | [109-e] **Agreement**The work scope of Type-II codebook refinement for high/medium velocities includes refinement of the following codebooks, based on a common design framework:* Rel-16 eType-II regular codebook
* Rel-17 FeType-II port selection (PS) codebook

FFS: Whether to prioritize/down-select from the two | **Support (equal priority for) both Rel-16 eType-II and Rel-17 FeType-II:** Huawei/HiSi**Down-select to only (prioritize) Rel-16 eType-II:** Apple, DOCOMO, MediaTek, NEC, Xiaomi, Samsung, Lenovo, Intel, Xiaomi. Qualcomm, Apple, DOCOMO, Ericsson, ZTE, Nokia/NSB, LG, Spreadtrum, CMCC**Down-select to only (prioritize) Rel-17 FeType-II:** Huawei/HiSi |
| 2.2 | [109-e] **Agreement**The work scope of Type-II codebook refinement for high/medium velocities includes down selection from the following codebook structures (for discussion purposes):* Alt1. Time-domain basis,
	+ Alt1A: Time-domain basis commonly selected for all SD/FD bases, e.g.$\left(W\_{f}^{\*}⨂W\_{1}\right)W\_{2}W\_{t}^{H}$
	+ Alt1B: Time-domain basis independently selected for different SD/FD bases
* Alt2. Doppler-domain basis
	+ Alt2A: Doppler-domain basis commonly selected for all SD/FD bases, e.g. $W\_{1}\tilde{W}\_{2}(W\_{f}⨂W\_{d})^{H}$
	+ Alt2B: Doppler-domain basis independently selected for different SD/FD bases
	+ Note that $W\_{d}$ may be the identity as a special case
* Alt3. Reuse Rel-16/17 (F)eType-II codebook with multiple $W\_{2}$ and a single $W\_{1}$ and $W\_{f}$ report.

**Proposal 2.B**: For the Rel-18 Type-II codebook refinement for high/medium velocities, down-select from the following codebooks structures:* Alt2A: Doppler-domain basis commonly selected for all SD/FD bases, e.g. $W\_{1}\tilde{W}\_{2}(W\_{f}⨂W\_{d})^{H}$
	+ Note that $W\_{d}$ may be the identity as a special case
* Alt2B: Doppler-domain basis independently selected for different SD/FD bases
	+ Note that $W\_{d}$ may be the identity as a special case
* Alt3. Reuse Rel-16/17 (F)eType-II codebook with multiple $W\_{2}$ and a single $W\_{1}$ and $W\_{f}$ report.

**FL Note**: This topic has been discussed OFFLINE [1] | **Alt2A:** Huawei/HiSi, Samsung, ZTE, Spreadtrum, Google, Lenovo, OPPO, CATT, NEC, Intel, CMCC, Qualcomm, Apple, DOCOMO, Ericsson, Nokia/NSB (Wd=I)**Alt2B:** Fraunhofer IIS/HHI, Apple**Alt3:** IDC, Lenovo, CEWiT, Ericsson**Proposal 2.B:*** **Support/fine:** Huawei/HiSi, Samsung, ZTE, Spreadtrum, Google, Lenovo, OPPO, CATT, NEC, Intel, CMCC, Qualcomm, Apple, DOCOMO, Ericsson, Nokia/NSB, Fraunhofer IIS/HHI, IDC, CEWiT, LG, Xiaomi
* **Not support:**
 |
| 2.3 | [109-e] **Agreement**The work scope of Type-II codebook refinement for high/medium velocities includes down selection from the following Doppler-/time-domain basis waveforms for codebook design: * Alt1. Orthogonal DFT (with or without rotation factor)
* Alt2. Oversampled DFT
* Alt3. Other waveforms, e.g. DCT, Slepian
* Alt4. Identity (i.e. no Doppler-/time-domain compression)

**Proposal 2.C**: For the Rel-18 Type-II codebook refinement for high/medium velocities, on the DD/TD basis waveforms:* Down-select or combine from the following Doppler-/time-domain basis waveforms:
	+ Alt1. Orthogonal DFT
		- TBD (by RAN1#110bis): whether rotation is used or not
		- FFS: identical or different rotation factors for different SD components
	+ Alt2. Identity (i.e. no Doppler-/time-domain compression)
* FFS: Whether Doppler-/time-domain (DD/TD) basis vector length (*N*4) is RRC-configured or reported by the UE
* FFS: Whether the number of selected DD/TD basis vectors (for Alt1) is RRC-configured or reported by the UE
 | **Proposal 2.C:*** **Support/fine:** Huawei/HiSi, OPPO, Spreadtrum, NEC, Intel, Samsung, ZTE, Xiaomi, vivo, Lenovo, CATT, Fraunhofer IIS/HHI, MediaTek, CEWiT, Qualcomm, Apple, DOCOMO, Sharp, Nokia/NSB, Google, Ericsson, LG, CMCC
* **Not support:**

**FL Note:** This is the summary from Tdocs:* **Alt1:** Huawei/HiSi, OPPO, Spreadtrum, NEC, Intel, Samsung, ZTE, Xiaomi, vivo, Lenovo, CATT, Fraunhofer IIS/HHI, MediaTek, CEWiT, Qualcomm, Apple, DOCOMO, Sharp
	+ **No rotation:** Huawei/HiSi, OPPO, Apple, DOCOMO
	+ **w/ rotation:** Samsung, ZTE, Xiaomi, Fraunhofer IIS/HHI
* **Alt2:** CEWiT, Sharp
* **Alt3:** Samsung
* **Alt4:** vivo, MediaTek, Nokia/NSB

Most companies also propose that the length and # selected basis vectors are RRC-configured. |
| 2.4 | Question: Can the Rel-18 Type-II codebook refinement for high/medium velocities be used with the following assumption?1. Legacy UE procedure for CSI measurement/calculation
2. gNB-side prediction (to be incorporated in the spec, assumed by the UE in CSI calculation)
3. UE-side prediction (to be incorporated in the spec, assumed by the UE in CSI calculation)

**Proposal 2.D**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the assumption of the UE-side prediction * FFS: as an optional feature, whether or not UE-side prediction is always assumed with the Rel-18 Type-II codebook refinement for high/medium velocities
* On the definition of UE-side prediction, down-select from the following alternatives:
	+ Alt1. UE “predicting” channel/CSI after the slot with a reference resource
		- FFS: location of the reference resource
	+ Alt2. UE “predicting” channel/CSI after slot n (where the CSI is reported)
	+ Alt3. UE “predicting” channel/CSI after the slot(s) where CSI-RS resides
 | **Legacy:*** **Yes:**
* **No:** Lenovo

**gNB-side prediction (to be specified, assumed by the UE in CSI calculation):** * **Yes**: Lenovo, Fraunhofer IIS/HHI, Qualcomm, DOCOMO, LG, Spreadtrum(2nd preference), Xiaomi
* **No**: Ericsson, vivo, Nokia/NSB, Huawei/HiSi, Samsung, ZTE

**UE-side prediction (to be specified, assumed by the UE in CSI calculation):** * **Yes**: IDC, Huawei/HiSi, Samsung, ZTE, vivo, Lenovo (optional), CATT, CMCC, Fraunhofer IIS/HHI (optional), Qualcomm (optional), Apple (optional), DOCOMO (optional), Nokia/NSB, Google, Intel, MediaTek, NEC, LG, Spreadtrum(1st preference)
* **No:**

**Proposal 2.D:*** **Support/fine:** IDC, Huawei/HiSi, Samsung, ZTE, vivo, Lenovo, CATT, CMCC, Fraunhofer IIS/HHI, Qualcomm, Apple, DOCOMO, Nokia/NSB, Google, Intel, MediaTek, NEC, LG, Spreadtrum
* **Not support:**
 |
| 2.5 | What constitutes “UE-side prediction”?* Alt1. UE “predicting” channel/CSI after the slot with a reference resource
* Alt2. UE “predicting” channel/CSI after slot n (where the CSI is reported)
* Alt3. UE “predicting” channel/CSI after the slot(s) where CSI-RS resides
 | **Alt1:** Qualcomm, Samsung, LG, ZTE**Alt2:** Huawei/HiSi, vivo, Nokia/NSB (2nd pref), Lenovo, Google, Intel**,** MediaTek, Ericsson, Spreadtrum, CATT, CMCC**Alt3:** Samsung, DOCOMO, NEC, Nokia/NSB (1st pref) |
| 2.6 | [109-e] **Agreement**On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, *at least for discussion purposes*, define the following:* Assume a CSI report in slot *n*, and let the length of the DD/TD basis vector be *N*4
	+ Note that basis vector has no span/window in time-domain, only length
* CSI-RS measurement window of [*k*,*k*+*W*meas –1], representing the window in which CSI-RS occasion(s) are measured for calculating a CSI report
	+ *k* is a slot index and *W*meas is the measurement window length (in slots)
	+ Note: In the legacy Rel-16/17 CSI, the CSI-RS occasion(s) are configured in *CSI-ReportConfig*
* CSI reporting window of [*l*,*l*+*W*CSI –1], associated to the CSI report in slot *n*
	+ *l* is a slot index and *W*CSI is the reporting window length (in slots)
* CSI reference resource(s) in time-domain
	+ The location of a CSI reference resource is denoted as *n*ref (slot index)

[109-e] **Agreement**On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, consider *at least* the following alternatives for potential down-selection:* Alt1: *n*ref (CSI reference resource slot) as boundary
	+ Alt1.A:  *l* + *W*CSI –1 ≤ *n*ref
	+ Alt1.B:  *l* ≥ *n*ref
	+ Alt1.C: *l* < *n*ref and *l* + *W*CSI –1 > *n*ref
* Alt2: *n* (report slot) as boundary
	+ Alt2.A: *l* + *W*CSI –1 ≤ *n*
	+ Alt2.B: *l* ≥ *n*
	+ Alt2.C: *l* < *n* and *l* + *W*CSI –1 > *n*
* Alt3: End slot of *W*meas (*k* + *W*meas –1) as boundary
	+ Alt3.A: *l* + *W*CSI –1 ≤ *k* + *W*meas –1 with the following as a special case: *l=k,* *W*CSI = *W*meas
	+ Alt3.B: *l* ≥ *k* + *W*meas –1
	+ Alt3.C: *l* < *k* + *W*meas –1 and *l* + *W*CSI –1 > *k* + *W*meas –1 with the following as special cases:
		- *l=k,* *l* + *W*CSI = *n*
		- *l=k,* *l* + *W*CSI > *n*

FFS: whether *n*ref represents the slot index of Rel-15 CSI reference resource or a newly defined CSI reference resourceFFS: whether/how the CSI measurement window and reporting window are configured**Proposal 2.F**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, down-select at least one from the following alternatives:* Alt1.A:  *l* + *W*CSI –1 ≤ *n*ref
	+ *n*ref (CSI reference resource slot) as boundary
* Alt1.B:  *l* ≥ *n*ref
	+ *n*ref (CSI reference resource slot) as boundary
* Alt2.B: *l* ≥ *n*
	+ *n* (report slot) as boundary
* Alt3.B: *l* ≥ *k* + *W*meas –1
	+ End slot of *W*meas (*k* + *W*meas –1) as boundary
 | **Alt1.A:** Spreadtrum, Xiaomi, LG, Fraunhofer IIS/HHI, Qualcomm, DOCOMO**Alt1.B:** IDC, ZTE, LG, CMCC, DOCOMO**Alt2.B:** Huawei/HiSi, Spreadtrum, vivo, Google, OPPO, CATT, Intel, CMCC, MediaTek, Ericsson, Nokia/NSB, DOCOMO (optional)**Alt3.B:** CMCC, Fraunhofer IIS/HHI, Nokia/NSB, Samsung, NEC, [Apple]**FL Note**: This topic and proposal have been discussed OFFLINE [1]. * Alt1.A: Qualcomm, DOCOMO, LG, Intel, Xiaomi
* Alt1.B: Qualcomm, ZTE, LG, OPPO, CMCC, Intel, IDC
* Alt1.C: Qualcomm, ZTE, LG, NEC
* Alt2.A:
* Alt2.B: MediaTek, vivo, OPPO (1st pref), NEC, CMCC, CATT, Huawei, HiSi, Ericsson, Intel, Google, Nokia/NSB (2nd pref)
* Alt2.C:
* Alt3.A: Samsung, DOCOMO, MediaTek (no need to define Wmeas), Apple (gNB-side prediction $l=k, W\_{CSI}=W\_{meas}$), Fraunhofer IIS/HHI (gNB-side prediction $l=k, W\_{CSI}=W\_{meas}$), Google,
* Alt3.B: Samsung, OPPO, NEC, CMCC, Nokia/NSB (1st pref)
* Alt3.C: Samsung, NEC

Some discussion points:* Concern on x.C (UE complexity): MediaTek, Spreadtrum, Xiaomi, vivo
* Concern on gNB-side prediction (e.g. Alt3.A): vivo, Ericsson, ZTE, Nokia/NSB
* UE-side (only) prediction (x.B) is supported by a number of companies, at least as an optional feature

Based on the offline discussion, I have narrowed down the alternatives by removing the ones with concern and lack of support. *Please fit your preferences on the four remaining alternatives. Else it would be hard for us to focus our discussion.* |
| 2.7 | CSI-RS resource types/structures **supported** for measurement (discussion on whether/how the legacy Resource setting needs enhancement will take place in later rounds)**Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures:* Time-domain behaviour for each NZP CSI-RS resource: periodic, semi-persistent, aperiodic
* The use of K≥1 NZP CSI-RS resources:
	+ FFS: whether the resources are in the same CSI-RS resource set, other details

[109-e] **Agreement**On potential refinement of Resource setting configuration associated with Type-II codebook refinement for high/medium velocities, study the following options to assess whether/how the legacy Resource setting configuration needs to be enhanced for “burst” measurement:* Periodic (P) CSI-RS: periodicity and offset
* Semi-persistent (SP) CSI-RS: activation/deactivation, periodicity, and offset
* Aperiodic (AP) CSI-RS: triggering, offset of a group of AP CSI-RS resources

FFS: Support for K>1 NZP CSI-RS resources association with Type-II codebook refinement for high/medium velocitiesFFS: Whether specification support for jointly utilizing two types of CSI-RS time-domain behaviors is needed | **Proposal 2.G:*** **Support:** Google, Samsung, Nokia/NSB, Lenovo, DOCOMO, MediaTek, Qualcomm, LG, Spreadtrum, ZTE, Xiaomi, NEC, OPPO, CATT, CMCC
* **Not support:** vivo
 |
| 2.8 | The need for DD/TD (compression) unit (analogous to PMI sub-band for Rel-16 codebook)[109-e] **Agreement**For the Type-II codebook refinement for high/medium velocities, further study the following issues:* The need for basis type indicator, if both a trivial basis (e.g. identity) and a non-trivial (e.g. DFT) basis are supported, and if so, whether implicit or explicit
* The need for DD/TD (compression) unit (analogous to PMI sub-band for Rel-16 codebook)

**Proposal 2.H**: For the Rel-18 Type-II codebook refinement for high/medium velocities, support DD/TD (compression) unit (analogous to PMI sub-band for Rel-16 codebook) as a codebook parameter.* FFS: whether this parameter is defined as a function of another parameter
* FFS: whether this is used for PMI only, or PMI/CQI
 | **Yes:** OPPO, Samsung, LG, MediaTek, Qualcomm (same as time-interval b/w two consecutive CSI-RS occasions, e.g. periodicit for P-CSI-RS), Ericsson, Spreadtrum, ZTE (configurable, and subjective to UE capability), Xiaomi, Nokia/NSB, CMCC**No:**  |
| 2.9 | For one CSI reporting instance associated with the Type-II codebook refinement for high/medium velocities, for a given CQI sub-band and a given layer, how many CQIs (sampled across time-/Doppler-domain) are included?  | **Only 1:** Google, Qualcomm**≥1 (configurable):** ZTE, NEC, Samsung, Ericsson, Nokia/NSB, Lenovo, DOCOMO |
|  |  |  |

Table 3B Type II Doppler: summary of observation from SLS

|  |  |  |
| --- | --- | --- |
| **Company** | **Metric** | **Key observation** |
| Huawei/HiSi | SLS: avg. UPT vs overhead | * For R17 FeTypeII codebook enhancement, Alt2B can only achieve ~1% performance gain compared Alt2A.
* For R16 eTypeII codebook enhancement, Alt2B can only achieve ~0.3% performance gain compared Alt2A.
* For R17 FeType II and R16 eTypeII codebook enhancement, there’s no obvious difference between performance of Alt1A, Alt1B and Alt2.
 |
| ZTE | SLS: (Avg, 5%, 95%) UPT | Regarding On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, based on SLS simulation results in UMa, we can observe:* Under UE-side prediction (H-based with Wiener filter and extrapolation), a dominant performance can be obtained via exploring Doppler-domain information compared with legacy under the same RS overhead.

In 20~30km/h, a maximal performance gains over legacy can be observed (it implies that a typical scenario for this CSI enhancement), and then lower or larger than this range, the performance gain is decreased. |
| Vivo | NMSE vs reporting window | * It is effective that UE adopts Auto Regressive to predict channel based on prior raw channel information, on the contrary, there is little performance gains if gNB predicts channel based on DFT basis and corresponding projection coefficients reported in CSI.
* For CSI prediction in UE side,
	+ In medium/high velocity scenario, it requires a number of CSI-RS occasions (e.g., >10 occasions) for UE measurement to achieve acceptable performance.
	+ With sufficient number (e.g., 16, 32, …) of CSI-RS occasions for measurement, UE can predict CSI in a larger size of CSI reporting window (e.g., more than 10 ms)
	+ The configuration of CSI-RS for measurement (e.g., periodicity) needs to match the UE speed.
 |
| OPPO | SLS: UPT | Observation 1: * Supporting TD unit (e.g., 4 slots@15kHz) can reduce UE complexity without obvious performance degradation
* The performance gain of oversampling is negligible at medium velocity (30km/h)

Observation 2: Performance of DFT/DCT/Slepian are similar. Identity basis degrades performance-overhead tradeoff severely.Observation 3: CQI prediction has 2%-3% performance gain for 30km/h-60km/h velocity. |
| Intel | LLS | As it can be seen from the evaluation results, the performance for 1 and 2 Doppler-domain basis vectors is similar while significant performance gains are observed with 4 and 8 Doppler-domain basis vectors.As it can be observed from the above results. Reporting of robust PMI with single Doppler domain basis vector leads to performance improvement comparing to the legacy Rel-16 PMI codebook. |
| Samsung | SLS: UPT vs overhead | * DFT-based gNB-side prediction does not outperform Rel-16 baseline
* UE-side prediction achieves improved UPT vs overhead trade-off, but requires multiple CQIs
 |
| Fraunhofer IIS/HHI | SLS: UPT s overhead | Enhanced Type II CB with Doppler domain information outperforms Rel. 16 eType-II CB in terms of both performance and feedback overhead by a large margin. |
| MediaTek | SLS. UPT | * With a good balance between CSI-RS overhead and prediction performance, reducing CSI-RS periodicity and CSI feedback period can provide a higher throughput gain.
* Linear prediction does not perform well under CSI-RS burst measurement.
* For Type-II codebook refinement for high/medium velocities, CSI interpolation can be a good alternative to reduction of CSI-RS periodicity and CSI feedback period.
* For UMa 60 km/h, it is beneficial to support lower CSI-RS periodicity and CSI feedback period.
 |
| Qualcomm | SLS: UPT, overhead | Evaluations in Figure 4 shows certain gain can be observed for beam-specific TD basis selection over beam-common.Observation 3: Alt.B(s) have shorter TD basis length N4 than Alt.C(s), and certain performance loss can be observed at a same extrapolation length. Diagram  Description automatically generatedFigure 10. Rel-18 gain over baseline Rel-16 |
| Ericsson | SLS: UPTLLS: Throughput vs SNR | SLS: Based on the results we have presented so far with Alt3 codebook structure of Rel-18 Type II Doppler codebook, we can see that how many W2’s need to be reported is scenario specific.SLS: UE-side predictionWe note that for Scenario (a) 1 CSI per report performs roughly the same as 5 CSI per report, which indicate that predicting and accounting for the scheduling delay yields the main performance benefit. For Scenario (b) the 5 CSI per report clearly outperforms the 1 CSI case, however, accurate AR based predictions require more and denser sampled CSI measurements for Scenario (b).LLS:For the considered channel, measurement window and the prediction method used; it can be observed that feeding back a single CSI derived from a predicted channel when accounting for the feedback delay performs as good as the case of feeding back 5 CSI, as shown by the (1 CSI, AR, B=10, d=5, R=5) curve. |
| Nokia/NSB | LLS: cdf of cosine similarity, cdf of CQISLS: UPT vs speed | * When comparing MMSE channel predictor performance to a zero-order holder baseline, the gain observed in eigenvector-based cosine similarity distortion tends to be much smaller for CQI, which is more indicative of system-level throughput.
* To compare Type-II-Doppler with baseline Type-II, we assume the same CSI-RS and CSI reporting periodicity. If the comparison is done by assuming, for the baseline, a CSI reporting periodicity $N\_{4}$ times smaller than that of Type-II-Doppler such that the same number of CSIs are reported on average per given period, compression gain rather than prediction gain would dominate as we increase $N\_{4}$, even at low Doppler spread.
* A comparison between R16 Type-II with one CSI per reporting period and Type-II-Doppler with UE-side prediction and two CSIs per reporting period, assuming the same CSI reporting periods for the two systems, shows gains of 2%, 2.6, 2.7% in mean UE throughput for speeds of 10,30,60 km/h, respectively, and gains of 4.6%, 1.3%, 1.4% in cell-edge UE throughput, for speeds of 10,30,60 km/h, respectively.
 |
| **Summary**: * Some companies show significant gain in throughput with Doppler-domain compression at various UE speeds, while other show quite marginal gain at around 10kmph (and almost no gain at higher speeds such as 30/60 kmph). In terms of using Doppler-domain compression, a few companies argue that no compression (identity basis) with multiple W2/CQI (in time) seems to offer better performance.
* Some companies, based on their simulation results, suggest that UE-side prediction (with spec support in measurement and calculation behavior) is necessary to guarantee the observed gain while gNB-side prediction isn’t beneficial.

  |

**General observation**:

* Table 3.A:
	+ [2.1]
* Table 3.B:

Table 4 Additional inputs: issue 2

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | 1. **Check and, if needed, update your view in Table 3A/B, especially on the moderator proposals**
2. **Share additional inputs here, if needed**
3. **More moderator proposals may be added in the next revision**
 |
| Apple | * In Table 3A row 2.4 regarding prediction, we removed our support of gNB-side prediction that requires specification
	+ We do support gNB-side prediction as the baseline, but we do not think it necessarily requires specification impact.
	+ In the current system, gNB can already perform prediction based on multiple UE CSI reports. The issue is that UE will not compress the CSI exploiting channel time domain properties unlike spatial (W1) and frequency (Wf) properties.
	+ In our view, to exploit channel time domain properties, CSI can have both the compression and prediction. With CSI compression, gNB can know multiple samples of the channel in time domain (assume it is at least critically sampled to handle the desired doppler), then gNB can use the compressed CSI from UE to perform prediction.
	+ We do not have strong preference to specify anything related to gNB prediction, it can be largely proprietary solution subject to each infra-vendor

[Mod] Correct. gNB can choose to perform advanced processing such as prediction. This is a NW implementation issue. But since we are discussing spec impact, it is only related to UE procedure on CSI calculation and measurement. The question on spec-based gNB-side prediction is whether a UE should assume that the gNB always performs CSI prediction such that the UE can, e.g. relax the BLER requirement within the CSI reporting window W\_CSI.].  |
| Samsung | Issue 2.5: we can also support alt1Issue 2.6: our preference still is 3.C since includes the measurement window. Re the UE complexity issue with Altx.C, in our view, it depends on DD/TD unit size. If the DD unit size is sufficiently large, there is no ‘significant’ UE complexity issue with Altx.C.[Mod: In the offline discussion, Samsung also supports Alt3.A and Alt3.B. Since Alt3.B is still on the table I added Samsung there. It seems MediaTek still has concern on Alt3.C (see below) so I will not add Alt3.C back.]Proposal 2.G: support with an FFS: details on periodicity and offset values for P or SP CSI-RSs, when K>1 (e.g. same periodicity p and different offset 🡪 CSI-RS burst with periodicity smaller than p)[Mod: All FFS points are now replaced by “details” which are obviously in need of further discussion] |
| Lenovo | - Re Proposal 2.B, the note under Alt2.A regarding supporting ***Wd*** = **I*N*4** as a special case implies that Alt3 is not needed, since reporting multiple **W2** corresponding to a fixed **W1**, **Wf** is equivalent to **Wd** being identity. [Mod: I agree but Alt3 has additional details on reporting 1 W1 and multiple W2, for instance. The main proponents seem to prefer to have it as a separate Alt for now. We can always combine in later rounds in this meeting.]- Similarly, Proposal 2.C is also strongly related to the note in Alt2.A, if ***Wd*** = **I*N*4** is supported as a special case, then both Alt1 and Alt2 of Proposal 2.C are implicitly supported. Given that, we support both Proposal 2.B and 2.C - We support Proposal 2.G |
| DOCOMO | For issue 2.8, if we support Alt3 in issue 2.2 (i.e., no DD/TD compression for W2), we think the need of DD/TD unit itself may depend on whether to support UE-side prediction, and/or how configurable UE-side prediction can be. In case of no UE-side prediction, we think the unit may be implicit information given by CMR configuration. Even if UE-side prediction is supported, the need of DD/TD unit may still depend on the details of the prediction at UE. We are not very sure whether we are talking about the need of explicit definition of unit only. From our perspective, at least for UE-side prediction (which may be majority preference at least as optional), an explicit definition of DD/TD unit can indeed be considered. [Mod: Thanks for the thoughtful analysis which I also share. It would be good if we can finalize the CB structures and the need for UE-side prediction first.]For issue 2.6, we would like to clarify that we are also open to consider supporting UE-side CSI prediction. Our point is that since it may be an optional feature, it may also be good to consider UE without sophisticated capability of CSI prediction. In other words, we are not sure if focusing on Alt2.B-like approach only would be good. [Mod: Understood]Some additional views from us are added.  |
| Google | Proposal 2.B: SupportProposal 2.C: SupportProposal 2.F: We would like to understand the concern on Alt 3A a little bit. It is said there is concern for gNB side prediction. But we would like to clarify the potential gNB behavior for Alt 1A/1B/3B. Would these alternatives require gNB prediction? If not, how gNB uses the reported CSI?[Mod: My understanding is that (during offline) some companies observe that gNB-side prediction performs badly, and UE-side prediction is needed to ensure good performance of Type-II Doppler CB. Alt3A doesn’t facilitate UE-side prediction (and it introduces a new entity CSI-RS window that is not in legacy system). Hence, since some prediction is needed to ensure benefit of Type-II Doppler, it will be gNB-side, which performs badly. So those companies have concern on 3.A ☺]Proposal 2.G: Support  |
| Intel | **Issues 2.2, 2.3 and 2.4**: In our understanding Alt. 3 for Proposal 2.B is the same as Alt. 2 [Mod: Please see my comment to Lenovo]for Proposal 2.C and it is related to the system with channel prediction at the gNB. In our view Issue 2.4. is more important and shall be discussed before the actual codebook structure. [Mod: Tend to agree, at least to be discussed and handled in parallel, if possible]Our preference for Issue 2.4. is UE-side prediction.**Issue 2.5 and 2.6**: For Issue 2.5 we prefer Alt 2 since precoder for time instances after the report can’t be used for the gNB. So, there is no need to report the corresponding precoders. So, our preference is Alt 2B for proposal 2F. |
| MediaTek | Proposal 2.C: We prefer not to use “down-select” as we think both alternatives can be supported. $N\_{4}$ can be used to determine which basis is used. For small $N\_{4}$, identity matrix is used as the basis.[Mod: Added “combine”]Issue 2.5: We support Alt. 2.Issue 2.6: Efficiency is important for UE implementation as UE’s power is limited. Even if the UE complexity can be moderate, any redundancy should be avoided from power saving’s perspective.Proposal 2.G: Support, but we prefer not to add more FFS as they can be discussed in later rounds.[Mod: Now replaced by “FFS: details”] |
| Qualcomm | **Re issue 2.4 question (gNB-side prediction v.s. UE-side)**This issue strongly depends on W-based extrapolation v.s. H-basedOne main concern regarding W-based extrapolation than H-based in mainly the introduced phase uncertainty after SVD (Nokia, ZTE raise this issue).[Mod: In my understanding this is related to gNB-side prediction, not in general.]However, there is a missed consideration for phase uncertainty over time (an unfortunate pity):Denote Tx and Rx phase uncertainty at time instance t as $D\_{Tx}\left(t\right)$ and $D\_{Rx}\left(t\right)$, the channel is actually$H\_{D}\left(t\right)=D\_{Rx}\left(t\right)H\left(t\right)D\_{Tx}\left(t\right)=H\left(t\right)e^{jθ\left(t\right)+jϕ\left(t\right)}$, where$D\_{Rx}\left(t\right)=\left[\begin{matrix}e^{jϕ\left(t\right)}&&\\&\ddots &\\&&e^{jϕ\left(t\right)}\end{matrix}\right]$ (size $N\_{Rx}×N\_{Rx}$), $D\_{Tx}\left(t\right)=\left[\begin{matrix}e^{jθ\left(t\right)}&&\\&\ddots &\\&&e^{jθ\left(t\right)}\end{matrix}\right]$ (size $N\_{Tx}×N\_{Tx}$)Precoder can naturally cancel the phase uncertainty over time: $SVD\left(H\_{D}^{H}\left(t\right)H\_{D}\left(t\right)\right)=SVD\left(H^{H}\left(t\right)H\left(t\right)\right)=V\left(t\right)Σ^{2}V\left(t\right)$, while H-based extrapolation cannot.Then come back to the issue of phase uncertainty due to SVD, it also exists for FD (over per-subband SVD precoders) for legacy Rel-16 eType-II, and same elimination implementation can also be applied to TD.Therefore, regarding which one of the two (W-based v.s. H-based) is more doable, we think it needs further study, and CSI window Alt1/3.A is better not removed at current stage.[Mod: Please check my comment to Samsung and Apple.]**Re proposal 2.F (CSI window)**Regarding Alt1/3.C, it can provide a better performance with longer N4 (TD basis with higher Doppler resolution, and evaluation results can be found in our contribution, Figure 6)In our understanding, the three alternatives in the above figure are the main candidates with essential difference and supported respectively by many companies. To focus more on performance study, we suggest to remove Alt2.A, Alt2.C, or Alt1/3.B;Furthermore, Alt1 and Alt3 group can be merged without defining Wmeas, instead Alt3 boundary slot can be defined as: *A latest slot having a UE-received CSI-RS occasion ≥⌊Z'/14⌋ slots (for AP-report) or ≥4 or 5 slots (for SP-report) prior to the PUSCH slot*, which is similar to Rel-15 slot nref (can be a same slot)[Mod: I agree but we need to check if other companies can agree. Some are very particular about the reference points. This will be discussed in offline session]**Re proposal 2.C (TD basis)**For Alt1/3.A or Alt2.B, we suggest to compare the performance with non-orthogonal (or rotated orthogonal) DFT basis, to Alt1/3.C with orthogonal DFT basis;For Alt1/3.C, we think orthogonal DFT basis w/o rotation is enough**Support proposal 2.B, 2.G****One more issue to consider**PUSCH scheduling can be an issue to address for accommodating all CSI-RS occasions b/w PDCCH and PUSCH, potentially causing two issues:• Issue 1: Longer latency for UL-SCH conveyed on the report PUSCH;• Issue 2: Potentially reduced UL throughput due to the in-order HARQ rule: No scheduling is feasible in between[Mod: We can handle this in later rounds (if we have good progress on high-priority items) or next meeting] |
| Mod V11 | **Minor revisions on some proposals 2.C and 2.G per inputs** |
| NEC | **Proposal 2.B:** Support and prefer Alt 2A.**Proposal 2.C:** Support the DD/TD basis waveform part, and we prefer to combine both alts.While regarding the length and number of DD/TD basis, we think it’s also related to the DD/TD basis waveform type, as velocity varies, and can be well obtained at UE side, for example, if UE speed changes to be low, legacy codebook is sufficient (no DD/TD compression), and in this case, we think there is no need to report multiple DD/TD bases. **Proposal 2.F:** Even we still prefer previous Alt 3C, while we are fine with the proposal, and prefer Alt 2B or 3B. **Proposal 2.G:** Fine in general. Based on the description, we’d like to clarify, is it possible to configure different time domain behaviors per NZP CSI-RS resource? [Mod: this is a part of FFS details] |
| Google2 | Thanks moderator for answering the question below. Just some follow-up.Proposal 2.F: We would like to understand the concern on Alt 3A a little bit. It is said there is concern for gNB side prediction. But we would like to clarify the potential gNB behavior for Alt 1A/1B/3B. Would these alternatives require gNB prediction? If not, how gNB uses the reported CSI?[Mod: My understanding is that (during offline) some companies observe that gNB-side prediction performs badly, and UE-side prediction is needed to ensure good performance of Type-II Doppler CB. Alt3A doesn’t facilitate UE-side prediction (and it introduces a new entity CSI-RS window that is not in legacy system). Hence, since some prediction is needed to ensure benefit of Type-II Doppler, it will be gNB-side, which performs badly. So those companies have concern on 3.A ☺][Google2: It looks other than Alt 2B, all the other alternatives listed, e.g. Alt 1A/1B/3B, could also require gNB-side prediction? Without gNB-side prediction, I am not sure how gNB uses the reported CSI in these alternatives?][Mod: Agree that Alt2.B is the cleanest. Agree about 1.A. 1.B and 3.B don’t need gNB prediction] |
| OPPO | Support 2.B, 2C, 2.F, 2.GIssue 2.4, we support UE-side prediction. We share similar view as Apple and we are open to gNB prediction (if it’s feasible) since it is simpler for UE implementation and less (maybe zero) spec impact.Issue 2.5, we support Alt2. |
| Ericsson | We are supportive of Proposal 2.C.In **Issue 2.5,** we added our support to Alt 2.For **Proposal 2.G,** could we clarify that the K≥1 NZP CSI-RS resources are within one NZP CSI-RS resource set?[Mod: Good catch]On **Issue 2.8,** we are ok with DD/TD (compression) unit. |
| LG | Issue 2.1: We support to down select Rel-16 eType-II codebook only.Proposal 2.B: support.Proposal 2.C: we are not sure combining two alternatives is needed but we are ok with the current proposal.Proposal 2.F: we support the proposal but our preference is Alt 1. According to current specification, UE can measure CMR no later than CSI reference resource. As a result, for any slot after CSI reference resource, regardless of it is after reporting slot or before, UE needs channel prediction. In this sense, CSI reporting window for prediction should be defined after reference resource slot.Proposal 2G: support. |
| Spreadtrum | Updated our preference in the table above. |
| Spreadtrum2 | For Proposal 2.C, we support Alt1. Alt2 can be supported only when the CSI report corresponds to a single CSI measurement occasion, i.e. the length of DD basis is 1.Issue 2.4: We marked our 2nd preference for gNB-side prediction. Based on the potential enhancements on CSI measurement and compressed reporting, the performance of gNB-side prediction at least can be better than gNB implementation/UE transparent manner. |
| ZTE | Proposal 2.B: Alt2.A is supported. If going with Alt3, we think that the multiple W2 may be carried by respective UCI/CSI report.Proposal 2.C: Support, and Alt1 is prefered.Issue 2.4: We have concerns on gNB-side prediction. Thanks for other companies' clarification. But, it seems that there is misunderstanding for our thoughts.* + “Then come back to the issue of phase uncertainty due to SVD: $SVD\left(H\_{D}^{H}\left(t\right)H\_{D}\left(t\right)\right)=SVD\left(H^{H}\left(t\right)H\left(t\right)\right)=V\left(t\right)Σ^{2}V\left(t\right)$, while H-based extrapolation cannot.” On the contrary, in our views, because of the above SVD, the Doppler related parameter is canceled or contaminated.
		- In such case, a Doppler basic vector in channel information H(t), , may be cancelled out, but also some more mixed Doppler shift over different Doppler basis are introduced. As a result, it can be observed that, for each NZP elements for across the list of instances, we can observe too many Doppler basis vectors, even for LOS scenarios. But, on the other hands, for UE-side prediction (H-based), the original Doppler information can be reserved well, and it is beneficial for guaranteeing the performance of Doppler-prediction/extrapolation.
		- In short, we think that the appropriate method is to estimate a list of H(t) with high accuracy (e.g., by AR or Wiener), and then CSI compression is performed based on the list. On the other words, in such case, any additional extension based on the CSI compression (e.g., DFT basis) in gNB side may be meaningless.

Proposal 2.F/Issue 2.5: In our views, down-selection from Alt1/2/3 is much relevant to CQI determination in such case. In our views, we prefer to reuse the legacy CSI reference resource (well justified in RAN4). If going with Alt2, we fail to understand why we need to provide future TPMI but an old CQI. It is also against the current spec description for CQI/PMI determination. |
| Fraunhofer IIS/Fraunhofer HHI | Issue 2.1: Down select to prioritize only Rel. 16Proposal 2.B: We are in general fine supporting either Alt 2A or 2B except for the special case. In our understanding, when $W\_{d}=I$, UE reports only one PMI that will be applied for many future slots like in Rel. 16. If the length of $N\_{4}$ is small, UE can always use the fallback solution (i.e., Rel.16). Therefore, we are not sure about the need of this special case. Proposal 2.C: Compared to Rel. 16 eType II codebook, no significant performance gain has been observed for the Rel. 18 Doppler codebook when a DFT basis with no oversampling is used, however, the performance improved significantly with increasing oversampling factor. Also, we noticed that the rotation factor of the strongest Doppler component of each beamformed channel/SD component is also different. A very high oversampled DFT basis can be realized by supporting orthogonal DFT basis with different rotation factors for different SD components. Therefore, we think this issue may be worth studying more in detail. Moreover, we don’t think combining Alt 1 and Alt 2 is needed. We request FL to add the FFS point highlighted in yellow to proposal 2.C  **Proposal 2.C**: For the Type-II codebook refinement for high/medium velocities, on the DD/TD basis waveforms:* Down-select or combine from the following Doppler-/time-domain basis waveforms:
	+ Alt1. Orthogonal DFT
		- TBD (by RAN1#110bis): whether rotation is used or not
		- FFS: identical or different rotation factor for different SD components
	+ Alt2. Identity (i.e. no Doppler-/time-domain compression)
* Doppler-/time-domain (DD/TD) basis vector length (*N*4) is RRC-configured
* The number of selected DD/TD basis vectors is RRC-configured

[Mod: Done]Issue 2.4: At this stage, we prefer equal support for both gNB-side and UE-side prediction. After reading the Tdocs, we realize that companies have different implementation schemes for the prediction and precoder calculation. In the following, we try to summarize the different approaches used.

|  |  |  |
| --- | --- | --- |
| M1 - Channel based prediction | M2 - Precoder based prediction  | M3 - Precoder based prediction |
| Channel prediction based on various filtering mechanisms  | Precoder calculation using per-subband per-slot SVD | Channel transformation to angle-delay-Doppler domain |
| Precoder calculation using per-subband per-slot SVD | Determination of SD, FD and DD components and the corresponding precoder coefficients  | Calculation of dominant SD, FD and DD components and the corresponding channel coefficients in the angle-delay-Doppler domain |
| Determination of SD, FD and DD components and the corresponding precoder coefficients  | gNB prediction based on the received CSI (precoder information) | Precoder calculation using a single SVD (of size NR x 2LMN) on the channel coefficients in the angle-delay-Doppler domain  |
| UE prediction |  | gNB prediction based on the received CSI (precoder information)  |
| Comments: results vary depending on the number of channel samples used for prediction.  | Comments: results in bad performance as the phase continuity between subbands and slots is lost | Comments: here the precoder represents the channel and can be used for prediction as phase continuity is preserved, hence can be used for prediction |

For gNB prediction, few companies have used M2 and concluded that gNB prediction is bad. Per-subband per-slot SVD destroys the phase continuity and hence the resulting precoder cannot be used for prediction. Using a single SVD (in the angle-delay-Doppler domain) across all subbands and slots as done in M3 preserves the phase continuity and hence can be used for prediction and consequently outperforms M2 in terms of performance. At this stage, it is not appropriate to conclude that gNB prediction is bad without correct implementation or stating all implementation details. Also, M2 requires more computation resources due to per subband per slot SVD than M3 where only a single SVD is needed. Therefore, we suggest companies to also think about the UE complexity. We understand the comment that gNB-side prediction is a network implementation issue, and we only specify UE procedures in the spec. Since gNB-side prediction is a network implementation issue, gNB will either perform prediction or not. In case if gNB can perform prediction, UE reports only measured CSI, whereas in gNB cannot do prediction (UE prediction), UE reports only the predicted CSI. This means UE procedures must be specified for both UE side prediction as well as gNB side prediction.  |
| Xiaomi | Proposal 2.B: In principle, we support the proposal. But, we should rethink that the performance may be different if SD and FD basis are jointly selected for Alt1 and FD and TD basis are jointly selected for Alt2, respectively.Proposal 2.C: SupportIssue2.4: Proposal 2.F depends on this issue. Thus, we should firstly discuss this issue. We agree with QC’s comments. We should further study gNB-side predication at current stage.Proposal 2.F: It can be discussed after discussion on issue 2.4.Proposal 2.G: SupportIssue2.8： Support to define DD/TD compression unit. |
| Huawei, HiSilicon | For proposal 2.C, we support Alt 1. For Alt 2, it seems the legacy CSI feedback can already achieve it. And we are not sure how to combine the two alternatives.For issue #2.4, we prefer to use UE side prediction. And for issue #2.5, we prefer alt 2.For proposal 2.F, we are fine to the proposal by narrowing down a bit for further down-selection. |
| vivo | **Proposal 2.B**We support Alt 3.**Proposal 2.C**On the value of N4>=1, we think it is beneficial to let UE recommend the used N4 values and DD/TD basis. The reason is that in UE prediction, the size of CSI report window (i.e., how long UE can predict) highly depends on the UE speed and Doppler channel condition, which can only be well known by UE. Further, as we still have the option to support identity matrix as the basis, which does not require DD compression, the number of selected DD/TD basis vectors is only valid for the case requiring DD compression.Hence we think the following revision is needed.**Proposal 2.C**: For the Type-II codebook refinement for high/medium velocities, on the DD/TD basis waveforms:* Down-select or combine from the following Doppler-/time-domain basis waveforms:
	+ Alt1. Orthogonal DFT
		- TBD (by RAN1#110bis): whether rotation is used or not
	+ Alt2. Identity (i.e. no Doppler-/time-domain compression)
* Doppler-/time-domain (DD/TD) basis vector length (*N*4>=1) is RRC-configured or reported by UE
* The number of selected DD/TD basis vectors (if supported) is RRC-configured or reported by UE

[Mod: Made the two bullets FFS for now]**Proposal 2.F**We continue to support 2.B. For Alt 1.A, which is gNB prediction, we haven’t observed a gNB vendor supporting this Alt. In fact, most of the gNB vendors supports UE prediction. If we don’t have confidence from gNB vendors to have a good performance for prediction, we shouldn’t support them in the specification.**Proposal 2.G**We have concern on supporting aperiodic CSI-RS for this high/medium CSI enhancement. Based on our study, to have a satisfied prediction performance, it is needed to use sufficient number of CSI-RS occasion (e.g., 16 for 2-ms CSI-RS periodicity) to perform measurement. 16 CSI-RS occasions mean at least 32 ms to measure CSI-RS. In 30kHz SCS, it is 64 slots. Such huge delay makes to trigger aperiodic CSI-RS nearly impossible as it introduces large CSI latency. It does not make sense that gNB triggers CSI-RS and wait more than 64 slots to get the CSI. Further, if the CSI-RS periodicity is larger, saying 4-ms, more CSI-RS occasions will be needed to ensure the performance, e.g., 32 occasions in our evaluation. Such latency will increase to 256 slots, which is not practical at all for aperiodic CSI-RS.Further, the need to have multiple CSI-RS resources for measurement is not justified. In our understanding, at least periodic or semi-persistent CSI-RS does not require multiple resources to measure. UE can just uses the multiple periodic CSI-RS occasions. |
| Nokia/NSB | **Issue 2.5**: we prefer Alt 3 (first preference) but are ok with Alt 2 (second preference). Strictly speaking Alt3 seems the most accurate answer, because any channel/CSI estimated after the latest CSI-RS measurement occasion no later than the CSI reference resource is “predicted” based on past measurements. Alt3 also simplifies the timeline of the predicted channel/CSIs because it only depends on the timing of the CSI-RS measurements. For example, with Alt 3, the prediction filters may be calculated/updated/reused for different report timing offsets, whereas with Alt 2, the predicted slots depend on the report timing offset indicated in DCI.**Issue 2.8**: the TD/DD unit may be defined as function of other parameters, such as the separation of CSI-RS occasions and it is related to the size of the reporting window and the number of reported CSIs |
| CATT | **Issue 2.1:** We prefer to prioritize Rel-16 eType-II codebook.**Proposal 2.B:** support.**Proposal 2.C:** support.**Issue 2.5:** support Alt 2**Proposal 2.F:** support**Proposal 2.G:** support. |
| Mod V32 | **Revised proposal 2.C (vivo’s input to keep RRC open), 2.G (Ericsson’s input). Added 2.D and 2.H** |
| MediaTek | **@ Qualcomm:** We have tried to predict $H^{H}\left[n\right]H[n]$, but unfortunately the performance is not comparable with predicting $H[n]$ directly. As for predicting singular vectors $V[n]$, we observe that prediction/extrapolation is very different from compression. Note that no CSI extrapolation in frequency domain is needed for the current NR. Phase alignment can improve the compression performance, but it does not seem helpful for prediction/extrapolation. That said, we can be fine if companies would like to further study Alt1, 3A until the next RAN1 meeting.On the other hand, we cannot accept Alt1, 3C. We agree that a larger $N\_{4}$ may enhance Doppler resolution, but it can also be achieved by introducing rotation factor or oversampling. To see this, we apply a DFT to $f[n]$ of length $N\_{4,1}+N\_{4,2}$: $F\left[k\right]=\sum\_{n=-N\_{4,1}}^{N\_{4,2}-1}f[n]e^{-j2πkn/(N\_{4,1}+N\_{4,2})}$, where the last $N\_{4,2}$ CSI are predicted. Now define the ratio $r=\frac{N\_{4,2}}{N\_{4,1}+N\_{4,2}}$. Then, we have $F\left[k\right]=\sum\_{n=-N\_{4,1}}^{N\_{4,2}-1}f[n]e^{-j2πrkn/N\_{4,2}}$. A less capable UE can instead calculate $F\left[k\right]=\sum\_{n=0}^{N\_{4,2}-1}f[n]e^{-j2πrkn/N\_{4,2}}$, which is equivalent to zero padding. If gNB knows the value of $r$, then the reconstruction of predicted CSI are the same with or without using the past CSI for compression. Therefore, with rotation factor or oversampling, it can be up to UE implementation whether to use the past CSI for compression or not.**@ LG**: Indeed, UE needs channel prediction after the last CSI-RS transmission occasion. However, we fail to see how it implies every predicted CSI needs to be reported to gNB. |
| Samsung | Proposal 2.F: we still think Alt3.C should be included. As pointed out by QCM, it can be beneficial to achieve higher resolution for the DD components. Also, regarding the additional complexity with 3.C, in our view, it depends on the DD unit size and #DD units. If DD unit size is large (e.g. 4 or 8), the complexity issue is marginal. From our perspective, we don’t need to report PMI/CQI for each slot (i.e. DD unit size = 1), we can report fewer than that by using DD unit of larger size.[Mod: Please see my previous comments. Sorry, I will not add Altx.C since it will be a total waste of online/offline time due to growing list of serious concern. I hope you understand and please focus on your 2nd or 3rd preferences that are at least acceptable for further discussion.] Proposal 2.G: suggest to keep that the newly added text “in the same CSI-RS resource set” as FFS. Whether 1 set is sufficient or not may depend on the value of K which we have not discussed.[Mod: OK]Proposal 2.H: we can have DD/TD unit (same or different) for PMI and CQI. So, suggest to add an FFS* FFS whether this is used only for PMI or PMI/CQI

[Mod: OK] |
| CMCC | **Issue 2.1:** We prefer prioritize Rel-16 eType-II codebook.**Proposal 2.B**: Support.**Proposal 2.C:** Support.**Proposal 2.D:** Support.At least UE-side prediction should be an optional feature to facilitate prediction accuracy.As for the definition of UE-side prediction, we prefer Alt2.**Issue 2.5:** Support Alt 2**Proposal 2.F:** Support**Proposal 2.G:** Support.**Proposal 2.H:** Support. |
| DOCOMO | Proposal 2.F: One clarification question from our side is that do we need to pick up a single alternative only? Isn’t it possible to e.g., cover multiple alternatives by making the window configurable? Or, are we discussing about the minimum to be supported in Rel-18 (i.e., additional alternative may be considered later)? [Mod: For now, we simply list alternatives. We will discuss this on day 1 offline to ensure companies are aligned in understanding. I don’t see why we need >1 solutions. So only one should be chosen. Also note that this is related to the reference for, e.g. UE-side prediction and whether the codebook is ALWAYS used with (optional) UE-side prediction. If the group agrees that the codebook can be used without UE-side prediction, the legacy CSI measurement/calculation procedure is another alternative (based on reference resource, and not one of the listed alternatives, although similar to Alt1.A with W\_CSI=1)]Proposal 2.H: We agree with Samsung’s FFS. |
| MediaTek | **@ ZTE:** CQI is calculated based on PMI and our preference is that only the PMIs no earlier than the reporting slot should be reported. Then, naturally the reference resource for CQI calculation should be updated. We don’t see a sound reason why CQI needs to calculate based on the legacy CSI reference resource. The legacy CSI reference resource can be used for CSI measurement, but a new CSI reference resource for CSI reporting should be specified.**@ HW:** The legacy CSI feedback assumes a CSI reference resource before reporting slot. If the spec is not updated, it means UE needs to calculate a CSI not aligned with the current spec. Also, our simulation results show that in high-speed scenarios we cannot afford a large CSI reporting window. If DD/TD unit equal to CSI-RS periodicity=5ms is supported, we observe only $N\_{4}\leq 2$ can provide a decent performance gain. Therefore, Alt 2 in Proposal 2C, i.e., identity, should be supported. If DD/TD unit can be less than CSI-RS periodicity, $N\_{4}$ can be larger and we observe better performances. However, it also implies higher UE complexity and thus we think DD/TD unit less than CSI-RS periodicity should be UE optional. To summarize, we support both DFT and identity and a threshold on $N\_{4}$ can be introduced to determine which basis is used.**@ FHG:** Thank you for the analysis. Our understanding is that for M3, the output of the single SVD operation is different from the common understanding of precoders. Could you clarify whether individual SVDs need to be performed for each subband and slot after gNB-based prediction?**@ Nokia:** For Alt 2, the prediction filters can also be calculated/updated/reused for different report timing offsets. Your concern seems to be about the case where the DD/TD unit is larger than 1. However, it can be up to UE implementation how to determine one CSI for the entire DD/TD unit. For example, the calculated PMI may be best fit of a middle/end slot of the DD/TD unit, rather than the first slot.**@ DOCOMO:** Among Alt1.B, Alt2.B, and Alt3.B in Proposal 2F, we fail to identify the need to support more than one of them. Our understanding of Proposal 2F isOption 1: Support only one of Alt1.B, Alt2.B, and Alt3.BOption 2: Support Alt1.A and only one of Alt1.B, Alt2.B, and Alt3.B[Mod: For now, we simply list alternatives. We will discuss this on day 1 offline to ensure companies are aligned in understanding. Please check my above comment to DOCOMO] |
| vivo | **Proposal 2.D**To achieve UE side prediction, CSI corresponding to a future slot needs to be reported. To have a clear and aligned understanding on the time location of the CSI between UE and gNB is important for implementation and RAN4 test. Whether legacy definition of CSI reference resource still works in this situation requires careful study in RAN1. Hence we think the following FFS point is needed.**Proposal 2.D**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the assumption of the UE-side prediction * FFS: as an optional feature, whether or not UE-side prediction is always assumed with the Rel-18 Type-II codebook refinement for high/medium velocities
* On the definition of UE-side prediction, down-select from the following alternatives:
	+ Alt1. UE “predicting” channel/CSI after the slot with a reference resource
		- FFS where the reference resource locates
	+ Alt2. UE “predicting” channel/CSI after slot n (where the CSI is reported)
	+ Alt3. UE “predicting” channel/CSI after the slot(s) where CSI-RS resides

[Mod: ok]**Proposal 2.H**We generally see the need of defining DD/TD unit. We think it is needed to clarify that at least one DD/TD unit should be supported, which corresponds to the case that W\_CSI=1.**Proposal 2.H**: For the Rel-18 Type-II codebook refinement for high/medium velocities, support DD/TD (compression) unit (analogous to PMI sub-band for Rel-16 codebook) as a codebook parameter.* FFS: whether this parameter is defined as a function of another parameter
* At least 1 DD/TU unit (W\_CSI = 1) is supported

 [Mod: We can discuss this later. But for now Fraunhofer has concern on adding this (below)]**Issue 2.9**This can be an issue of next-level of details for future discussion after we decide UE or gNB prediction is supported.  |
| Fraunhofer IIS/Fraunhofer HHI | We have concerns supporting small values of N4 and W\_CSI =1. With small values of N4, we don’t think Doppler components are captured/calculated accurately and instead of Doppler shifts, only Doppler spread is captured. Based on our evaluations with 4 ms CSI-RS periodicity, at least 3 CSI-RSs are needed to accurately capture the Doppler shifts. Re N4 =1, this is already supported in Rel. 16 codebooks, and we think there is no need to specify it again.  |
| Mod V48 | **Minor revision on proposals 2.D, G, H per inputs (mainly on FFS wording)** |
| Sharp | Proposal 2.B: Support.Proposal 2.C: Support.Proposal 2.D: Support.Proposal 2.F: SupportProposal 2.G: Support.Proposal 2.H: Support. |

### Issue 3: TRS-based reporting of time-domain channel properties (TDCP)

Table 5A Summary: issue 3

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 3.1 | [109-e] **Agreement**The work scope of TRS-based TDCP reporting focuses on the following use cases for evaluation purposes:* Targeting medium and high UE speed, e.g. 10-120km/h as well as HST speed
* Aiding gNB to determine
	+ CSI reporting configuration and CSI-RS resource configuration parameters,
	+ Precoding scheme, using one of the CSI feedback based precoding schemes or an UL-SRS reciprocity based precoding scheme
* Aiding gNB-side CSI prediction

[109-e] **Agreement**For Rel-18 CSI enhancements, proceed to support and specify the following features (the previously agreed work scopes apply):* Type-II codebook refinement for CJT mTRP
* Type-II codebook refinement for high/medium UE velocities exploiting time-domain correlation/Doppler-domain information
* UE reporting of time-domain channel properties (TDCP) measured via CSI-RS for tracking
	+ The use case of aiding gNB-side CSI prediction is to be confirmed in RAN1#110

**Conclusion 1.A**: For the Rel-18 TRS-based TDCP reporting, there is no consensus in confirming the use case of aiding gNB-side CSI prediction.**FL Note**: Need to decide whether this use case is kept or not. This topic has been discussed OFFLINE [1] | **TDCP use case of “aiding gNB-side CSI prediction”*** **Confirm**: CATT, DOCOMO
* **Remove**: Huawei/HiSi, [Lenovo], Ericsson, vivo

[Mavenir] Propose to add additional use cases:* Aiding gNB to determine
	+ whether to enable joint channel estimation for PUSCH/PUCCH or not and the time domain window size if applicable.

[Mod: Similar proposal was brought up in the last meeting but it was opposed by many. It is not within the scope of CSI agenda item 9.1.2]* + TDCP-aware (Doppler shift aware) LA

[Mod: It is not within the scope of CSI agenda item 9.1.2][Mod: Re use cases, we appreciate the proposals for new use cases. But the use cases have been finalized in the last meeting. Unless the group can agree on adding new use cases, we cannot go back and add new ones.] |
| 3.2 | [109-e] **Agreement**The work scope of TRS-based TDCP reporting includes down selection from the following TDCP parameters:* Alt1. Doppler shift
* Alt2. Doppler spread **(=max Doppler shift)**
* Alt3. Cross-correlation in time
* Alt4A. Relative Doppler shift of a number of peaks in CIR
* Alt4B. Relative Doppler shifts of different TRSs
* Alt5: CSI-RS resource and/or CSI reporting setting configuration assistance
 | **Alt1:** IDC, Samsung, Spreadtrum, Mavenir, Google, OPPO, CATT(for use case of aiding CSI configuration), Xiaomi, LGE, CEWiT, Apple, Sharp, DOCOMO**Alt2:** Huawei/HiSi, Spreadtrum, vivo, OPPO, CATT(for use case of aiding CSI configuration), Xiaomi, LGE, CEWiT, Apple, Sharp, Nokia/NSB,Mavenir, DOCOMO**Alt3:** vivo, OPPO, CEWiT, Ericsson**Alt4A:** Google,Xiaomi,CATT**Alt4B:** ZTE, Samsung, Spreadtrum**Alt5:** MediaTek, Qualcomm |
| 3.3 | [109-e] **Agreement**The TRS-based TDCP reporting is down selected from the following alternatives:* Alt1 (stand-alone): TDCP reporting comprises auxiliary feedback information to enable refinement of CSI reporting configuration, and/or codebook configuration parameters, and/or (to be confirmed in RAN1#110) gNB-side CSI prediction
	+ Aperiodic reporting is supported
	+ FFS: Whether periodic, semi-persistent and/or event-triggered (UE-initiated) reporting are supported
* Alt2 (non-stand-alone): TDCP reporting corresponds to a subset of the UCI parameters associated with a codebook/PMI for high/medium velocities, reported by the UE and measured via TRS
	+ FFS: The associated codebook(s)/PMI(s)

**Proposal 3.C**: The Rel-18 TRS-based TDCP reporting comprises stand-alone auxiliary feedback information to enable refinement of CSI reporting configuration, and/or codebook configuration parameters, and/or (to be confirmed in RAN1#110) gNB-side CSI prediction* Not conditioned on other UCI parameters
* Not reported together with CQI/PMI/RI/(CRI) associated with a codebook
	+ Note: This does not prevent TDCP reporting from being multiplexed with other UCI parameters on PUCCH and/or PUSCH
* Note: Aperiodic reporting is supported (per agreed Alt1 in RAN1#109-e)

**FL Note**: This topic has been discussed OFFLINE [1]. Stand-alone-only received unanimous support.  | **Proposal 3.C:*** **Yes:** IDC, Huawei/HiSi, Samsung, Spreadtrum, vivo, Mavenir, Google, NEC, Intel, Xiaomi, LGE, CMCC, MediaTek, Apple, Docomo, Sharp, Ericsson, Nokia/NSB, Sony, Qualcomm, CATT, Fraunhofer IIS/HHI
* **No:**
 |
| 3.4 | Whether the following time-domain behaviour of TDCP reporting is supported:* Periodic
* Semi-persistent
* Event-triggered (UE-initiated)
 | **Periodic:*** **Yes:** Mavenir, Google, Ericsson, ZTE, vivo, CATT
* **No:** Spreadtrum, Samsung, Lenovo, MediaTek, LG, OPPO, CMCC

**Semi-persistent:*** **Yes:** Mavenir, Google, Ericsson, ZTE, vivo, CATT
* **No:** Spreadtrum, Samsung, Lenovo, MediaTek, LG, OPPO, CMCC

**Event-triggered/UE-initiated:*** **Yes:** Mavenir, Samsung, MediaTek, Lenovo
* **No:** Google, LG, OPPO, vivo, CMCC
* **Needs Further Study:** Ericsson, ZTE, CATT
 |
| 3.5 | At least for single-TRP, whether using >1 TRS resources for TDCP measurement is supported in addition to only 1 TRS resource | **Yes:** Samsung, Google, ZTE Nokia/NSB (aperiodic reporting) **No:**  |
|  |  |  |

Table 5B TDCP: summary of observation from LLS/SLS

|  |  |  |
| --- | --- | --- |
| **Company** | **Metric** | **Key observation** |
| Mavenir | LLS: RMS error, standard deviation, bias | * Higher speed would take more RMS error when SNR is enough high, but RMS error in lower speed could be slightly higher when SNR is lower. Standard deviation and bias are higher with increasing speed.
* RMS error, standard deviation and bias is higher with longer delay spread.
 |
| CATT | LLS: normalized TP vs SNR | Compared with no gNB-side CSI prediction, the single Doppler reporting has slight performance gain (0.5dB), and obvious performance gain (1-2dB) can be achieved by the solutions with multiple Doppler reporting with the enhanced matching algorithm. |
| Ericsson | SLS: Avg. UPT vs UE speedLLS: mean autocorrelation estimate vs correlation lag | SLS* Reciporcity-based precoding has better performance at 3km/h for both SU-MIMO and MU-MIMO; however, at UE speeds above 10km/h the feedback-based precoding outperforms the reciprocity-based.
* Type II CSI gives better performance at 3km/h, but at UE speeds above 10km/h and higher, type I CSI gives better performance.
* Precoding based on Type I CSI feedback is more robust to channel aging than precoding based on Type II CSI feedback.
* The cross-over points of performance for both evaluated use cases are at low speed, e.g, 10km/h.

LLS* Maximum doppler shift would be the same for channels with vastly different channel variabilities, and it does not reflect how fast channel varies with time.
* Estimating maximum Doppler shift from the autocorrelation function has lower bias and standard deviation than from estimates of channel peaks.
* Estimates based on intra-TRS autocorrelation lags doesn’t give decent accuracy below 50km/h.
* Estimates based on inter-TRS : autocorrelation lags of 20 or 40 slots perform best at 3km/h; autocorrelation lags of 10 and 5 slots performs best at 6km/h and 10km/h respectively.
 |
| **Summary**: * Companies demonstrate the increasing challenge in estimation accuracy as the UE speed is increased. One company suggests that correlation-based TDCP offers better accuracy than Doppler-shift-based TDCP
 |

**General observation**:

* Table 5.A:
	+ [3.1]
* Table 5.B:

Table 6 Additional inputs: issue 3

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | 1. **Check and update your view in Table 5, especially on the moderator proposals**
2. **Share additional inputs here if needed**
3. **More moderator proposals may be added in the next revision**
 |
| Samsung | Issue 3.4: we don’t support P and SP TDCP reporting. In our view, TDCP reporting should be aperiodic or event-triggered (UE-initiated) since its reporting is needed only when the UE speed is larger than a threshold.  |
| Lenovo | - We agree with Samsung views on Issue 3.4 regarding aperiodic and/or event-triggered reporting- We also request some clarity from proponents of standalone TDCP reporting to ensure a concise scope of TDCP reporting. While aiding the network to refine CSI Reporting/Resource configuration seems reasonable, aiding the gNB-side prediction appears to be an open-ended objective and may differ per scenario/network implementation. Given that, we prefer to have a more in depth discussion on the quantities/parameters to be signaled as part of TDCP reporting for further clarity [Mod: This is a good input. For the types of TDCP, we need to have better clarity on criteria as well as description of each proposal] |
| Google | To clarify our concern for issue 3.4, in our view, there could also be some benefit for event triggered L1 report. Not only for TDCP report, but also for beam report. But such may require a lot of RAN2 effort, similar to BFR. We are a bit concerned about the work load. [Mod: Thanks for bringing up this good point. There might be some parallel effort later on in Rel-18 mobility enhancement. If this is supported, some inter-WI coordination may be needed] |
| MediaTek | Issue 3.4: We share a similar view as Samsung. P/SP TDCP reporting is inefficient as the configured periodicity can easily result in either redundancy or insufficiency. |
| Qualcomm | Support proposal 3.C |
| Mod V11 | **No revision on proposal** |
| NEC | Fine with proposal 3.C |
| OPPO | Support proposal 3.C.On issue 3.4, we think aperiodic reporting is sufficient for TDCP reporting. |
| Ericsson | On **Issue 3.2,** in our view, we should first decide about report parameters/quantities for TDCP reporting for this meeting. [Mod: Agree but currently the view diverges. From FL perspective we can agree on 3.C before this. Then we will spend time on 3.2 to discuss the details of each candidate scheme and possible merging of, e.g. Doppler-based proposals]In our contribution [R1-2207505](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2207505.zip) we’ve provided simulation results to show the use cases where using TDCP measurement can give significant gains to decide what CSI-feedback scheme to use or whether to use reciprocity based precoding. We’ve explained in depth with simulation on how **autocorrelation** (i.e. Option 3: cross-correlation) can be used as a straight forward and reliable TDCP reporting parameter. To address the use cases we are after, we need a measure of the channel variability in time, and the autocorrelation is a direct measure of this.We show that the Doppler spread metric fmax, i.e. the maximum Doppler shift, is a very bad measure of channel variability in time since different channels with the same fmax can have very different autocorrelation as shown in the figure below.Chart, line chart  Description automatically generatedThe square root of the second moment of the Doppler power spectrum is another potential measure of the Doppler spread. It correctly describes the behavior of the autocorrelation for low lags, since the second moment of the Doppler power spectrum is proportional to the second derivate of the autocorrelation function at lag zero. However, it doesn’t give any information about the zero-level crossing point of the Autocorrelation function (as can be seen from the figure above) which is also important to know.We also note that most likely a Doppler spread measure would in reality be estimated based on measurements of the Autocorrelation function, and since it’s the channel variability we are interested in, it then makes more sense to report the autocorrelation directly. One can in principle estimate Doppler spread based on the Doppler shift of identified peaks in the channel impulse response. We have tried this, but it gives much worse accuracy than the autocorrelation based method and it’s also a very complex measurement. In the figure below we compare a peak based estimate of the maximum Doppler shift with an autocorrelation based estimate. The autocorrelation based estimate totally outperforms the channel peak based estimate. It has both lower bias and lower standard deviation than the peak based estimate. Hence, the best option is to report the autocorrelation function for multiple autocorrelation lags. This gives the gNB maximum information and the signaling load is anyway very small. We suggest to perform down-selection among the alternatives in **Issue 3.2** based on evaluation results.Chart, line chart  Description automatically generatedOn **Issue 3.4** we support Periodic and Semi-persistent report. For Event triggered we think this can be studied further. **Issue 3.5** seems to be related to Alt4B in Issue 3.3. For Alt 3 in Issue 3.3 we would need report autocorrelation function for a number of autocorrelation lags, so more than 1 TRS burst is beneficial for a UE to measure. But if we are talking about more than 1 TRS resource configuration for M-TRP in Issue 3.5, we would need to decide the measurement quantity and agree on use cases first. In **Issue 3.5,** could we first clarify if the >1 TRS resources are from a single TRP or if they corresponding to multiple TRPs?[Mod: It is at least for sTRP, clarified] |
| LG | Issue 3.4: we have similar view with SS/Oppo/MTK/Lenovo and AP reporting is sufficient. |
| ZTE | Issue 3.4: First of all, periodic and semi-persistent report initialized by gNB should be supported firstly. Then we are open to further consider event-triggered report. Alternatively, periodic/event-triggered report may be combined as what we did for PHR report (a timer+some event-driven condition).Issue 3.5, regarding E///’s comment, in our views, it can be from the single TRP or multi-TRP. * For single TRP, it may be much relevant to some narrower beam (e.g., FR2).

Then, for the multi-TRP/HST scenarios, FR1 should be additionally considered. From our perspective, a typical case is relevant to how to divide UEs into two or more categories (pedestrians, a person in a car or a HST) related to respective UE velocities/channel properties. With more than one TRS(s), the impact of UE-side oscillator can be canceled by the differential manner. |
| Xiaomi | Issue3.2: update our viewProposal 3.C: SupportIssue3.4: We also think aperiodic reporting is sufficient, and we are open to discuss event-triggered report. |
| vivo | **Proposal 3.C**OK**Issue 3.4**We are okay for periodicity and semi-persistent reporting. For the UE initiated reporting, it will cause significant work load and spec impact in both RAN1 and RAN2. Given we already have a large scope for CJT CSI and Doppler CSI in a limited time budget, we have concern on introducing it without justified benefit. [Mod: Tend to agree ☺ this would involve RAN2 as well] |
| Nokia/NSB | **Issue 3.2**: it would help in this meeting to identify a more precise definition or examples of the reported quantities, so that a more accurate comparison can be made between, for example, reporting Doppler spread and time auto-correlation[Mod: Yes, we will spend time to do this in later rounds in this meeting]**Issue 3.5**: we think a use case for >1 TRS resources is for aperiodic TDCP reporting triggered with a legacy aperiodic TRS set for high speed UEs. |
| CATT | Add our observation from LLS in the above Table 5B.Fine with proposal 3.COn issue 3.4, since the use case of gNB-side prediction still need to be confirmed in this meeting, time-domain behaviour of TDCP reporting might need to be discussed separately based different use cases. |
| Mod V31 | **Added conclusion 1.A.** **Re issue 3.2, companies please check the comment from Ericsson on correlation-based TDCP** |
| CMCC | **Proposal 3.C**: Support.**Issue 3.4:** We also think AP TDCP reporting is sufficient. Periodic or semi-persistent reporting maybe a little inefficient. |
| CATT | Update our views in the above Table 5A, add our observation from LLS in the above Table 5B again.**On conclusion 1.A:** Not support. For TDD system, the problem of expired CSI still exists, but there is no solution currently. And the aiding of gNB-side is a simple and effective solution. In addition, there are very few companies expressing their attitudes, and the objecting companies did not give a clear reason and evaluation results at least for TDD system. Hence, we think it's too early to draw this conclusion at this stage. Based our contribution in R1-2206377, we provide the feasibility Analysis and simulation results for the use case gNB-side prediction. It can be observed from the simulation results that compared with no gNB-side CSI prediction, the single Doppler reporting have slight performance gain(0.5dB), and obvious performance gain (1-2dB) can be achieved by the solutions with multiple Doppler reporting with the enhanced matching algorithm.[Mod: Please note that this conclusion is based on observation that some companies want to remove this use case, hence the group cannot confirm this in RAN1#110 (i.e. need to be removed). Since it was agreed that we need to confirm this by RAN1#110 (to avoid delaying work on TDCP), we cannot postpone this. However, since this doesn’t impact proposal 3.C, I can give some time for the proponents (e.g. CATT) to try to convince companies wanting to remove this use case until the last online session on CSI, i.e. it will not be presented for endorsement on day 1] **Figure 1 Performance comparisons of alternatives, TDD, 60Km/h, MCS 4** |
| vivo | **Conclusion 1.A**We are OK. |
| Fraunhofer IIS/Fraunhofer HHI | Support Proposal 3.C |
| Mod V48 | **No revision in proposals.** **@CATT: Please check my comment on your input for conclusion 3.A** |
| Lenovo | One question to the moderator: an agreement was made in RAN1#109-e, as follows:AgreementThe work scope of TRS-based TDCP reporting focuses on the following use cases for evaluation purposes:* Targeting medium and high UE speed, e.g. 10-120km/h as well as HST speed
* Aiding gNB to determine
	+ CSI reporting configuration and CSI-RS resource configuration parameters,
	+ Precoding scheme, using one of the CSI feedback based precoding schemes or an UL-SRS reciprocity based precoding scheme
* Aiding gNB-side CSI prediction

Seems that conclusion 1.A would cancel the last use case. If that is correct, in our understanding there might be a conflict here, since the prior two bullets of the agreement imply some form of aiding gNB to determine CSI parameters targeting medium/high UE speed. To me it seems the first two bullets on one hand and the third bullet on the other hand are strongly correlated, and hence the proposed conclusion can cause more problems than solutions later on, especially if gNB side prediction is supported for Type-II codebook for high speed. More importantly, we prefer to have a concise, well-defined use case before concluding to omit other use cases.  |
| Sharp | We support Proposal 3.C |
| Mavenir | **Issue 3.2:** From the complexity’s viewpoint, the time-correlation-based Doppler shift estimation is equivalent to time correlation estimation on the UE side. In addition, Doppler shift is more straightforward than time correlation and can save BS effort to calculate Doppler shift per UE. In addition, given the same Doppler shift, different SCS and correlation lag may result in different time correlation values. As a result, to provide the same channel time variability information as Doppler shift, time correlation needs to be reported together with correlation lags which makes TDCP design more complicated. Then report quantities need further study for Doppler shift and time correlation based TDCP.**Issue 3.4:** Current spec has already supported P and SP reporting for CSI reporting, so P and SP reporting can reduce the workload and should be a starting point. On the other hand, event-triggered reporting also has some benefits, like reducing the overhead of signaling. So, we also propose to support event-triggered reporting, but a reporting period still needs to be defined. |

# References

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