**3GPP TSG-RAN WG1 #118R1-24xxxx**

Maastricht, NL, August 19th–23rd, 2024

**Title : Summary on the channel model adaptation and extension**

**Source : Moderator (ZTE)**

**Agenda item : 9.8.2**

**Document for : Discussion and Decision**

# Introduction

Based on the following relevant scope of the SI for 7-24 GHz channel model,

|  |
| --- |
| * *Adapt/extend as necessary the channel model of TR38.901 at least for 7-24 GHz, including at least the following aspects for applicable scenarios:*    + *Near-field propagation (with consideration being given to consistency between near-field and far-field)*   + *Spatial non-stationarity* |

this contribution summarizes the proposals in companies’ input under the AI 9.8.2 with following aspects:

* Channel model for Near field propagation
* Channel model for Spatial non-stationarity
* Other aspects

The details of each part are provided in corresponding section below and the agreements achieved in RAN1#116-bis and RAN1#117 are listed in Appendix-A for reference.

# **Views on the near-field propagation**

## **Necessity and clarification on near-field phenomenon**

### **1.1.1 Company view (Round-1)**

In RAN1#116bis meeting, the agreement to clarify the main target of near-field modelling (i.e., study the impact of wavefront) is achieved.

|  |
| --- |
| Agreement  For the near-field channel model:   * The impact of the assumption of wavefront is only considered from the perspective of antenna array. * The near field for each element within the antenna array is not considered in this SI. |

To further align the understanding of the terminology near-field channel model, i.e., assumption on the wavefront, the following views are summarized:

* [Qualcomm] highlights that the near-field modeling is to be interpreted as reference to spherical wavefront modeling. And additionally, the terminology of ‘spherical wavefront’ is used by [Huawei, HiSilicon, InterDigital, Intel, LGE, ZTE, vivo, CATT, NVIDIA, Samsung, MediaTek, Apple, CEWiT] when discussing the near-field channel model.
* [Ericsson] mentions that the wavefront can be different, e.g., spherical, cylindrical or other if interactions such as diffraction occur along the propagation path.

Regarding the justification on the necessity of near-field channel model, [Huawei, HiSilicon, InterDigital, Intel, LGE, ZTE, vivo, OPPO, CATT, NVIDIA, Fujitsu, Samsung, MediaTek, BUPT, CMCC, Apple, CEWiT] share the same views that the near-field channel model shall be considered. More specifically, inputs on following two aspects are summarized:

* Channel characteristic:

[BUPT, CMCC, ZTE] provide the measurement and RT-simulation results, which show that the impact of the near-field can be observed for channel characteristics, i.e., delay, angular variation in the near-field channel paths.

* Other metric, e.g., performance related:
  + [Huawei, HiSilicon] analyzes the correlation between channel coefficients under planar-and spherical-wavefront assumptions, and results show that channel coefficients under planar- and spherical-wavefront assumptions can differ greatly.
  + [ZTE] provides the preliminary simulation results to show the performance different with consideration on the impact of near-field channel.
  + [QC] highlights that even though there is a convergence trend observed between SWM-2 and PWM models, RAN1 needs to establish thresholds for sufficient convergence for NMSE and SGCS metrics based on the system-level performance impact.
  + [Ericsson] mentions that non-planar wavefront modeling may have insignificant impact on system-level simulations for UMa scenario. But it also further clarifies that it may be premature to rule out the need for non-planar wavefront modeling at this point.

Additionally, [vivo] mentions that the channel model behaving the un-parallel element-paired channel link should be prepared prior to starting the 6G specification in RAN1. [LGE, NVIDIA] highlight that the appropriate model and technique tailored to the characteristics of the near-field region is essential. [ZTE] further clarifies that the criteria to assess the necessity of near-field model should only rely on the observed channel properties, and the performance evaluation is out of scope of channel model study. [Ericsson] also mentioned that whether spherical-wave incidence and/or spatial non-stationarity should be modeled on the UE side.

According to the above inputs, from FL’s perspective,

* For the terminology: In general, the “non-planar wavefront” is more accurate to describe the impact of different propagation. Considering the majority’s view, i.e., spherical wavefront, can be considered to represent the impact of near-field.
* For the necessity: According to the measurement results and analysis provided from companies, for channel modelling, the existence and impact of near-field phenomenon have been clearly identified, which verifies the necessity of the near-field channel modelling. Regarding the observations based on the other metrics, it depends on the potential solution used for evaluation. For this SI, detailed investigation on technique part is out of scope.

Then, from FL’s perspective, the following is proposed:

### ***Proposal 1-1-1:***

*RAN1 confirms that the modelling of near-field propagation characteristics (i.e., characteristics of spherical wavefront) is necessary.*

Companies are encouraged to share your views and also encourage to add the new measurement/simulation results to the excel sheet for source data collection.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Intel | We support the proposal in principle. We prefer to keep the more accurate terminology of “non-planar wavefront”, instead of spherical wavefront. |
| Ericsson | In our contribution R1-2406742 we have investigated the necessity and not yet seen any clear evidence that non-planar wavefront modelling is necessary. Further studies are needed as well as aligning companies’ views on suitable metrics and near-field definitions. Therefore, we believe it is too early to progress with this proposal.  We further agree with Intel that “non-planar wavefront” is the more accurate terminoly. |
| InterDigital | In principle, we support the proposal, however we are open to have further discussion on this topic. |

## **1.2 Antenna assumption for the near-field channel modeling**

### **1.2.1 Company view (Round-1)**

In last RAN1#117 meeting, as for the aperture size of antenna array for channel model study, the following agreement has been achieved with some value is still pending issue.

|  |
| --- |
| Agreement  For the assumption on the aperture size of antenna array, the following is considered for near-field and spatial non-stationarity channel model study, e.g., simulation/measurement and calibration:   * Up to 1.5 m for UMa with maximum antenna elements in the array is [5k] for single Polarization. * Up to 1 m for UMi with maximum antenna elements in the array is [2.22k] for single Polarization. * Up to [0.71] m for Indoor factory with maximum antenna elements in the array is [1.12k] for single Polarization. * Up to [0.25 (for rectangular antenna array), 0.5 (for linear antenna array)] m for Indoor office with maximum antenna elements in the array is [138, 24] for single Polarization, respectively. |

In this meeting, companies’ views on the assumption of aperture size are summarized as following:

* For the UMa scenario:
  + [Intel, Ericsson, Qualcomm] propose to remove the bracket, i.e., confirming that maximum antenna elements in the array is 5k for single polarization.
  + [Samsung] proposes that the maximum antenna elements is 4k for single polarization.
  + [Apple] proposes that the maximum antenna elements is 4050 for single polarization.
* For the UMi scenario:
  + [Intel, Ericsson, Qualcomm] propose to remove the bracket, i.e., confirming that maximum antenna elements in the array is 2.22k for single polarization
  + [Samsung, Apple] propose that the maximum antenna elements shall be changed to 1.8k for single polarization.
* For the Indoor factory scenario:
  + For the maximum aperture size:
    - [Intel, Nokia, Samsung, Apple, Ericsson, Qualcomm] propose to remove the bracket for the maximum aperture size, i.e., confirming that up to 0.71 m for Indoor factory.
  + For the maximum antenna elements:
    - [Intel, Nokia, Ericsson, Qualcomm] propose to remove the bracket for the maximum antenna elements, i.e., confirming that maximum antenna elements in the array is 1.12k for single polarization
    - [Samsung] proposes that the maximum antenna elements in the array is 1k for single polarization.
    - [Apple] proposes that the maximum antenna elements is 882 for single polarization.
* For the Indoor office scenario:
  + For the maximum aperture size:
    - [Intel, Nokia, Samsung, Ericsson, Qualcomm] propose that the bracket for the aperture size can be removed, i.e., confirming that up to 0.25 (for rectangular antenna array), 0.5 (for linear antenna array) m for Indoor office scenario.
    - [Apple] proposes that up to 0.25m on the aperture size for rectangular antenna array is considered for the Indoor office scenario.
  + For the maximum antenna elements:
    - [Nokia, Ericsson, Qualcomm] propose to remove the bracket for the maximum antenna elements, i.e., confirming that maximum antenna elements in the array is 138, 24 respectively.
    - [Intel] proposes that the maximum antenna elements is 273, 80 for single polarization respectively.
    - [Samsung] proposes that the maximum antenna elements is 65, 24 for single polarization respectively.
    - [Apple] proposes that the maximum antenna elements is 128 for single polarization.

Additionally, [Fujitsu] highlights that in real deployment, only a part of antenna elements on a panel may be activated, e.g., for the purpose of network energy savings. Thus, not only the maximum antenna size, but realistic antenna size should also be assumed. [vivo] highlights that a reference point representing the position of the antenna array (e.g., center of antenna array) shall be determined since the position of the reference point on the antenna array may impact the performance evaluation.

According to the above analysis, from FL’s perspective, it seems that for UMa, UMi and Indoor factor, it’s more reasonable to confirm the previous value by removing the bracket. For indoor office, **the number of antennas can be further revised since the maximum number is considered**. For other two issues, it seems irrelevant to the channel model discussion.

Then, the following proposal is provided:

### ***Proposal 1-2-1-1:***

*The following agreement in RAN1#117 can be revised as:*

|  |
| --- |
| For the assumption on the aperture size of antenna array, the following is considered for near-field and spatial non-stationarity channel model study, e.g., simulation/measurement and calibration:   * Up to 1.5 m for UMa with maximum antenna elements in the array is 5k for single Polarization. * Up to 1 m for UMi with maximum antenna elements in the array is 2.22k for single Polarization. * Up to 0.71 m for Indoor factory with maximum antenna elements in the array is 1.12k for single Polarization. * Up to 0.25 (for rectangular antenna array), 0.5 (for linear antenna array) m for Indoor office with maximum antenna elements in the array is 273, 80 for single Polarization, respectively. |

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Intel | We support the proposal in principle.  For the last bullet (Indoor office), regarding the exact values of the maximum number of elements, we found some typo in calculation of the range of elements for 7-24GHz for the rectangular case. Here is the revised calculation for clarification: The aperture size of 0.25m corresponds to a square of size ~25/sqrt(2)=17.68m x ~25/sqrt(2)=17.68m, which can fit up to ~68 elements at 7GHz and ~800 elements at 24GHz for single polarization at λ/2 spacing. So, although we are Ok with the value of 273 which falls within the range of 68 - 800 elements, there is nothing special about the exact value of 273. For example, a value of 2^8 = 256 could be considered as a more practical choice. We are open to other suggestions for this value as well. As such, we suggest to revise last bullet as follows:   * Up to 0.25 (for rectangular antenna array), 0.5 (for linear antenna array) m for Indoor office with maximum antenna elements in the array is 256, 80 for single Polarization, respectively. |
| InterDigital | OK |

## **1.3 Details of near-field channel modeling**

### **1.3.1 Modelling for System level simulation**

#### **1.3.1.1 Large scale parameters determination**

**1.3.1.1.1 Company view (Round-1)**

In last RAN1#117 meeting, following working assumption has been made:

|  |
| --- |
| Working Assumption  For the near-field channel modeling, no changes are expected on both value and parameter generation procedure of at least following large-scale parameters in existing TR 38.901:   * Pathloss model, SF, LOS probability * FFS:DS, ASA, ASD, ZSA, ZSD, K factor |

In this meeting, the majority companies [Huawei, HiSilicon, Intel, Nokia, CATT, OPPO, Samsung, MediaTek, Apple, Qualcomm, CEWiT, ZTE] propose to confirm the working assumption that the no changes are expected on both value and parameter generation procedure of existing Pathloss model, shadow fading, LOS probability parameters. While [InterDigital] proposes that the Pathloss model may require some modifications to account for the contributions from different array elements for near-field scenario.

As for the DS, ASA, ASD, ZSA, ZSD and K factor, [InterDigital, CEWiT] propose that the supported range of some parameters may need to be adjusted, and [Samsung] proposes that further discussion is needed for these parameters. However, the majority companies [Huawei, HiSilicon, CATT, Intel, Nokia, OPPO, MediaTek, Apple, Qualcomm, ZTE] propose that no changes are expected on both value and parameter generation procedure of these parameters. The detailed analysis is listed as following:

* [Intel] highlights that among the large-scale parameters, SF, DS, ASA, ASD, ZSA, ZSD, and K factor do not depend on TRP and/or UE locations or their distances.
* [CATT] highlights that the large-scale parameters reflect the variation over relatively large areas and long periods of time, there is no significant change between different antenna elements on the same antenna panel.
* [MediaTek] proposes that the delay spread represents the time difference between the arrival of the earliest and latest multipath components, while the angular spreads represent the dispersion in the arrival angles of these components. These parameters are only to reflect the propagation environment and used to generate the basic set of small-scale parameters for the BS-UE link.
* [Apple] proposes that the impact on large scale parameters is negligible and it does not have impact on scenario/network layout/antenna parameters, as well as coefficient generation.

From FL’s perspective, according to companies’ views, no changes are expected on the existing Pathloss model, shadow fading and LOS probability parameters. As for the other large-scale parameters (e.g., DS, ASA, K factor), as highlighted by some companies above, it is only to reflect the propagation environment and used to generate the basic set of small-scale parameters for the BS-UE link, thus no changes are also expected on these parameters.

Then, following is proposed from FL’s perspective:

***Proposal 1-3-1-1-1:***

*For the near-field channel modeling,**no changes are expected on both value and parameter generation procedure of the following large-scale parameters in TR 38.901****:***

* *Confirm the WA in RAN1#117: Pathloss model, SF, LOS probability*
* *DS, ASA, ASD, ZSA, ZSD, K factor*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Intel | We support the proposal. |
| Ericsson | We support the proposal. |
| InterDigital | Our suggestion is split the proposal to two parts. In the first part we could agree on that no change are expected on “parameter generation procedure”. However, for the value range, there is no rush, and should keep it as WA. |

#### **1.3.1.2 Small scale parameters determination**

**1.3.1.2.1 Direct path between BS and UE**

###### **1.3.1.2.1.1 Company view (Round-1)**

In last RAN1#117 meeting, following agreements have been achieved regarding the details to model the antenna element-wise channel parameters of direct path between BS and UE:

|  |
| --- |
| ***Agreement***  *For near-field channel, if necessary, to model the following antenna element-wise channel parameters of direct path between TRP and UE,*   * *Phase* * *with Option-2 “Determined by the antenna element locations of both TRP and UE”.*   ***Agreement***  *To align the understanding of the terminology for channel model study, the following figures are considered as the reference:*   * *For direct path:*     ***Conclusion***  *For near-field channel, no changes are expected on the following parameters for direct path.*   * *Amplitude, polarization matrix* |

In last meeting, phase has been agreed to be modeled as the antenna element-wise channel parameters for the direct path between the BS and UE, and no changes are expected on the amplitude and polarization matrix for direct path. In this meeting, regarding which remaining channel parameters are necessary to be modeled as the antenna element-wise channel parameters, following are summarized according to companies’ input.

* Angular domain parameters:
* [Huawei, HiSilicon, InterDigital, LGE, Intel, ZTE, Apple, BUPT, CMCC, CATT, MediaTek, CEWiT] propose to model the antenna element-wise angular domain parameters. More specifically, [LGE] highlights that it’s necessary to account for the angular differences for the use cases where the angle difference is to be considered finely, such as positioning. [ZTE] highlights that the variation of angular domain parameters will result in the variation of 3D radiation power of antenna element, especially considering the imperfect pattern in the realistic deployment. [Apple] mentions that the closer the distance between TRP and UE, the larger the difference among different antenna element pairs.
* [vivo, Qualcomm] propose that there is no need to model the antenna element-wise angular domain parameters. More specifically, [vivo] provides the simulation results to show that the SGCS between the antenna element-wise angle and the antenna center-wise angle is almost equal to one. [Qualcomm] provides the simulation results and shows that the inclusion of angular domain parameters has minimal impact.
* [Samsung] proposes that whether the updates for angular domain parameters is needed shall be discussed.
* Delay:
* [ZTE, LGE, CATT, MediaTek, Qualcomm] propose to model the antenna element-wise delay parameters.

[LGE] highlights that in use cases that demand such precise timing measurements, modelling the antenna element-wise delay differences can be important. [ZTE] provides the measurement results to demonstrate that the delay variation among antenna elements will exceed the delay resolution. [CATT] mentions that delay varies significantly even within a short range. [MediaTek] mentions that this level of precision enables a precise representation of signal curvature through space, a phenomenon that gains prominence and significance in the near-field domain.

[Qualcomm] proposes that the framework provided in 7.6.2.1 of TR 38.901 for more accurate modelling of delays for large antenna arrays can be reused.

* [vivo, Huawei, HiSilicon, Apple, CEWiT] propose that there is no need to model the antenna element-wise delay parameters. More specifically, [vivo] provides the evaluation results to show that the SGCS between the antenna element-wise delay and antenna center-wise delay is almost equal to one.
* [Samsung] propose that whether the updates for delay parameters is needed shall be discussed.
* Doppler shift:
* [LGE, ZTE, Intel, CATT, MediaTek, Apple] propose to model the antenna element-wise Doppler shift parameters.

More specifically, [LGE] highlights that the AoA difference for each element caused by the characteristics of the spherical wave can have a significant impact on the Doppler shift. [ZTE] highlights that considering the potential new use case, e.g., UAV, ATG or sensing, which is sensitive to the accuracy of Doppler estimation along with high speed, it’s more reasonable to model the antenna element-wise Doppler shift. [CATT, Apple, ZTE] mention that the Doppler shift is related to the arrival angle, so it also should be modelled per antenna element pair. [MediaTek] mentions that by accurately simulating these critical factors, the model enhances its predictive accuracy.

* [Huawei, HiSilicon, vivo, CEWiT] propose no change is needed on Doppler shift parameters. [vivo] provides the evaluation results to show the SGCS between the antenna element-wise Doppler shift and the antenna center-wise Doppler shift is almost equal to one.

Besides, [Qualcomm] proposes that how accurately we need to model spherical wavefront model shall be considered, then different options can be considered based on overall impact on simulation outcomes. And [Samsung] proposes that RAN1 strives to validate channel parameters updates through measurement and ray-tracing experiment.

According to the above views, it seems that the main reasons to preclude the modelling for some parameters are:

* The variation is small and may be negligible;
* The impacts on certain performance related metric is negligible.

However, all above points are based on certain assumption, e.g., setup as bandwidth, antenna model, scenario and potential technical related usage. Since the channel model will be the basis for all potential technical study, if considering the new use cases, e.g., positioning or sensing use cases, it seems to be necessary to model other parameters. Additionally, the complexity to model this parameter is also limited.

Thus, following is proposed from FL’s perspective:

###### ***Proposal 1-3-1-2-1-1:***

*For near-field channel, to model the following antenna element-wise channel parameters of direct path between TRP and UE,*

* *Angular domain parameters, delay, Doppler shift.*

*with Option-2 “Determined by the antenna element locations of both TRP and UE”.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Intel | We support the proposal. |
| Ericsson | Don’t agree. It appears that the only difference between the proposal and the agreement from RAN1#117 is the removal of the words “if necessary”. But as discussed in our response to Proposal 1-1-1 we don’t believe there is consensus on this yet. |
| InterDigital | We support the proposal. |

**1.3.1.2.2 Non-direct paths between BS and UE**

###### **1.3.1.2.2.1 Company view (Round-1)**

In last RAN1#117 meeting, following agreements have been achieved regarding the details to model the antenna element-wise channel parameters of non-direct path between BS and UE:

|  |
| --- |
| **Agreement**  For near-field channel, if necessary, to model the following antenna element-wise channel parameters of non-direct path between TRP and UE,   * Angular domain parameters (i.e., AoA, AoD, ZoA, ZoD), Delay, phase, Doppler shift, Amplitude * FFS: Impacts on the polarization   The following options are considered:   * Option-1: The cluster location-based approach, wherein the cluster location is obtained with following alternatives:   + Alt-1: cluster location is derived based on at least the distance between the BS/UE and clusters.   + FFS: How to obtain the distance.   + FFS: Other parameters.   + Alt-2: cluster location is directly dropped and generated. * Option-2: The parameter-based approach with following detailed alternatives:   + Alt-1: Introduce the model of variation rate of parameter over antenna elements.   + Alt-2: Modelling the variation by taking the existing spatial consistency procedure of TR 38.901 as baseline. * Option-3: The curvature-based approach   **Agreement**  To align the understanding of the terminology for channel model study, the following figures are considered as the reference:   * For non-direct path: |

* Issue#1: Antenna element-wise channel parameters for the non-direct paths:

As for the non-direct paths between BS and UE, [Qualcomm, LGE] propose that whether the spherical wavefront model shall be extended to the non-direct path needs further study and depends on the overall difference in the outcome simulations/measurement results with and without spherical wavefront model. While according to companies’ inputs, the majority companies share the detailed views on how to model the antenna element-wise channel parameters for the non-direct path between BS and UE.

Regarding which channel parameters are considered to be modeled as the antenna element-wise channel parameters for the non-direct paths between BS and UE, following are summarized according to companies’ input.

* Angular domain parameters:
* [Huawei, HiSilicon, InterDigital, Intel, OPPO, NVIDIA, BUPT, CMCC, MediaTek, CEWIT, Apple, ZTE] propose to model the antenna element-wise angular domain parameters.
* [Qualcomm] proposes not to model the antenna element-wise angular domain parameters.
* [vivo] proposes that whether the antenna element-wise angle needs to be modeled or not can be determined by evaluation results.
* Delay:
* [Intel, OPPO, NVIDIA, BUPT, CMCC, MediaTek, ZTE, Qualcomm] propose to model the antenna element-wise delay parameters. More specifically,

[MediaTek] mentions that this level of precision enables a precise representation of signal curvature through space, a phenomenon that gains prominence and significance in the near-field domain.

[ZTE] provides the measurement results to demonstrate that the delay variation among antenna elements for the non-direct path will exceed the delay resolution.

[Qualcomm] proposes that the framework provided in 7.6.2.1 of TR 38.901 for more accurate modelling of delays for large antenna arrays can be reused.

* [Huawei, HiSilicon, vivo, Apple] propose that no change is needed on delay parameters. More specifically,

[vivo] mentions that similar to the direct path, due to the A/D sampling interval, small difference does not affect the channel frequency response after DFT processing.

* Phase:
* [Huawei, HiSilicon, InterDigital, Intel, ZTE, vivo, OPPO, NVIDIA, BUPT, CMCC, MediaTek, Apple, CEWIT, Qualcomm, ZTE] propose that the antenna element-wise phase parameters shall be modeled for the non-direct path.
* Doppler shift:
* [Intel, OPPO, NVIDIA, MediaTek, Apple, ZTE] propose to model the antenna element-wise Doppler shift parameters.
* [Huawei, CEWiT] proposes that no change is needed on the Doppler shift parameters.
* [vivo] proposes that if antenna element-wise angle has been modeled, Doppler shift can be modeled in the same way as angle.
* Amplitude:
* [Huawei, HiSilicon, InterDigital, ZTE,vivo, Apple, CEWiT, Qualcomm] propose there is no need to model the antenna element-wise amplitude.
* [Intel, OPPO, NVIDIA, MediaTek] propose that the antenna element-wise amplitude can be considered.
* Polarization matrix:
* [Huawei, HiSilicon, InterDigital, Intel, Apple, CEWiT, ZTE, Qualcomm] propose that no changes are expected on the polarization matrix.

Additionally, similar as the direct path, [Qualcomm] proposes that how accurately we need to model spherical wavefront model shall be considered, then different options can be considered based on overall impact on simulation outcomes.

* Issue#2: Methods to determine the antenna element-wise channel parameters

Besides, in last meeting, three options have been proposed regarding how to calculate the antenna element-wise channel parameters for the non-direct path. [vivo, LGE, Fujitsu, Samsung] highlight that it’s better to down select one option from the three options considering the cost of computational complexity of simulations and the characteristics of all options. And following views are summarized according to companies’ inputs:

* Option-1: [Huawei, HiSilicon, InterDigital, vivo, OPPO, Fujitsu, NVIDIA, Apple, Qualcomm, CEWiT, BUPT, CMCC]
* Alt-1: [Huawei, HiSilicon, InterDigital, vivo, OPPO, Apple, Qualcomm]. More specifically,

[Huawei, HiSilicon, InterDigital, vivo, Qualcomm] proposes that the multi-bounce model shall be considered. And [vivo] highlights that that modeling the exact location of the first-bounce and the last-bounce scatters is beneficial to offer the accuracy of channel model and ensure the difference of channel characteristics between different antenna pairs and the continuity of channel characteristics between adjacent antenna elements.

[Huawei, HiSilicon, Qualcomm] mention that the delay and angle of a ray generated according to current 38.901 can be treated as the observed delay and angle at the reference antenna element, which is used to locate the first-/last-bounce scatterer.

[InterDigital] proposes that the first bounce distance and last bounce distance for the cluster can be determined from a uniform distribution. And the existing spatial consistency procedure can be extended to calculate the channel parameters due to the UE/BS mobility.

* Alt-2: [vivo, NVIDIA, CEWiT]. More specifically,

[vivo] highlights that if RAN1 agrees on Alt-2 of Option-1, the multiple bounce models, where the distance between the first-bounce scatter to the transmitter and the last-bounce scatter to receiver that are stochastically generated can be a starting point.

[CEWiT] proposes that a cluster dropping boundary is identified and drops physical clusters only within the boundary, and modeling the first cluster and the last cluster locations are sufficient to incorporate the near-field effects.

* [BUPT, CMCC] propose that cluster locations can be efficiently and accurately determined by combining Alt-1 and Alt-2 of Option-1, and the distances between the clusters and BS accurately follow a log-normal distribution.
* Option-2: [Intel, ZTE, CATT, MediaTek].
* Alt-1: no company prefers to the Alt-1 of Option-2.
* Alt-2: [Intel, ZTE, CATT, MediaTek]. More specifically,

[ZTE] proposes the detailed procedure based on existing spatial consistency procedure with updates to illustrate this method.

[Intel] proposes that the existing Procedure A of section 7.6.3.2 of TR 38.901 can be re-used for modeling cluster delays, cluster powers, and cluster departure and arrival angles for near-field channel modeling.

[MediaTek] proposes that the existing spatial consistency feature, along with multiple antenna arrays/panels (grouping of antenna elements), can be used to implement near-field effects for both direct and non-direct paths.

* Option-3: [Ericsson]

[Ericsson] highlights that for each ray or each cluster, determine the two radii of curvature at the BS by drawing two random samples from some stochastic distribution, then the phase shift and other angular domain parameters can be calculated.

Additionally, considering that different companies have different preference on the above three options, following views on the Pros & Cons of each option are summarized according to companies’ inputs:

|  |  |  |  |
| --- | --- | --- | --- |
| Option/Alts | | Pros | Cons |
| Option-1 | High-level | [OPPO] highlights the Option-1 aligns the desire of using unified modeling structure.  [Fujitsu] highlights that Option-1 can provide stable baseline for discussion since it is straightforward extension of the current existing model in TR 38.901. | [Intel, LGE] highlight that the Option-1 may not guarantee a unified channel model for near-field and far-field without modifying the existing far-field channel generation procedure of TR 38.901, which incurs additional effort in 3GPP.  [Ericsson] highlights that the Option-1 implicitly assumes that the cluster location is the source of a spherical wave, which is very restricted and can only generate two of the four types of wavefront. |
| Alt-1 | [vivo, Qualcomm] highlight that it allows assigning a physical location to a cluster without incurring any additional changes to the existing stochastic framework. | [ZTE] highlights that it treats the scatter (or reflective surface) as a single point, which does not match the real reflection characteristics.  [BUPT, CMCC] mention that the Alt-1 method is highly complex and time-consuming to simulate. |
| Alt-2 | / | [ZTE] highlights that it violates the structure and procedure of existing stochastic model.  [Samsung] mentions that it requires defining various parameters, resulting in increased complexity.  [BUPT, CMCC] mention that it lacks the necessary parameters/distributions for directly generating the cluster location. |
| Option-2 | Alt-1 | / | [ZTE] highlights that the variation rate of parameters under the different configuration and scenarios can be different, which increases the difficulty and complexity.  [vivo] highlights that it relies on many experimental results and each antenna configuration needs a pre-determined table to deal with, resulting in a low flexibility. |
| Alt-2 | [ZTE] highlights that the generated antenna element-wise channel parameters follow spherical wave characteristics, and does not treat the scatter as a single point.  [CATT] highlights that this approach has less specs impact.  [MediaTek] highlights that it can maintain the integrity of existing model, adapt to different antenna configurations and scenarios, offer flexible application possibilities, and provide low complexity and memory usage. | [vivo] highlights that the model of antenna element-wise phase is exactly the same as that for far-field channel model, and cannot satisfy the spherical wave characteristics in near-field. |
| Option-3 | | [Ericsson] proposes that this approach allows the rate of variation of parameters to be directly calculated from the two radii of curvature of the wavefront. | [vivo] highlights that the Option-1 incurs the same consequence as the Option-3, but Option-3 employs somewhat uncertain implementation mechanism. |

Moreover, as for the methods to determine the antenna element-wise channel parameters, [InterDigital, Intel, OPPO, ZTE, BUPT, CMCC] highlights that the cluster-wise antenna element-wise channel parameters can be determined firstly, then the ray-wise antenna element-wise channel parameters can be obtained. While [Huawei, HiSilicon, Ericsson] mentions that the ray-wise antenna element-wise channel parameters can be directly determined according to the specific methods.

According to the companies’ views above, following are proposed from FL’s perspective:

###### ***Proposal 1-3-1-2-2-1:***

*For near-field channel, the following parameters of the non-direct path between TRP and UE should be modeled as antenna element-wise parameter.*

* *Phase, Doppler shift, Angular domain parameters, delay*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Intel | We support the proposal.  In addition, we propose to add Amplitude to the list here. Please see our comment for the next proposal. |
| Ericsson | Don’t agree to remove the words “if necessary” from the RAN1#117 agreement. |
| InterDigital | Support. |

###### ***Proposal 1-3-1-2-2-2:***

*For near-field channel, no changes are expected on following parameters of the non-direct path between TRP and UE:*

* *Amplitude, polarization matrix.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Intel | We expect no changes to the polarization matrix.  For Amplitude, since the cluster power assignment depends on the cluster delays per Step 6 of TR38.901, the Amplitude generation cannot simply kept “unchanged”. The issue will be that the existing P\_n in TR38.901 is a function of which will not exist (or will be revised), if the cluster delays are modeled as antenna element-wise parameters. |
| Ericsson | We support the proposal. |
| InterDigital | A similar view as Intel. |

###### ***Proposal 1-3-1-2-2-3:***

*For near-field channel, the antenna element-wise channel parameters of non-direct path between TRP and UE can be determined by following options:*

* *Option-1: The cluster location is derived based on at least the distance between the BS/UE and clusters.*
  + *FFS: How to obtain the distance.*
  + *FFS: Other parameters.*
* *Option-2: The antenna element-wise channel parameters are determined based on the existing spatial consistency procedure of TR 38.901 with updates.*
  + *FFS: Details to obtain the antenna element-wise parameters.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Intel | We support the proposal. |
| Ericsson | Don’t agree to remove the words “if necessary” from the RAN1#117 agreement.  We prefer to keep option 3 from the RAN1#117 agreement. As pointed out in our contribution R1-2406742 Option 1 has serious limitations since it can only generate spherical waves which is a special case for the wavefront. Furthermore, the “cluster location” as defined by its direction of arrival or departure and the distance to the last interaction point would give a very wrong curvature for the simple case of a single specular reflection, as this figure shows.    It is unclear how the spatial consistency procedure in Option 2 should be updated but it likely suffers from the same limitations and drawbacks as Option 1.  In contrast, Option 3 would entail a simple, backwards-compatible addition to the existing stochastic model. The wavefront curvature, specified by two radii and an orientation, is stochastically generated per ray or per-cluster, and used to calculate the phase and delay shift across the antenna array. If the radii are infinite the process results in exactly the same channel as in the existing model, and if they are equal, the resulting waveform is spherical, but with a curvature that may not be determined by the “cluster location”, which is more accurate as per the above example. |
| InterDigital | Support proposal. |

Additional aspects related to the small-scale channel parameters are also proposed by companies. For example:

* [CEWiT] proposes that the number of strongest clusters, cluster delay offset, ray mapping, power association to rays within a cluster for the near-field from measurements shall be validated.
* [InterDigital, CEWiT] propose that the exponential decay behaviors of cluster power with respect to their delays are not observed in Near-Field measurements, which may need to be revisited for near-field effect.

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
|  |  |

#### **1.3.1.3 Channel coefficient determination**

##### **1.3.1.3.1 Company view (Round-1)**

In this meeting, some companies [Huawei, HiSilicon, vivo, InterDigital, Intel, ZTE, Qualcomm] provide the detailed formula of channel coefficients for the near-field channel model, and [Samsung] also proposes that RAN1 shall discuss how to reflect the spherical wavefront impact into existing structure in terms of phase. Thus, according to companies’ inputs, following views are summarized:

* **For the LOS channel coefficient:**
* If modeled, the phase parameters:
* [Huawei, HiSilicon, vivo, InterDigital, Qualcomm, CEWiT] propose that the phase can be directly expressed by the position information of corresponding antenna element pair, e.g., ,or .
* [Intel, Samsung] propose that the phase can be expressed by the approximation of the Taylor expansion with first two items, e.g., .
* [ZTE] proposes that the existing two spherical unit vectors in the phase part can be updated to the spherical unit vector of corresponding antenna element pair, e.g., .
* If modeled, the angular domain parameters:
* [Huawei, HiSilicon, InterDigital, ZTE, Intel, Qualcomm, CEWiT] propose that angular parameters in the field pattern of transmit antenna element and receive antenna elements can be updated to the antenna element-wise angular domain parameters, e.g.,
* If modeled, the Doppler shift parameters:
* [Intel] proposes that the Doppler shift can be updated to
* [ZTE, Qualcomm] propose the spherical unit vector in the Doppler shift part can be updated to the spherical unit vector of corresponding antenna element pair, e.g.,
* If modeled, the delay parameters:
* [ZTE] proposes that the delay parameters can be updated to
* [Qualcomm] proposes that the framework provided in 7.6.2.1 of TR 38.901 for more accurate modelling of delays for large antenna arrays can be reused.
* **For the NLOS channel coefficient:**
* If modeled, the phase parameters:
* [Huawei, HiSilicon, InterDigital, vivo, Qualcomm, CEWiT] propose that the phase is expressed by the distance information between the clusters and antenna elements of BS/UE can be directly expressed by e.g., ;
* [Intel] proposes that the phase can be updated to ;
* [ZTE] proposes that the existing spherical unit vector can be updated to the spherical unit vector of corresponding antenna element pair, e.g., .
* If modeled, the angular domain parameters:
* [Huawei, HiSilicon, ZTE, InterDigital, Intel, Qualcomm, CEWiT] propose that angular parameters in the field pattern of transmit antenna element and receive antenna elements can be updated to the antenna element-wise angular domain parameters, e.g., , .
* If modeled, the Doppler shift parameters:
* [ZTE, Qualcomm, vivo] proposes to update the Doppler shift to
* [Intel] proposes to update the Doppler shift to
* If modeled, the delay parameters:
* [ZTE] proposes that delay parameters can be updated to .
* [Qualcomm] proposes that the framework provided in 7.6.2.1 of TR 38.901 for more accurate modelling of delays for large antenna arrays can be reused.

From FL’s perspective, since the phase for direct path is already agreed to modelled, the detailed changes can be discussed. Among all options, updating the phase as is more aligned with the existing framework for channel coefficient generation. So, the following is proposed:

##### ***Proposal 1-3-1-3-1:***

*For near-field channel, the following equation is adopted to model the phase of direct path between TRP and UE as antenna element-wise channel parameter:*

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Intel | We do not support the proposal.  One of the key properties of near-field channel model is the phase of the channel for direct path is a non-linear function of antenna element locations. This is a well-known phenomenon in the near-field literature. This key phenomenon is missing in the current proposal. |

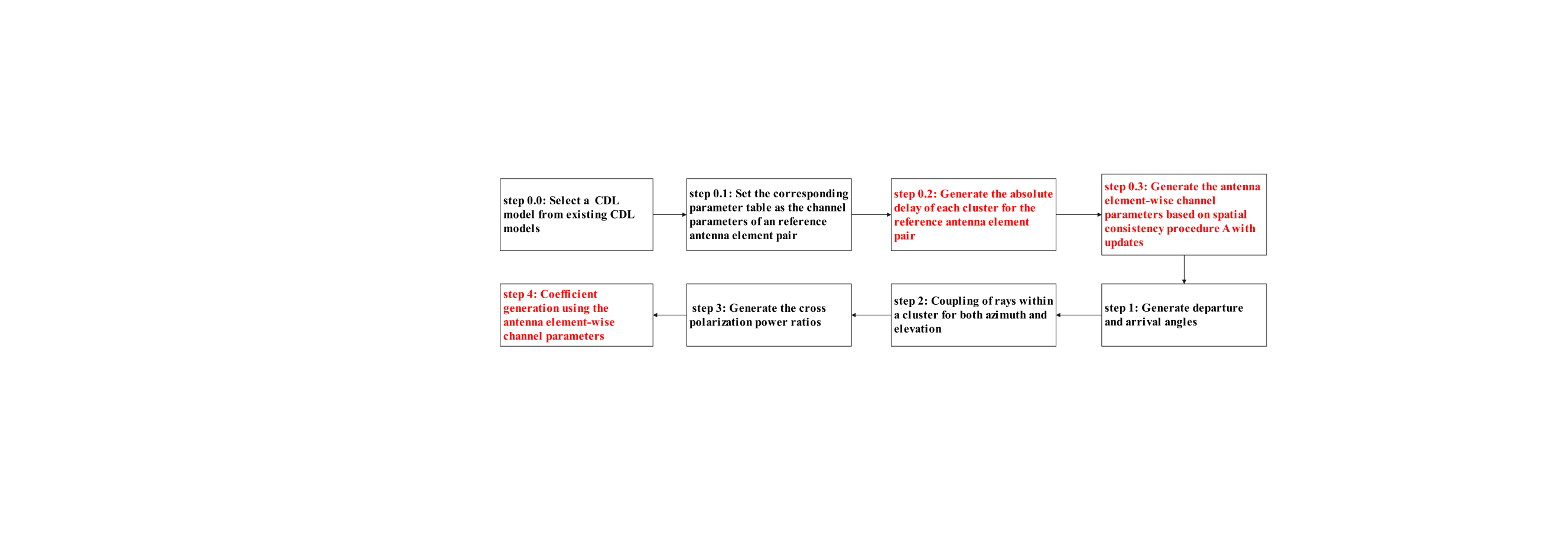
Regarding other parameters, companies can further share the views, e.g., comparison among different options.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | For non-direct paths, a common view appears to be that the phase and the delay can be determined using a per-element distance compared to a distance to a reference point. Similarly, the per-element Doppler shift can be determined using the time derivative or rate of change of this distance difference. But there are different views on how to determine this distance, e.g. the different options in Proposal 1-3-1-2-2-3 and the agreement from RAN1#117. Perhaps an agreement can be made on the use of some element-specific distance and its time derivative with FFS on how to determine that distance? |

### **1.3.2 Modelling for link level simulation**

#### **1.3.2.1 Company view (Round-1)**

In this meeting, in addition to the discussion of system level evaluation for near-field channel model, [ZTE] proposes that the link level evaluation for near-field channel model shall also be considered. And considering that the 3D locations of both TRP and UE is not given in the link level evaluation, [ZTE] proposes that the antenna element-wise channel parameters for the link level evaluation can also be obtained based on existing spatial consistency procedure A with updates. Following is an example for the step-wise procedure of the link level evaluation to obtain the antenna element-wise channel parameters proposed by [ZTE].



From FL’s perspective, how to determine the antenna element-wise channel parameters in the link level evaluation is also an important aspect of channel model. This issue shall be considered together with the discussion on the details and methods for the system level evaluation along with the difference between the link level evaluation and system level evaluation realization procedure shall be considered when determining the specific methods.

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | We are fine to study updates to the link-level model. The wavefront curvature approach is straightforward to apply also to link simulations by tabulating the curvatures of each cluster in the CDL tables. |

## **1.4 Methodology for the near-field channel modelling**

### **1.4.1 Criteria to define the near-field region**

#### **1.4.1.1 Company view (Round-1)**

In last RAN1#116bis meeting, following agreement has been achieved:

|  |
| --- |
| **Agreement**  For the study of near-field channel modelling, at least following aspects should be considered:   * Whether/How to define the near-field region. * The parameters variation for each ray/cluster across different antenna element pairs. |

In this meeting, [Intel, ZTE, CATT, Samsung, Apple, CEWiT, Qualcomm] highlight that the near-field region shall be defined. [Intel] proposes that RAN1 to consider defining soft criteria for leveraging near-field models and state that near-field modelling is applicable for evaluation scenarios that contain links that meet such criteria. [ZTE] highlights that the criteria to define the near-field region shall both consider the modelling accuracy to capture the different propagation characteristics and the complexity of modelling methodology. And [CEWiT] highlights that near-field region can be defined in terms of the capability of the channel to support more than one data stream in LOS.

Regarding how to define the near-field region, [ZTE, Intel, CATT, Apple, CEWiT, Qualcomm] propose that the channel model error-based way can be used to determine the boundary. More specifically:

* [Intel] proposes that for the direct path, the near-/far-field condition can be defined as smallest 3D distance beyond which the near-field component of the channel phase.
* [CATT] proposes that the effective Rayleigh distance, a scaled Rayleigh distance with a scaling factor of 0.4 can be used to define the near-field region.
* [Apple] mentions that the far-field region and near-field region is separated at Rayleigh distance.
* [CEWiT] proposes two options, with option-1 is to use one-half of Rayleigh distance for densely populated UEs, and opion-2 is to use Rayleigh distance for sparely populated UEs.
* [Qualcomm] mentions that a Rayleigh distance-based threshold can be used for determining whether SWM is required or not for different panel sizes and different frequencies.

Additionally, [ZTE] proposes that the performance metric-based way shall not be considered for the criteria, since the criteria to determine the boundary between the near-field region and far-field region is mainly used to clearly capture the near-field propagation characteristics from the channel modelling perspective.

From FL’s perspective, according to the above summary, the majority companies propose to define such criteria based on channel model error, which can be considered as a potential and feasible way. Thus, following is proposed:

#### ***Proposal 1-4-1-1:***

*The impacts on the variation of antenna-element wise channel parameters-based method can be considered to define the near-field region.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Intel | The proposal is not clear. |
| Ericsson | The question of whether to define a near-field region should be addressed before the question of how. In our contribution R1-2406742 we explored several different near-field region definitions when attempting to assess the necessity non-planar wavefront modelling. However, it is not yet given that the channel modelling actually needs such a definition. For instance, all of the three options to generate the wavefront behavior in the RAN#117 agreement will work whether or not a suitable near-field definition exists or has been agreed on. Whether to apply non-planar wavefront modelling or not can perhaps be left for companies’ decision in their respective implementations, based on their specific needs and understandings.  What could be useful is if the TR provides some guidance on situations where non-planar wavefront modelling may be appropriate. But this returns to the question of necessity, which needs further studies. |
| InterDigital | We have a similar view as Ericsson. Such definition is really not necessary. As it has been mentioned in earlier meetings, the objective is to have a model that can accurately depict the channel for near and far UEs, and for that definition of near field region is not needed. |

### **1.4.2 Near-field/far-field condition of non-direct paths**

#### **1.4.2.1 Company view (Round-1)**

In last RAN1#116bis meeting, following agreement has been achieved:

|  |
| --- |
| **Agreement**  The near- or far-field condition should be studied for the direct path and non-direct paths between BS and UE.   * The near-/far-field condition for the direct path may be assessed by using the 3D BS-UE distance.   + FFS: The determination of near-/far-field condition for the non-direct paths * Note: The direct path is referring to the LoS ray in the TR 38.901 in principle. * Note: The non-direct paths are referring to the cluster/ray(s) without including LoS ray in the TR 38.901. |

In this meeting, as for the granularity to determine the near-/far-field condition of non-direct paths, [Intel] proposes that for determination of near-/far-field condition for the non-direct paths, different granularities, i.e., per TX-cluster and cluster-RX links, one Far-field/near-field determination for TX-cluster links and one far-field/near-field determination for cluster-RX links, per TX-cluster-RX links, entire NLOS channel, or the entire channel, can be considered. While [ZTE, OPPO, Apple] propose that the near-/far-field condition shall be determined per cluster.

Besides, as for how to determine the near-/far-field condition for the non-direct paths, following options are summarized according to the inputs:

* Option-1: Follow the direct path [CATT].
* Option-2: Assessed by using the distance between antenna array and cluster location [Intel, OPPO, Apple].

[Apple] proposes that the distance between TRP and a cluster can be compared with the Rayleigh distance, and whether a cluster is within the near-field region can be determined.

* Option-3: Introduce the near-field probability to measure the probability that the non-direct paths between BS and UE are in near-field condition [ZTE].

Additionally, [Intel] proposes that different near-/far-field conditions for different parameters can also be considered. And [Samsung] mentions that the impact between BS and clusters may differ depending on whether the UE’s location is in the near-field or far-field region.

Then, following is proposed from FL’s perspective:

#### ***Proposal 1-4-2-1-1:***

*The granularity of near- or far-field condition for the non-direct paths between BS and UE should be determined per cluster.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | It is unclear what is meant by granularity. We are in favor of different clusters having different curvatures, that can assume any value between a minimum and maximum. If the curvature is sufficiently large, the plane-wave approximation may be accurate. |
| InterDigital | First, not sure what is meant by granularity and condition. Second, we don’t think a condition is needed |

#### ***Proposal 1-4-2-1-2:***

*The near- or far-field condition for the non-direct paths between BS and UE can be determined by following options:*

* *Alt-1: Follow the near- or far-field condition for the direct path*
* *Alt-2: Assessed by using the distance between antenna array and cluster locations*
* *Alt-3: Determined by the near-field probability*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | The wavefront curvatures of the non-direct paths can be both smaller and larger than the curvatures of the direct path, so Alt-1 seems inappropriate. As discussed in our contribution R1-2406742, the “cluster location” is not useful for determining the wavefront except in special circumstances such as single diffuse scattering interaction along the propagation path. Alt-3 seems to introduce a stochastic probability, but we instead prefer that the wavefront curvature is generated using a stochastic process. The probability alone does not quantify the amount of non-planarity which the wavefront curvature does. |
| InterDigital | What is the objective of the condition? In general, we don’t think a condition is needed. |

### **1.4.3 Methodology of channel realization**

#### **1.4.3.1 Company view (Round-1)**

In last RAN1#116bis meeting, following agreement has been achieved:

|  |
| --- |
| Agreement  For near-field channel model, RAN1 strives to design a unified model to explicitly reflect the new properties of near- and existing properties of far-field under the structure of existing stochastic model TR 38.901.   * FFS: whether the same or different implementations, e.g., procedures/equations, are used for near- and far-field channel realization |

In this meeting, regarding whether the same or different implementations are used for near-field and far-field channel realization, [InterDigital, Intel, vivo] propose that the same implementation are used to keep the consistency, and [vivo] provides the analysis to illustrate the additional generation burden can be ignored. While [Huawei, HiSilicon, ZTE, CATT, CEWiT] propose that different implementation is used since the complexity of model will significantly increase if using the same procedures. And [Samsung] proposes that RAN1 shall discuss the same/different implementation method considering channel consistency and computational complexity.

Additionally, regarding the RMa scenario, [vivo] proposes that impact of near-field on channel modelling is relatively insignificant due to the cell range and the lower possibility to deploy the large-scale antenna arrays, which can be de-prioritized in the near-field study.

Besides, [Fujitsu] proposes that application condition of near-field model should be clarified e.g., in terms of deployment scenario (frequency, antenna array assumption, cell size), and it could be useful for future study to clarify the scenario where near-field model impact is not negligible when compared with the case with only far-field model.

Then, considering the model complexity, companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | We believe that non-planar wavefront modelling should be an optional component in the channel model. For simulations involving smaller antenna arrays the results should be the same whether the optional component is implemented or not. But many simulations may compare different array sizes or frequencies where the wavefronts may be essentially planar in one case and non-planar in another case. This strongly speaks for a unified model rather than two separate procedures that would result in a lack of comparability. |

Regarding the detailed channel coefficient generation procedure, the companies’ inputs are summarized and shown in Appendix-B.

From FL’s perspective, it seems reasonable to update the relevant component as the element-wise parameter in existing equation. Regarding the proposed updates on the diagram, it can be considered for reference and detailed changes can be discussed later once the details of model are stable.

Companies are encouraged to share your views regarding the above content if any.

|  |  |
| --- | --- |
| Companies | Comments and Views |
|  |  |

## **1.5 Others**

In addition, some proposal from individual company is also provided:

* [Samsung] proposes that the existing channel models lack terms representing distinct phases of field patterns for each antenna element, and the update of channel parameters with weighting vectors of each antenna element should be considered.

From FL’s perspective, companies are encouraged to share your views on the above issues:

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | We agree that in reality no antenna elements in an array have identical radiation patterns due to manufacturing tolerances and mutual coupling, however, this is more of a hardware implementation aspect that may be outside the scope of channel modelling. |

# **Views on Spatial non-stationarity**

## **2.1 Necessity and clarification on spatial non-stationarity phenomenon**

### **2.1.1 Company View (Round-1)**

According to contributions, the following measurement/simulation results are provided regarding the phenomenon of spatial non-stationarity:

* [BUPT, CMCC]: In the UMa and indoor scenario, the variation of the power of the cluster under different subarrays can be obviously observed.
* [Huawei]: Given that the birth and death phenomenon for clusters can be observed along the large antenna array, the spatial non-stationarity model should also be considered.
* [ZTE]: In UMi scenario, if a ray/cluster is blocked, the power of the ray/cluster will decrease significantly. From the simulation results, it can be seen that the power of penetration ray/cluster is small enough to ignore in the spatial non-stationary model.
* [Ericsson]: A measurement campaign in an urban macrocell utilizing a large antenna array and wide bandwidth has been performed. Partial shadowing of large antenna arrays due to building edges can result in significant power gradients across the antenna array.
* [Nokia]: Measurement is conducted under the assumption of realistic smartphone antenna pattern, it can be seen that the human hand can cause element-wise blockage to the UE side.
* [Qualcomm]: In the measurement of indoor and outdoor scenarios, channel magnitude across the gNB antennas can be observed, but it does not directly indicate SNS.

Based on the above observations, the following proposal is provided:

### ***Proposal 2-1-1:***

*The spatial non-stationarity characteristics (i.e., the antenna element-wise power variation due to the partial blockage at either BS or UE side) should be supported in the channel modelling.*

Companies are encouraged to share your views and also encourage to add the new measurement/simulation results to the excel sheet for source data collection.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | Agree |
| InterDigital | Support |

## **2.2 Details of spatial non-stationarity channel modeling**

### **2.2.1 Impact on the ray/cluster of elements**

#### **2.2.1.1 Company View (Round-1)**

In RAN1#117 meeting, the following agreement was made. In this section, companies’ views are summarized on the FFS points on the value for power variation and impacts on the phase.

|  |
| --- |
| Agreement  For the modelling of spatial non-stationarity, if necessary, the variation (e.g., reduction) of power for the impacted ray/cluster within the element-pair link should be modelled.   * FFS: The value for power variation * FFS: Impacts on the phase |

**Value for power variation**

According to contributions, 14 companies [Huawei, InterDigital, vivo Intel, ZTE, Apple, CATT, NVIDIA, Ericsson, BUPT, CMCC, Samsung, Qualcomm, CEWiT] have discussed the value of power variation of antenna element/pair for modelling spatial non-stationarity. Regarding how the power varies when the ray/cluster is in blocked or invisible, the following two options are considered by companies:

* Option 1: Power attenuation [Huawei, InterDigital, NVIDIA, Ericsson, BUPT, CMCC, Apple, Qualcomm, CEWiT]
  + [Huawei]: The power attenuation factor is modelled as below:
  + [InterDigital]: Blockage model A and B has addressed the power attenuation due to blockage and this power attenuation can be used for injunction with spatial non-stationary status for a path, i.e., visible/blockage, reflection, or diffraction.
  + [NVIDIA]: For the modelling of spatial non-stationarity, the variation (e.g., reduction) of power for the impacted ray/cluster within the element-pair link should be modelled.
  + [Ericsson]: The power gradients due to partial shadowing are well predicted by a simple knife-edge diffraction model.
  + [BUPT, CMCC]: For the value of the power attenuation factor can use 0 to represent the death of the clusters and a range of variation to represent the birth of the clusters and the variation of power along the array.
  + [Apple]: For the modelling of spatial non-stationarity, the power reduction of the impacted cluster is proportional to the visibility region (VR) over the total TRP antenna panel region.
  + [Qualcomm]: Reuse the knife-edge diffraction model with potential enhancements to apply to large antenna array
  + [CEWiT]: Sub-array(s) physical location relative to the cluster(s) physical location is required to enable modeling of different PDPs as well as power variations for spatial non-stationarity.
* Option 2: Set to zero [vivo, CATT, Samsung, Qualcomm, ZTE]
  + [ZTE]: For the modelling of spatial non-stationarity, the power for the impacted ray/cluster can be ignored and reduced to 0 in the blockage area.
  + [vivo]: Study whether 0 or 1 could be a starting point to model the impact of spatial non-stationarity on power.
  + [CATT]: For the modelling of spatial non-stationarity, if a cluster is invisible for an antenna element, its power factor is set to zero
  + [Samsung]: RAN1 consider that the power for the impacted ray/clusters in spatial non-stationarity modelling is set to zero
  + [Qualcomm]: Portions of the array that fall outside the visibility region of a cluster do not see any paths to/from that cluster.

For power attenuation, [InterDigital, Ericsson, Qualcomm] emphasize that the knife edge attenuation model in existing blockage model can well predict the power attenuation. Additionally, [BUPT, CMCC, Qualcomm, vivo, InterDigital] observe that spatial non-stationarity effect may occur due to different reasons, e.g. blockage, incomplete scatterer, limited visibility, the power attenuation may be different according to different reasons.

**Impact on phase**

Based on companies’ contributions, the following views are collected on the SNS impact on phase:

* + [ZTE]: For the modelling of spatial non-stationarity, phase change due to blockage can be ignored.
  + [vivo]: For the impact of spatial non-stationarity on phase, if the power attenuation factor is modeled as 0 when the links of antenna elements and clusters are invisible, then the impact of phase could be ignored.
  + [Ericsson]: Continue to study whether the blockage model in TR 38.901 can be enhanced to model also phase.

From FL’s perspective, majority companies agree to model the power attenuation, the companies that support VP or VR suggest to define an attenuation factor, while companies that support physical blocker prefer to reuse existing knife edge attenuation model in TR 38.901. As for impact on phase, considering the limited input, FL suggests to further discuss whether to model the impact on phase. Then, the following proposal is provided.

#### ***Proposal 2-2-1-1:***

*For the modelling of spatial non-stationary,* the variation (e.g., reduction) of power for the impacted ray/cluster within the element-pair link should be modelled *as:*

* *If visible probability (VP) or visibility region (VR) is adopted,*
* *A power attenuation factor within [0 1] is introduced.*
* *FFS: Details on how to determine the exact value for each cluster*
* *If physical blocker-based approach is adopted,*
* *Reuse knife edge attenuation model in TR 38.901 in blockage Model-B to model the power attenuation*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | We are in favor, though we suggest reformulating the last bullet as   * *Adapt the existing knife edge attenuation model in TR 38.901 in blockage Model-B to model the power attenuation per element* |
|  |  |
| InterDigital | Support |

## **2.3 Methodology for the spatial non-stationarity modeling**

In RAN1#116-bis and RAN1#117, the following agreements are achieved:

|  |
| --- |
| Agreement  For the modelling of spatial non-stationarity, at least the following options can be studied to identify the impacted ray/cluster and element-pair link:   * Option 1: Introducing per ray/cluster the visible probability, or visibility region for set of antenna element * Option 2: Introducing the physical blocker to emulate the blockage impact on the link for each element-pair   Note: The consistency across antenna elements and across clusters should be guaranteed.  Agreement  For the modelling of spatial non-stationarity, if necessary, if visible probability (VP) or visibility region (VR) is adopted, at least the following aspects should be considered for definition of VR/VP:   * Granularity of visible probability or visibility region (e.g., per cluster or per ray) * Determination of visible probability (e.g., distribution) or visibility region (e.g., size, location)   Agreement  For the modelling of spatial non-stationarity, if necessary, if physical blocker-based approach is adopted, the following aspects should be considered for definition of blocker:   * Blocker size/type:   + FFS: Additional blocker size/type compared to the Table 7.6.4.2-5 in TR 38.901.   + FFS: Different blocker sizes/types are considered to emulate the antenna element-wise blockage effect at the BS and UE side * Blocker location, e.g. distribution of the blocker, relative distance between blocker and BS or UE * FFS: Number of physical blockers to be considered. |

According to the contributions in this meeting, the following views are provided on the 2 methodologies for spatial non-stationarity:

* Option 1: Introducing per ray/cluster the visible probability, or visibility region for set of antenna element
* Supported by InterDigital, Huawei, LGE, vivo, Apple, BUPT, CMCC, Qualcomm, CEWiT
* Option 2: Introducing the physical blocker to emulate the blockage impact on the link for each element-pair
* Supported by InterDigital, Intel, Nokia, ZTE, Ericsson, MediaTek, Qualcomm

Similar number of proponents support each option, so the details for each option are discussed in next sections before down-selection on the 2 options.

**2.3.1 Visible probability or visibility region**

**2.3.1.1 Company View (Round-1)**

Based on companies’ views, the following details are proposed by companies on how to define visible probability or visibility region:

* Granularity of visible probability or visibility region
* Per ray [InterDigital, Huawei]
* Per cluster [ZTE, vivo, CATT, Apple, Qualcomm, LGE]
* Visibility region shape
* Rectangle [Qualcomm, ZTE, CATT]
* Circle [vivo, CATT]
* Quadrilateral [vivo]
* Visibility region size and determination
* [ZTE]: The ratio of visible elements to the total number of antenna elements can be used as a parameter to measure the size of the visible region. For the ratio generation process, the following aspects should be considered: (1) For LOS rays, generate the ratio of visible elements based on the probability function:;(2) For NLOS clusters, generate the ratio of visible elements based on uniform distribution
* [Huawei]: Define the attenuation factor as a function of distance between the elements and the first-bounce scatterer, the attenuation factor increases with the decreasing of distance.
* [vivo]: The size of the visibility region should be correlated to the distance between antenna array and cluster.
* [CATT]: For the modelling of spatial non-stationarity, the CDF of VR size can be modelled as an exponential distribution in horizontal and vertical dimensions respectively.
* [Apple]: VP and VR size depend on the distance between TRP and cluster
* [Qualcomm]: Randomly determined with a minimum size limit;

Moreover, [ZTE, Qualcomm] propose to also consider the ratio/probability of UEs and clusters that have SNS impact.

From FL’s perspective, majority companies consider to model the VP or VR per cluster and in rectangle, as for VR size, companies’ views are divergent, regarding the granularity and definition of visible probability or visibility region, the following is proposed:

***Proposal 2-3-1-1:***

*For the modelling of spatial non-stationarity, if visible probability or visibility region is adopted,*

* *Visible probability or visibility region is modeled per cluster*
  + *FFS Ratio of UEs and clusters that have SNS impact*
* *Rectangle can be considered as starting point for shape of VR with following alternatives to define the size:*
  + *Alt 1: VR size is defined as number of elements generated by a distribution*
    - *FFS distribution*
  + *Alt 2: VR size is determined based on distance between antenna array and cluster*
    - *Note: Cluster location is required in this alternative*
  + *Alt 3: VR size is randomly generated with a minimum size limit*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | The RAN1#116bis agreement contains the following note:  “Note: The consistency across antenna elements and across clusters should be guaranteed”.  This means that the amplitude and phase should vary smoothly across the antenna array with no discontinuities in their derivatives. It is unclear to us how the use of visibility probability or visibility regions can achieve this behavior. |
| InterDigital | In general, we prefer not to have proposals (***Proposal 2-3-1-1*** , ***Proposal 2-3-2-1***) discussing next-level options for decisions that have not been made. For example, for this case, we should first discuss and agree whether visibility probability approach or physical blocker is to be used, and then we could discuss options for the agreed proposal. |

**Consistency**

As for the correlation across antenna elements and across clusters, the following views are provided for maintaining the correlation across elements and clusters

* [Huawei]: Define the attenuation factor as a function of distance between the elements and the first-bounce scatterer so as to guarantee the consistency across elements and clusters.
* [ZTE]: Visible probability, or visibility region for set of antenna element (i.e., Option-1) cannot guarantee the consistency across antenna elements and across clusters simultaneously
* [CATT]: For the modelling of spatial non-stationarity, RAN1 FFS the relationship between the size of VR and the system central frequency, the variation of VR size with respect to the distance from the cluster to the gNB antenna array and the correlation of the adjacent clusters to the same antenna element/sub-arrays

From FL’s perspective, the method of visible probability and visibility region cannot naturally guarantee the consistency across elements and across clusters, so additional restrictions are required to maintain the correlation.

Companies are invited to provide views on how to guarantee the consistency.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | See comment above. |
|  |  |

**2.3.2 Physical blocker**

**2.3.2.1 Company View (Round-1)**

**Blocker size/shape**

Regarding the size or shape of blocker, [Fujitsu, ZTE, InterDigital, Qualcomm] propose to reuse Table 7.6.4.2-5 as definition of blocker. Additionally, the following blocker types are discussed by companies:

* [ZTE, Ericsson] mentions that to model the impact of the building, a new blocker can be considered to emulate, e.g., surrounding buildings or edge of building,
* [Nokia] proposes to further consider the impact of the self-blockage, e.g., hand, in the case as Single hand grip, dual-hand grip, and head with one hand grip.

Regarding the blocker location, [ZTE, Ericsson, Nokia] think it’s also important to consider the SNS effect at UE side, especially considering the realistic smartphone antenna pattern. Moreover, [Qualcomm] thinks single blocker between UE and BS can be considered.

From FL’s perspective, the above-mentioned details from companies can be considered in the definition of blocker.

***Proposal 2-3-2-1:***

*For the modelling of spatial non-stationarity, if physical blocker-based approach is adopted, the following additional blocker type can be considered:*

* *Building edge*
* *UE-side (self-blockage) blocker*
  + *FFS blocker types such as Single hand grip, dual-hand grip, and head with one hand grip.*
* *FFS: the number and the location of the blocker between BS and one specific UE.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | Agree |
| InterDigital | In general, we prefer not to have proposals (***Proposal 2-3-1-1*** , ***Proposal 2-3-2-1***) discussing next-level options for decisions that have not been made. For example, for this case, we should first discuss and agree whether visibility probability approach or physical blocker is to be used, and then we could discuss options for the agreed proposal. |

**Methodology**

Regarding the reusing of blockage model B, since a physical blocker is dropped, it can be used in both UE and BS side. [Intel] highlights that the Blockage Model B to consider additional blocking object types specific to 7-24 GHz frequency range and large gNB antenna aperture, e.g., bus, truck, billboard, etc. [InterDigital] supports to reuse of the existing blockage Model B as a starting point for supporting spatial non-stationary properties. [Ericsson] mentions that introducing physical blockers to model spatial non-stationarity and adapt the existing blockage model B in TR 38.901 so that it can optionally determine the blockage per antenna element.

[ZTE] highlights that the only pending point is to determine the blockage condition per antenna element, the following options are proposed:

* Option 1: Different rotations are performed so that the arrival direction of each receive antenna element of the corresponding path is always perpendicular to the screen.



* Figure x. Rotation of the blocker changes with the element pair
* Option 2: A reference antenna element pair is determined so that the arrival direction of the corresponding path is perpendicular to the screen, the blockage conditions of other element pairs can be directly determined under such rotation.



* Figure y. Rotation of the blocker is determined according to reference element pair

With the above options, whether the element pair is blocked can be determined as follows, if the sub-path intersects the screen in both top and side view, the cluster of the element pair can be determined as blocked by the screen, otherwise, the cluster of the element pair can be determined as not blocked by the screen.

Based on companies’ views, the following is proposed:

***Proposal 2-3-2-2****:*

*For the modelling of spatial non-stationarity, if physical blocker-based approach is adopted, the existing procedure of blockage model B is reused with following candidate updates to determine the blockage condition per antenna element:*

* *Option 1: For each ray/clsuter, rotating the blocker to ensure the arrival/departure direction at each Receive/Transmit antenna element is always perpendicular to the screen, respectively.*
* *Option 2: For each ray/clsuter, rotating the blocker to ensure the arrival/departure direction at the reference Receive/Transmit antenna element is perpendicular to the screen. For other antennas, the blockage conditions is determined under such rotation.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson | We have no preference but note that the two options are dependent on any progress on whether departure/arrival directions are modelled per element or not. |
| InterDigital | Same comment as the last one. |

Additionally, some other solutions are proposed by individual companies, e.g.,

* [Nokia] proposes that to model the self-blockage, introducing the new blockage model-A by replacing the 3GPP self-blocking model A with the parameter represented in Table 3.

Table 3: New proposed near-field element-wise self-blockage model for 6G.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Antenna Port** | **Added loss in Free-Space** | **Added loss for a one hand grip (Portrait)** | **Added loss for a dual hand grip (Landscape)** | **Added loss for head and one hand grip** |
| **AP#1** | 0 dB | 0 dB | 9 dB | 1 dB |
| **AP#2** | 0 dB | 0 dB | 5 dB | 3 dB |
| **AP#3** | 0 dB | 3 dB | 9 dB | 12 dB |
| **AP#4** | 0 dB | 12 dB | 5 dB | 3 dB |

* [Intel, MediaTek] mentions that the existing blockage Model A with updates can also be used to emulate the SNS. For example,
  + [Intel] proposes that the following updates to blockage Model A to incorporate spatial non-stationarity are further studied: 1). Update of the model parameters from gNB perspective defined in Table 7.6.4.1-2 of TR 38.901; 2). Disabling self-blockage when evaluated from gNB perspective; 3). Recalculation of virtual blocking screen location and dimensions for antenna elements not collocated with the antenna reference point.
  + [MediaTek] proposes that if necessary, utilize TR 38.901 spatial consistency and blockage A along with multiple antenna arrays/panels (grouping of antenna elements) to model spatial non-stationarity effects.

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
|  |  |
|  |  |

### **2.3.3 Modelling for link level simulation**

**2.3.3.1 Company View (Round-1)**

In this meeting, in addition to the discussion of system level evaluation, [ZTE] also proposes to study the link level channel model to incorporate the SNS impacts. Since the link level simulation is to emulate the propagation between BS and single UE, e.g., without consideration on consistency cross UEs and BS sites, the following diagram for link level simulation is introduced based on visible probability and visibility region approaches:



Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Ericsson |  |

# Proposals for discussion

# Conclusion

# Reference

R1-2405866 Considerations on the 7-24GHz channel model extension Huawei, HiSilicon

R1-2405885 On Channel Model Extension for FR3 InterDigital, Inc.

R1-2407201 Discussion on channel model adaptation/extension Intel Corporation

R1-2406062 Discussion on channel modelling adaptation/extension for 7-24GHz LG Electronics

R1-2406129 Discussion on the channel model adaptation and extension ZTE Corporation, Sanechips

R1-2406140 Discussion on Channel model adaptation/extension of TR38.901 for 7-24GHz Nokia

R1-2406199 Views on channel model adaptation/extension of TR38.901 for 7-24GHz vivo

R1-2406253 Discussion on channel model adaptation and extension OPPO

R1-2406385 Views on channel model adaptation/extension of TR38.901 for 7-24GHz CATT

R1-2406491 Channel model adaptation of TR 38901 for 7-24 GHz NVIDIA

R1-2406518 Discussion on channel model adaptation/extension for 7-24 GHz Fujitsu

R1-2406667 Discussion on channel model adaptation/extension of TR38.901 for 7 - 24 GHz Samsung

R1-2406742 Discussion on adaptation and extension of channel model Ericsson

R1-2406743 Discussion on near-field propagation and spatial non-stationarity BUPT, CMCC

R1-2406766 Discussion on channel modelling enhancements for 7-24GHz for NR MediaTek Inc.

R1-2406859 Channel Model Adaptation and Extension of TR38.901 for 7-24 GHz Apple

R1-2407046 Channel Model Adaptation/Extension of TR38.901 for 7-24GHz Qualcomm Incorporated

R1-2407073 Channel model adaptation/extension of TR38.901 for 7-24 GHz CEWiT

# Appendix-A

RAN1#117

|  |
| --- |
| Agreement  For the assumption on the aperture size of antenna array, the following is considered for near-field and spatial non-stationarity channel model study, e.g., simulation/measurement and calibration:   * Up to 1.5 m for UMa with maximum antenna elements in the array is [5k] for single Polarization. * Up to 1 m for UMi with maximum antenna elements in the array is [2.22k] for single Polarization. * Up to [0.71] m for Indoor factory with maximum antenna elements in the array is [1.12k] for single Polarization. * Up to [0.25 (for rectangular antenna array), 0.5 (for linear antenna array)] m for Indoor office with maximum antenna elements in the array is [138, 24] for single Polarization, respectively.   Working Assumption  For the near-field channel modeling, no changes are expected on both value and parameter generation procedure of at least following large-scale parameters in existing TR 38.901:   * Pathloss model, SF, LOS probability * FFS:DS, ASA, ASD, ZSA, ZSD, K factor   Agreement  For near-field channel, if necessary, to model the following antenna element-wise channel parameters of direct path between TRP and UE,   * Phase   with Option-2 “Determined by the antenna element locations of both TRP and UE”.  Agreement  For near-field channel, if necessary, to model the following antenna element-wise channel parameters of non-direct path between TRP and UE,   * Angular domain parameters (i.e., AoA, AoD, ZoA, ZoD), Delay, phase, Doppler shift, Amplitude * FFS: Impacts on the polarization   The following options are considered:   * Option-1: The cluster location-based approach, wherein the cluster location is obtained with following alternatives:   + Alt-1: cluster location is derived based on at least the distance between the BS/UE and clusters.   + FFS: How to obtain the distance.   + FFS: Other parameters.   + Alt-2: cluster location is directly dropped and generated. * Option-2: The parameter-based approach with following detailed alternatives:   + Alt-1: Introduce the model of variation rate of parameter over antenna elements.   + Alt-2: Modelling the variation by taking the existing spatial consistency procedure of TR 38.901 as baseline. * Option-3: The curvature-based approach.   Agreement  For the modelling of spatial non-stationarity, if necessary, the variation (e.g., reduction) of power for the impacted ray/cluster within the element-pair link should be modelled.   * FFS: The value for power variation * FFS: Impacts on the phase   Agreement  For the modelling of spatial non-stationarity, if necessary, if visible probability (VP) or visibility region (VR) is adopted, at least the following aspects should be considered for definition of VR/VP:   * Granularity of visible probability or visibility region (e.g., per cluster or per ray) * Determination of visible probability (e.g., distribution) or visibility region (e.g., size, location)   Agreement  For the modelling of spatial non-stationarity, if necessary, if physical blocker-based approach is adopted, the following aspects should be considered for definition of blocker:   * Blocker size/type:   + FFS: Additional blocker size/type compared to the Table 7.6.4.2-5 in TR 38.901.   + FFS: Different blocker sizes/types are considered to emulate the antenna element-wise blockage effect at the BS and UE side * Blocker location, e.g. distribution of the blocker, relative distance between blocker and BS or UE * FFS: Number of physical blockers to be considered.   Agreement  To align the understanding of the terminology for channel model study, the following figures are considered as the reference:   * For non-direct path:      * For direct path:     Conclusion  For near-field channel, no changes are expected on the following parameters for direct path.   * Amplitude, polarization matrix |

RAN1#116-bis

|  |
| --- |
| Agreement  The antenna array is assumed for the near-field study.  Agreement  For the study of near-field channel modelling, at least following aspects should be considered:   * Whether/How to define the near-field region * The parameters variation for each ray/cluster across different antenna element pairs   Agreement  The following scenarios defined in TR38.901 should be considered for the study/modelling of near-field.   * UMa,UMi, Indoor office and Indoor factory * FFS: RMa and other new scenarios   Agreement  For the assumption on the aperture size of antenna array, the following is considered as reference for channel model study.   * up to [TBD] m, or [TBD] lambda for UMi * up to [TBD] m, or [TBD] lambda for UMa * up to [TBD] m, or [ TBD] lambda for Indoor office * up to [TBD] m, or [TBD] lambda for Indoor factory   Agreement  For the near-field channel model:   * The impact of the assumption of wavefront is only considered from the perspective of antenna array. * The near field for each element within the antenna array is not considered in this SI.   Agreement  For near-field channel model, RAN1 strives to design a unified model to explicitly reflect the new properties of near- and existing properties of far-field under the structure of existing stochastic model TR 38.901.   * FFS: whether the same or different implementations, e.g., procedures/equations, are used for near- and far-field channel realization   Agreement  The near- or far-field condition should be studied for the direct path and non-direct paths between BS and UE.   * The near-/far-field condition for the direct path may be assessed by using the 3D BS-UE distance.   + FFS: The determination of near-/far-field condition for the non-direct paths * Note: The direct path is referring to the LoS ray in the TR 38.901 in principle. * Note: The non-direct paths are referring to the cluster/ray(s) without including LoS ray in the TR 38.901.   Agreement  For near-field channel, if necessary, to model the following antenna element-wise channel parameters of direct path between TRP and UE,   * Angular domain parameters (i.e., AoA, AoD, ZoA, ZoD), Delay, initial phase, Doppler shift, Amplitude * FFS: Impacts on the polarization   The following options are considered:   * Option-1: Determined by the locations of both TRP and UE. * Option-2: Determined by the antenna element locations of both TRP and UE   Agreement  The following scenarios defined in TR38.901 should be considered for studying/modelling of spatial non-stationarity   * UMi, UMa, Indoor office and Indoor factory * FFS: RMa and other new scenarios   Agreement  For the modelling of spatial non-stationarity, at least the following options can be studied to identify the impacted ray/cluster and element-pair link:   * Option 1: Introducing per ray/cluster the visible probability, or visibility region for set of antenna element * Option 2: Introducing the physical blocker to emulate the blockage impact on the link for each element-pair * Note: The consistency across antenna elements and across clusters should be guaranteed. |

# Appendix-B

* Near-field channel coefficient generation
* InterDigital:



* ZTE:



* CATT:



* Qualcomm:

A diagram of a process

Description automatically generated

* CEWiT:

A diagram of a cluster of data

Description automatically generated

* BUPT, CMCC:



# Appendix-C

## Spatial non-stationarity channel coefficient generation

* [ZTE]: For system level simulation, consider the following procedure



Figure 20. Channel coefficient generation procedure.

* [ZTE]: For link level simulation, consider the following procedure



Figure 28. Procedure for link level simulation of spatial non-stationarity.

* Step 0-3: Same as the existing procedure for CDL channel generation;
* Step 4: Determine how much and which clusters have SNS feature;
  + Generate the ratio of clusters with SNS features based on a normal distribution ;
  + Randomly identify which clusters/ray possess the SNS feature according to this ratio;
* Step 5: Generate VR for clusters and update the power (e.g., variation (e.g., reduction)) for invisible antenna element;
  + VR size: Use the ratio of visible elements to represent the size of VR.
    - For LOS rays, generate the ratio of visible elements based on the probability function:;
    - For NLOS clusters, generate the ratio of visible elements based on uniform distribution;
  + VR shape: Rectangular shape as an example;
  + Power: Reduced the received power of invisible elements to 0 for clusters/rays with SNS features.
* Step 6: Generate the element-wise channel coefficient;
* [Huawei]: **Step 1-10:** Generate the delays, angles, and initial phases for a pair of reference antenna elements.

**Step 10.5:** For each ray:

1. Locate the first-bounce scatterer.

* The scatterer locating approach in the section 3.4 of [4] can be referred to.

1. Calculate the visible probability as well as the distances between the first-bounce scatterer and each BS antenna elements.
2. Calculate the power attenuation factor.

**Step 11-12:** Generate channel coefficients according to formula (6)-(7) and apply pathloss and shadowing.

(6)

(7)

* [vivo]:
* For NLOS case
* For LOS case
* [CATT]: For modelling of spatial non-stationary, the steps of “Generate delay”, “Generate cluster powers” based on TR 38.901 should be modified



* [CEWiT]: According to the current TR 38.901, the channel co-efficient generation procedure comprises of 12 steps. Some of these steps are modified to incorporate the effects of Near-Field Propagation and Spatial Non-Stationarity which are elaborated as follows.

A diagram of a cluster of data

Description automatically generated