**3GPP TSG RAN WG1 Meeting #102-e R1-** **2006973**

**E-meeting, August 17th – 28th, 2020**

**Agenda Item: 8.1.4**

**Source: Huawei, HiSilicon**

**Title: Discussion Summary for CSI enhancements MTRP and FR1 FDD reciprocity**

**Document for: Discussion and Decision**

# Introduction

Evaluation assumption for MTRP and FR1 FDD reciprocity have been discussed offline. Detailed comments from each individual company after Phase 1 EVM can be found in Appendix. Followed by Phase 2 input, Phase 2 EVM discussion has concluded following possible changes for Rel-17 CSI enhancements for MTRP and FR1 FDD reciprocity, on top of Rel-16 EVM for MIMO WI.

For Evaluation Assumptions for CSI reporting for DL multi-TRP and/or multi-panel transmission

* The agreements of Rel-16 evaluation assumptions for DL multi-TRP/panel transmission can be the start point in Rel-17. Further agreements of evaluation assumptions, if any and applicable, from other Rel-17 M-TRP objectives can be considered as well.
* The baseline is CSI reporting supporting DL multi-TRP/panel transmission, up to Rel-16 including multiple CSI reporting etc.

For Evaluation Assumption for CSI enhancement

* Considering SLS assumptions for CSI enhancement in Rel-16, i.e. Table 2, as a starting point with following potential revisions/clarifications in red.

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Duplex, Waveform  | FDD (TDD is not precluded), OFDM  |
| Multiple access  | OFDMA  |
| Scenario | Dense Urban (Macro only) is a baseline. Other scenarios (e.g. UMi@4GHz 2GHz, Urban Macro) are not precluded. |
| Frequency Range | FR1 only, 2GHz with duplexing gap of 200MHz between DL and UL, optional for 4GHz |
| Inter-BS distance | 200m  |
| Channel model | Considering following two options of reciprocity model for FDD as a starting point, further discussing and finalizing remaining details of channel modelling methodology for FDD channel reciprocity in RAN1 102e* + Opt. 1: The reciprocity model of DL/UL channel is based on Section 5.3 of TR 36.897
	+ Opt. 2: The reciprocity model of DL/UL channel is based on Section 7.6.5 of TR 38.901 with different DL/UL frequency.
	+ Note that further modifications/clarifications based on Option 1 or 2 to generate UL channel are not excluded.
 |
| Antenna setup and port layouts at gNB | Companies need to report which option(s) are used between* 32 ports: (8,8,2,1,1,2,8), (dH,dV) = (0.5, 0.8)λ
* 16 ports: (8,4,2,1,1,2,4), (dH,dV) = (0.5, 0.8)λ

Other configurations are not precluded. |
| Antenna setup and port layouts at UE | 4RX: (1,2,2,1,1,1,2), (dH,dV) = (0.5, 0.5)λ for rank > 22RX: (1,1,2,1,1,1,1), (dH,dV) = (0.5, 0.5)λ for (rank 1,2) Other configuration is not precluded. |
| BS Tx power  | 41 dBm for 10MHz, 44dBm for 20MHz, 47dBm for 40MHz |
| BS antenna height  | 25m  |
| UE antenna height & gain | Follow TR36.873  |
| UE receiver noise figure | 9dB |
| Modulation  | Up to 256QAM  |
| Coding on PDSCH  | LDPCMax code-block size=8448bit  |
| Numerology | Slot/non-slot  | 14 OFDM symbol slot |
| SCS  | 15kHz  |
| Simulation bandwidth  | 20 MHz for 15kHz as a baseline (optional for 10 MHz with 15KHz), and configurations which emulate larger BW, e.g., same sub-band size as 40/100 MHz with 30kHz, may be optionally considered |
| Frame structure  | Slot Format 0 (all downlink) for all slots |
| MIMO scheme | For low RU, SU-MIMO with rank adaptation are assumed For medium/high RU, SU/MU-MIMO with rank adaptation is assumed  |
| MIMO layers | For all evaluation, companies to provide the assumption on the maximum MU layers (e.g. 8 or 12) |
| CSI feedback  | Feedback assumption at least for baseline scheme* CSI feedback periodicity (full CSI feedback) : 5 ms,
* Scheduling delay (from CSI feedback to time to apply in scheduling) : 4 ms
 |
| Overhead  | Companies shall provide the downlink overhead assumption |
| Traffic model | FTP model 1 with packet size 0.5 MbytesOther FTP model is not precluded. |
| Traffic load (Resource utilization) | * 70% for SU/MU-MIMO with rank adaptation
* 20% for SU-MIMO with rank adaptation

Companies are encouraged to report the MU-MIMO utilization. |
| UE distribution | - 80% indoor (3km/h), 20% outdoor (30km/h)  |
| UE receiver | MMSE-IRC as the baseline receiver |
| Feedback assumption | Realistic |
| Channel estimation | Realistic |
| Evaluation Metric | Throughput and CSI feedback overhead as baseline metrics. Additional metrics, e.g., ratio between throughput and CSI feedback overhead, can be used.Maximum overhead (payload size for CSI feedback)for each rank at one feedback instance is the baseline metric for CSI feedback overhead, and companies can provide other metrics. |
| Baseline for performance evaluation | Rel-16 PS eTypeII Codebook is the baseline for performance and overhead evaluation. (Type I Codebook can be considered at least for performance evaluation)* Note that it is encouraged to disclose further details of beamforming mechanism/ordering over CSI-RS ports/resources.
 |
| SRS modeling for UL channel estimation | SRS periodicity with 5ms/10msSRS error modeling in Table A.1-2 in 36.897. * Companies shall report SRS configuration details if different from that table.
* Further discussing and finalizing remaining details of SRS configurations and Δ (Delta) in RAN1 102e
 |
| FDD DL/UL calibration error model at gNB | Further discussing FDD DL/UL calibration error model, e.g. R1-144943, and finalizing associated details in RAN1 102e if need. |

Based on RAN1 102e contributions shown in References, some remaining issues for EVM will be further discussed and finalized in RAN1 102e. Some high level discussion of potential enhancement can be found in the summary below, i.e. in section 2.2 and 2.3. The highest priority of RAN1 102e is to finalize all details of EVM, to ensure that RAN1 can start proper SLS evaluations for incoming meetings.

# Summary of CSI enhancement for FDD

## Remaining issues on EVM

#### 2.1.1 Channel Modelling for FDD Reciprocity

According to the email offline discussion conclusion, the following two options of reciprocity model for FDD can be used as the starting points to discuss the channel modelling methodology for FDD channel reciprocity.

* Opt. 1: The reciprocity model of DL/UL channel is based on Section 5.3 of TR 36.897
* Opt. 2: The reciprocity model of DL/UL channel is based on Section 7.6.5 of TR 38.901 with different DL/UL frequency.
* Note that further modifications/clarifications based on Option 1 or 2 to generate UL channel are not excluded.

As described in Section 5.3 of TR 36.897 and Section 7.6.5 of TR 38.901, both Opt. 1 and Opt. 2 have assumed that the angle and delay of clusters are reciprocal. Therefore, we may focus on the property of reciprocity of angle and delay between DL and UL channels before diving into detailed channel generation mechanism.

With our best understanding, there are 19 companies that have proposed their opinions on the reciprocity of angle and delay of FDD DL and UL channels, which are summarized in Table 1.

**Table 1 Summary of companies’ Preference**

|  |  |
| --- | --- |
|  | **Supporting Companies** |
| Angle and delay for FDD DL and UL is reciprocal. **(15 Companies)** | VIVO, Samsung, Ericsson, CATT, OPPO, Nokia, FUTUREWEI, Lenovo/Motorola Mobility, LGE, ZTE, DOCOMO, Intel, InterDigital, Apple, Huawei/HiSi |
|
| Angle and delay for FDD DL and UL is non-reciprocal.  **(4 Companies)** | Fraunhofer IIS/Fraunhofer HHI, Qualcomm, Sony, Sharp |

As shown in Table 1, VIVO, Samsung, Ericsson, CATT, OPPO, Nokia, FUTUREWEI, Lenovo/Motorola Mobility, LGE, ZTE, DOCOMO, Intel, InterDigital, Apple and Huawei/HiSi consider that the angle and delay are reciprocal between FDD DL and UL channels. For example, Nokia supports that the path delays, Doppler speeds and angles of each path can be assumed reciprocal between UL and DL, while fast fading coefficients associated with the propagation paths cannot be assumed reciprocal because the depolarisation effects on the phase of the fast fading coefficients caused by diffraction and transmission are frequency dependent. And Ericsson also supports that the physical environment (location and relative power of clusters) is reciprocal between UL and DL, and the actual realization of each ray is random due to random initial phases. And according to the measurement data of some typical scenarios, Huawei/HiSi holds that the reciprocity in delay exists between FDD DL and UL channels in various environments. In addition, few companies prefer that the angle or delay is not reciprocal, or the reciprocity of angle and delay needs to be further studied in FDD channels. For instance, Qualcomm prefers that the permittivity and permeability of a medium are frequency dependent, which determine that power and angle are frequency dependent. And based on the measurement data, Fraunhofer considers that angles are reciprocal for FDD channels, however delay reciprocity does not hold in many cases.

***Observation 1: There is the majority view assuming that angle and delay between FDD DL and UL channels are fully reciprocal***

***Proposal 1: For EVM for FDD CSI enhancement in Rel-17, cluster delays and angles resulting from fast fading channel generation are the same for FDD DL and UL channels.***

|  |  |
| --- | --- |
| Company | Comments |
| Fraunhofer IIS/ Fraunhofer HHI | Although the path delays are reciprocal, it does NOT imply that the delays of the channel taps of the impulse response of the uplink and downlink channels are reciprocal as well. Due to the limited bandwidth of the system, each channel tap is typically a superposition of multiple paths. The phases of these paths are different for the uplink and downlink channels. The different phases of the paths lead to a different superposition of the channel taps for the uplink and downlink channels as shown by measurement results in our tdoc [10]. This means although the path delays are reciprocal, the channel tap delays are non-reciprocal! We believe that this is a critical issue for the Rel. 17 port selection codebook as the channel models in discussion only partially reflect the real-world. Therefore, before proceeding any further we propose to thoroughly investigate the channel models otherwise we may end up in specifying a useless feature.The observation of non-reciprocity of the delays does not depend on the UE speed. The field measurement results shown in our Tdoc also holds for static scenarios, where the UE is completely immobile. Moreover, the results are shown for instantaneous snapshots and no time averaging is considered. Note that for static scenarios, time averaging over multiple snapshots has no effect compared to no time averaging. For the channel models considered for modeling the FDD reciprocity, the delay reciprocity holds for the majority of cases, and the delays are only slightly misaligned, whereas the field measurement results show that the delays are completely misaligned and this particular behavior is observed in most of the cases. @Futurewei – Just to clarify, the bin distance is 100 ns and not 25 ns as it is shown in the figures. With a 100 ns bin resolution, the delays are separated by up to 2 bins. This means the delay separation in between the UL and DL peaks extends up to 200 ns. Therefore, the argument of delay reciprocity cannot be established. Unfortunately, there has been an error in the scaling of the x-axis. Moreover, delay reciprocity in LOS and NLOS cannot be established in a majority of cases from our observations and discussing about a single case where reciprocity holds is not logical. We will rectify the error and the corrected x-axis scale will be presented in a new Tdoc which will be distributed asap. In addition, more measurement results will also be presented in the new Tdoc.  |
| Ericsson | Agree with the proposal. One observation that may explain the differences in reciprocal vs no-reciprocal channel for the parameters is that some companies could have assumed an instantaneous snapshot of the channel while other companies assume some time averaging of the channel over multiple snapshots. Would be good to clarify this for companies that have measurement/simulation results.  |
| Qualcomm | Two companies show different field test results of delay reciprocity based on snapshot, still no clear evidence supporting proposal 1. Assuming both the two field-tests provided are correct, it means that poor reciprocity scenario exists in real world, so seems we should not assume reciprocity at least in delay. |
| LG | We have similar view with QC. Field test results from two companies are based on different speed of a receiver, e.g., 3km/h, and 16km/h(not very high). From this perspective, it may be expected that DL/UL reciprocity error on delay could be impacted by receiver’s speed. So, in this stage, we think that more robust solutions to use delay reciprocity can be discussed when non-ideal FDD reciprocity is considered. |
| Huawei/HiSilicon | We share the same view with Ericsson. Also we would like point out that “the path delays are reciprocal” From Fraunhofer, which is also our understanding. The angle and delay of each path of the channel are reciprocal and the phase is not reciprocal, which is consistent with channel models 36.897 and 38.901. As for comparative analysis of actual field measurement and 3GPP channel modeling mechanism based on Section 5.3 of TR 36.897 (i.e. option 1 which is considered to be too optimal by some companies), it can be found that the phenomenon observed by option 1 and by Huawei/Fraunhofer field measurement are comparable, due to multipath superposition with random phase. Actually adopting option 1 can be even more mis-aligned among PDP UL and UL than some field measurement results. **UL & DL PDPs based on 3GPP 3D Channel Model (Section 5.3 of TR 36.897)** |
| Intel | Given that two companies have different observations from field measurement results, reciprocity of delay taps may not hold in some cases. However, since there is no time in RAN1 to study the channel model, in our view channel model from 36.897 can be used for performance evaluations to see the gains for the enhancements achieved assuming high reciprocity of channel taps.  |
| China Unicom | Agree with Ericsson and Huawei. Some instantaneous parameters, such as the path delays and angle of each path can be assumed reciprocal between UL and DL. |
| Samsung | As baseline, the model should be for the scenario of interest (reciprocity in this case). The model based on 36.897 is for the reciprocity. Some companies have discussed/shown that it matches with the actual channel measurements. So, we prefer it as baseline.  |
| FUTUREWEI | Agree with the proposal. Regarding the measurement data from Fraunhofer IIS/Fraunhofer HHI, it is observed that the differences between the first dominant delay of UL and DL are within 50 ns, which is just a half of the time resolution achievable with a 10 MHz measurement bandwidth, i.e., 1/10 MHz = 100 ns. In our opinion, the difference is not caused by the lack of UL/DL delay reciprocity, it is just a result of the achievable time resolution in the measurement. In fact, out of the 12 first dominant delay differences observed from Figures 5-7 in R1-2005785, one of them is 0 ns, eight are 25 ns, and three are 50 ns, resulting in an average difference of around 29 ns, which are quite small compared to the time resolution of 100 ns in the measurement. This is similar to the situation in a real system, where the accuracy of the time delay measurement achievable is also limited by the CSI-RS/sounding bandwidth used. |

Under the condition that the reciprocity of angle and delay exists between FDD DL and UL channels, most companies, including VIVO, Samsung, Ericsson, CATT, OPPO, Nokia/NSB, Huawei/HiSi and FUTUREWEI prefer channel model Opt.1 since it is more specific parameter generation and specifically designed for reciprocity modelling. Lenovo/Motorola Mobility, LGE and Qualcomm consider that Opt.2 may be more realistic than Opt.1. In addition, ZTE clarifies that cluster powers should be generated independently for DL and UL channels.

***Observation 2: In terms of how to generate DL and UL channels with the reciprocity of angle and delay, 8 companies prefer Opt.1 because it is specially designed for FDD reciprocity. 4 companies consider Opt.2 or some modifications may be more realistic.***

***Proposal 2: For EVM for FDD CSI enhancement in Rel-17, Down-select one option from following Alternatives in RAN1 102-e***

***- Alt 1: Adopt the channel model Opt.1, i.e. based on Section 5.3 of TR 36.897, to generate FDD DL and UL channels.***

***- Alt 2: Adopt the channel model Opt.2, i.e. based on Section 7.6.5 of TR 38.901, to generate FDD DL and UL channels, with following modifications:***

* ***Different per-cluster shadowing is generated for DL and UL, and DL (or UL) angles are generated based on DL (or UL) cluster powers. Then UL (or DL) uses the same angles and its own cluster powers to generate the channel matrix.***
* ***XPR is generated independently for DL and UL.***

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| --- | --- |
| Company | Comments |
| Lenovo/MotM | We support Alt 2; the channel is based on Sec. 7.6.5 of TR 38.901. As discussed in our contribution (R1-2009526), we are concerned the very strong reciprocity assumptions in Alt 1 would have detrimental impact on the robustness of the codebook design, especially that no definitive evidence has been given that proves Alt 1 is more accurate. A solution based on a weaker reciprocity model would still be effective if the reciprocity in reality is stronger, however the converse is not necessarily true.  |
| Ericsson | We support Alt 1. |
| Qualcomm | Support Alt2 as a comprise (if proposal 1 gets through). Even though field test results provided by HW show reciprocity in angle and delay, the reciprocity does not hold for power. This could be resulted by the per-cluster shadowing and XPR. Also share similar view to Lenovo/MotM that Alt2 would make the solution more robust and solid. |
| LG | Support Alt.2. We have similar view with Lenovo/MotM, and QC.  |
| Huawei/HiSilicon | We support Alt 1. |
| Intel | In our view at least Alt 1 should be supported for the evaluations (Alt. 2 is not precluded).  |
| Chian Unicom | Support Alt 1. |
| Samsung | Support Alt 1 |
| FUTUREWEI | Support Alt 1 |
| NTT DOCOMO | Support Alt 1. However, we would like to bring into attention one important factor we think should be considered when exploiting FDD reciprocity. That is, due to the difference in UL and DL wave lengths in FDD systems, estimated spatial covariance in the UL is not the same as spatial covariance in the DL, for phased arrays (due to different antenna correlations). In fact, this issue arises due to array processing and there is nothing to do with angle/delay reciprocity associated with the physical propagation environment. The issue is studied well in academic literature and we think it is important to consider this factor when proposing FDD partial reciprocity-based enhancements for Type II port selection CB |

#### 2.1.2 System Error Modelling

According to the outcome of Phase 2 email discussion, some remaining issues are to be solved.

**SRS Error modelling**

Ten companies, including vivo, CATT, ZTE, FUTUREWEI, Huawei/HiSi, LG Electronics, Ericsson, Qualcomm, Nokia Shanghai Bell and OPPO, propose to adopt the SRS error model in Table A.1-2, i.e., $\tilde{H}$=$α\left(H+E\right)$. Furthermore, with regarding to detailed parameters, five companies, including Ericsson, Qualcomm, Huawei/HiSi, Nokia/Nokia Shanghai Bell and Vivo have proposed to use $Δ=9dB$. There is no company proposing different SRS error modelling or associated value of $Δ$.

A few companies have mentioned additional parameters related to SRS error model, for example, using 8 groups corresponding to 4 symbols and comb 2 per 5ms (Ericsson); replacing path loss to coupling loss (Vivo); using the same bandwidth as CSI-RS; number of SRS ports = 1; Tx power based on UL power control (Samsung); using the same SRS periodicity and configuration as CSI-RS (Vivo); using the same bandwidth as CSI-RS; larger comb value, e.g., 12; number of OFDM symbols: 1,2,4 (CATT); using some random phase rotation is introduced to each hop of the SRS (FUTUREWEI). However given vastly different preferences, it is hardly to converge further for additional details of SRS configurations.

***Proposal 3: For EVM for FDD CSI enhancement in Rel-17, using SRS error model in Table A.1-2 in 36.897 with Δ=9 dB.***

* ***Companies are encouraged to disclose SRS configuration parameters, if differently***

|  |  |
| --- | --- |
| Company | Comments |
| Lenovo/MotM | Support the rapporteur’s proposal |
| Ericsson | Support. Using 8 groups corresponding to 4 symbols and comb 2 per 5ms can be seen as a recommendation for a starting point.  |
| Qualcomm | Ok |
| LG | Support |
| Huawei/HiSilicon | Support the rapporteur’s proposal |
| Intel | Support |
| China Unicom | Support |
| Samsung | Support the SRS error model part. Re SRS configuration, we still prefer to agree to one SRS configuration parameters as baseline to align its impact on performance across companies.  |
| FUTUREWEI | Support  |
| NTT DOCOMO | We are fine with the proposal |

**FDD DL/UL Calibration Error Modelling**

ZTE, LG Electronics, Huawei/HiSi, Qualcomm, Nokia/Nokia Shanghai Bell, CATT and Samsung have proposed to adopt the calibration error model in R1-144943. There is no other preference with regarding to calibration error model. Therefore, it is proposed to use the calibration error model in R1-144943 as baseline.

With regarding to detailed parameters, three alternatives were suggested whereas amplitude error (expressed in decibels) and phase error are normal distribution with {0.35dB, 2.5degrees} or {0.7, 5 degrees} as standard deviation, or uniform distribution within [-0.35dB, 0.35dB] and [-5degrees, 5degrees], respectively.

Then, we can have the following proposal:

***Proposal 4: For EVM for FDD CSI enhancement in Rel-17, using the following calibration error model***

$$\hat{H}\_{UL}=H\_{UL}⋅E=H\_{UL}⋅\left(\begin{matrix}a\_{1}e^{jθ\_{1}}&\cdots &0\\\vdots &\ddots &\vdots \\0&\cdots &a\_{N}e^{jθ\_{N}}\end{matrix}\right)$$

* $\hat{H}\_{UL}$ ***is the spatial UL channel at gNB side with calibration error***
* $H\_{UL}$ ***is the ideal spatial UL channel without calibration error***
* ***E represents the mismatch of transmission and reception circuits of gNB***
* $a\_{i}$ ***is the amplitude error***
* $θ\_{i}$ ***is the phase error***
* ***N is the number of antennas at gNB side***

***With parameters by down-selecting one Alt from following in RAN 102e:***

* ***Alt 1: amplitude error (expressed in decibels) and phase error are normal distribution with 0.35dB and 2.5 degrees standard deviation, respectively;***
* ***Alt 2:*** ***amplitude error (expressed in decibels) and phase error are normal distribution with 0.7dB and 5 degrees standard deviation, respectively;***
* ***Alt 3: amplitude error (expressed in decibels) and phase error are uniform distribution within [-0.35dB, 0.35dB] and [-5degrees, 5degrees], respectively.***

|  |  |
| --- | --- |
| Company | Comments |
| Lenovo/MotM | We support Alt 2 |
| Ericsson | Alt 2 |
| Qualcomm | We prefer Alt2/3. Besides, the error should be added independently per-subcarrier due to non-ideal frequency response of circuitry and thermal noise across the UL and DL band. |
| LG | We prefer Alt.2 |
| Huawei/HiSilicon | We support Alt 1.  |
| Intel | Slight preference on Alt. 2. |
| Samsung | Support Alt 2 |
| FUTUREWEI | Support Alt 1 |

#### 2.1.3 General Procedure over Beamformed CSI-RS

CATT, ZTE, Lenovo/Motorola Mobility, Nokia/Nokia Shanghai Bell, OPPO, Qualcomm, FUTUREWEI, Huawei/HiSi have disclosed some procedure of enhanced Type II port selection codebook based on partial channel reciprocity, for example CATT in R1-2005689 includes 3 general steps.



**Figure 1: Procedure of enhanced Type II port selection codebook (R1-2005689)**

Using above 3 steps as example, it is encouraged that companies disclose some key implementation assumptions, for the sake of technical discussion and comparison.

* Beamforming bases applied to CSI-RS ports/resources

With regarding to beamforming vectors/matrices applied to beamformed CSI-RS ports/resources, VIVO, OPPO, Nokia/Nokia Shanghai Bell and Huawei/HiSi have considered both DFT-based and SVD-based beamforming. Qualcomm have considered SVD-based beamforming. Intel and Lenovo/Motorola Mobility have considered DFT-based beamforming.

* Spatial and/or Frequency domain precoding

Qualcomm, CATT, ZTE, Lenovo/Motorola Mobility, Huawei/HiSi have considered precoded CSI-RS ports/resources via both spatial and frequency domains, for example in Figure 2 from Qualcomm (R1-2006796), whereas in the precoder on FD unit n is dependent on the n-th entry of the corresponding FD basis.

* The beamforming weight of CSI-RS on the *n*-th PRB/SB is$b\_{l}∙ f\_{m}^{H}[n]$ **,** where$b\_{l} $is the SD basis and$f\_{m}[n]$is the *n***-**th entry of the FD basis $f\_{m}$**.**



**Figure 2. One example of CSI-RS precoding using SD and FD bases (R1-2006796)**

* CSI Measurement Behavior over beamformed CSI-RS

Lenovo/Motorola Mobility, ZTE, Huawei/HiSi have considered that UE does average in frequency domain to decompress the residual delay vectors to get wideband coefficients. ZTE and Huawei/HiSi has considered that UE can perform a wideband SVD of the wideband coefficients obtained by averaging in frequency domain, to derive the feedback coefficients.

***Proposal 5: For EVM for FDD CSI enhancement in Rel-17, companies are encouraged to describe general procedure with regarding to beamforming bases applied to CSI-RS ports/resources, spatial and/or Frequency domain precoding, CSI measurement behavior over beamformed CSI-RS, etc. for the sake of RAN1 discussion.***

* ***Note that whether there is spec impact is up to further RAN1 discussion.***

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| Company | Comments |
| Lenovo/MotM | Although we support CSI-RS beamforming process across both spatial and frequency domain, we believe it should not be included in the specification (we have provided design outlines in our contribution for evaluation purposes only). The network should have the freedom to (i) design the CSI-RS beamforming matrix, and (ii) configure the value of *Mv* based on the beamforming design.  |
| Ericsson | In our view, classical beamforming using DFT based precoding with or without gNB side delay compensation per dual polarized beam, is the baseline CSI-RS precoding but studying also whether more advanced e.g. spatial and frequency domain eigen beamforming provides benefits is of interest. |
| Qualcomm | In our view, if FD bases are used for CSI-RS precoding, its impact to DL channel estimation should be considered in the realistic CSI-RS channel estimation of SLS. |
| LG | Support proposal |
| Huawei/HiSilicon | gNB implementation will not be specified, in our understanding. Any spec impact (if agreeable), which may be needed at UE side, is up to further RAN1 discussion. It is not a part of EVM decision but is only used for technical discussion and comparison. It is encouraged to disclose a certain details to ensure some common understanding among companies since they may (may not) have a great impact on the performance. It is up to each company to investigate/compare different beamforming mechanisms.  |
| Intel | We support the proposal. |
| China Unicom | gNB implementation should not be included in the specification. The network should have the freedom to (i) design the CSI-RS beamforming matrix. |
| Samsung | In our view, we should align the following for EVM* DFT or SVD-type precoding
* UE-specific or cell-specific CSI-RS precoding
 |
| FUTUREWEI | Support the proposal |
| NTT DOCOMO | We support the proposal. Further, we think CSI-RS beamforming across spatial and delay domains should be done at the gNB. However, since this can be handled spec. transparently, necessary spec. modifications required to obtain maximum gains at the UE side from spatial/delay domain CSI-RS beamforming, should be discussed. For instance, as we have captured in our tdoc R1-2006724, with the delay pre-compensation at the gNB (essentially delay domain beamforming), observed channel at the UE side becomes almost frequency flat. Hence, CSI reporting considering larger SB sizes or even WB reporting is enough and should be supported from the spec. |

#### 2.1.4 Others EVM related issues

There are other EVM related proposals as follows:

* **ZTE**: Clarify 20% for SU-MIMO or SU/MU-MIMO with rank adaptation.
* **Ericsson**: For CSI-RS transmission, use a power backoff of X= (n-1)\*2 dB where n is the number of CDM groups/symbol used for the CSI-RS resource.
* **Samsung:** Whether CSI-RS is UE-specific or cell-specific should be discussed, and the CSI-RS overhead should be included in UPT calculation accordingly.
* **Lenovo/Motorola Mobility:** 4 GHz with duplexing of 200 MHz between DL and UL; Type-I codebook or Rel. 16 Type-II codebook as a baseline
* **vivo:** The impact of timing difference between gNB and UE should be further evaluated and studied.
* **Intel:** Cell-specific or UE-specific CSI-RS precoding can be considered

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| --- | --- |
| Company | Comments |
| Lenovo/MotM | Regarding the baseline, our only concern about adopting R16 eType-II PS codebook is the lack of clarity of the CSI-RS beamforming design. This may lead to performance disparities in the baseline, which is highly undesirable. We are OK with adopting R16 PS codebook as baseline if we agree on an explicit design for the CSI-RS beamforming (for evaluation purposes).  |
| Qualcomm | We also think DL CSI-RS overhead should be considered in evaluation. Beamformed CSI-RS is usually UE-specific, considering that CSI-RS ports may be precoded by FD-SD bases in FDD reciprocity study, the number of ports used may be larger than eT2 PS where only SD bases are applied. These extra number of ports consumes system throughput. |
| LG | Support SS’s suggestion.  |
| Intel | Support proposal from Samsung.  |
| Samsung | Support our proposal ☺ |

## CSI Enhancement for FDD

Eight companies have shared their views on codebook design, which can be summarized in Table 3.

**Table 3 Codebook Design Framework**

|  |  |  |
| --- | --- | --- |
| **Category** | **Brief description** | **Companies** |
| Alt1. Based on R16 eType II PS codebook | * Based on Rel.16 Type II PS codebook, potentially with some extensions/ modifications
 | Intel, Lenovo/Motorola Mobility, Samsung, Nokia/Nokia Shanghai Bell, DCM, FUTUREWEI, Huawei/HiSi |
| Alt2. Based on R15 Type II PS codebook | * W=W1W2, W1 indicate the selected ports beam, and W2 be the port combination coefficients matrix
 | CATT |
| Alt3. New framework for the codebook design | * New Type II PS design with potentially different codebook structure and parametrization from Rel.16 Type II PS design
* Example: separate or joint port selection across SD and FD
 | Samsung |

Moreover, companies have shared potential codebook enhancements based on Rel.16 Type II PS codebook as following:

* **Samsung:**
	+ Based on Rel.16 Type II PS codebook with small modifications
		- Example: free port selection in W1, reporting only a subset of PMI components (from Rel.16 Type II PS codebook).
	+ New Type II PS design with potentially different codebook structure and parametrization from Rel.16 Type II PS design
		- Example: separate or joint port selection across SD and FD
* **Lenovo/Motorola Mobility:** Introduce additional parameter values for Rel. 16 Type-II port selection codebook, e.g., include WB reporting with M=1. Other changes to parameters, parameter values are FFS.
* **NTT DOCOMO/INC:**
* Consider separate triggering for reporting of CSI components associated with angle(s) and delay(s), i.e., $W\_{1,l}$ and $W\_{f,l}$, in Type II PS codebook in addition to currently available simultaneous reporting of all the CSI components.
* Introduce larger SB sizes compared to what is already available in NR Rel-15/16, e.g. SB sizes of 12, 16 PRBs etc.
* **Nokia/Nokia Shanghai Bell:** Consider possible restrictions or reductions in size of the PMI indicators for SD basis, FD basis and bitmap to complement the reciprocity-based estimates performed by the gNB. These modifications should not change the structure of the PMI and should result in a smaller UCI overhead.
* **FUTUREWEI：**If gNB can utilize angle and delay information to generate appropriate beamformed CSI-RS ports, thus resulting in a smaller *Mv* and *L* for CSI feedback, many of the CSI feedback fields can be reduced.
* **Huawei:** The enhancements are as follows
	+ $W\_{1}$ is enhanced by relaxing restrictions of$ W\_{1}$ to improve performance, e.g. more than 4 ports can be selected freely;
	+ $W\_{f}$ can be limited with very few vector(s), e.g. one or two;
	+ $W\_{f}$ can be enabled with a larger value of R (*numberOfPMISubbandsPerCQISubband*) , e.g. R=4.
* **Apple:** For CSI enhancement utilizing partial reciprocity of DL/UL channels, more dynamic wideband and subband CSI reporting configuration can be considered.

It can be more or less pre-mature to conclude during the first Rel-17 MIMO meeting. Therefore companies are encouraged to study further, taking into account agreed EVM in RAN1 102e and following proposal.

***Proposal 6: Taking Type II port selection codebook enhancement (based on Rel.15/16 Type II port selection) as a starting point, study following aspects, taking into account trade-off among UE complexity, performance and reporting overhead:***

* ***Basic codebook structure based on Rel.15/16 Type II port selection***
* ***Enhancements on*** $W\_{1}$ ***quantization, e.g., free port selection in*** $W\_{1}$ ***and/or modified value range of*** $L$***;***
* ***Enhancements on*** $W\_{f}$ ***quantization, e.g., smaller*** $M\_{v}$ ***and/or modified value range of R;***
* ***Restrictions/Relaxation, e.g. in the size of the PMI indicators for SD basis, FD basis and bitmap.***
* ***Enhancements on reporting mechanism, e.g., separate triggering for reporting of*** $W\_{1}$ ***and*** $W\_{f}$***, and/or reporting only a subset of PMI components;***
* ***Other enhancement are not excluded.***

|  |  |
| --- | --- |
| Company | Comments |
| NTT DOCOMO | We are fine with the FL proposal |

## Others

The other proposals about codebook enhancements are listed as follows:

* **AT&T:** Exploiting the power delay and power Doppler profiles to track long term and frequency domain changing trends can significantly improve the feedback overhead.
* **Intel:** In order to provide some margin for estimation of the FD vectors at the gNB, estimation of contagious set with larger number of FD vectors can be considered at the gNB.
* **Sony:** In TDD and FDD FR1 systems, the UE can signal to the BS the DL covariance matrix of noise and interference.
* **Vivo:** The gNB can search for the several strongest taps from SRS and indicate them to UE. The only thing UE needs to do is to compute the coefficients of the taps gNB indicates.
* **Nokia/Nokia Shanghai Bell:**
* Consider techniques to reduce the total number of CSI-RS resources/ports needed to configure reciprocity-aided Type II PS reports for multiple UEs, for example, by introducing flexible RRC configurations and/or resource/port sharing between UEs.
* Consider efficient mechanisms to configure and trigger wideband SRS transmission jointly with reciprocity-aided CSI reports in order to minimise UL resource occupation and UE power consumption and to reduce the number of trigger states

# Summary of CSI enhancement for Multi-TRP

## Remaining issues on EVM

Based on contributions, it seems that no much further discussion is required. Vivo has suggested to clarify implementation details in the MTRP CSI simulation, e.g. RSRP threshold determination suitable for multiple TRP connections. Moreover, some companies, Intel, CATT, CMCC, vivo, Lenovo/Motorola Mobility, OPPO have proposed CSI enhancements for MTRP with other deployment scenarios, e.g. for URLLC, non-ideal backhaul, HST, non-overlapped PDSCH, multi-DCI based MTRP transmission. Whilst RAN1 shall strive to minimize spec impact by unifying multiple usages of CSI enhancements, companies are encouraged to disclose application scenarios for their proposals.

***Proposal 7: For EVM for MTRP based CSI enhancement in Rel-17,***

* ***The agreements of Rel-16 evaluation assumptions for DL multi-TRP/panel transmission can be the start point in Rel-17. Further agreements of evaluation assumptions, if any and applicable, from other Rel-17 M-TRP objectives can be considered as well.***
* ***The baseline is CSI reporting supporting DL multi-TRP/panel transmission, up to Rel-16 including multiple CSI reporting etc.***
* ***Companies are encouraged to disclose implementation details, e.g. RSRP threshold and applicable scenarios***

|  |  |
| --- | --- |
| Company | Comments |
| Lenovo/MotM | We support the rapporteur’s proposal |
| Ericsson | We support the proposal. |
| Qualcomm | Support Rapporteur's proposal |
| LG | Support proposal |
| Huawei/HiSilicon | We support the rapporteur’s proposal. |
| Intel | Support |
| Samsung | Support Rapporteur’s proposal |
| NTT DOCOMO | We support the proposal. |

## CSI Enhancement for Multi-TRP

Many companies, Samsung, Qualcomm, Ericsson, Nokia, MTK etc., have mentioned that CSI measurement and reporting in Rel-15/16 CSI is still insufficient to support M-TRP transmission, and concerned about the potential increase of the number of CSI reports, or signaling latency/overhead, or multiple M-TRP transmission hypotheses etc.

Based on our understanding of contributions, RAN1 proposals are extremely diverse in RAN1 102e and we hardly find any commonality among two companies’ proposals, which are usually differentiated each other for a certain details, about configurations, measurement behaver, CSI reporting mechanism etc. For the sake of discussion, RAN1 proposals can be roughly categorized as following so that companies can understand each other better (at least for what we are discussing about) and strive to find certain commonality in RAN1.

In RAN1 102e, the categorization does not intent to down-selection but provide a certain assistance what RAN1 can analyze and compare in future meetings:

* **Category 1** - *For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs. The UE will determine CSI reporting qualities based on pre-defined rule(s) across TRPs and report CSI within a single CSI report.*
* FUTUREWEI: a UE is configured with a group of NZP resources for a report configuration, and the UE decides whether each of the group of NZP resources is CM, IM, or muting
* vivo:
	+ - The MTRP CSI feedback can be enhanced by associating multiple CSI ReportConfigs/CSI-ResourceConfigs/CSI Resource sets
		- increase the information element in a CSI-ReportConfig, such as increasing the amount of CSI resource settings and increasing the amount of resource sets in a CSI-ReportConfig
* Samsung: Another approach for reducing reporting overhead is to configure multiple {CMR, IMR} pairs in a CSI-RS resource set associated with a single CSI report.
* ZTE: LTE liked CSI enhancement for single-DCI based SDM MTRP.
* For one CSI reporting, support two sets of CRI/RI/PMI
* MTK: For CSI enhancement of NCJT, study the following alternatives:
* Alt. 1: One CRI can be associated with two NZP CSI-RS resources for channel measurement.
* Alt. 2: One CSI-RS resource can have two port groups, each associated with one distinct TCI state.
* CATT: To support NC-JT with single PDSCH, joint CSI measurement based on associated CSI-RS resources for coordinated TRPs/panels can be considered
* Ericsson: gNB may configure a UE with N>1 NZP CSI-RS resources in a resource setting for channel measurement where each of the N NZP CSI-RS resources may be associated with one TRP. Then, in the corresponding CSI report, the UE can select a subset M < N (e.g., 2) CRIs and report this as part of the CSI report, where M NZP CSI-RS resources are used for channel measurement.
* NTT DOCOMO/INC: For multiple CSIs in a CSI report, the inter-TRP interference can be considered by assuming the CMR of one TRP as the IMR of the other TRP
* Qualcomm: Study the pros and cons of the following two approaches to enable CSI report for SDM scheme:
* Approach 1: Support two TCI states for one CSI-RS resource for CMR, where the CSI-RS ports consists of two port groups associated with the two TCI states.
* Approach 2: Support two CMRs corresponding to two CSI-RS resources for a NCJT CSI hypothesis.
* NEC: For multi-TRP/panel transmission, inter-TRP/panel interference measurement can be based on CSI-RS resource(s) configured for channel measurement for other TRPs
* Intel: CSI design specified for NC-JT transmission in LTE FeCoMP is considered as a starting point for discussion
* CSI measurements for MTRP are configured as multiple CSI-RS resources corresponding to one CSI report settings
* Multiple transmission hypotheses are considered at the UE for CSI reporting including NC-JT and DPB/DPS
* CMCC: Two CRI and corresponding CQI, RI and/or PMI could be reported in joint CSI reporting, whether one or two CQI/RI/PMI is reported is related to the transmission scheme
* Spreadtrum: To achieve more accurate interference measurement, we prefer not to explicitly configure CMR of one TRP as IMR of another TRP. When calculating interference of one TRP, the measurement of CMR of another TRP should be additionally as the inter-layer interference
* Apple: In Rel-17 CSI enhancement for MTRP, consider the enhancement to both CSI measurement configuration and CSI report quantity configuration to reflect the reciprocal relationship between CMR and IMR, especially for NCJT
* **Category 2** – *Within a implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs, the UE will determine CSI reporting qualities based on pre-defined rule(s) and reporting multiple CSIs with multiple CSI reports.*
* vivo: The MTRP CSI feedback can be enhanced by associating multiple CSI ReportConfigs/CSI-ResourceConfigs/CSI Resource sets. Both separate CSI reporting and joint CSI reporting should be supported.
* Lenovo/Motorola Mobility: CSI feedback corresponding to each TRP is decomposed into two CSI reports, each including information corresponding to two different sets of layers
* LG: Support enhancement for CQI reporting reflecting inter-TRP interference based on NZP CSI-RS resource for IM.
* by reporting RI/PMI/CQI for one TRP together with updated CQI for another TRP in which the RI/PMI are reflected as interference.
* by reporting RI/PMI for one TRP together with joint CQI reporting for single DCI based multi-TRP transmission
* Huawei/HiSilicon: If two CSI reporting are triggered by one trigger state, UE will do joint CSI measurement and reporting based on the CSI-RS resources related to the two CSI reporting
* NTT DOCOMO/INC: For a CSI-ReportConfig, both separate and joint CSI measurement/reporting for multiple TRPs can be considered.
* Spreadtrum: Support joint CSI feedback and separate CSI feedback for NC-JT.

In additional to above two categories, many companies provide further detail designs shown as Table 4, e.g. enhancement for resource configurations, enhancement for joint/separated report quantities, measurement hypotheses etc. It is unlikely to dive into very fine decision of CSI enhancement very soon in RAN1, until RAN1 has fully understood and agreed a certain measurement behavior for M-TRP/Panel based transmission. Therefore, for the sake of reference, we have summarized more proposal details from companies, and listed them in following Table as reference.

**Table 4 Summaries of Detailed Design (Next Level) for CSI Enhancement for MTRP**

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| MTK | * For joint CSI reporting of NCJT, individual PMI and RI are generated for each CMR
* The allowed RI pairs can be specified for joint CSI reporting to limit signaling overhead, and it should be configurable to allow one of the RIs to be reported as 0.
* For joint CSI reporting of NCJT, the number of CQI to be reported is configurable.
* One CSI report can have K≥1 CRIs, where K is configurable.
* If interference measurement is performed on NZP CSI-RS, there can be more than one NZP CSI-RS resource as CMR, where for each CMR there is a bitmap indicating which NZP CSI-RS resource(s) in nzp-CSI-RS-ResourcesForInterference is used as associated IMR.
 |
| CATT | * Indication/configuration/report on the transmission scheme assumed for CSI calculation can be considered.
* A t least the following CSI feedback quantities need to be supported:
* PMI/RI for each TRP/panel
* CQI for each codeword or TRP
 |
| NEC | * Enhancement on CSI measurement and feedback for dynamic switching between single-TRP and multi-TRP transmission should be supported
 |
| Intel | * The following aspects are for further study
* Number of CSI-RS resources corresponding to different TRP configured for one CSI report setting
* CSI reporting for different MTRP transmission hypothesis including NC-JT and DPB/DPS
 |
| Lenovo/Motorola Mobility | * For each channel hypothesis, two CSI reports are needed to design the appropriate precoder, based on whether the hypothesis supports single TRP transmission or NCJT.
* For each channel hypothesis, two CSI reports are needed to design the appropriate precoder, based on whether the hypothesis supports single TRP transmission or NCJT.
* Joint CSI reporting can be considered, where each CSI report includes up to two sets of CRI, PMI, RI, and LI. The CSI resource setting and CSI reporting setting are FFS
* For NCJT with transmission rank exceeding 4, the differences in the rank indicator fed back for CSI reports corresponding to two TRPs should not exceed one
 |
| Spreadtrum | * Support limited rank pair for NC-JT, e.g., {1,1}, {1,2}, {2,1},{2,2}.
* Study how to demonstrate the validity of CSI parameters for joint reporting in NC-JT
 |
| QC | * Support one-to-one mapping between CSI-IM and CRI codepoint for a given CSI-ReportConfig
* SDM CSI report should consist of one CRI, one CQI, two RIs, two LIs, and two PMIs.
* If a CSI-ReportConfig consist of both single-TCI state and multi-TCI state hypothesis types, UE reports two CSIs corresponding to the best hypothesis within a given type and the corresponding CRIs.
 |
| Nokia | * For S-DCI based M-TRP operations, consider solutions to reduce the CSI reporting overhead by allowing a UE to select one or more CSI reports amongst the configured transmission/interference hypotheses
* Consider solutions to optimise CSI-RS resource configurations, triggering and reporting mechanisms for S-DCI based M-TRP operations with 2 TRPs
 |
| Ericsson | * Evaluate UE assisted multi/single-TRP hypothesis selection feedback where the UE decides on single-TRP transmission or multi-TRP NC-JT transmission hypothesis based on its measurements and indicate the preferred hypothesis to the gNB
 |

***Proposal 8: For CSI enhancement for multi-TRP, study following aspects***

* ***Category 1 - For a reporting setting CSI-ReportConfig, more than one CSI-RS port groups in a resource or resources or resource sets are associated to different TRPs. The UE will determine CSI reporting qualities based on pre-defined rule(s) across TRPs and report CSI within a single CSI report.***
* ***Category 2 – Within a implicit/explicit set of reporting settings CSI-ReportConfigs, which are associated to different TRPs, the UE will determine CSI reporting qualities based on pre-defined rule(s) and reporting multiple CSIs with multiple CSI reports.***
* ***Other enhancement are not excluded.***

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

## Others

Companies are also proposing other enhancements for Multi-TRP CSI which can be discussed further once basic Rel-17 CSI measurement enhancement is more or less understood by RAN1:

* **AT&T**
* Support DMRS/PDSCH based CSI estimation for UCI enhancements with single PDCCH based Multi-TRP transmission.
* Support new compact CSI report embedded in the HARQ-ACK feedback
* **Samsung:** Two-part UCI structure optimized for NC-JT CSI report.
* **Spreadtrum:** A new design of CSI composition and CSI Part 2 omission priority should be considered for joint reporting in NC-JT.
* **Sharp:** Fast CSI measurement and reporting should be introduced.
* **Qualcomm:** An SDM CSI hypothesis occupies two CPUs, two active resources, and a number of active ports corresponding to both TCI states. These numbers are separate from single-TRP hypotheses

# Proposals for Online/Offline Discussion

TBD

# Work Plan

* R1-102e: EVM and high level categorization/summary of FDD CSI/MTRP CSI
* R1-103e:
	+ FDD CSI: codebook design framework and identify enhancements of PMI quantization for rank 1
	+ MTRP CSI: down-select enhancement mechanism for MTRP CSI measurement. Given limited RAN1 time and complexity of MTRP CSI, we have to be very strict about what we can do in Rel-17MTRP CSI.
* R1-104:
	+ FDD CSI: identify enhancement of PMI quantitation for rank 2~4
	+ MTRP CSI: Starting from measurement enhancement, identify potential RAN1 impact, including CSI configuration, measurement, reporting, etc.
* R1-105:
	+ FDD CSI: PMI reporting mechanism and other RRC related impact
	+ MTRP CSI: Finalize major RAN1 decisions from R1 104 for M-TRP CSI
* R1-106: Final spec housekeeping, e.g. CSI CPU/priority/dropping/Upperbound etc for MTRP CSI.

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# Appendix

# Evaluation Assumptions for CSI reporting for DL multi-TRP and/or multi-panel transmission

In terms of evaluating CSI reporting for DL multi-TRP and/or multi-panel transmission to enable more dynamic channel/interference hypotheses for NCJT, targeting both FR1 and FR2, from FL perspective, Rel-16 SLS assumptions can be sufficient without the need of further discussion, which has covered both FR1/FR2, dense urban/indoor, eMBB/URLLC etc. Moreover, whether Rel-17 shall cover extended scenarios/assumptions in other M-TRP objectives can be discussed at corresponding M-TRP objectives, if need. Once those details from other M-TRP objectives can be confirmed and agreed in RAN1, CSI reporting enhancement for DL multi-TRP/panel transmission can accommodate those changes accordingly. The baseline is CSI reporting supporting DL multi-TRP/panel transmission, up to Rel-16.

Most companies, Samsung, ZTE, Intel, Ericsson, LGE, Lenovo, Motorola mobility, FutureWei, Vivo, Oppo, has considered to reuse Rel-16 SLS assumptions for M-TRP as much as possible.

|  |  |
| --- | --- |
| Company | Comments |
| Rapporteur | *The agreements of Rel-16 evaluation assumptions for DL multi-TRP/panel transmission can be the start point in Rel-17. Further agreements of evaluation assumptions, if any, from other Rel-17 M-TRP objectives can be considered as well.* *The baseline is CSI reporting supporting DL multi-TRP/panel transmission, up to Rel-16.*  |
| Ericsson | Using Rel-16 assumptions is ok. Note that using multiple CSI report settings etc are also tools available for baseline assessment. |
| InterDigital | Reuse Rel-16 SLS assumptions and Rel-16 CSI reporting mechanism. |
| Intel | Agree with the rapporteur. |
| ZTE | We agree with the above proposal to reuse the Rel-16 evaluation assumptions and use the CSI reporting schemes up to Rel-16 as a baseline.  |
| Huawei/Hisi | Agree with rapporteur to use Rel-16 EVM as starting point |
| Nokia/NSB | Ok with Rapporteur proposal |
| MotM/Lenovo | We are OK with reusing Rel. 16 SLS assumptions and CSI reporting mechanisms |
| Samsung | Agree that Rel-16 M-TRP SLS assumption becomes the baseline. On top of that, we think the following agreement for Rel-16 M-TRP EVM needs to be considered as well.AgreementFor eMBB multi-TRP/panel performance evaluation, FTP traffic model 1 with packet size 0.5Mbytes as a baseline, and other traffic model is not precluded. RU=20/40/60% are baseline, and optional low RU (e.g. 5/10) can be considered. |
| vivo | Reuse Rel-16 SLS evaluation assumptions. Moreover, ideal backhaul and non-ideal backhaul, single-DCI and multi-DCI assumptions need to be clarified. |
| OPPO | Support Rapporteur’s proposal.  |
| Qualcomm | Ok with Rapporteur proposal. Potential agreements for other Rel-17 M-TRP objectives can be considered when applicable. |
| LG | Support rapporteur’s proposal |
| Apple | We agree with the proposal from the Rapporteur |
| Fraunhofer | OK with rapporteur’s proposal. |
| FUTUREWEI | Agree with Rapporteur proposal. |
| CATT | Support rapporteur’s proposal. |

# Evaluation Assumptions for Type II port selection codebook enhancement

## Evaluation Assumption for CSI enhancement

In terms of evaluating Type II port selection codebook enhancement (based on Rel.15/16 Type II port selection) where information related to angle(s) and delay(s) are estimated at the gNB based on SRS by utilizing DL/UL reciprocity of angle and delay, from the FL perspective, Rel-16 SLS assumptions for eType II codebook design can be considered as the starting point of further discussion, e.g. commented by Intel, Huawei, CATT, Lenovo/Motorola, OPPO. Some remaining issues, due to introduce DL/UL reciprocity, shall be revisited and aligned within RAN1 as much as possible.

|  |  |
| --- | --- |
| Company | Comments |
| Rapporteur | Considering SLS assumptions for CSI enhancement in Rel-16, i.e. Table 2, as a starting point with potential revisions/clarifications in following sections.  |
| Ericsson | Agree with rapporteur to use Table 2 as starting point although -rel.16 should be the baseline. |
| InterDigital | Agree with rapporteur proposal |
| Intel | Agree with the rapporteur. |
| ZTE | Okay to use the SLS assumptions from Rel-16 eType II as a starting point.  |
| Huawei/Hisi | Agree with rapporteur to use Table2 as starting point  |
| Nokia/NSB | Agree |
| MotM/Lenovo | We support the rapporteur’s proposal |
| Samsung | Support the rapporteur’s proposal |
| vivo | Agree with rapporteur proposal |
| OPPO | Support rapporteur’s proposal |
| Qualcomm | Agree with rapporteur’s proposal. |
| LG | Support rapporteur’s proposal |
| Apple | We agree with the proposal from the Rapporteur |
| Fraunhofer | OK with rapporteur’s proposal. |
| FUTUREWEI | Agree with Rapporteur proposal. |
| CATT | Agree with Rapporteur’s proposal. |
| NTT Docomo | We are fine with Rapporteur’s proposal |

## Channel Model for FDD partial reciprocity

Channel model for frequencies from 0.5 to 100 GHz can be found in TR38.901 [3]. However, in order to evaluate Type II port selection codebook utilizing information related to angle(s) and delay(s) estimated at the gNB based on SRS due to DL/UL reciprocity, a channel model including both Uplink and Downlink channels shall be clarified, especially for a FDD band. Section 7.5 of TR 38.901 seems to be insufficient in terms of clarity of how to model FDD partial reciprocity.

To avoid unnecessary ambiguity, there are three possible options to model FDD partial reciprocal channels and the majority of companies, Samsung, Intel, Huawei, CATT, Ericsson, FUTUREWEI, vivo, OPPO, Nokia may prefer Opt 1. Opt 2 or 3 is preferred by Lenovo. Moreover, ZTE, Apple, LG has commented that at least FDD channel reciprocity modeling shall be discussion without clear preference yet.

* Opt. 1: The reciprocity model of DL/UL channel is based on Section 5.3 of TR 36.897
* Opt. 2: The reciprocity model of DL/UL channel is based on Section 7.6.5 of TR 38.901 with different DL/UL frequency.
* Opt. 3: The reciprocity model of DL/UL channel is based on Section 7.6.5.1 of TR 38.901

Opt.1 was designed and agreed specifically for FDD reciprocity in LTE, which has clearly described the relationship between uplink and downlink channel parameters in FDD in terms of instantaneous channel generation. Therefore Opt. 1 can be relatively easy to be adopt on top of TR 38.901 to mitigate changes of SLS, so as to evaluation assumptions.

Opt.2 has described how to generate channel parameters from different frequencies, which can be correlated in terms of large/small scale parameters. Opt.2 may be mainly designed for carrier aggregation with frequency duplexing distance between two CCs larger than a FDD band, as commented by Ericsson. It is noted that 38.901 is inconsistent by saying that angles and delays are the same for all frequencies while the corresponding spreads are frequency dependent.

Opt. 3 has provided an alternative to ensure that cluster delays/angles are frequency-independently. However the main drawback of section 7.6.5.1 is that the generation mechanism differs significantly from the approach described in Section 7.5. Therefore Section 7.6.5.1 may lead to profound RAN1 effort by adjusting channel modeling mechanisms for both DL and UL channel in SLS, and potentially require extra calibration effort since Section 7.6.5.1 may not be commonly used by RAN1 in previous releases.

|  |  |
| --- | --- |
| Company | Comments |
| Rapporteur | Prefer Option 1 |
| Ericsson | Option 1 |
| InterDigital | Option 1 |
| Intel | Prefer Option 1. |
| ZTE | The differences between Option 1 and 2 are the following aspects.1. Whether per-cluster shadowing in cluster power generation for UL and DL is same. Option 1 assumes same per-cluster shadowing, while Option 2 assumes independent generation.
2. Whether the random value X\_n,m to generate XPR is same for UL and DL. Option 1 assumes same XPR for DL and UL, while Option 2 assume independent generation on X\_n,m. In addition, XPR generation in NR channel model (901) is different from LTE (873). In LTE, the random value X is same for all cluster and rays, while NR assumes independent generation for different clusters and rays.

Rather than arguing between Option 1 and Option 2, we can just try to make a decision on the above two questions. From our perspective, to assume independent generation of these two random values is more realistic, and it will make the evaluation and potential enhancements more robust.Regarding the comment “*It is noted that 38.901 is inconsistent by saying that angles and delays are the same for all frequencies while the corresponding spreads are frequency dependent.*”, we don’t agree with that. In option 2, it clearly says the angular and delay spreads are same for different frequencies. The different part is the scaling of these spreads, which is only used in FR2. Since the target of this enhancement is for FR1, the scaling will not be used. Hence the spreads are same for UL and DL in Option 2, which is same as Option 1. |
| Huawei/Hisi | Option1 |
| Nokia/NSB | Option 1 |
| MotM/Lenovo | Option 2. We agree with ZTE’s comment regarding the consistency of TR 38.901. We are concerned Option 1 is too optimistic and may lead to significant gap between simulations & actual performance in the field |
| Samsung | Option 1 |
| vivo | Option 1 |
| OPPO | Option 1 |
| Qualcomm | Option 2. We share similar view to MotM/Lenovo. We think considering frequency dependent delay and angle is critical. This is because the ermittivity and permability of a medium are frequency dependent. These two factors determine the properties of the refracted EM waves Thus, it is natural that delay and angle are frequency dependent. We should not ignore them if the focus is to evaluate FDD reciprocity. |
| LG | Prefer Option 1. |
| Apple | We think ZTE/MotM/Qualcomm raised a very good point. We slightly prefer option 2. At least, we think it is worthwhile to further understand the difference between option 1 and optional 2, since it is possible that option 1 will result in high reciprocity than option 2 |
| Fraunhofer | Similar view than ZTE/MotM/QC/Apple. We prefer Option 2. Measurements performed by Fraunhofer that will be presented in the August meeting show that the delay reciprocity is not always satisfied. Due to the limited system bandwidth, each channel tap of the impulse response is always given by a superposition of several paths/rays of the channel. Although the delays of the paths are more or less reciprocal for the considered frequency range, the phases of the paths can be different for the UL/DL channels. These phase differences lead to a different superposition of the path components of each channel tap for the UL/DL channels. Measurement results show that in sparse environments or LoS only conditions, the angular and delay reciprocity holds, but in dense environments or NloS conditions, the delay reciprocity may not always hold. |
| FUTUREWEI | Prefer Option 1 and we are open to modifications on top of TR 36.897 to make it more realistic. |
| CATT | Prefer Option 1. |
| NTT Docomo | We prefer Option 1 |

## UL sounding based on SRS

One of remaining issues of clarification for evaluation assumption is for UL channel estimation based on SRS. Many companies, Huawei, Ericsson, Futurewei, Samsung, ZTE, Apple, Lenovo/Motorla, Vivo, Nokia, has commented that realistic UL channel estimation shall be considered. CSI acquisition based on partial channel reciprocity needs to obtain information related to angle(s) and delay(s) from SRS. There it can be worth discussing some evaluation assumptions related to SRS configuration details, e.g. SRS periodicity/SRS BW suggested by Samsung, CATT, Vivo and Nokia, and UL channel estimation odeling after generating UL channel, e.g. SRS error model provided in Table A.1-2 of TR 36.897 suggested by Huawei and Ericsson, which can be relatively easy to be implemented by companies’ SLS simulators and gives rise to reasonable estimation error of angle(s)/delays of propagation paths obtained from UL sounding.

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| --- | --- |
| Company | Comments |
| Rapporteur | Consider following SRS modeling for UL channel estimation:* SRS periodicity with 5ms/10ms
* SRS error odeling in Table A.1-2 in 36.897. Companies shall report SRS configuration details if different from that table.
 |
| Ericsson | Support Rapporteur proposal |
| InterDigital | Agree with the Rapporteur proposal as the baseline. Any further detail can be discussed as needed. |
| Intel | Agree with the rapporteur. |
| ZTE | * SRS periodicity can be aligned with CSI report and CSI-RS periodicity.
* Agree to use SRS error odeling in 36.897.
 |
| Huawei/Hisi | Agree with Rapporteur’s proposal |
| Nokia/NSB | * SRS periodicity is OK
* SRS error model: our preference is to adopt realistic channel estimation for the UL as done for the DL. The SRS error model in Table A.1-2 of 36.897 seems rather simplistic: the additive noise variance depends on a fudge factor ($Δ$) whose calculation/value is not clear.
 |
| MotM/Lenovo | We support the rapporteur’s proposal |
| Samsung | We also prefer a more realistic UL channel estimation. The choice of the fudge factor ($Δ$) should not be arbitrary.SRS periodicity modeling is OKTo avoid the effect of different SRS assumptions on results across companies, we suggest to align other SRS configuration parameters, at least the following* BW: same as CSI-RS or smaller BW
* Number of ports: 1 or > 1
* Tx power: same for all Ues, or based on UL power control (wit max 23 dBm, for example)
 |
| vivo | In general ok with the proposalSRS periodicity modeling is fine, better to agree on a single value e.g. 10ms.For the error modeling in Table A.1-2 in 36.897, prefer coupling-loss-based SINR calculation and constant delta. |
| OPPO | Fine with the proposal.For SRS error modeling, support to reuse Table A.1-2 in 36.897, and companies can report the number of SRS groups (if different from 4 in LTE) and value of delta. |
| Qualcomm | Agree with rapporteur’s proposal. |
| LG | Support rapporteur’s proposal |
| Apple | We agree with the proposal from the Rapporteur |
| Fraunhofer | Support rapporteur’s proposal. |
| FUTUREWEI | Agree with Rapporteur proposal. |
| CATT | Support Rapporteur’s proposal. |
| NTT Docomo | We are fine with Rapporteur’s proposal. Further, we also prefer realistic UL channel estimation and to have prior agreement on SRS BW as well |

Table 3 SRS Error Modelling (Table A.1-2 in 36.897)

|  |  |
| --- | --- |
| Parameters | Values |
| SRS error modelling | , according to [5][6] - Note |
| NOTE: is the estimated channel, is the channel response in frequency domain, is the white complex Gaussian variables with zero mean and variance , is the scaling factor . The details of calculation on  should be provided by each company and additional factors (e.g, SRS interference due to UL traffic, non-perfect open loop power control, UE TX antenna gain imbalance modelling) may be considered. where, Interference power:* + no intra-cell SRS interference
	+ for inter-cell SRS interference: UEs are randomly grouped to 4 groups in baseline cases, UEs in the same group (in different cells) would interfere with each other’s SRS;
		- Use pathloss/linkloss for interference calculation
		- Inclusion of CAZAC sequence gain needs to be clarified

Signal power:* + Use open loop power control (based on linkloss from serving cell)
	+ Ex: SINR based on pathloss can be derived by:

 where  is the received SINR of the target UE t at cell c, M is the number of SRS interferers considered in the simulation, is the transmit power of UE i based on open loop power control, is the pathloss from UE i to cell c. Δ (Delta):* + The details of delta derivation should be provided by each company
	+ Example can be a constant value of 9 dB
	+ Other values are not precluded, and may be determined by LLS or other look-up table

 Note that baseline is given by the following - “4 groups” corresponds to 2 SC-FDMA symbols and 2 comb per 5ms for SRS transmission. “no intra-cell SRS interference” assumes that in a SC-FDMA symbol not more than 4 CSs are used for SRS transmission simultaneously.Each company should provide detailed assumptions including power control parameter settings (e.g., alpha, P0) in a contribution. Note that example of power control setting parameters existed in R1-144943. |

## Frequency Range

As Huawei has commented that NR operating bands below 3GHz are typically around 2.1GHz. Duplexing distance for 2.1GHz is around 200 MHz in general. Ericsson also commented that having a duplexing distance of 200 MHz is appropriate if 2GHz carrier frequency is used. If 4 GHz is selected, then 30 kHz SCS can be used, for 2 GHz, 15 kHz can be used. Nokia commented that DL carrier frequency, duplexing gap and simulation bandwidth shall be clarified

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| Company | Comments |
| Rapporteur | Suggest to revise it as “FR1 only, 2GHz and 4GHz, with duplexing gap of 200MHz between DL and UL.” |
| Ericsson | Ok with the proposal but it is better to decide on a single frequency as baseline to align evaluations. Duplex gap of 200 MHz is ok. |
| InterDigital | Agree with Ercisson’s comment. A single frequency, preferably 4 GHz, should be sufficient. |
| Intel | Agree with Ericsson. We prefer to use 2 GHz as baseline carrier frequency value since it is broadly used for FDD systems. |
| ZTE | Okay to assume 2GHz and 4GHz. 4GHz should be included in the baseline set. |
| Huawei/Hisi | Agree with Ericsson’s suggestion. For single frequency, “2GHz” may be better in order to align RAN1 efforts as close as to operator’s FDD deployment. Required simulation efforts of adopting 2GHz can be marginal.  |
| Nokia/NSB | * Preferably agree on a single frequency of 2GHz as baseline.
* Duplexing gap of 200MHz is ok. Note that bands n1/n65 (2.1GHz) have duplexing gap close to 200MHz but other popular bands, such as n2/n25 (1.9GHz) have duplexing distance closer to 100MHz. However, we are ok with taking the larger of these two for evaluations.
 |
| MotM/Lenovo | Support 4 GHz with 200 MHz duplexing distance. This setup would serve as lower bound to performance at lower frequency carriers and/or smaller duplexing distances |
| Samsung | Support 2GHz and duplexing gap of 200MHz as baseline |
| vivo | Support 2GHz for uplink and 2.2GHz for downlink |
| Qualcomm | We think 2GHz should be prioritized if the focus is FDD. We support 200MHz duplexing distance. |
| LG | Support Ericsson’s suggestion. We prefer to use 2 GHz as baseline. |
| Apple | We can focus on 2GHz with 200MHz duplexing separation |
| Fraunhofer | Support 2 GHz and 4 GHz and 200 MHz duplexing gap. |
| FUTUREWEI | Prefer using a single frequency of 2 GHz as baseline. Ok with duplexing gap of 200 MHz. |
| CATT | Prefer to use a single frequency of 2 GHz as baseline. |
| NTT Docomo | We prefer 4 GHz with 200 MHz duplexing gap |

## Simulation bandwidth/ BS Tx power

For simulation bandwidth, Ericsson has commented that choosing 10 MHz will only give 100 ns delay resolution and prefer to 40 MHz as the baseline. Huawei prefers 50MHz BW considering CTC/CUC spectrum sharing. Vivo prefers both 10MHz/20MHz bandwidth for downlink and 15 KHz/30KHz.

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| Company | Comments |
| Rapporteur | Suggest to revise it as “10/20 MHz for 15kHz as a baseline, and configurations which emulate larger BW, e.g., same sub-band size as 40/100 MHz with 30kHz, may be optionally considered.”Suggest to revise as “41 dBm for 10MHz, 44dBm for 20MHz, 47dBm for 40MHz” |
| Ericsson | Suggest to use 40 MHz, 47 dBm and 30 kHz SCS as baseline. Other parameter values are also of interest for the study (as to investigate the sensitivity of the proposed feature to e.g BW) but are optional. |
| InterDigital | Agree with rapporteur proposal |
| Intel | In our view single baseline BW value should be agreed for evaluations (other BW values are not precluded). We have slight preference to use 20 MHz/30 kHz/44 dBm as baseline since it is a good compromise between 10 MHz and 40 MHz BW. |
| ZTE | Considering NR deployment in 2GHz and 4GHz, we prefer to at least include one larger BW size into the baseline set, e.g., 30 or 40 MHz. |
| Huawei/Hisi | Agree with rapporteur proposal. If the single option is preferred as the baseline, our preference is 20MHz with 15kHz as a compromise.  |
| Nokia/NSB | Support Rapporteur proposal. |
| MotM/Lenovo | We support the rapporteur’s proposal |
| Samsung | Support Rapporteur proposal |
| vivo | Agree with rapporteur proposal |
| Qualcomm | We support rapporteur’s proposal (15kHz with 10/20MHz BW) except for 40MHz. Considering sounding performance and overhead, it seems 40MHz BW is not a typical scenario. So, it is preferred to narrow down the scope to save simulation effort. |
| LG | Support rapporteur’s proposal, but we think single option would be better. We prefer to use 20 MHz with 15kHz as a baseline. |
| Apple | We agree with the proposal from the Rapporteur |
| Fraunhofer | Support rapporteur’s proposal. |
| FUTUREWEI | Agree with Rapporteur proposal. |
| CATT | We prefer a single baseline bandwidth. 20MHz bandwidth is ok to us. |
| NTT Docomo | We are fine with Rapporteur’s proposal |

## Baseline for performance evaluation

The baseline for performance evaluation for enhancing Type II port selection codebook (based on Rel.15/16 Type II port selection) in Rel-17 shall be revised accordingly and commented by Huawei, Futurewei, Oppo, ZTE, Nokia and CATT. To be consistent with previous releases with a fair comparison, Huawei, Futurewei, Oppo prefer to use Rel-16 port-selection eTypeII codebook as the baseline and beamformed CSI-RS overhead of PS eTypeII codebooks can be aligned among different releases.

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| Company | Comments |
| Rapporteur | Rel-16 PS eTypeII Codebook is the baseline for performance and overhead evaluation. (Type I Codebook can be considered at least for performance evaluation) |
| Ericsson | Agree with rapporteur proposal |
| InterDigital | Agree with rapporteur proposal |
| Intel | Agree with the rapporteur. |
| ZTE | We are okay to use Rel-16 eType II PS as baseline scheme. |
| Huawei/Hisi | Agree with rapporteur proposal |
| Nokia/NSB | Agree with Rapporteur. In addition, because eType II PS performance depends on the beamforming applied to CSI-RS and beam ordering, to facilitate comparison, companies should indicate the type of beams and ordering used in their evaluations, or we could agree on what beams to use for the baseline (e.g. DFT beams with natural ordering of beam index to port index). |
| MotM/Lenovo | We support the rapporteur’s proposal |
| Samsung | Both regular Type II and PS Type II are baseline, since we never compared regular and PS Type II in Rel.15/16.Regarding beamforming applied to CSI-RS, two alternatives can be considered* Alt1: orthogonal DFT beams
* Alt2: ideal Eigen vectors (for performance bound)

Regarding beam ordering, a simple ordering can be used, e.g., beam0  port0, beam1  port2, ….Another aspect to consider is how model the overhead associated with UE-specifically beamformed CSI-RS (vs. non-UE-specifically or non-precoded CSI-RS) in UPT calculation. The overhead impact could be significant for large number of beamformed CSI-RS ports.Finally, the SRS overhead for schemes with beamformed CSI-RS should also be considered.  |
| vivo | Agree with rapporteur proposal, if agreement on the CSI-RS beamforming method can be reached, such as following R-16 eTypeII orthogonal beam calculated by UE at the beginning of simulation.If the CSI-RS beamforming method cannot be aligned or is too complex to realize, R-16 eTypeII Codebook can be the baseline. |
| Qualcomm | Agree with rapporteur’s proposal. Companies are encouraged to provide the beamforming method together with their simulation results. We also think UE-specific CSI-RS overhead should be considered in UPT calculation. |
| LG | Support rapporteur’s proposal. |
| Apple | We agree with the proposal from the Rapporteur |
| Fraunhofer | Support rapporteur’s proposal. |
| FUTUREWEI | We support Rapporteur’s proposal in general. Modeling of CSI-RS measurement error should also be considered for both baseline and enhanced schemes. |
| CATT | Support Rapporteur’s proposal. |
| NTT Docomo | We are fine with Rapporteur’s proposal. Further, we also think, it is better if companies can share specific details about the considered beamforming for CSI-RS or a prior agreement can be made on CSI-RS beamforming method  |

## Traffic modelling and MIMO scheme

There are some minor text updates to ensure consistency of evaluation assumption descriptions for CSI reporting enhancement WIDs in Rel-16 and Rel-17 commented by Ericsson.

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| --- | --- |
| Company | Comments |
| Rapporteur | Traffic load (Resource utilization):* 50/70% for SU/MU-MIMO with rank adaptation
* 20% for SU-MIMO or SU/MU-MIMO with rank adaptation
* Companies are encouraged to report the MU-MIMO utilization
 |
| Ericsson | Agree with rapporteur proposal |
| InterDigital | Agree with rapporteur proposal |
| Intel | We prefer to decrease number of alternatives for resource utilization (RU) value up to 2. Significant difference in the observations is not expected for evaluations with 50% and 70% RU. Hence, we propose to refine the proposal from rapporteur as follows. Traffic load (Resource utilization):* ~~50/70%~~60% for SU/MU-MIMO with rank adaptation
* 20% for SU-MIMO or SU/MU-MIMO with rank adaptation

Companies are encouraged to report the MU-MIMO utilization |
| ZTE | Rapporteur proposal is okay to us. |
| Huawei/Hisi | Agree with rapporteur proposal |
| Nokia/NSB | Support Rapporteur porposal |
| MotM/Lenovo | We support the rapporteur’s proposal |
| Samsung | Support Rapporteur proposal |
| vivo | Agree with rapporteur proposal |
| Qualcomm | We prefer 20% for SU-MIMO and a single RU (either 50%/60%/70%) for SU/MU-MIMO. Evaluating 20% RU for SU/MU seems not necessary. |
| LG | Support QC’s suggestion. |
| Apple | We are okay with the proposal from the Rapporteur |
| Fraunhofer | Support rapporteur’s proposal. |
| FUTUREWEI | Agree with Rapporteur proposal. |
| CATT | Agree with Rapporteur’s proposal. |
| NTT Docomo | We are fine with Rapporteur’s proposal. |

## Other considerations

There are other discussion points preferred by a few companies which may be discussed, if desirable with sufficient details:

* Samsung, Ericsson and Nokia has commented about PAPR issues for >=8 CSI-RS ports or with a fixed power back-off for CSI-RS transmission according to the number of CDM groups/symbols for configured CSI-RS resources.
* Samsung and Nokia has commented about UL/DL reciprocity errors due to different Tx-Rx RF circuitry errors/impairments
* Samsung has commented about frequency offset modelling according to the FDD reciprocity model in 36.897
* Vivo has commented about potential modelling of misaligned RX timing assumption between UE and gNB

|  |  |
| --- | --- |
| Company | Comments |
| Samsung | Since UL/DL reciprocity and calibration errors due to different Tx-Rx RF circuitry errors/impairments is a practical issue, and can have significant impact on performance, we prefer to include it in this evaluation. We are fine with any simple modelling for this. |
| Qualcomm | We share similar view to Samsung. Since this is reciprocity study, Tx/Rx calibration error (at least for gNB side) should not be bypassed. Similar to TDD system, basic calibration can be done via connecting each Tx to a reference Rx antenna and connecting each Rx to a reference Tx antenna. This would lead to a per Tx-Rx pair residual calibration error. Compared to TDD system a larger residual error should be employed considering that the Tx and Rx circuitry are on different frequency. |
| Apple | Typically for FDD spectrum, UE is not required to perform Tx/Rx calibration. Even for the TDD spectrum, our understanding is that the current NR specification does not address the FR1 TDD channel reciprocity adequately, in the sense that, there is no exact UE capability indicating whether UE has the Tx/Rx calibration and no requirement on the calibration error etc. So we agree with Samsung and Qualcomm, the calibration error should be considered for the partial-reciprocity study. |
| Fraunhofer | Same view than Samsung. For a more realistic performance analysis, Tx/Rx calibration error modelling should be included in the evaluation.  |