**3GPP T****SG-RAN WG4 Meeting #112 R4-2413427**

**Maastricht, Netherlands, Aug 19 – Aug 23, 2024**

**Agenda item:** 8.14.3

**Source:** Moderator (Nokia)

**Title:**  Topic summary for [112][327] FS\_NR\_demod\_SCM

**Document for:** Information

# Introduction

This document summarises the contributions for FS\_NR\_demod\_SCM under AI 8.14.3 at RAN4#112.

FS\_NR\_demod\_SCM was agreed at RAN Plenary, with the SID being under [RP-241610](https://www.3gpp.org/ftp/meetings_3gpp_sync/ran/Docs/RP-241610.zip).

This topic is introduced in RAN4 demodulation at RAN4#112 with a completion by RAN#108 in June 2025.

A work plan for the demodulation will aim to be agreed during RAN4#112 to enable timely completion of the study item.

# Topic #1: General

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| T-doc number | Company | Proposals / Observations |
| [R4-2411044](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411044.zip) | Nokia | **Observation 1:** A work plan is required, which should be agreed upon during RAN4#112.**Observation 2:** The Spatial Channel Model TR has been allocated as TR 38.753**Proposal 1: RAN4 shall follow the ‘draft pCR’ process with submission of a ‘big pCR’ during RAN4#115****Proposal 2: RAN4 shall identify relevant deployment scenarios which can highlight any existing limitations****Proposal 3: RAN4 shall agree to the following work plan** |
| [R4-2411557](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411557.zip) | BT plc | **Observation 1:** Both 5G-Advanced and potential 6G technologies will require a trusted, versatile and flexible channel model.**Proposal 1: The SCM shall (a) address current deployment scenarios, (b) possess flexibility to address future use cases, (c) ensure performance scaling of features.****Observation 2:** 3GPP technologies for SU-MIMO, MU-MIMO and Multi-cell MIMO are widely deployed in mobile networks and continue to evolve.**Proposal 2: RAN4 shall focus on SU-MIMO, MU-MIMO and Multi-Cell MU-MIMO scenarios in priority order.****Observation 3:** Table 1 (*copied below by moderator)* provides a set of important system characteristics necessary for assessment of the SCM**Proposal 3: RAN4 shall ensure the following properties of the channel model are reflected as a minimum:**

|  |  |
| --- | --- |
| **Scenario property** | **Characteristic/value** |
| Number of transmitter ports for DL | **4**,8,32 [64,128,256] |
| Number of receiver ports for DL | **2,4,**8 |
| Antenna elements  | Cross-polarised dipoles |
| Port-to-to polarisation mapping | First Ntx/2 ports to one polarisation, remaining Ntx/2 ports to the orthogonal polarisation |
| Receive port imbalance | Several dB |
| Long-term stability & consistency | As dictated by scenario, e.g. several frames |

**Observation 4:** Eigenmodes of measured MIMO channels in field deployments deliver varying qualities of signal transmission. Averaged across the specific observation set presented here, the MIMO channels’ eigenmodes exhibit gain offsets of approximately 8, 17 and 29 dB for modes 2, 3 and 4 relative to the strongest eigenmode.**Proposal 4: the channel generated by the SCM shall exhibit variations in channel eigenmodes similar to that in the sample measurements presented. In particular, there should be difference between eigenmode gains, for example 8, 17 and 29 dB for modes 2, 3 and 4 relative to the strongest eigenmode on average across model realisations.****Observation 5:** Long-term stability and consistency with expected behaviour in a measurement scenario is observed.**Proposal 5: the channel generated by the spatial channel model shall exhibit explainable, and consistent spatial domain preferences.****Observation 6:** Receiver ports experience imbalance in received power due to propagation environment. Energy leakage between polarisations is asymmetric across polarisations, frequency-selective, and variable across receiving ports with same polarity. **Proposal 6: Correlation and cross-polarisation discrimination properties for the modelled channel shall reflect the variability observed in the field, e.g. through appropriate adjustment of** $κ\_{n,m}^{-1}$ **factors in Equation 7.2-9 in TR38.827.** |
| [R4-2412320](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412320.zip) | Ericsson | Proposal 1 RAN4 consider following content for the study report of SCM.1. Investigate the feasibility of CDL models in TR38.827.
	1. Difference from legacy CDL models.
	2. Comparison to existing TDL models in requirements.
	3. Trial simulation on one model to check performance and implementation difference between companies.
	4. Modification if necessary.
2. Investigate the feasibility of extension method by TDL with antenna correlation matrix mentioned by TR38.901.
	1. Feasibility of existing correlation matrix.
	2. Comparison to existing TDL models in requirements and CDL models in 38.827. Especially on complexity and feasibility of implementation.
	3. Derive proper spatial channel models for MIMO simulation if necessary.
	4. Trial simulation on one model to check performance and implementation difference between companies.
3. Choose one set of models from modified CDL models and/or TDL models from item 1 and 2.
	1. Align all parameter configurations.
	2. Trial simulations and result comparison.
	3. Potential enhancement in the future.
4. Investigate the complexity of conformance tests.
	1. Test setup and procedure. Check if current setup can be reused or not.
	2. Channel implementation.
	3. Test uncertainty and tolerance analysis.
	4. Trial tests if possible.
5. Investigate the potential test cases based on the consensus of SCM methodology if necessary.
	1. Deliver a list of suitable cases from existing UE demodulation requirements with suggested priority for new requirements.
	2. Proper test metric per test cases.
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## Open issues summary

### Sub-topic 1-1: Technical Report Aspects

**Issue 1-1-1: Usage of big pCR approach**

Proposals:

* Option 1: RAN4 shall follow the ‘draft pCR’ process with submission of a ‘big pCR’ during RAN4#115 (Nokia)

Recommended WF:

* For discussion during meeting, with an aim to agree process during RAN4#112

**Issue 1-1-2: Content of Technical Report**

Proposals:

* Options: RAN4 consider the following content for the study report of SCM, including the following topics:
	+ Deployment scenario match *(Samsung)*
	+ Identify Existing Limitations *(Nokia)*
	+ Limitation of the current channel models and impact to UE receiver BB processing *(Samsung)*
	+ Explore Modelling Approaches *(Nokia)*
	+ Investigate the feasibility of CDL models in TR38.827. *(Ericsson)*
	+ Investigate the feasibility of extension method by TDL with antenna correlation matrix mentioned by TR38.901. *(Ericsson)*
	+ Develop Test Methodology *(Nokia)*
	+ Choose one set of models from modified CDL models and/or TDL models *(Ericsson)*
	+ Investigate the complexity of conformance tests. *(Ericsson, Samsung)*
	+ Investigate the potential test cases based on the consensus of SCM methodology if necessary. *(Ericsson, Samsung)*
	+ Feasibility of introducing RAN4 performance requirements (stability, repeatability, alignability) *(Samsung)*
	+ Document Conclusions *(Nokia)*

Recommended WF:

* For discussion at meeting, draft of the TR spec structure to be worked on during the meeting, with the below as potential starting point for discussion.

|  |
| --- |
| * Deployment Scenarios
	+ Identification of limitation of current channel models, and impact to UE processing
* Spatial Channel Modelling Approaches
	+ Feasibility of CDL models in TR38.827
	+ Feasibility of extended TDL models
* Test Setup and considerations
	+ Choose [one] set of models from modified CDL models and/or TDL models
	+ Investigate potential test cases based on the consensus of SCM methodology
	+ Investigate the complexity of conformance tests.
* Feasibility of introducing RAN4 performance requirements (stability, repeatability, alignability)
* Document Conclusions
 |

### Sub-topic 1-2: Work Plan

**Issue 1-2-1: Work Plan**

Proposals:

* Option 1: RAN4 to discuss any proposed modifications to the Channel Models in 38.827 before moving to the simulation alignment step *(Qualcomm)*
* Option 2: RAN4 shall agree to the following work plan *(Nokia)*

|  |  |  |
| --- | --- | --- |
| Meeting No. | Date | Details |
| RAN4#112 | August 24 | **Identify Existing Limitations (Phase 1):**Scenario Discussed and early AlignmentInitial Scenario Configuration Alignment**Explore Modelling Approaches (Phase 2):**Potential approaches to channel modelling discussed |
| **RAN #105 (September 25)** |
| RAN4#112-bis | October 24 | **Identify Existing Limitations (Phase 1):**Scenarios agreed**Explore Modelling Approaches (Phase 2):**Initial simulation parameter alignmentConsidered channel model alignment |
| RAN4#113 | November 24 | **Explore Modelling Approaches (Phase 2):**Simulation parameters agreed**Develop Test Methodology (Phase 3)**:Testability DiscussionsInitial simulations**Document Conclusions (Phase 4):**Draft TR structure agreedWork split agreed |
| **RAN #106 (December 25)** |
| RAN4#114 | Feb 25 | **Develop Test Methodology (Phase 3):**Simulation Alignment**Document Conclusions (Phase 4):**Initial discussion on potential conclusionsDraft TPs |
| **RAN #107 (March 25)** |
| RAN4#114-bis | March 25 | **Develop Test Methodology (Phase 3):**Further Simulation Alignment**Document Conclusions (Phase 4):**Draft conclusionsDraft TPs |
| RAN4#115 | May 25 | **Document Conclusions (Phase 4):**big pCR |
| **RAN #108 (June 25)** |

Recommended WF:

* Option 1 is contained within option 2, thus option 2 may be agreeable during the meeting.
* Discuss during meeting if the proposed work plan under option 2 can be agreed during RAN4#112.

# Topic #2: Spatial Channel Modelling Methodology

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| T-doc number | Company | Proposals / Observations |
| [R4-2411119](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411119.zip) | CATT | **Proposal 1: To study the limitation of the current (i.e. up to and including Release 18) channel models, for example, MIMO channel correlation matrices doesn’t indicate combined gain of same signal from MIMO antennas varied with spatial angle.****Proposal 2: Study how to define antenna array model including element response pattern, antenna polarization model, and array response pattern for spatial channel model for demodulation performance requirement.****Proposal 3: Study what CDL model parameters are used for spatial channel model for demodulation performance requirement.** |
| [R4-2411300](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411300.zip) | Nokia | **Observation 1:** TDL (low) channel models do not have spatial preferences that remain stable for more than single digit ms. Instantaneous spatial preferences are much less strong than TDL+antCorr, CDL, or field measurements suggest for deployment. Furthermore, there is no (antenna) correlation modeled, i.e., the channel rank/condition is always optimal. Hence, TDL (low) is ill suited to model MIMO channels for demodulation requirements, and CSI (e.g., PMI) requirements in particular.**Observation 2:** TDL with 3GPP antenna correlation channel models do exhibit a strong spatial preference that is limited to singular broadside direction for all paths. This spatial deficiency limits the usefulness of SDM transmitters and receivers, that rely on signal subspaces that can be separated in the spatial domain. Furthermore, this decreases the channel condition and coupled with the choice of “continuous squared exponential decay” antenna correlation extension modelling, which almost 100% correlates one pair of antennas, makes full rank transmission over the TDL channel virtually impossible due to bad channel conditioning. Hence, TDL+antCorr is ill suited to model MIMO channels for CSI (e.g., PMI) requirements, and demodulation requirements in particular.**Observation 3:** The TR 38.827 based CDL channel model exhibits multiple longer-term stable directions, differing per path, with speed/delta-frequency/delta-time dependent evolution of spatial modulation, and explainable channel condition/rank scaling. It directly includes provisions for dual polarizations, with cross polarization leakage and polarization-wise radiation patterns, and it can spatially consistently be extended to multiple receiver setups. Hence, the TR 38.827 based CDL channel model is well suited to model MIMO channels for demodulation and CSI requirements.**Proposal 1: Consider TR 38.827 based CDL channel models, especially CDLC UMa, in the study item.****Observation 4:** By specifying receive side channel model antenna assumptions for the TR 38.827 CDL channel model, a comparable and alignable baseband referenced channel “black box” is created, that models spatial MIMO effects in an implementation agnostic manner.**Proposal 2****: For conducted and virtual cable testing, amend the TR 38.827 CDL model to include receive side channel model antenna assumptions as ULA, X-pol, lambda/2, rotation/slant matched to transmitter polarizations.****Observation 5:** For 2CW features, only 827 CDL can create the expected inter-CW performance difference at feasible SNR levels, which is needed to fully test a 2CW SDM receiver and correctly model performance scaling in deployment.**Observation 6:** Both 827 CDL and TDL+antCorr feature control over the strength of antenna correlation, and thus channel condition/rank. TDL (low) does not model this. 827 CDL additionally features reasonable geometrically determined values, that follow explainable and predicable antenna properties.**Observation 7:** The number of slots required for the relative TPUT KPI to stabilize is comparable between TDL+antCorr and CDL. Both need about 50% more samples than TDL low.**Observation 8:** TPUT differences due to receiver covariance calculation/application implementations resulting in different complexity for interference mitigation are highlighted by 827 CDL over the full SNR range, by TDL+antCorr over for high SNR, and for TDL the effect averages out over the simulation time. TDL+antCorr exhibits very high SNR requirements and saturation effects due to ill conditioned channel.**Proposal 3: RAN4 shall focus on SU-MIMO, MU-MIMO and Multi-Cell MU-MIMO in priority order.****Proposal 4:** **Compare TDLC300-100, TDLC300-100 medA, and 827 CDLC UMa with ULA X-pol, in the following use cases (ordered by priority) to ultimately agree, which channel models are suitable to define demod performance requirements for each use case: (1) SU 8T8R 8-layer TPUT, random vs. fixed PMI, and differing receiver implementations. (2) SU PMI reporting (CB type TBD), follow PMI vs. random PMI. (3) MU 2 or 3 receivers, 1 transmitter TPUT, precoding strategy TBD, and differing receiver implementations. (4) MU 2 or 3 receivers, 1 transmitter, PMI reporting (CB type TBD), follow PMI vs. random PMI (5) MU 2 receivers, 2 transmitters. All considering TE implementability.** |
| [R4-2411301](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411301.zip) | Nokia | *Simulation Results Only* |
| [R4-2411390](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411390.zip) | Apple | **Observation #1:** For the FRC requirements defined for 2 CW, defining a channel condition with different SNR on the different layers doesn’t test the UE any differently.**Observation #2:** UE processing is tested sufficiently for cancelling inter-user interference in MU-MIMO scenarios and Type II PMI reporting with TDL channel model. There is no necessity to make the test set up complicated by combining the two. **Observation #3:** RAN4 has employed TDL channel models for a long time.**Observation #4:** RAN4 has employed techniques to introduce spatial aspects in TDL channel model for requirements definition. For example – (1) Beam steering for PMI reporting requirements, (2) Spatial correlation matrix for Multi-RX in FR2**Proposal #1: Justify the need for spatial channel model, identify limitations of TDL or spatially filtered TDL channel model.** **Proposal #2: RAN4 to identify scenarios/ test set-up that test UE processing differently with spatial channel model compared to TDL / spatially filtered channel model****Proposal #3: Test scenarios or test set up shall be limited to those used by RAN4 for NR.** **Proposal #4: RAN4 to study if the performance with modified CDL channel to ensure repeatability and alignment of performance among companies.** **Proposal #5: Use UMi-CDL-A and UMa-CDL-C for initial performance evaluation.****Observation #5:** The channel models in the TR are defined for specific scenarios, carrier frequency, with some assumptions of RMS delay spread and UE velocity.**Proposal #6: RAN4 to study if the same channel model can be defined for all carrier frequencies/ bands in given frequency range – example FR1/ FR2.** **Observation #6:** The CDL channel model defined can only be for a certain UE velocity.**Proposal #7: If determined as necessary and feasible to introduce spatial channel model, RAN4 shall not define any new requirements with it in Rel-19 – for either Rel-19 WIs or earlier WIs** |
| [R4-2412321](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412321.zip) | Ericsson | **Observation 1:** The original CDL models in TR38.901 are modified in TR38.827 on angle values with different scaling factors and extended to fit for different deployment scenarios.**Observation 2:** The methodology described by TR 38.827 are detailed and instructive which could be a good start point for further optimization on model profile and implementation.**Observation 3:** Scenario dependent CDL model would cause more effort on parameters’ feasibility checking for a new test case, and also might lead to a large set of channel model profile in specifications.**Observation 4:** Existing demodulation requirements only use TDL model with same correlation matrix on all taps.**Observation 5:** To have TDL model with per-tap correlation matrix, detailed evaluation would be needed, and the output model profile would be more complex if the number of both antenna ports and taps are high.**Observation 6 :** The current demodulation test setup could be reused if only consider antenna pattern impact in channel model.**Observation 7:** The performance difference between two codewords are clear under 8x8 scenario with FR1 CDL-C Uma model and legacy CDL-C model.**Observation 8:** The performance degradation by using FR1 CDL-C Uma model compared to TDLC300-100 is obvious.Based on the discussion in the previous sections we propose the following:**Proposal 1 Prioritize CDL model extension method described in TR38.827 compared to TDL model extension method.****Proposal 2 Align CDL channel model implementation starting from CDL-C FR1 Uma model in 38.827.** |
| [R4-2412322](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412322.zip) | Ericsson | *Simulation Results Only* |
| [R4-2412328](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412328.zip) | MediaTek inc. | **Proposal #1: We propose RAN4 to consider the option of *multi-cluster TX-RX beam steering* with TDL model for spatial channel modelling.****Observation #1:** The existing dual-cluster beam steering feature does not increase the spatial degrees of freedom of the MIMO channel since the clusters have the same AoA in the RX side.**Observation #2:** Increasing the number of orthogonal TX-RX beam steering clusters increases the effective spatial degrees of freedom of the channel.**Observation #3:** CW-specific TX-RX BS clusters can be used to effectively scale CW-specific demodulation and decoding performance.**Observation #4:** The parameters of the multi-cluster TX-RX beam-steering channel model can be selected to create desired channel properties, and to match the scope of any MIMO performance test.**Observation #5:** Spatial properties of CDL channel models are pre-defined and fixed, and there is no guarantee of finding suitable models for all MIMO performance tests.**Proposal #2: We propose spatial properties of channel model to be configurable to guarantee finding of suitable models for all MIMO performance tests.** |
| [R4-2412535](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412535.zip) | Samsung | **Proposal 1: The study on spatial channel model shall take following aspects into consideration:*** Deployment scenario match
* Test complexity
* Feasibility of introducing RAN4 performance requirements (stability, repeatability, alignability)
* Limitation of the current channel models and impact to UE receiver BB processing

**Proposal 2: Using following test cases as example cases for further study:*** SU-MIMO: 8Rx with 6-layer transmission test case
* MU-MIMO: R16 Type-II codebook PMI test case

**Proposal 3: RAN4 needs to further evaluate the feasibility of using the channel model of TR 38.827 for demodulation requirements.** |
| [R4-2412762](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412762.zip) | Huawei,HiSilicon | **Observation1:** The biggest difference between current channel model for RAN4 demodulation requirements and realistic channel model is that different tap always has different spatial component.**Proposal 1: RAN4 shall not define new requirements with new channel model for traditional demod/CSI test, only study the approach of channel modelling, simulation alignment uncertainty and test complexity.****Proposal 2: RAN4 should guarantee that the new channel model has appropriate channel capacity/freedom. I.e., The new channel model can support high rank and reasonable test SNR range.****Proposal 3: RAN4 to use CDLs in combination with array assumptions indicated in 38.901 for TDL extension.** **Proposal 4: Use assumptions and steps in clause 2.1 for TDL extension modelling.****Proposal 5: RAN4 to use following parameters in 38.827 as baseline for demod tested specific CDL channel model** * **Coupling pattern of ray angles in Table 7.2-6.**
* **BS Antenna Parameters (Mg, Ng, Me, Ne, P, dH, dv) in Table 7.2-7**
* **Random initial phase in table 7.2-8**
* **UE velocity and travelling direction based on different channel model.**

**Proposal 6: RAN4 to further discuss following parameters/procedures:*** **Local coordinate systems for UE and BS**
* **Antenna elements coordinates for UE and BS**
* **Beamforming (Weight vector for each antenna element)**
* **How map CSI ports to antenna elements. (2/4/8/16/32 ports)**
* **UE antenna configurations and radiation pattern**

**Proposal 7: RAN4 should discuss whether to simplify the CDL channels in 38.827 for the purpose of demodulation test like did for TDL channel. If yes, RAN4 should discuss the approach mentioning that different cluster have not only power but also angular information.** |
| [R4-2412793](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412793.zip) | ZTE Corporation, Sanechips | **Observation 1.** The SINR between MIMO layers is not only influenced by the channel model but also depends on the specific implementation of the equalizer and precoding design.**Observation 2.** The criteria for selecting the MCS should be clearly defined.**Observation 3.** Considering multiple layers as a correspond scenario for identification.**Observations 4.** Further discussion are needed regarding detailed simulation assumptions and parameters. **Observations 5.** The test method can select methods form TS 38.827 as a starting point for research.**Observation 6.** The RTS testing method can serve as a foundational approach for wireless cable in FR2. |
| [R4-2413056](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413056.zip) | Qualcomm Incorporated | **Proposal 1: For implementation alignment RAN4 should focus on discussing SCM details assuming FR1 conducted test first, according to the SI description;****Proposal 2: For FR1 Conducted Tests, RAN4 to consider CDL Channel Models parameters as defined in Section 7.2.1 of 38.827 as a starting point;****Proposal 3: RAN4 to discuss any proposed modifications to the Channel Models in 38.827 before moving to the simulation alignment step;****Proposal 4: Once agreements is reached on the SCM modeling, RAN4 should identify the benefits of the chosen approach (e.g. CDL) compared to existing models (ie. TDL);****Proposal 5: RAN4 to down-select a number of FR1 conducted UE-MIMO requirements in 38.101-4 as reference test cases for performance alignment in this SI.****Proposal 6: For the initial alignment RAN4 to focus on SU-MIMO requirements only, for both UE and BS Demodulation requirements. MU-MIMO test cases can be simulated after SU-MIMO results are reasonably aligned.****Observation 2:** Channel Models defined in Section 7.2.1 of TR 38.827 do not include base station antenna filtering;**Proposal 7: RAN4 should discuss how to distinguish in the model, the application of the beamforming (intended as precoder selection at the gNB/TE TX antennas) and the application of the beamsteering (spatial beam direction towards the intended receiver);****Proposal 8:RAN4 should discuss the random components that influence the stochastic Spatial Channel Models under study and how to configure them during the simulation;****Proposal 9:RAN4 should consider the expected average and variance of the simulation results over multiple trials and simulation durations, and how this impacts the definition of the requirements;** **Proposal 10: RAN4 to consider the impact on testing duration when using SCM within the framework of the current RAN5 procedure (using a single random seed), and evaluate whether to ask for RAN5’s input if necessary;****Observation 4:** SCM defined in TR 38.827 maintain a preferred angular distribution;**Observation 5:** TDL-based testing is not impacted by different implementations of UE algorithms for spatial processing;**Proposal 11: RAN4 to consider the impact on UE-specific implementation performances when testing requirements using an SCM with a preferred angular distribution;** |
| [R4-2413272](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413272.zip) | Keysight Technologies UK Ltd | **Observation 1:** For UE demodulation performance requirements up to Rel-18, channel models used are based on Tapped Delay Line model.**Observation 2:** Tapped Delay Line models don’t show the performance observed in RAN1 nor the one expected in actual deployments.**Observation 3:** An alternative to Tapped Delay Line models used in UE demodulation performance requirements is Cluster Delay Line models, already in use in MIMO OTA requirements defined in 3GPP TS 38.151.**Observation 4:** Phase difference between channel coefficients on adjacent BS antennas in CDL channel models is more realistic than in the case of TDL models.**Observation 5:** Temporal correlation function of a CDL model is more realistic than the one of TDL model.**Observation 6:** With a TDL model there are no specific angles of arrival or departure in the channel. Moreover, the phasing in antenna arrays (indicates angles) varies wildly over time in a TDL model. This phenomenon does impact both single and multi-user cases.**Observation 7:** CDL channel models are feasible including acceptable results uncertainty while associated test system complexity is not significantly increased. |

## Open issues summary

### Sub-topic 2-1: Common for all Methodologies

**Issue 2-1-1: Deployment Scenario**

Proposals:

* Option 1: The Spatial Channel Model shall address current deployment scenarios and possess the ability to scale to future deployments. *(BT Plc)*
* ~~Option 2: Test scenarios or test set up shall be limited to those used by RAN4 for NR.~~ *~~(Apple)~~*

Recommended WF:

* For discussion during meeting.

**Issue 2-1-2: Scenarios selection based on spatial Domain impact on UE processing**

Proposals:

* Option 1: RAN4 to identify scenarios that test UE processing differently with spatial channel model compared to TDL / spatially filtered channel model. *(Apple)*
* Option 2: RAN4 to consider the impact on UE-specific implementation performances when testing requirements using an SCM with a preferred angular distribution. *(Qualcomm)*

Recommended WF:

* For discussion at meeting, noting that this will guide the discussion on SCM Methodologies but may not result in a direct agreement.

**Issue 2-1-3: Frequency Ranges for Study**

Proposals:

* Option 1: For implementation alignment RAN4 should focus on discussing SCM details assuming FR1 conducted test first, according to the SI description *(Qualcomm, Samsung)*

Recommended WF:

* Confirm during meeting the prioritisation of FR1, as per the SI description.

**Issue 2-1-4: Uplink and Downlink coverage**

Proposals:

* Option 1: Both Uplink and Downlink shall be included in the study *(Qualcomm)*

Recommended WF:

* For discussion at meeting, potentially deciding on prioritization during RAN4#112.

**Issue 2-1-5: Test Cases for SU-MIMO (if agreed)**

Proposals:

* Option 1: 8 Rx *(Samsung, Nokia, BT)*
	+ Option 1a: 6 Layer PDSCH *(Samsung)*
	+ Option 1b:
		- 8 Layer PDSCH, Random vs. Fixed PMI, different receivers *(Nokia, BT)*
		- 8 Layer PMI Reporting (CB Type TBD) Random vs. Fixed PMI *(Nokia, BT)*
* Option 2: For UE demodulation keep the same configuration parameters as existing requirements *(Qualcomm, Apple)*
* Option 3: Test scenarios or test set up shall be limited to those used by RAN4 for NR. *(Apple)*

Recommended WF:

* For discussion at meeting, for which test cases to focus on.

**Issue 2-1-6: Test Cases for MU-MIMO (if agreed)**

Proposals:

* Option 1: MU-MIMO *(Samsung, Nokia, BT)*
	+ Option 1a: PDSCH, with 2 or 3 receivers *(Nokia, BT)*
	+ Option 1b: R16 Type-II codebook PMI Reporting *(Samsung)*
* Option 2: Test scenarios or test set up shall be limited to those used by RAN4 for NR. *(Apple)*
* Option 3: Focus on SU-MIMO first. *(Qualcomm)*

Recommended WF:

* For discussion at meeting, for which test cases to focus on.

**Issue 2-1-7: Number of Transmitter Ports for DL**

Proposals:

* Option 1: 4,8,32 [64,128,256] *(BT Plc)*
* Option 2: 2,4,8,16,32 *(Huawei)*

Recommended WF:

* For discussion at meeting, related to test cases chosen.

**Issue 2-1-8: Number of receiver demodulation branches for DL**

Proposals:

* Option 1: 2,4,8 *(BT Plc)*

Recommended WF:

* For discussion at meeting, related to test cases chosen.

**Issue 2-1-9: Spatial Domain Preferences of channel model**

Proposals:

* Option 1: The channel generated by the spatial channel model shall exhibit explainable, and consistent spatial domain preferences. *(BT Plc)*

Recommended WF:

* For discussion at meeting, with a focus on how to quantify consistent spatial domain preferences.

**Issue 2-1-10: Capacity of Spatial Channel Model**

Proposals:

* Option 1: RAN4 should guarantee that the new channel model has appropriate channel capacity/freedom. i.e., The new channel model can support high rank and reasonable test SNR range *(Huawei)*

Recommended WF:

* For discussion at meeting, noting that this will be highly dependent on the test case.

**Issue 2-1-11: Requirements applicability to difference CCs**

Proposals:

* Option 1: RAN4 to study if the same channel model can be defined for all carrier frequencies/ bands in given frequency range *(Apple)*

Recommended WF:

* For discussion at meeting.

**Issue 2-1-12: Correlation and Cross-Polarisation Discrimination**

Proposals:

* Option 1: Correlation and cross-polarisation discrimination properties for the modelled channel shall reflect the variability observed in the field e.g. through appropriate adjustment of $κ\_{n,m}^{-1}$factors in Equation 7.2-9 in TR38.827. *(BT Plc)*

Recommended WF:

* For discussion at meeting, with particular attention to how to include in each methodology if agreed, and how to quantify.

**Issue 2-1-13: Port to polarisation/antenna mapping**

Proposals:

* Option 1: First N Tx/2 ports to one polarisation, with the remaining N Tx/2 ports to the orthogonal polarisation *(BT Plc)*

Recommended WF:

* For discussion at meeting

**Issue 2-1-14: Receive Port Imbalance:**

Proposals:

* Option 1: Several dB *(BT Plc)*

Recommended WF:

* For discussion at meeting

*Moderator Note: It is unusual to discuss port imbalance in demodulation discussions; however as this relates to channel modelling improvements it can be discussed during RAN4#112.*

**Issue 2-1-15: Comparison to sample measurements**

Proposals:

* Option 1: The channel generated by the SCM shall exhibit variations in channel eigenmodes similar to that observed in real sample measurements. *(BT Plc)*

Recommended WF:

* For discussion at meeting

**Issue 2-1-16: Beamforming/Beamsteering**

Proposals:

* Option 1: RAN4 should discuss how to distinguish in the model, the application of the beamforming (precoder selection) and the application of the beamsteering (spatial beam direction towards the intended receiver) *(Qualcomm)*

Recommended WF:

* For discussion at meeting

### Sub-topic 2-2: TDL Based Methodologies

**Issue 2-2-1: Tap Delay Line Parameters**

Proposals:

* Option 1: Legacy TDLC300-100, and TDLC300-100 medA for comparison *(Nokia)*

Recommended WF:

* Potentially agree for legacy TDL parameters to use TDLC 300-100 and TDLC 300-100 medA for comparison purposes. For discussion.

**Issue 2-2-2: TDL Model Extensions**

Proposals:

* Option 1: RAN4 to consider the option of multi-cluster TX-RX beam steering with TDL model for spatial channel modelling *(Mediatek)*
* Option 2: Derive TDL antenna correlation per tap from angular information defined in CDL parameter table as noted in R4-2412762 *(Huawei)*

Recommended WF:

* For discussion at meeting

### Sub-topic 2-3: CDL Based Methodologies

**Issue 2-3-1: Cluster Delay Model**

Proposals:

* Option 1: Use the CDL (FR1) parameters defined in 38.827 for initial alignment *(Qualcomm, Huawei, CATT)*
	+ Option 1a: Use 38.827 UMi-CDL-A and UMa-CDL-C for initial performance evaluation *(Apple)*
	+ Option 1b: Use 38.827 UMa-CDL-C for initial alignment *(Nokia, Ericsson)*
* Option 2: RAN4 needs to further evaluate the feasibility of using the channel model of TR 38.827 for demodulation requirements. *(Samsung, Apple)*
* Option 3: For conducted and virtual cable testing, amend the TR 38.827 CDL model to include receive side channel model antenna assumptions as ULA, X-pol, lambda/2, rotation/slant matched to transmitter polarizations. *(Nokia)*

Recommended WF:

* For discussion at meeting on a down selection of which CDL candidates should be used for the study.

**Issue 2-3-2: Antenna Array Model**

Proposals:

* Option 1: Study how to define antenna array model including element response pattern, antenna polarization model, and array response pattern for spatial channel model for demodulation performance requirement. *(CATT)*
* Option 2: CDL model to include receive side channel model antenna assumptions as ULA, X-pol, lambda/2, rotation/slant matched to transmitter polarizations. *(Nokia)*
* *Option 3: RAN4 to specify the UE antenna radiation pattern*

Recommended WF:

* For discussion at meeting on the approach to include antenna array model.

**Issue 2-3-3: Flexibility of CDL**

Proposals:

* Option 1: Spatial properties of a CDL should be configurable to guarantee finding of suitable models for all MIMO performance tests. *(Mediatek)*

Recommended WF:

* For discussion at meeting on the required flexibility.

**Issue 2-3-4: Local Coordinate System**

Proposals:

* Option 1: RAN4 to discuss the parameters for local coordinate systems for UE and BS *(Huawei)*

Recommended WF:

* For discussion at meeting.

**Issue 2-3-5: Antenna Coordinates**

Proposals:

* Option 1: RAN4 to discuss the parameters for antenna elements coordinates for UE and BS *(Huawei)*

Recommended WF:

* For discussion at meeting.

**Issue 2-3-6: Simplifying CDL**

Proposals:

* Option 1: RAN4 should discuss whether and how (if needed)to simplify the CDL channels in 38.827 for the purpose of demodulation test like did for simplified TDL channel in clause B.2.1 of 38.101-4. *(Huawei)*

Recommended WF:

* For discussion at meeting on whether CDL should be simplified.

**Issue 2-3-7: Beamforming**

Proposals:

* Option 1: RAN4 to specify the beam direction for simulation alignment (Weight factor for each BS antenna element) *(Huawei)*

Recommended WF:

* For discussion at meeting.

**Issue 2-3-8: Map CSI ports to antenna elements**

Proposals

* Option 1: RAN4 to specify how to map *different* number of CSI ports to physical antenna elements. (Huawei)

Recommended WF:

* For discussion at meeting.

### Sub-topic 2-4: Comparison of methodologies

**Issue 2-4-1: Limitations of current RAN4 approaches**

Proposals:

* Option 1: To study the limitation of the current (i.e. up to and including Release 18) channel models *(CATT, Apple)*

Recommended WF:

* For discussion at meeting

*Moderator Note: It is expected that issue 2-4-1 may be overtaken by discussions on issue 2-1-5 and issue 2-1-6, whereby relevant test cases for study are discussed.*

**Issue 2-4-2: Prioritization of TDL and CDL Methodologies**

Proposals:

* Option 1: Prioritize CDL model extension method described in TR38.827 compared to TDL model extension method. *(Ericsson)*

Recommended WF:

* For discussion at meeting on the prioritization of the different methodologies.

**Issue 2-4-3: Average and variance**

Proposals:

* Option 1: RAN4 should consider the expected average and variance of the simulation results over multiple trials and simulation durations, and how this impacts the definition of the requirements. *(Qualcomm)*

Recommended WF:

* For discussion at meeting, with a focus on the metrics of average and variance.

**Issue 2-4-4: Impact of Randomness**

Proposals:

* Option 1: RAN4 should discuss the random components that influence the stochastic Spatial Channel Models under study and how to configure them during the simulation. *(Qualcomm)*

Recommended WF:

* For discussion at meeting.

**Issue 2-4-5: Comparison Approach**

Proposals:

* Option 1: Compare TDLC300-100, TDLC300-100 medA, and 827 CDLC UMa with ULA X-pol, in the following use cases (ordered by priority) *(Nokia)*:

(1) SU 8T8R 8-layer TPUT, random vs. fixed PMI, and differing receiver implementations.

(2) SU PMI reporting (CB type TBD), follow PMI vs. random PMI.

(3) MU 2 or 3 receivers, 1 transmitter TPUT, precoding strategy TBD, and differing receiver implementations.

(4) MU 2 or 3 receivers, 1 transmitter, PMI reporting (CB type TBD), follow PMI vs. random PMI

(5) MU 2 receivers, 2 transmitters

* Option 2: RAN4 shall focus on SU-MIMO, MU-MIMO and Multi-Cell MU-MIMO scenarios in priority order *(BT Plc)*

Recommended WF:

* For discussion at meeting regarding the approach and prioritization of comparison test cases.

### Sub-topic 2-5: Testability and TE aspects

**Issue 2-5-1: Impact on Testing Duration**

Proposals:

* Option 1: RAN4 to consider the impact on testing duration when using SCM within the framework of the current RAN5 procedure (using a single random seed) and evaluate whether to ask for RAN5’s input if necessary. *(Qualcomm)*

Recommended WF:

* For discussion at meeting, noting this will be dependent on the test setup and SCM methodology.

### Sub-topic 2-6: Requirements and Other

**Issue 2-6-1: Definition of New Requirements**

Proposals:

* Option 1: RAN4 shall not define new requirements with the new channel model in this study item *(Huawei, Apple)*
	+ Option 1a: RAN4 shall not define any new requirements with a spatial channel model in Rel-19 WIs or earlier WIs *(Apple)*

Recommended WF:

* Confirm during the meeting that no new requirements will be defined in this Study Item, as per the SI description. Discuss during the meeting whether no new requirements will be defined in Rel-19 WIs.

# Disposition of TDocs

|  |  |  |
| --- | --- | --- |
| T-doc number | Suggested Status | Comments (Optional) |
| [**R4-2411119**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411119.zip) | Noted |  |
| [**R4-2411300**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411300.zip) | Noted |  |
| [**R4-2411301**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411301.zip) | Noted |  |
| [**R4-2411390**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411390.zip) | Noted |  |
| [**R4-2412321**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412321.zip) | Noted |  |
| [**R4-2412322**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412322.zip) | Noted | *Simulation results* |
| [**R4-2412328**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412328.zip) | Noted |  |
| [**R4-2412535**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412535.zip) | Noted |  |
| [**R4-2412762**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412762.zip) | Noted | *Simulation results* |
| [**R4-2412793**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412793.zip) | Noted |  |
| [**R4-2413056**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413056.zip) | Noted |  |
| [**R4-2413272**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413272.zip) | Noted |  |
| [**R4-2411119**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411119.zip) | Noted |  |
| [**R4-2411300**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411300.zip) | Noted |  |
| [**R4-2411301**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411301.zip) | Noted |  |
| [**R4-2411390**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411390.zip) | Noted |  |