**3GPP TSG-RAN WG1 #118bisR1-24xxxx**

Hefei, China, October 14th–18th, 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,

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| * *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, RAN1#117 and RAN1#118 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.

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| 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. |

The necessity and clarification on near-field channel model have been discussed during the last several meetings, however, there was no consensus on this issue till now. The confirmation on necessity&clarification of near-field channel model is essential for the further and detailed discussion, which has been proposed and mentioned by some companies in the contribution of this meeting.

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

* [Qualcomm] highlights that the near-field modeling is to be interpreted as reference to spherical wavefront modeling.
* [Ericsson] provides the ray-tracing simulation results to show that the only a small fraction of the waves in an UMa scenario are non-spherical or non-planar, thus no need to model wavefronts that are neither planar nor spherical in the UMa scenario.
* Additionally, [Huawei, HiSilicon, InterDigital, Intel, LGE, ZTE, vivo, CATT, LGE, InterDigital, Intel, NVIADIA, Sony, Samsung, Apple] use the terminology of ‘spherical wavefront’ when discussing the near-field channel model.

According to the above summary, almost all companies share the common view that the terminology of near-field characteristics is to be interpreted as the spherical wavefront characteristics.

Regarding the justification on the necessity of near-field channel model, following views are summarized according to companies’ inputs:

* most companies [Huawei, HiSilicon, InterDigital, Intel, LGE, ZTE, vivo, CATT, NVIDIA, Samsung, MediaTek, BUPT, CMCC, OPPO, Sony, Fujitsu, Apple] share the same views that the near-field channel model shall be considered. More specifically,
  + [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.
  + [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.
  + [ZTE, BUPT, CMCC] provide the measurement 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.
  + [LGE, NVIDIA] highlight that the appropriate model and technique tailored to the characteristics of the near-field region is essential.
* [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.
* [Qualcomm] conducts the system-level simulation to evaluate the difference between the spherical wavefront modeling (SWM) and planar wavefront modeling(PWM), and proposes that there does not appear to be a strong need to introduce SWM in 38.901, and further evaluations may be required to better justify the need for introducing SWM in 38.901, e.g., the impact of modeling SWM on system-level communication metrics.

Additionally, [Fujitsu] proposes that RAN1 to discuss the deployment scenario (frequency, antenna array assumption, cell size, etc) where the effect of near-field model is significant e.g., based on the measurement/evaluation result comparison with the applied models.

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

* For the terminology: It seems that the views on the terminology of near-field of all companies are converged, i.e., spherical wavefront, shall 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.

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| Companies | Comments and Views |
| Huawei, HiSilicon | Fine. |
| Samsung | It may be somewhat premature to draw such a conclusion. The evaluations from the companies are still ongoing, and sufficient results have not yet been collected for all scenarios. After further research, we consider that it would be reasonable to reach a conclusion. So, it would be prudent to postpone this proposal. |
| vivo | According to the analysis and experiment measurements so far, the impact due to the near-field phenomenon is obvious, especially on the phase, which could effect the spatial performance significantly. Hence, it is the time to confirm modeling the near-field propagation characteristics. |
| QC | Suggest postponing/revisiting after further progress is made on modelling for non-direct paths.  Current system level sims suggest no impact to overall network performance. We need to better justify the need to include this in 38.901.  Please give companies more time, especially regarding the modelling for indirect paths. |
| Apple | Yes |
| CATT | Agree. Expect any further study will not change this conclusion. |
| LGE | Do not support.  As our comment about Proposal 1-2-1-2-1-3, we think discussed approaches for near-field channel modelling of non-direct path have several limits. We need time to further discuss on this, so (if necessary) we suggest to confirm about direct path first as follow: ***Proposal 1-1-1:*** *RAN1 confirms that the modelling of near-field propagation characteristics (i.e., characteristics of spherical wavefront) of direct path between TRP and UE is necessary.* |
| Ericsson | Don’t agree. The proponents of near-field modeling have not provided system level simulation results, only comparison of channel coefficients. It is unclear if the observed differences in channel coefficients have any impact at all on communication performance. The investigations by Ericsson and Qualcomm do not suggest that they do.  Furthermore, the proposal is lacking mention of when near-field modeling is necessary. It is clearly unnecessary for SISO simulations. If near-field modeling is added as an optional component in the TR, there should be clear guidance on when this optional component should be used. |
| Nokia | It is too soon to state that it is necessary to model the near field propagation characteristics.  However, it will be beneficial to clarify that spherical wavefront is considered for near-filed propagation. |
| ZTE | Support.  There are sufficient measurement results proving that near field effect can be clearly observed in the antenna element wise parameters, then considering that channel model is the basis for any future technology study, an accurate modelling of near field propagation should be confirmed to allow different simulation assumption in future discussion. |
| InterDigital | Support  Given all the available analysis, modeling of the NF propagation characteristics is needed. Whether such modeling is always necessary for all NF-based deployment scenario is a secondary question that can be answered only if we have an accurate NF model. |

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

### **1.2.1 Modelling for System level simulation**

#### **1.2.1.1 Small scale parameters determination**

**1.2.1.1.1 Direct path between BS and UE**

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

In last RAN1#118 meeting, following agreements have been achieved regarding the details to model the antenna element-wise channel parameters of direct path between BS and UE:

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| **Agreement**  For near-field channel, the following formula is adopted to model the phase of direct path between TRP and UE as antenna element-wise channel parameter:  ,  where the refers to the vector determined by the location of antenna element u and s. The refers to the 3D distance between reference antenna at TRP and UE side. |

In the previous 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, vivo, ZTE, CATT, LGE, BUPT, CMCC, InterDigital, Intel, Samsung, Qualcomm, Apple] propose to model the antenna element-wise angular domain parameters. More specifically,

[vivo] highlights that though the element-wise angle modeling has little impact on communication performance, the possible effects on other technical performance shall be considered[vivo, ZTE], such as positioning[LGE].

[BUPT, CMCC, ZTE] provide the measurement data of AOD to indicate that there is the angular variation among different antenna elements in the near-field channel paths.

[Samsung] highlights that the different elements within the array will experience varying angular relationships with UE, which means that the radiation power contribution of each element to the total received signal will differ, depending on its position and angle with respect to UE.

* Delay:
* [vivo, ZTE, CATT, LGE, Qualcomm, Apple] propose to model the antenna element-wise delay parameters. More specifically,

[vivo] highlights that although the element-wise delay modeling has little impact on communication performance, but it may have certain positive effects on other technical performance, such as positioning. And [LGE] highlights that in use cases that demand such precise timing measurements, modelling the antenna element-wise delay differences can be important.

[ZTE] provide the measurement delay results to show that the delay variation will exceed the delay resolution. And [CATT] highlights that delay varies significantly even within a short range, the propagation distances of different antenna element pairs are not the same, and different arrival times appear on different antenna element pairs.

[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, OPPO] propose that there is no need to model the antenna element-wise delay parameters. More specifically,

[Huawei, HiSilicon] highlight that the influence on channel coefficient of delay is negligible, and the considerable simulation complexity incurred also demotivates its modelling.

[OPPO] highlights that in typical scenarios, the delay difference among different antenna elements would be up to ~1ns, which is negligible compared to the propagation delay.

* [Samsung] mentions that even though the wavefront is non-planar, the small inter-element spacing means that the delay introduced due to distance differences is negligible, thus proposes that RAN1 to discuss whether the updates for delay is needed.
* Doppler shift:
* [vivo, ZTE, CATT, LGE, Intel, Apple] propose to model the antenna element-wise Doppler shift parameters. More specifically,

[vivo] highlights that when element-wise angle is modeled, the element-wise angle can be used directly for element-wise Doppler shift without introducing additional complexity.

[ZTE] mentions that the potential new use cases, e.g., UAV, sensing is sensitive to the accuracy of Doppler estimation along with high speed.

[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.

* [Huawei, HiSilicon] propose no change is needed on Doppler shift parameters.

[Huawei, HiSilicon] highlight that given the small antenna array is always assumed at the UE side, its impact on channel coefficient is not that noteworthy.

* [Samsung] proposes that RAN1 to discuss whether the updates for Doppler shift parameters is needed.
* [Qualcomm] provides the simulation results to show that under the different configuration of values of velocity and observation time that result in a displacement of no more than 1 meter, the impact of the Doppler term on the near-field channel model is observed to be marginal and can be deprioritized.

According to the above views, almost all companies share the same views that the antenna element-wise angular domain parameters shall be modeled.

As for the delay and Doppler shift parameters, the main reason to preclude the modelling for these parameters are that the variation is small and may be negligible. However, the variation of antenna element-wise delay and Doppler shift parameters is related to the specific simulation setup/analysis assumption, e.g., bandwidth, velocity, aperture size and etc, and the channel model will also be the basis for all potential technical study of the new use cases, e.g., positioning or sensing use cases, thus it seems to be necessary to model the antenna element-wise delay and Doppler shift parameters. Besides, the complexity to model this parameter is also limited.

Thus, following is proposed from FL’s perspective:

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

*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, delay, Doppler shift.*

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

Companies are encouraged to share your views.

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| Companies | Comments and Views |
| Huawei, HiSilicon | As well captured by FL, we support to only model antenna element-wise angular domain parameters. |
| Samsung | If companies have confirmed the impact of each parameters, we are fine with the proposal |
| vivo | Support |
| QC | Don’t support. Our simulations indicate none of the above are necessary. A large volume of academic papers also does not take these impacts into consideration.  Further, on delay, 38.901 already offers methods to address this in Section 7.6.2.  Also, since the 38.901 channel model does not translate the UE location when considering Doppler, the combination of highly location-centric aspect such as near field modelling with Doppler, but without UE translation makes for a very odd pairing.  Lots of underlying issues here. Very difficult to give the go-ahead at this moment. |
| Apple | Yes |
| CATT | OK |
| LGE | Support |
| Ericsson | Ok. For delay, the existing framework in Clause 7.6.2 of 38.901 can be extended/reused. |
| ZTE | Support.  Whether near field makes difference on these parameters highly depends on the assumption and set-up, e.g. delay depends on simulation bandwidth, doppler shift depends on UE velocity, if these parameters are not modelled, the future technology study with large bandwidth or high UE speed can not find an accurate channel model to study relevant characteristic. Furthermore, modelling these parameters can improve the accuracy of channel model with very limited additional implementation complexity. Therefore, these parameters should be modelled. |
| Mediatek | The existing framework in Clause 7.6.2 of 38.901 could be reused for delay. It could be needed to further study how to further consider spatial consistency and complexity for angular domain parameters. |
| InterDigital | Support the angular domain parameters and delay. For Doppler, we don’t seem a strong necessity and urgency. |

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

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

In last RAN1#118 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:

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| **Agreement**   * For near-field channel, no changes are expected on following parameters of the non-direct path between TRP and UE: * Polarization matrix * FFS: Amplitude   **Agreement**   * For near-field channel, if necessary, the following parameters of the non-direct path between TRP and UE should be modeled as antenna element-wise parameter. * Phase * FFS: Doppler shift, Angular domain parameters, delay   **Agreement**  For near-field channel, if necessary, the antenna element-wise channel parameters of non-direct path between TRP and UE can be determined by one of the following candidate options:   * Option-1: The antenna element-wise channel parameters are derived based on at least the distance between the BS/UE and a point associated with cluster.   + FFS: How to obtain the distance.   + FFS: Other parameters.   + FFS: association between a point and a cluster * 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.   Note: Companies are encouraged to check the Option-3 including the similarity/difference with Option-1. |

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

In this meeting, [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. Further, regarding which remaining 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, vivo, ZTE, CATT, OPPO, InterDigital, Intel, NVIDIA, Qualcomm, Apple, Samsung] propose to model the antenna element-wise angular domain parameters. More specifically,

[vivo] provides the results to show that the SGCS between the antenna element-wise angle and the antenna center-wise angle is small in some case, thus the impact of angle shall be considered.

[ZTE] provides the measurement angle results to show the angle variation among the different antennas of whole antenna array.

* [MediaTek] proposes not to model the antenna element-wise angular domain parameters.
* Delay:
* [vivo, ZTE, CATT, OPPO, Intel, NVIDIA, Qualcomm, Apple] propose to model the antenna element-wise delay parameters. More specifically,

[vivo] justifies that the SGCS between the antenna element-wise delay and antenna center-wise delay is small in some case especially with 400M bandwidth and the the antenna element-wise delay should be modeled in near field.

[ZTE] provides the measurement delay results to show that the delay variation will exceed the delay resolution, which verifies that the antenna element-wise delay of the non-direct path needs to be modeled for the near-field channel.

[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] propose that no change is needed on delay parameters. More specifically,

[Huawei, HiSilicon] highlight that the influence on channel coefficient of delay is negligible, and the considerable simulation complexity incurred also demotivates its modelling.

* [Samsung] proposes that RAN1 shall discuss whether the updates of delay is needed.
* Doppler shift:
* [Huawei, HiSilicon, MediaTek, InterDigital] propose that no change is needed on the Doppler shift parameters. Specifically,

[Huawei, HiSilicon] highlight that given the small antenna array is always assumed at the UE side, its impact on channel coefficient is not that noteworthy.

* [ZTE, CATT, OPPO, Intel, NVIDIA, Apple, vivo] propose to model the antenna element-wise Doppler shift. More specifically,

[vivo] proposes to model the antenna element-wise Doppler shift parameters if antenna element-wise angle is modeled, and highlights that though the SGCS between the antenna element-wise Doppler shift and the antenna center-wise Doppler shift is almost equal to one, if antenna element-wise angle is modeled, the antenna element-wise Doppler shift is modeled without no extra cost.

* [Samsung] proposes that RAN1 shall discuss whether the updates of Doppler shift is needed.
* [Qualcomm] provides the simulation results to show that under the different configuration of values of velocity and observation time that result in a displacement of no more than 1 meter, the impact of the Doppler term on the near-field channel model is observed to be marginal and can be deprioritized.
* Amplitude:
* [Huawei, HiSilicon, vivo, ZTE, OPPO, InterDigital, Samsung, MediaTek, Qualcomm, Apple] propose there is no need to model the antenna element-wise amplitude.

[Qualcomm] highlights that that since large scale parameters are also deprioritized, barring any major changes to the overall structure of clusters and rays and the power distribution among the rays constituting a cluster, impact of amplitude can also be deprioritized for indirect paths.

* [Intel, NVIDIA] propose that the antenna element-wise amplitude can be considered.

[Intel] proposes that the cluster power is generated according to the step 6 of TR 38.901 using the antenna element-wise cluster delays.

Additionally, [InterDigital] further proposes that the existing spatial consistency procedure of TR38.901 can be incorporated into the channel coefficient generation procedure proposed for near-field channel modeling for updating element-wise angular domain parameters due to the UE/BS mobility.

According to the majorities’ views, the antenna element-wise angular domain parameters shall be modeled. And according to the measurement&simulation data results provided by some companies, it’s better to model the antenna element-wise delay and Doppler shift parameters for the non-direct path to construct an accurate model. While for the amplitude, it’s majority views that no changes are expected on this parameter.

Then, the following FL’s proposals are provided:

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

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

* *Doppler shift, Angular domain parameters, Delay*

Companies are encouraged to share your views.

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| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilicon | As well captured by FL, we support to only model antenna element-wise angular domain parameters. |
| Samsung | Same with Proposal 1-2-1-1-1-1 |
| vivo | Support |
| QC | We don’t even have a methodology in place to understand how to handle non-direct paths.  Unclear how the FL expects companies to comment on this.  Suggest focusing on establishing a methodology for modeling and then coming back to these questions. |
| Apple | Yes |
| CATT | OK |
| Ericsson | Ok. For delay, the existing framework in Clause 7.6.2 of 38.901 can be extended/reused. |
| ZTE | Support with same reason on Proposal 1-2-1-1-1-1 |
| Mediatek | The existing framework in Clause 7.6.2 of 38.901 could be reused for delay. It could be needed to further study how to further consider spatial consistency and complexity for angular domain parameters. |
| InterDigital | Support the angular domain parameters and delay. For Doppler, we don’t seem a strong necessity and urgency. |

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

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

* *Amplitude*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilicon | Support. |
| Samsung | Support |
| vivo | Support |
| Apple | Yes |
| CATT | OK |
| Ericsson | Support |
| ZTE | Support |
| Mediatek | Support |
| InterDigital | Support |

* Issue#2: Methods to determine the antenna element-wise channel parameters of non-direct paths

In last RAN1#118 meeting, two options have been proposed regarding how to calculate the antenna element-wise channel parameters for the non-direct path. In this meeting, [vivo, LGE, Fujitsu] highlight that it’s better to down select one option from the two options considering the cost of computational complexity of simulations and the characteristics of all options. Following views are summarized according to companies’ inputs:

* Option-1: derived based on at least the distance between the BS/UE and a point associated with cluster[Huawei, HiSilicon, Ericsson, vivo, OPPO, InterDigital, Fujitsu, Samsung, Apple, BUPT, CMCC].

For this Option-1, following detailed issues are further discussed according to some companies’ inputs:

* *Sub-issue#1*: How to obtain the distance between the BS/UE and a point associated with cluster:
* [Huawei, HiSilicon, vivo] propose that the distance between the BS and the first-bounce scatterer and the distance between the last-bounce scatterer and the UE can be obtained by solving an optimization problem of minimizing the propagation distance between the first and last bounce scatterer. And such distance shall be subject to the delay value generated by existing procedure in TR38.901.

[Huawei, HiSilicon, vivo] explicitly propose that the first/last-bounce scatterer shall be located per ray. And [Huawei, HiSilicon] mentions that the and should subject to : , , where the minimum distance might be fixed according to the scenario and center frequency, e.g., 1 m for outdoor propagation and 0.1 m for indoor propagation.

[Huawei, HiSilicon, vivo, InterDigital] propose that for NLOS ray, the multi-bounce model is assumed, and the single-bounce model can be treated as a special case[vivo, InterDigital].

* [BUPT, CMCC, OPPO] propose that the distances between the clusters and the BS/UE are randomly generated according to a distribution, e.g., log-normal distribution[BUPT, CMCC].

[OPPO] mentions that for the strong NLOS cluster arrivals in small scale fading, assuming they are scattered just once. And [OPPO] further mentions that for antenna-element-wise channel cluster delays, an antenna-element- pair based variation can be added to . Or alternatively, using Option-1 to re-calculate the antenna-element-wise cluster delay.

* [Ericsson] proposes that the distance between the BS/UE and a point associated with a cluster equals the curvature of the wavefront. The curvature of the wavefront is according to a stochastic model that is fitted to ray-tracing simulations.
* *Sub-issue#2*: The association between a point and a cluster:
* [Huawei, HiSilicon] mention that such a point associated with cluster could be the image position to match the reflection characteristics.
* [Fujitsu] proposes that the center position of the clusters can be assumed as such a point associated with cluster for simplicity.
* Option-2: determined based on the existing spatial consistency procedure of TR 38.901 with updates [CATT, LGE, Intel, Qualcomm, ZTE]. Specifically,
* [CATT] proposes to reuse the existing spatial consistency procedure B of TR 38.901 for non-direct paths, which is simpler compared with spatial consistency procedure A. And the step 5,6,7 of the channel coefficient generation procedure in TR 38.901 are replaced by the steps of the spatial consistency procedure B, the element-wise channel parameters are generated by a random procedure.
* [Intel, Qualcomm] propose to reuse the existing spatial consistency procedure A.
* [MediaTek] proposes to utilize TR 38.901 spatial consistency along with multiple antenna arrays/panels (grouping of antenna elements) to model near-field effects.
* [ZTE] proposes that instead of directly reusing existing procedure, the antenna element-wise channel parameters shall be determined based on the existing spatial consistency procedure A with some updates, i.e., determine the image of antenna element at BS side, calculate the antenna element-wise angular domain parameters firstly according to the cluster delay and angular domain parameters of reference antenna element pair that generated by existing TR38.901, then calculate the antenna element-wise delay and phase parameters. While if directly reusing existing spatial consistency procedure A, i.e., calculate the delay firstly, then the angular and phase parameters, which will result in the model of antenna element-wise phase to be exactly same as the far-field channel model.
* [ZTE] also proposes a compromised way of Option-1 and Option-2. Specifically,
* For the non-direct paths assuming all interactions along the path are reflected rays, only consider one distance d between the reference antenna element of UE and a point associated with cluster, and the distance d is equal to the whole propagation distance of non-direct path between the reference antenna element pair, which shares the similar methodology as Option-2 that based on existing spatial consistency procedure A with some updates.
* Otherwise, following the Option-1 to consider the two distances between the reference antenna elements of BS/UE and a point associated with first/last scatterer shall be considered, respectively. And this two distances can be generated following a specific distribution.

While [NVIDIA] proposes that the antenna element-wise channel parameters of the indirect path between TRP and UE should be determined by the cluster location-based approach, where cluster location is directly dropped and generated in a deterministic manner. And [Samsung, Fujitsu] consider the Option-1 as a starting point, and [Samsung] highlights that the discussion can continue if Option-2 and the curvature method are able to encompass all the characteristics of the channel parameters

Furthermore, no matter which options above, the total pathlength/delay of each NLOS ray should be known, the absolute delay should be computed based on the generated relative delay, and [ZTE, Huawei, HiSilicon] highlights that the existing methods in Section 7.6.9 in TR 38.901 can be referred, where the distribution of the offset  should be given for all the scenarios, and some values for other scenarios are proposed in contribution for 9.8.1 of [ZTE].

Additionally, some companies provides the views on the Pros & Cons and the characteristics of each option, in order to better understand&evaluate the two options, the detailed views are summarized according to companies’ inputs:

|  |  |  |
| --- | --- | --- |
| Option/Alts | Pros | Cons |
| Option-1 | [vivo] highlights that Option-1 ensures that the cluster delay&angle in reference point can be consistent with the original ones.  [InterDigital] mentions that Option-1 can more accurately reflect the spherical wave effect of a NF transmission.  [Fujitsu] mentions that Option-1 is straightforward extension of the current existing model in TR 38.901 to consider change in scattering condition depending on the distance between Tx and Rx. [ZTE] highlights that though Option-1 cannot match the reflection features, it can be applicable to other propagation interaction features. | [Ericsson] mentions that the interpretation that this point coincides in direction and distance with the first (or last) interaction point in the propagation path is not consistent with the occurrence of common interactions such as specular reflections or diffractions.  [LGE] mentions that option 1 which needs to generate distances between each clusters and BS/UE is unsuitable.  [Intel] highlights that it may not guarantee a unified channel model, which incurs additional effort in 3GPP to test/validate new channel model for far-field.  [MediaTek] mentions that it requires significant experimental effort to make the model highly accurate.  [Qualcomm] mentions that Option-1 may not always guarantee a feasible cluster location without requiring changes in the generation of departure/arrival angles and it lacks of convergence between PWM and SWM at longer UE-gNB distances. |
| Option-2 | [CATT] highlights that such methods has less specs impact.  [LGE, Qualcomm] mentions that it does not require additional memory and has low computational complexity.  [Fujitsu, ZTE] mentions that option 2 can provide multiple scattering points that is more realistic assumption.  [MediaTek] highlights that this method provides a robust solution for simulating near-field characteristics without the need for a major overhaul of the entire channel model. | [Ericsson] mentions that the use of Option-2 for non-planar wavefronts is not obvious and may need to exceed the validity range of the existing spatial consistency modeling in TR 38.901.  [vivo] mentions 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. And it makes a huge change for departure angle due to the assumption of single refection point.  [Fujitsu] mentions that it is not clear how the assumption of the multiple scattering points affects the final propagation outcome when compared with option 1. |
| Similarities of two options [ZTE] | --both needs to generate distance along with a point associated with cluster  --both are based on deterministic and geometric way to calculate the antenna element-wise channel parameters  --both requires to generate absolute propagation delay | |
| Difference of two options[ZTE] | --Option 1 requires to generate 2 distances for general case while Option 2 needs to generate 1 distance.  --Option 1 calculates the Tx side parameters based on one point and calculates the Rx side parameters based on another point, Option 2 calculates the Tx side and Rx side parameters based a single point.  --In Option 1, the absolute delay is used as an upper bound to derive the distribution of distances, while in Option 2, the absolute delay will directly determine the virtual point.  --Option 1 assumes that the cluster can be modeled as a secondary point source, while Option-2 assumes all interactions along the non-direct path are based on pure reflection, neither one can perfectly represent the realistic propagation environment. | |

For the method to calculate the antenna element-wise channel parameters for the non-direct path, according to the summary above, it’s clear that this two options share some similarities&differences, and each option has its own pros&cons. According to the above summary, following are observed from FL’s perspective:

* For the Option-1: since the near-field characteristics is to be interpreted as spherical wavefront, the curvature wavefront based method is same as the way to interpret such a point associated with cluster that coinciding in direction and distance with the first/last interaction points in the propagation paths. And though the Option-1 cannot match the reflection features, it can be applicable to some other propagation features.
* For the Option-2: it should be emphasized that as proposed by [ZTE], some updates of existing spatial consistency procedure A shall be considered to calculate the antenna element-wise channel parameters of non-direct paths, since the directly use of existing procedure will result in the model of phase to be exactly same as the far-field channel model. And Option-2 can be applicable to the cases that all interactions along the NLOS path are reflection rays.

In this way, the compromised method of Option-1 and Option-2, which combines the advantages of two options and considers the applicability for different propagation features, can be considered as an reasonable method.

Then, following are proposed from FL’s perspective:

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

*For near-field channel, if necessary, the antenna element-wise channel parameters of non-direct path between TRP and UE can be derived as:*

* *For the reflected paths, the Option-2 is used, i.e., by considering only one distance d between the reference antenna element of UE and a point associated with cluster.*
  + *The distance d is equal to the propagation distance of non-direct path, which is calculated based on the absolute delay of each path.*
* *For the non-reflected paths, the Option-1 is used, i.e., two distances*  *between the reference antenna elements of BS/UE and a point associated with first/last scatterer shall be considered, respectively.*
  + *FFS: How to obtain the distance .*
* *The ratio of the reflected paths for all non-direct path is introduced per BS-UE link.*
  + *FFS: How to determine the ratio.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilcon | Not support.  Assuming the deterministic propagation environment (e.g., reflected/non-reflected paths) for the stochastic channel model is not preferred. |
| Samsung | One question regarding the proposal content. The term of 'reflected path' is unclear. We consider that the concept of reflection in an NLOS path need to be defined first.  Additionally, we have a concern about merging option 1 and option 2. As mentioned in the FL’s proposal, option 2 considers a cluster as a single point, while option 1 considers it as two points. If we combine these two methods, the channel coefficient generation will need to be bifurcated, which could increase implementation complexity. Therefore, we would like to ask whether it might be better to explore just one option. |
| vivo | Option-2 is the special case where the first scatter and the last scatter are the same. Therefore, Option-1 covers Option-2. As an implementation, we can start Option-1 to fine the locations of the first scatter and the last scatter by solving an optimization problem. If the solution does not exist (only 0.1% probability occurs), it can fall into the case of a single bounce scatter, solving the optimization problem again by changing either the angle of departure or the angle of arrival. Having both options is duplicative, and Option-2 is not necessary. |
| QC | We suggest one unified approach. The current channel model does not make any distinction between non-direct paths as reflected paths or non-reflected paths.  We prefer to not introduce these new terminologies as they have not been studied or validated.  One option could be to use Option (2) as the starting point, while allowing for an additional dithering of the distance. This ensures the radius of curvature is al least partially decoupled from the cluster location.  Option 1 with the two bounce cluster model is proving to be computationally complex and also leading to certain artifacts in the channel model reflecting its weakness. |
| Apple | Not supporting.  We do not support to separate the cases of reflected paths and non-reflected paths, which complicates the modeling.  For reflected paths, it is unclear why only the distance between UE’s reference antenna element and cluster point is considered. We should also consider the distance between gNB’s antenna element and cluster point. |
| CATT | Not support. Prefer one single solution. |
| LGE | Do not support  Before making a decision, we have to discuss first on which option can reflect real near-field propagation characteristics of non-direct paths. If near-field propagation characteristics of non-direct paths can be represented properly by one single options, we prefer to down-select one option to reduce computational complexity. |
| Ericsson | Don’t support. Unnecessarily complicated. Instead, propose to directly quantify the stochastic distributions for distances d1 and d2 through measurements or ray-tracing experiments. |
| ZTE | Support.  These 2 options have similarity on utilizing distance for geometry calculation, the difference is the definition of the point associated with the cluster.  For Option 1, two points are generated and associated with first bounce scatterer and last bounce scatterer, while the parameters at BS side are calculated with the first point and the parameters at UE side are calculated with the second point. If this multi-bounce cluster falls into a single bounce scatter, it’s still different from Option 2.    Option 1  For Option 2, As shown in the figure below, the point associated with cluster is the image of the antenna element, which is based on the specular reflection propagation. The UE side parameters are directly calculated based on this point associated with cluster, but the BS side parameters are calculated by transformation of the parameters of the point. This Option 2 can cover single bounce reflection and multi-bounce reflection, where Xn=1 refers to odd number of reflections and Xn = -1 refers to even number of reflections.    Option 2  This proposal actually combines these 2 options depending on the origin of the NLOS cluster, i.e. if reflection is the dominant origin of the propagation, Option 2 can be more accurate modelling method, otherwise, Option 1 can be considered to model the point as secondary source, that’s why the reflected path is considered as the condition to determine the options. |
| InterDigital | Okay, however as Samsung stated the terms reflected and non-reflected should be clarified (indirect and direct paths) |

#### **1.2.1.2 Channel coefficient determination**

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

In this meeting, some companies [Huawei, HiSilicon, vivo, ZTE, CATT, InterDigital, Qualcomm] provide the detailed formula of channel coefficients for the near-field channel model. Thus, according to companies’ inputs, following views are summarized:

* **For the LOS channel coefficient:**
* If modeled, the angular domain parameters:
* [Huawei, HiSilicon, ZTE, CATT, InterDigital, Intel, Qualcomm] 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, CATT, Intel, 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 , where is the delay difference between the direct path of antenna element pair and the direct path of reference antenna element pair.
* [CATT] proposes that the delay parameters can be updated to , where are the delays between transmit antenna element and receive antenna element of the direct path, and are derived by normalizing , and are drawn randomly from the formula .
* [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, vivo, ZTE] 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., , where , represents the distance between the last-bounce scatterer and Rx reference antenna element/ antenna element u, respectively; represents the distance between the first-bounce scatterer and Tx reference antenna element/antenna element s, respectively.

[ZTE] further proposes that for the case considering one point associated with cluster, the phase can be expressed as , where represents the distance between the reference antenna element of UE and point associated with cluster, represents the distance between the antenna element *u* of UE and the image of antenna element *s* of BS.

* [CATT,Intel, MediaTek, Apple, Qualcomm] proposes that the phase is expressed by
* [InterDigital] proposes that the phase is expressed by
* If modeled, the angular domain parameters:
* [Huawei, HiSilicon, ZTE, CATT, InterDigital, Intel, Qualcomm] 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, CATT, Intel, Qualcomm] proposes to update the Doppler shift to
* If modeled, the delay parameters:
* [ZTE] proposes that delay parameters can be updated to , where is the delay difference for the cluster *n* between the delay of antenna element pair and the delay of reference antenna element pair
* [CATT, Intel] proposes that the delay parameters is updated to , where is the delay calculated according to the spatial consistency procedure B[CATT], and [Intel] proposes that is the normalized delay calculated according to the spatial consistency procedure A.
* [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.
* If modeled, the amplitude parameters:
* [Intel] proposes that the amplitude can be updated to .

From FL’s perspective, since the phase for non-direct path is already agreed to modeled, the detailed changes can be discussed. Among all options and the methods to calculate the antenna element-wise phase parameters for the non-direct paths, updating the phase as following can be considered:

* For the case considering two points associated with cluster, the phase term can be expressed as:

,

where , represents the distance between the last-bounce scatterer and Rx reference antenna element/ antenna element u, respectively; represents the distance between the first-bounce scatterer and Tx reference antenna element/antenna element s, respectively.

* For the case considering one point associated with cluster, the phase term can be expressed as:

,

where represents the distance between the reference antenna element of UE and point associated with cluster, represents the distance between the antenna element *u* of UE and the image of antenna element *s* of BS.

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

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

* *For the case considering two points associated with cluster,*

*,*

*where , represents the distance between the last-bounce scatterer and Rx reference antenna element/ antenna element u, respectively; represents the distance between the first-bounce scatterer and Tx reference antenna element/antenna element s, respectively.*

* *For the case considering one point associated with cluster, the phase term can be expressed as:*

*,*

*where represents the distance between the reference antenna element of UE and point associated with cluster, represents the distance between the antenna element u of UE and the image of antenna element s of BS.*

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilicon | Can be postponed until the group has reached a consensus on Proposal 1-2-1-2-1-3. |
| vivo | Support |
| Apple | We should first determine whether a single point or two points are associated with cluster.  For the case of two points associated with cluster, we do not prefer using reference distance. Instead, the following  accurately represents the phase. |
| LGE | Same view with HW’s |
| Ericsson | This proposal is premature until Proposal 1-2-1-2-1-3 has been resolved. |
| ZTE | Support |
| InterDigital | Support |

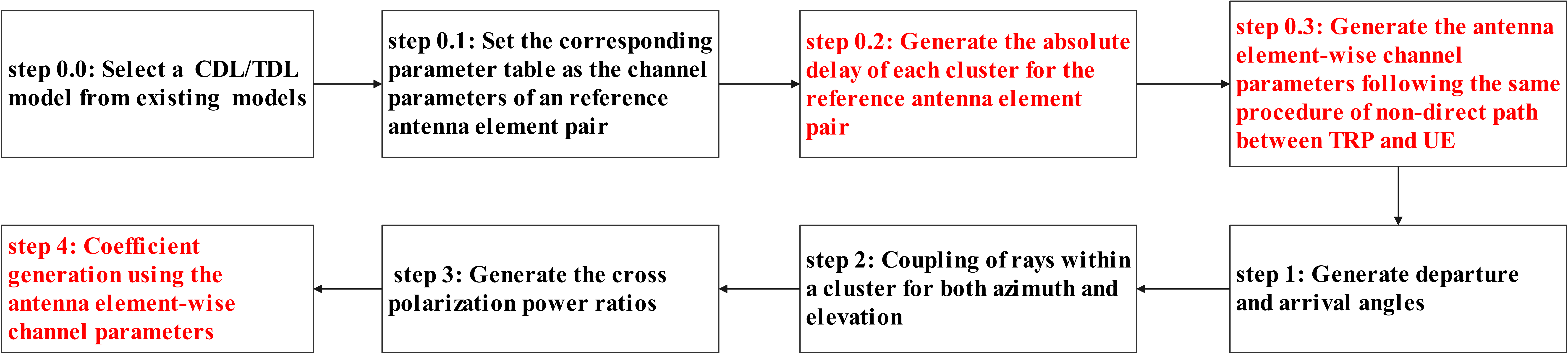
Regarding **other parameters**, companies can further share the views, e.g., comparison among different options.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Samsung | It needs to be discussed the way forward first on proposal 1-2-1-2-1-3. The detailed parameters can be discussed later. |
| vivo | For delay, angle and Doppler, the modeling way is obvious, and it can be directly used by introducing new antenna element indices of u and s, and modifying the channel response formula (for example for angle) as |
|  |  |

### **1.2.2 Modelling for link level simulation**

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

During the last several meetings, the discussion of near-field channel model have been mainly focused on the system level evaluation&procedure. While [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 following the same methods of non-direct path to obtain the antenna element-wise channel parameters. 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 |
| vivo | Support |
| Ericsson | Specific values for d1 and d2 can be tabulated for the CDL models. |

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

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

#### **1.3.1.1 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. |

The issue on whether to introduce a criteria to define the near-field region has been mentioned by some companies in last several meetings, but there has no consensus on this issue till now. And it has been discussed&proposed again by some companies in this meeting. [ZTE, CATT, Apple, Sony, LGE, Intel] highlight that the near-field region shall be defined, and [Intel] states that near-field modelling is applicable for evaluation scenarios that contain links that meet such criteria. And [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.

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

* [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.
* [Sony] compares the various definitions of the boundary between the near and far field, and proposes thatthe boundary between the near- and far-field of an antenna array should be drawn at distances about an order of magnitude smaller than the Fraunhofer distance, i.e., or so.
* [Apple] mentions that the Rayleigh distance can be used to determine the near-field region.

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 1-3-1-1:***

*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 |
| Huawei, HiSilicon | Can be postponed until the group has reached a consensus on Proposal 1-3-3-1-1. |
| vivo | Not support! This is because, whether to choose antenna-element wise channel parameters-based method or not is up to the solution in future release. From channel modeling perspective, RAN1 does not need to make any proposal or decision on it. |
| QC | We have system simulation results as well. We need to that into account when making such judgements. |
| Apple | Support |
| CATT | No need for this conclusion. Of course it ‘can’ be considered. |
| Ericsson | It needs to be clarified how such an agreement should be captured in the TR and how it would affect the channel modelling? We think this may be related to the guidance on when (optional) near-field modelling should be recommended, which ties strongly to the discussion on necessity and proposal 1-1-1. |
| ZTE | Support |
| InterDigital | This can be postponed for now. |

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

#### **1.3.2.1 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. |

Similar as the criteria issue, the near-field/far-field condition issues have also been discussed many times in previous meeting without reaching any agreements. 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. [ZTE, 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].
* 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, LGE].

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 the impact of non-direct paths needs to account not only for the BS-UE interaction but also for the BS-cluster interactions.

Then, following is proposed from FL’s perspective:

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

*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 |
| Huawei, HiSilicon | Can be postponed until the group has reached a consensus on Proposal 1-3-3-1-1. |
| Samsung | Support |
| vivo | Support |
| QC | May be best to try to answer the following question (1-3-2-1-1) first. |
| Apple | OK |
| CATT | Not support |
| Ericsson | Ok. |
| ZTE | Support |
| InterDigital | We don’t think this discussion is necessary. Once we develop an accurate NF channel model, it can seamlessly present the right channel for a given distance. |

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

*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 |
| Huawei, HiSilicon | Can be postponed until the group has reached a consensus on Proposal 1-3-3-1-1. |
| vivo | Similarly, determination of the near- or far-field condition for the non-direct paths between BS and UE is up to the solution in future release. From channel modeling perspective, RAN1 does not need to make any proposal or decision on it. |
| QC | Alt-2 may be okay if we go based on Opt 2 for indirect paths. Difficult to answer at this point. |
| Apple | Okay, and support Alt-2 |
| CATT | Alt1 for simplicity. In the end it is still statistical model whatever variation added here. |
| LGE | We think this discussion is very dependent on discussion on the Proposal 1-2-1-2-1-3. We suggest postpone this discussion until detail/necessity of modelling for non-direct paths has been confirmed. |
| Ericsson | Prefer Alt-2 but using the language of the RAN1#118 agreement: ”the distance between the BS/UE and a point associated with cluster”. Again, it should be further discussed how such a condition would be captured in the TR (see reply to Proposal 1-3-1-1). |
| ZTE | Support and prefer Alt-3. |
| InterDigital | Similar to the last proposal, we don’t think this discussion is necessary. Once we develop an accurate NF channel model, it can seamlessly present the right channel for a given distance. However, among the alternatives, Alt2 seems the most meaningful alternative. |

### **1.3.3 Methodology of channel realization**

#### **1.3.3.1 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, [OPPO] highlights that smooth transition to far field channel for near-field channel modelling, e.g. at the edge of the near-field region, shall be considered. In detail, [vivo, Intel] proposes that the same implementation are used to keep the consistency, and [vivo] provides the analysis to illustrate the additional generation burden can be ignored. And [vivo] further highlights that the unified channel model is used only in case that the near-field propagation needs to be considered in simulation. While [ZTE, CATT] 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.

Then, considering the model complexity, following are proposed from FL’s perspective

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

*The different implementations, e.g., procedures/equations, are used for near- and far-field channel realization.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilicon | Not support.  Given that the near-field channel realization introduces limited complexity, we prefer to adopt the same implementation for near- and far-field channel realization. |
| Samsung | The more discussion is needed. In real situations, near-field and far-field differ simply based on distance between BS and UE. If different implementations are applied depending on each field condition, it could indicate that the model does not accurately reflect reality. Therefore, we believe the study need to proceed in the direction of pursuing a unified model. |
| vivo | We believe that it is the unified channel model that RAN1 is developing. As we indicated, using the unified channel model does not increase the complexity too much (only 20% additional burden). The different implementation is not necessary. |
| QC | If we decide to support near field modelling, it might be best to capture it separately from the existing channel generation process. The overall framework may remain the same, but the equations may need to change. |
| CATT | Support. There is no contradiction between ‘unified channel’ model and different procedure/implementation for near/far field. |
| Ericsson | Possible complexity reduction methods should be up to companies’ implementation. |
| Nokia | If near filed modelling is decided to be specified, then we also prefer to define it separately from the existing models. However, when near-field is assumed, it should be continuity in between near-filed and far-field. |
| ZTE | If same equations are used for UEs in near field and far field, the simulation in the past based on existing 901 model for far field UE may have different observation for the simulation based on new model for far field UE, this may have impact on the existing MIMO and other technology design as well. |
| InterDigital | Don’t support, we have a similar view as Huawei. |

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 |
| vivo | Support |

## **1.4 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.
* [vivo] proposes that the RAN1 shall assume the center of antenna array as the reference point, since the position of the reference point on the antenna array may impact the performance evaluation.

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

|  |  |
| --- | --- |
| Companies | Comments and Views |
| vivo | Regarding the antenna array reference point, due to the large antenna aperture, the different reference points may result in different antenna height. This ambiguity should be avoided in performance evaluation. |

# **Views on Spatial non-stationarity**

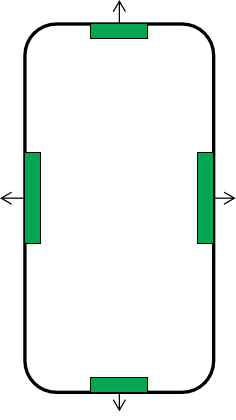
## **2.1 Necessity and clarification on UE side spatial non-stationarity**

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

According to contributions, the following views are provided on necessity of modelling spatial non-stationarity at UE side:

* [OPPO]: The antenna element-wise power variation at UE side is not needed.
* [InterDigital]: UE side antenna element blockage modeling can be supported by extension of Blockage Model A to per antenna element procedure.
* [Sony]: Modeling spatial non-stationarities, i.e., antenna element-wise power variations, at the UE side is unnecessary unless UEs, such as FWA UEs, or repeaters endowed with large physical arrays are considered for deployment in the 7–24 GHz band.
* [Fujitsu]: SNS impact at UE side is affected by the assumption on the hand holding types and UE antenna placement. If necessary, self-blockage for hand-held UEs can be additionally defined as the antenna element wise power variation.
* [Samsung]: If UE-side blockage modelling is needed, RAN1 discuss to antenna placements on the UE at first before discussing handgrip situation
* [Qualcomm]: RAN1 to consider modelling spatial non-stationarity due to partial blockage of UE antennas. Details on subsets of antennas impacted, hand grips, frequency dependency, probability of hand blockage to be discussed further. For more realistic UE antenna modeling (at least for calibration), the UE antennas are placed along the edges of a rectangle reflecting a UE form factor.
* [Nokia]: The human hand can cause element-wise blockage to the UE, which is not adequately modelled in the current TR 38.901 blockage models. The current portrait blockage model results in a significant performance gap when compared to realistic simulations of the single hand user grip case at 7.8 GHz.
* [ZTE]: Considering realistic UE antenna model as discussed in 9.8.1, the UE antennas can be placed at the center of the four edges, so as to take advantage of the device’s form factor and avoid interference from the user’s hand. Considering the revised UE antenna model, the aperture of the UE antenna could resemble that of a large antenna array, thereby making it imperative to account for spatial non-stationarity characteristics at the UE side.

According to the companies’ contributions, the following realistic UE antenna placements from [ZTE, Qualcomm, Samsung] can be shown as example for further consideration of UE side SNS.

A screen shot of a black background

Description automatically generated

Figure 2-1 Typical UE antenna placement

From FL’s perspective, based on realistic UE antenna model, the distance between different UE antenna elements is quire large so that the hand or head type blocker may probably have per element blockage impact. Based on the above observations, the following proposal is provided:

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

*The spatial non-stationarity characteristics at UE side, i.e., the antenna element-wise power variation, is supported in the channel modelling.*

Moreover, the detailed solutions for modelling the SNS at UE side can refer to the discussion in section 2.2.2.1 based on Blockage model B and the discussion in section 2.2.2.3 based on Blockage model A.

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilicon | Not support.  From our understanding, the impact of hand gripping, which embodies in the reactive region, is not appropriate to be classified as “spatial non-stationarity characteristics”. If companies really eager to specify its impact, UE antenna model discussion under AI 9.8.1 maybe a better place. |
| vivo | Support |
| QC | Support |
| CATT | Not support. De-prioritize UE side . |
| Ericsson | Support. If supported at the TRP then it is trivial to also support at the UE. |
| Nokia | Support |
| ZTE | Support.  UE antenna model may be introduced under AI 9.8.1 to reflect realistic UE antenna design, based on this assumption, it may further be impacted by the SNS, since the spacing between the UE antenna elements will be quite large. That is to say, the UE antenna model in 9.8.1 is the basis for the modelling UE side SNS. |
| Mediatek | Support |
| InterDigital | Not support, should deprioritize UE side. |

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

In RAN1#118, the following agreements regarding the methodology of SNS are achieved:

|  |
| --- |
| Agreement  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 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: * Adopt the existing knife edge attenuation model in TR 38.901 in blockage Model-B to model the power attenuation per element with following update as: * For each ray/cluster, rotating the blocker to ensure the arrival/departure direction at each Receive/Transmit antenna element is always perpendicular to the screen, respectively. * FFS: applicability and details for blockage Model-A   Agreement  For the modelling of spatial non-stationarity, if physical blocker-based approach is adopted, the following additional blocker type can be considered for blockage model B:   * Building edge for outdoor scenario * Small object, e.g., billboard, street lamp, pillar, for either indoor or outdoor scenario * FFS: UE-side (self-blockage) blocker for both indoor and outdoor scenario * Details, e.g., 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.  FFS: applicability and details for blockage Model-A  Agreement  For the modelling of spatial non-stationarity, if visible probability or visibility region is adopted,   * Visible probability or visibility region is modelled 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 derived based on distance between antenna array of BS and UE/cluster * Note: Cluster location is required in this alternative * Alt 3: VR size is randomly generated with a minimum size limit |

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, BUPT, CMCC, Qualcomm, ZTE, CATT, Apple
* 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, OPPO, NVIDIA, Samsung

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.

**2.2.1 Visible probability or visibility region**

According to the progress in last meeting, the following FFS parts are identified for remaining details of VP or VR based solution:

* Power attenuation factor
* Ratio of clusters with SNS impact
* Visibility region generation

#### 2.2.1.1 Power attenuation factor

##### 2.2.1.1.1 Company View (Round-1)

Based on companies’ views, the following details are proposed by companies on power attenuation factor:

* [Huawei]: the power attenuation factor is modelled as below:

where represents the distance between Tx antenna element and the first-bounce scatterer, and represent the minimum and maximum value among all , respectively, and C represents the roll-off coefficient between the visible and invisible region.

* [Ericsson]: The visibility probability/region approach to spatial non-stationarity lacks measurement data for validation and modeling methods to guarantee continuous power variations across the array.
* [vivo]: knife-edge diffraction model can be used to model the power attenuation factor within [0 1].
* For NLOS case
* For LOS case
* [CATT]: For the modelling of spatial non-stationarity, if a cluster is invisible for an antenna element, its power attenuation factor is modeled as: (1) Set to 0 (preferred). (2) A high attenuation factor, for e.g. -30 dB (optional modeling method). If attenuation factors affecting the transition across the edges of a visibility region are shown to be necessary, the power attenuation factor at the center of the VR can be 1, and the power attenuation factor at the edge of the VR can be 0. The attenuation factor in the middle area within [0 1] is calculated according to the distance from the center of the VR.
* [BUPT, CMCC]: The power attenuation factors along different antenna elements follows a normal distribution.
* [InterDigital]: The variation (e.g., reduction) of power for the impacted ray/cluster within the element-pair can be enhanced and introduced for modelling spatial non- stationarity of the channel. In addition, we can introduce a parameter, , as an indicator of path status, e.g., visible (reflection or direct path), non-visible/blockage or diffraction. For example,
* [Qualcomm]: If spatial non-stationarity is to be modeled on the gNB side, consider the following options for attenuation modelling outside the visibility regions:
* Option A: Portions of the array that fall outside the visibility region of a cluster do not see any paths to/from that cluster i.e., a binary determination.
* Option B: Portions of the array that fall outside the visibility region of a cluster see paths to/from that cluster with a high attenuation factor, for e.g. 30 dB.
* FFS: attenuation factors governing the transition across the edges of a visibility region
* [Apple]: For the modelling of spatial non-stationarity with the VP and VR approach, the power attenuation factor is equal to VR over the total number of TRP antennas.

From FL’s perspective, companies’ views are quite divergent, it seems more important to align the understanding on whether the power attenuation factor is the same or different for the antenna elements outside visible region, then the detailed solution can be further studied. Then, the following is proposed:

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

*For the modelling of spatial non-stationarity, down-select from the following options regarding the power attenuation factor:*

* *If visibility region is adopted, i.e. the visibility region is explicitly generated,*
  + *Option 1: The power attenuation factor is the same for the antenna elements outside of the visible region*
    - *The power attenuation factor is equal to VR over the total number of TRP antennas.*
  + *Option 2: The power attenuation factors are different for the antenna elements outside of the visible region*
    - *The power attenuation factor for an antenna element is calculated according to the distance from the center of the VR to the antenna element.*
* *If visible probability is adopted, i.e. the visibility region is not explicitly generated,*
  + *Option 1: The power attenuation factor is calculated based on knife edge diffraction model.* 
    - *FFS: details on how to apply the knife edge diffraction model*
  + *Option 2: The power attenuation factor is a function of the distance from antenna element to cluster location.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilicon | Given that a certain visibility region can be treated as a candidate consequence of visible probability, here we would like to add the following note:  *Note: the power attenuation factor for the fusion of visible probability and visibility region is not precluded.* |
| vivo | First of all, Option-1 should be modified as  Option 1: The power attenuation factor is the same for the antenna elements ~~outside~~ inside of the visible region.  Moreover, the power attenuation factor relies on the VR determination method. For example, using knife-edge diffraction model determines the power attenuation factor could generate the value between 0 and 1, even inside of VR. Therefore, it is too early to agree on this proposal.  Also, at this moment, it is too early to down select two options. We need to focus on the discussion between VR/VP and blockage schemes. |
| QC | Our understanding is that the visibility region approach is stochastic in nature. It may not be possible to apply the knife edge diffraction model.  We either adopt a physically consistent approach such as Blockage model B OR  Adopt a purely stochastic approach via the visibility region approach.  Might be best to not mix the stochastic components and physical components.  A separate discussion on whether we can adopt both the methods is also encouraged. |
| Apple | We prefer visible region approach as it is accurate. For the VR approach, we think Option 1 is simple and can be used. |
| CATT | Prefer further simplify the model. |
| Ericsson | There is no agreement that either of visibility region or visible probability is adopted. The main bullet needs to continue to reflect this. |
| ZTE | Companies’ views are quite divergent, it’s not clear on the details of some the options which may need further clarification. For example, how can knife edge attenuation model can be used with VR based solution, does it mean that the cluster is modelled as a circle or a rectangle? |
| InterDigital | As indicated by other companies, the proposal is not clear, need to re-formulate it. |

#### 2.2.1.2 Ratio of clusters with SNS impact

##### 2.2.1.2.1 Company View (Round-1)

Based on companies’ views, the following details are proposed by companies on Ratio of clusters with SNS impact:

* [Huawei]: For each ray, calculate visible probability and power attenuation factor
* [vivo]: There are about 25% of the clusters could be fully or partially impacted by the spatial non-stationarity in indoor scenario.
* [ZTE]: For the clusters of a UE, the ratio of clusters with SNS feature follows the normal distribution, e.g., ;

From FL’s perspective, limited companies provide results on how to determine the ratio of clusters with SNS impact, to simplify the issue, normal distribution can be adopted for the ratio of clusters with SNS impact, then, the following is proposed:

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

*For the modelling of spatial non-stationarity, if visible probability or visibility region is adopted, the ratio of clusters with SNS impact follows normal distribution.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilicon | Not support.  According to the observation in R1-2407684, the visible probability depends on the power of ray/cluster, which cannot be simply fitted by a normal distribution. |
| vivo | We are fine to define the ratio of clusters, but not sure of the exact distribution. It should be FFS. |
| QC | We may need more study. Preliminary ray tracing sims suggest that indirect paths/clusters that go through multiple reflections are the ones that may exhibit SnS. This would suggest that there is some correlation between cluster delay and SnS. |
| CATT | FFS distribution details. |
| Ericsson | Don’t agree. Further measurement data needed to progress. |
| ZTE | Fine |
| Mediatek | More measurement and simulation results could be needed. |
| InterDigital | We first need to make a decision as whether VP/VR should adopted. Once the decision is made, then we could discuss such details. |

#### 2.2.1.3 Visibility region generation

##### 2.2.1.3.1 Company View (Round-1)

Based on companies’ views, the following details are proposed by companies on visibility region generation based on the 3 alternatives agreed in last meeting:

* Alt 1:VR size is defined as number of elements generated by a distribution
  + [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 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;
  + [Huawei]: VP model can be fitted in the following exponential-distribution form:
* Alt 2: VR size is derived based on distance between antenna array of BS and UE/cluster
  + [OPPO]: For the modelling of spatial non-stationarity, if visible probability or visibility region is adopted, VR size is derived based on distance between antenna array of BS and cluster/UE.
  + [InterDigital]: Support Alt2, where VR size is derived based on the distance between the antenna array of BS and UE/cluster.
  + [Apple]: For the modelling of spatial non-stationarity, consider adopting the visible probability (VP) or visibility region (VR) approach, VP and VR size depend on the distance between TRP and cluster (i.e., Alt 2)
* Alt 3: VR size is randomly generated with a minimum size limit
  + [CATT]: For the modelling of spatial non-stationarity, support Alt3 to define VR size. Alt3: VR size is randomly generated with a minimum size limit.
  + [Qualcomm]: If spatial non-stationarity is to be modeled on the gNB side, visibility regions are assumed to be rectangular in shape. Visibility regions of a cluster are randomly determined with a minimum size limit.

Moreover, [vivo] proposes that VR or VR size may not necessarily need to be explicitly modeled or provided as a parameter for channel modeling, and instead, VR or VR size can be indirectly implemented by modeling ray/cluster power on each element-pair link (e.g., by knife-edge diffraction model). After obtaining the power of a cluster on all Tx antennas, the size of the corresponding VR can be figured. However, it’s not clear to FL how to use knife-edge diffraction model in VR solution.

These 3 alternatives have similar amount of support from companies, among these 3 options, Alt 2 requires deterministic cluster location which may not be acquired in link level simulation, Alt 3 is absolutely random generation, Alt 1 is more aligned as existing stochastic model for generating a parameter following a specific distribution. Therefore, the following is proposed:

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

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

* *Alt 1 is adopted, i.e. VR size is defined as number of elements generated by a distribution*
  + *FFS distribution*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| vivo | Similar to the answer in 2-2-1-1, at this moment, it is too early to make the down selection from two options. We need to focus on the discussion between VR/VP and blockage schemes. |
| Apple | Not support.  We think Alt 2 does not require the deterministic cluster location. Here, we only need the distance between antenna array of BS and UE/cluster. Considering this approach gets most supports, we think it could be considered. |
| Catt | Support. |
| ZTE | Support. |
| InterDigital | Our preference is Alt2 which is supported by majority of companies. Also, FL statement “Alt 2 requires deterministic cluster location which may not be acquired in link level simulation” is not accurate. |

**2.2.2 Physical blocker based approach**

According to the agreements in last meeting, the power attenuation can reuse the knife edge attenuation model in TR 38.901, and the extension of blockage model B to antenna element-wise model has also been accomplished, therefore, the remaining issues include the following:

* New blocker type/size
* Number and location of blocker
* Applicability of blockage model A

#### 2.2.2.1 New blocker type/size

##### 2.2.2.1.1 Company View (Round-1)

According to companies’ contributions, the following views are provided on the new blocker type/size:

* [ZTE]: the following blocker type/size can be introduced for both BS side and UE side:

**Table 7.6.4.2-5: Recommended blocker parameters**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Typical set of blockers** | **Blocker dimensions** | **Mobility pattern** |
| **Indoor; Outdoor; InF** | Human | Cartesian: w=0.3m; h=1.7m | Stationary or up to 3 km/h |
| **Outdoor** | Vehicle | Cartesian: w=4.8m; h=1.4m | Stationary or up to 100 km/h |
| **InF** | AGV | Cartesian: w=3m; h=1.5m | Up to 30 km/h |
| **InF** | Industrial robot | Cartesian: w=2m; h=0.2m | Up to 3 m/s |
| **Outdoor** | Billboard | Cartesian: w=2.4m; h=3.6m [5] | Stationary |
| **Outdoor** | Street lamp | Cartesian: w=0.4m; h=0.8m [6] | Stationary |
| **Indoor** | Pillar | Cartesian: w=0.3m; h=3m [7] | Stationary |
| **Indoor;Outdoor** | Human hand | Cartesian: w=0.2m; h=0.1m [8] | Stationary |
| **Indoor;Outdoor** | Human head | Cartesian: w=0.24m; h=0.20m [8] | Stationary |

* [CATT]: For the modelling of spatial non-stationarity, if physical blocker-based approach is adopted and new blocker types are modelled, the modelling of new blocker types can follow Table 7.6.4.2-5 in TR 38.901 by changing the parameters and limiting the height of the center of building edge for outdoor scenario.
* [InterDigital]: Extend blockers Type for blockage Model B method (TR 38.901, 7.6.4.2) to include other objects such as billboard, streetlamp, pillar, for either indoor or outdoor scenario, if their block size can be regulated as rectangular shape.
* [Intel]: 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.
* [NVIDIA]: Blockers, including building edges and small objects such as billboard, streetlamp, and pillar, are generated with deterministic locations, shapes and sizes in an environment and used to model spatial non-stationarity across BSs and UEs in the environment.
* [Qualcomm]: If spatial non-stationarity at the gNB-side is modeled using blockage models, aim to reuse the existing blockage model B in 38.901 with potential changes to attenuation models to better suit spatial non-stationarity. Further the following recommendations are made:
  + blocker type: rectangular screens
    - FFS: how to determine rectangular screens to model building edge
      * screens located closer to gNB ( < 20m)
      * screens have similar height as gNB
      * screens have very large width
* [Nokia]: Consider adding the element-wise blockage model for single hand grip, dual-hand grip, and head with one hand grip cases.

From FL’s perspective, it’s agreed to introduce billboards, pillars, street lamp in last meeting, it’s straightforward to discuss the exact width and height to capture these blocker types in Table 7.6.4.2-5. In addition, companies also show interest on UE side SNS since new realistic UE antenna model has been agreed in 9.8.1, then the new UE side blocker types such hand and head can be introduced, and based on the blockage model B, the UE side SNS can be easily evaluated by dropping the UE side blocker near the UE. As for blockage model A, a virtual screen may also need to be generated to extend to antenna element-wise blockage region, the blocker dimensions of UE side blocker may also be needed. Therefore, the following is proposed:

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

*For the modelling of spatial non-stationarity, if physical blocker-based approach is adopted, at least for blockage model B, the following new blocker type/size can be introduced in the Table 7.6.4.2-5 in TR 38.901:*

|  |  |  |  |
| --- | --- | --- | --- |
|  | *Typical set of blockers* | *Blocker dimensions* | *Mobility pattern* |
| *Outdoor* | *Billboard* | *Cartesian: w=2.4m; h=3.6m* | *Stationary* |
| *Outdoor* | *Street lamp* | *Cartesian: w=0.4m; h=0.8m* | *Stationary* |
| *Outdoor* | *Building edge* | *Cartesian: w=X m; h=Y m* | *Stationary* |
| *Indoor* | *Pillar* | *Cartesian: w=0.3m; h=3m* | *Stationary* |
| *Indoor;Outdoor* | *Human hand* | *Cartesian: w=0.2m; h=0.1m* | *Stationary* |
| *Indoor;Outdoor* | *Human head* | *Cartesian: w=0.24m; h=0.20m* | *Stationary* |

* *FFS: the value of X and Y for the blocker dimensions of building edge is needed.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Samsung | Support |
| QC | Prefer to leave human hand and head out of this list as they may need to be treated differently from the other objects. Might be best to have further discussion under UE-side SnS and how to model it. |
| Ericsson | Ok. |
| ZTE | Support.  Moreover, with the addition of new blocker types and sizes, the physical blocker based solution actually is complete for both BS side and UE side, the blocker can be dropped either near the UE or near the BS. |
| InterDigital | We first need to decide on use of physical blocker approach, then the supported types can be discussed. |

#### 2.2.2.2 Number and location of blockers

##### 2.2.2.2.1 Company View (Round-1)

According to companies’ contributions, the following views are provided on the number and location of blockers:

* [ZTE]: For BS side blockers, same as existing Blockage model B, the number of blockers (), their vertical and horizontal extensions ( and ), locations are all simulation assumptions, to allow different blocking scenarios to be constructed depending on the need of the particular simulation study. For UE side blockers, up to two nearest human hand-type blockers or one human head-type blocker may be adequate.
* [CATT]: For the modelling of spatial non-stationarity, if physical blocker-based approach is adopted, the number of blockers between BS and one specific UE should be limited, e.g. up to 4 blockers. The location of blockers between BS and one specific UE can be uniformly distributed among a circle. The center of the circle is BS location and the radius of the circle is the distance between BS and the specific UE.
* [InterDigital]: TR 38.901 blockage Model B method for introducing physical blocker location and size can be used to emulate the antenna element wise blockage effect for spatial non-stationary property.
* [Qualcomm]: Dropping adequate number of blockers to model the environment/scenario of interest. Further following recommendations are made:
  + blocker type: rectangular screens
    - FFS: how to determine rectangular screens to model building edge
      * screens located closer to gNB ( < 20m)
      * screens have similar height as gNB
      * screens have very large width

As mentioned by companies, in existing Blockage model B, the number of blockers, and locations are parameters in simulation assumptions depending on the evaluated scenario and technologies, then for BS side SNS, these 2 parameters can also be left for future simulation assumption discussion. While for UE side SNS, since 2 hands and one head are the main blockers, it’s reasonable to assume at most 2 hand type blockers and 1 head type blocker.

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

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

*For the modelling of spatial non-stationarity, if physical blocker-based approach is adopted, for blockage model B:*

* *For BS side SNS, number of blockers and locations are simulation assumptions same as existing blockage model B*
* *For UE side SNS, at most 2 hand type blockers and one head type blocker for a specific UE can be used in simulation*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilicon | Not support.  Similar to the response to proposal 2-1-1, considering BS side SNS is enough. |
| Samsung | At least for BS-side (main and 1st sub-bullet) consideration, we are okay |
| QC | Looks okay. |
| Ericsson | Support. |
| ZTE | Support |
| InterDigital | Ok with BS side, but should deprioritize UE side. |

#### 2.2.2.3 Applicability of blockage model A

##### 2.2.2.3.1 Company View (Round-1)

According to companies’ contributions, the following views are provided on the applicability of blockage model A:

* [ZTE]: For blockage model A, there is no actual blocker dropped for this model, instead, the blockage conditions are determined in a stochastic way based on the cluster’s directions and angular blocking regions, without knowledge of the blocker's location and size, the Blockage model A is not applicable to be extended to generate antenna element-wise blockage conditions to model spatial non-stationarity characteristics.
* [CATT]: Blockage model A adopts a stochastic method for capturing human and vehicular blocking, while model B adopts a geometric method for capturing e.g., human and vehicular blocking. Blockage model B is more realistic than model A, blockage Model-A is not supported.
* [Intel]: The following updates to blockage Model A to incorporate spatial non-stationarity are adopted:
  + Update of the model parameters from gNB perspective defined in Table 7.6.4.1-2 of TR 38.901,
  + Disabling self-blockage when evaluated from gNB perspective,
  + Recalculation of virtual blocking screen location and dimensions for antenna elements not collocated with the antenna reference point
    - For each ray/cluster, rotate the virtual blocker screen to ensure the arrival/departure direction at each Receive/Transmit antenna element is always perpendicular to the screen.
* [Samsung]: If the need for Model A arises, it would be necessary to first discuss how the blocking areas for both the building edges and individual antenna elements will be established under non-self blocking, similar to what was mentioned during the discussions about Model B.
* [MediaTek]: Blockage model A, when integrated into this framework, efficiently simulates the impact of obstacles such human bodies that may obstruct the path between the transmitter and receiver, causing attenuation effects. This model uses stochastic methods to represent the random nature and distribution of these obstacles, complementing the spatial consistency model by ensuring that the effects of blockages are consistently applied across different antenna elements.
* [Qualcomm]: Given that there is some precedence in modelling blockage on the UE side in Section 7.6.4.1 of 38.901, suggest using this section as a starting point for modelling SnS due UE-antenna blockage.
* [Nokia]: The current portrait blockage model A can be used to represent human body (torso) blockage.

Additionally, [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 |

Companies still want to extend blockage model A for modeling UE side SNS since this model is originally UE side model, and self-blockage region has been defined in this model. Although blockage model B as a geometry based solution can be used for both BS and UE, blockage model A can also be an alternative dedicated for UE side SNS in a stochastic way. As for the power attenuation, rather than introducing a specific value for each port as in Table 3 above, the existing formulas may be reused by taking into account the realistic UE antenna placement to better align with existing blockage model A.

From FL’s perspective, the following is proposed:

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

*For the modelling of spatial non-stationarity, if physical blocker-based approach is adopted, blockage model A can also be used for modelling UE side SNS with the following updates:*

* *Recalculation of virtual blocking screen location and dimensions for antenna elements not collocated with the antenna reference point*
  + *For each ray/cluster, rotate the virtual blocker screen to ensure the arrival/departure direction at each Receive/Transmit antenna element is always perpendicular to the screen.*

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Samsung | The discussion for necessity of UE-relevant modeling is needed, first |
| QC | More discussion may be needed. We do see the merits of the approaches being proposed by Nokia. Might be good to draw a more generation proposal with multiple options. |
| Ericsson | The main difference between Blockage models A and B is that the former only represents the blocker in the angular domain, i.e. which angular intervals that are blocked. To make this model reflect that different parts of the antenna array will see the blocker in slightly different directions, model A needs to be complemented with a distance to the blocker. But then it becomes more or less identical to model B. So there appears to be no need to consider both models separately. |
| ZTE | Support |
| Mediatek | Support. Spatial consistency and the relative antenna locations between UEs and gNBs could be considered to model/generate the slightly different blockage directions between UE antennas and gNB antennas. |
| InterDigital | We first need to make a decision on use of physical blocker approach, then the basis for blockage types can be discussed. |

## 2.3 Others

### **2.3.1 Cause of SNS**

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

According to companies’ contributions, the following views are provided:

* [Huawei]: First, the blockage effect caused by obstacles may lead to that multipaths can only be received by part of antenna elements in the antenna array. Second, when the physical size of an obstacle is smaller than that of the antenna array (i.e., incomplete scatterer), incomplete reflection, diffraction or scattering may happen in large antenna array.
* [vivo]: The causes for spatial non-stationary characteristics include: (1). Blockage: the object with relative limited size might not completely block the entire antenna array with a large aperture. (2). Non-blockage: the object with relative limited size in the propagation environment might no longer serve as the complete scatterer for the entire antenna array with a large aperture.
* [LGE]: For the modelling of spatial non-stationarity, impact of incomplete scatterer should be modelled.
* [BUPT, CMCC]: In obstructed environment, occlusion is the main cause of the spatial non-stationary phenomena of channel parameters on the array. In non-obstructed environment, power fluctuations are also observed and incomplete scattering is the main cause of the spatial non-stationarity.
* [InterDigital]: The non-direct path in a cluster may not be visible even without a physical blocker in the channel propagation due to the power variation caused by difference in angular domain parameters.
* [Qualcomm]: Spatial non-stationarity may arise due to limited visibility (depending on the dimensions of a reflectors/scatterer) or due to blockage (a physical entity obstructing the view of a portion of the array).

Companies are encouraged to share your views.

|  |  |
| --- | --- |
| Companies | Comments and Views |
| Huawei, HiSilicon | Based on companies’ input, we suggest the following observation:  *Observation*  *According to the inputs from multiple sources, incomplete scatterer may cause the spatial non-stationarity.* |
| Ericsson | Limited dimension of some scatterers may be of secondary importance to blocking. |
| InterDigital | We could postpone the discussion on this for now. |

### **2.3.2 Modelling for link level simulation**

**2.3.2.1 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 |
| vivo | The SNS due to either incomplete reflection or blockage occurs in wireless channel. The incomplete reflection and blockage are completely different phenomena, and modeling SNS for both phenomena does not conflict to each other. Therefore, RAN1 should model SNS for SLS simulation in consideration of both phenomena. |
| Ericsson | Better to use blocking model which already supports CDL. |

# Proposals for discussion

# Conclusion

# Reference

R1-2407684 Considerations on the 7-24GHz channel model extension Huawei, HiSilicon

R1-2407803 Discussion on adaptation and extension of channel model Ericsson

R1-2407875 Views on channel model adaptation/extension of TR38.901 for 7-24GHz vivo, BUPT

R1-2407932 Discussion on the channel model adaptation and extension ZTE Corporation, Sanechips

R1-2408061 Discussion on channel model adaptation/extension of TR38.901 for 7-24GHz CATT

R1-2408089 Discussion on channel modelling adaptation/extension for 7-24GHz LG Electronics

R1-2408096 Discussion on modeling near-field propagation and spatial non-stationarity in TR38.901 for 7-24GHz BUPT, CMCC

R1-2408156 Channel model adaptation and extension for 7-24GHz OPPO

R1-2408196 Discussion on Channel Model Extension for FR3 InterDigital, Inc.

R1-2408284 Discussion on channel model adaptation/extension Intel Corporation

R1-2408389 Channel model adaptation of TR 38901 for 7-24 GHz NVIDIA

R1-2408422 Discussion of channel model adaptation/extension of TR38.901 for 7–24GHz Sony

R1-2408499 Discussion on channel model adaptation/extension for 7-24 GHz Fujitsu

R1-2408660 Discussion on channel model adaptation/extension of TR38.901 for 7 - 24 GHz Samsung

R1-2408705 Discussion on channel modelling enhancements for 7-24GHz for NR MediaTek Inc.

R1-2408864 Channel Model Adaptation/Extension of TR38.901 for 7-24GHz Qualcomm Incorporated

R1-2408896 Discussion on Channel model adaptation/extension of TR38.901 for 7-24GHz Nokia

R1-2408485 On Channel Model Adaptation and Extension of TR38.901 for 7-24 GHz Apple

# Appendix-A

RAN1#118

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| Agreement  Previous agreement made in RAN1#117 is updated 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 256, 80 for single Polarization, respectively.   Agreement  Confirm the following working assumption made in RAN1#117.  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 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:   * DS, ASA, ASD, ZSA, ZSD, K factor   Agreement  The spatial non-stationarity characteristics, i.e., the antenna element-wise power variation at least at BS side, is supported in the channel modelling.  FFS: the antenna element-wise power variation at UE side  FFS: the causes and details of methodology for modelling the spatial non-stationarity characteristics   * Agreement * For near-field channel, no changes are expected on following parameters of the non-direct path between TRP and UE: * Polarization matrix * FFS: Amplitude   Agreement  For near-field channel, the following formula is adopted to model the phase of direct path between TRP and UE as antenna element-wise channel parameter:  ,  where the refers to the vector determined by the location of antenna element u and s. The refers to the 3D distance between reference antenna at TRP and UE side.  Agreement   * For near-field channel, if necessary, the following parameters of the non-direct path between TRP and UE should be modeled as antenna element-wise parameter. * Phase * FFS: Doppler shift, Angular domain parameters, delay   Observation  According to the inputs from multiple sources, partial blockage effect may cause the spatial non-stationarity.  Agreement  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 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: * Adopt the existing knife edge attenuation model in TR 38.901 in blockage Model-B to model the power attenuation per element with following update as: * For each ray/cluster, rotating the blocker to ensure the arrival/departure direction at each Receive/Transmit antenna element is always perpendicular to the screen, respectively. * FFS: applicability and details for blockage Model-A   Agreement  For the modelling of spatial non-stationarity, if physical blocker-based approach is adopted, the following additional blocker type can be considered for blockage model B:   * Building edge for outdoor scenario * Small object, e.g., billboard, street lamp, pillar, for either indoor or outdoor scenario * FFS: UE-side (self-blockage) blocker for both indoor and outdoor scenario * Details, e.g., 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.  FFS: applicability and details for blockage Model-A  Agreement  For near-field channel, if necessary, the antenna element-wise channel parameters of non-direct path between TRP and UE can be determined by one of the following candidate options:   * Option-1: The antenna element-wise channel parameters are derived based on at least the distance between the BS/UE and a point associated with cluster.   + FFS: How to obtain the distance.   + FFS: Other parameters.   + FFS: association between a point and a cluster * 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.   Note: Companies are encouraged to check the Option-3 including the similarity/difference with Option-1.  Agreement  For the modelling of spatial non-stationarity, if visible probability or visibility region is adopted,   * Visible probability or visibility region is modelled 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 derived based on distance between antenna array of BS and UE/cluster * Note: Cluster location is required in this alternative * Alt 3: VR size is randomly generated with a minimum size limit |

RAN1#117

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| 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

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| 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
* ZTE:



* CATT:



* Qualcomm:

A diagram of a process

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: Generate the power of cluster/ray with SNS impact based on power attenuation factor.
* 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 the spatial non-stationary, if VR-based approach is supported, the VR of the cluster at the antenna array can be applied in the step of “Generate cluster powers”. All the parameters are generated to model the VR for each cluster, such as location and size. Since the granularity of VR is per cluster, the effect of VR can be modelled of in the step of “Generate arrival & departure angle”.



* [BUPT, CMCC]: For modeling the effect of power variation caused by spatial non-stationary in 3GPP 38.901-based step-wise channel coefficient generation procedure, the power attenuation factorcan be introduced into the channel impulse response, as follows:

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