**3GPP TSG RAN WG1 #121 *R1-250xxxx***

**St Julian’s, Malta, May 19th – 23rd, 2025**

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| *CR-Form-v12.2* | | | | | | | | |
| **CHANGE REQUEST** | | | | | | | | |
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|  | **38.901** | **CR** | **Draft** | **rev** |  | **Current version:** | **18.0.0** |  |
|  | | | | | | | | |
| *For* [*HE**LP*](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* | | | | | | | | |
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| ***Proposed change affects:*** | UICC apps |  | ME | **X** | Radio Access Network | **X** | Core Network |  |

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| ***Title:*** | Draft CR to introduce channel model for ISAC | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Source to WG:*** | Xiaomi, AT&T | | | | | | | | | |
| ***Source to TSG:*** | R1 | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Work item code:*** | FS\_Sensing\_NR | | | | |  | ***Date:*** | | | 2025-4-7 |
|  |  | | | |  | |  | | |  |
| ***Category:*** | B |  | | | | | ***Release:*** | | | Rel-19 |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) … Rel-16 (Release 16) Rel-17 (Release 17) Rel-18 (Release 18) Rel-19 (Release 19)* | |
|  |  | | | | | | | | | |
| ***Reason for change:*** | | In RAN #102, the study item for channel modelling for ISAC was agreed. The output of the study item was agreed to be incorporated into TR 38.901. This CR captures the agreements/conclusions of the study item for channel modelling for ISAC. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Summary of change:*** | | New clause, i.e., 7.9 is added for the channel model for ISAC. The existing clauses 1, 2, 3, 4 and 6 are also updated to reflect the introduction of channel model for ISAC. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Consequences if not approved:*** | | The existing channel model for communications in TR 38.901 is not sufficient to address evaluation of sensing techniques for Integrated Sensing and Communications use cases. The existing models in TR38.901 are not designed for sensing, in particular they do not address target modelling and sensing, background environment modelling and differentiation from targets. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Clauses affected:*** | | 1, 2, 3.3, 4, 6.1, 6.2, 6.4, 7 | | | | | | | | |
|  | |  | | | | | | | | |
|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | |  | **X** | Other core specifications | | | | TS/TR ... CR ... | | |
| ***affected:*** | |  | **X** | Test specifications | | | | TS/TR ... CR ... | | |
| ***(show related CRs)*** | |  | **X** | O&M Specifications | | | | TS/TR ... CR ... | | |
|  | |  | | | | | | | | |
| ***Other comments:*** | |  | | | | | | | | |
|  | |  | | | | | | | | |
| ***This CR's revision history:*** | |  | | | | | | | | |

# 1 Scope

The present document captures the findings of the study item, "Study on channel model for frequency spectrum above 6 GHz" [2] and from further findings of the study item, "Study on New Radio Access Technology [22]", the study item "Study on Channel Modeling for Indoor Industrial Scenarios [23]" and the study item "Study on channel modelling for Integrated Sensing And Communication (ISAC) for NR [26]". The channel models in the present document address the frequency range 0.5-100 GHz. The purpose of this TR is to help TSG RAN WG1 to properly model and evaluate the performance of physical layer techniques using the appropriate channel model(s). Therefore, the TR will be kept up-to-date via CRs in the future.

This document relates to the 3GPP evaluation methodology and covers the modelling of the physical layer of both Mobile Equipment and Access Network of 3GPP systems.

This document is intended to capture the channel model(s) for frequencies from 0.5GHz up to 100GHz.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

**< Unchanged text omitted >**

[23] 3GPP TD RP-182138: "SID on Channel Modeling for Indoor Industrial Scenarios".

[26] 3GPP TD RP-242348: "Study on channel modelling for Integrated Sensing And Communication (ISAC) for NR ".

[27] 3GPP TD R1-2504948: "Information on validations for ISAC"

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] apply.

## 3.2 Symbols

For the purposes of the present document, the following symbols apply:

**< Unchanged text omitted >**

*ψ* Angular displacement between two pairs of unit vectors

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

**< Unchanged text omitted >**

ZSD Zenith angle Spread of Departure

STX Sensing Transmitter

SRX Sensing Receiver

ST Sensing Target

SPST Scattering Point of a ST

RCS Radar Cross-Section

EO Environment Object

UAV Unmanned Aerial Vehicle

AGV Automated Guided Vehicles

# 4 Introduction

At TSG RAN #69 meeting the Study Item Description on "Study on channel model for frequency spectrum above 6 GHz" was approved [2]. This study item covers the identification of the status/expectation of existing information on high frequencies (e.g. spectrum allocation, scenarios of interest, measurements, etc), and the channel model(s) for frequencies up to 100 GHz. This technical report documents the channel model(s). The new channel model has to a large degree been aligned with earlier channel models for <6 GHz such as the 3D SCM model (TR 36.873) or IMT-Advanced (ITU-R M.2135). The new model supports comparisons across frequency bands over the range 0.5-100 GHz. The modelling methods defined in this technical report are generally applicable over the range 0.5-100 GHz, unless explicitly mentioned otherwise in this technical report for specific modelling method, involved parameters and/or scenario.

Subsequently, at the TSG RAN #81 meeting the Study Item Description "Study on Channel Modeling for Indoor Industrial Scenarios" was approved [23]. The findings from this study item is also captured in the present technical report. The Industrial channel model was developed by considering new measurements and information in the literature. An overview list of all such contributions and sources is available in tdoc R1-1909706.

At TSG RAN #102 meeting the Study Item Description “Study on channel modelling for Integrated Sensing And Communication (ISAC) for NR” was approved. The findings from this study item are captured in Clause 7.9. The ISAC channel model was developed considering new measurements and information in the literature. An overview list of the sources is available in [27].

The channel model is applicable for link and system level simulations in the following conditions:

- For system level simulations, supported scenarios are urban microcell street canyon, urban macrocell, indoor office, rural macrocell, and indoor factory.

- Bandwidth is supported up to 10% of the center frequency but no larger than 2GHz.

- Mobility of either one end of the link or both ends of the link is supported

- For the stochastic model, spatial consistency is supported by correlation of LSPs and SSPs as well as LOS/NLOS state.

- Large array support is based on far field assumption and stationary channel over the size of the array.

- The sensing target is assumed in the far field of the sensing transmitter/receiver for the channel model(s) for ISAC in Clause 7.9.

# 5 Void

# 6 Status/expectation of existing information on high frequencies

## 6.1 Channel modelling works outside of 3GPP

This clause summarizes the channel modelling work outside of 3GPP based on the input from companies.

**< Unchanged text omitted >**

**QuaDRiGa (Fraunhofer HHI)**

- QuaDRiGa (QUAsi Deterministic RadIo channel GenerAtor) was developed at the Fraunhofer Heinrich Hertz Institute within the [Wireless Communications and Networks Department](http://www.hhi.fraunhofer.de/wn) to enable the modelling of MIMO radio channels for specific network configurations, such as indoor, satellite or heterogeneous configurations.

- Besides being a fully-fledged 3D geometry-based stochastic channel model (well aligned with TR36.873), QuaDRiGa contains a collection of features created in SCM(e) and WINNER channel models along with novel modelling approaches which provide features to enable quasi-deterministic multi-link tracking of users (receiver) movements in changing environments. QuaDRiGa supports Massive MIMO modelling enabled through a new multi-bounce scattering approach and spherical wave propagation. It will be continuously extended with features required by 5G and frequencies beyond 6 GHz. The QuaDRiGa model is supported by data from extensive channel measurement campaigns at 10 / 28 / 43 / 60 / 82 GHz performed by the same group.

**ETSI Industry specification group (ISG) Integrated sensing and communications (ISAC)**

- ETSI ISG ISAC plans to publish Group Report (GR) /ISC-002 that provides information on advanced ISAC channel modeling concepts and their validation through measurement, in addition to information on evaluation methodology framework, deployment scenarios and the corresponding potentially suitable frequency bands.

## 6.2 Scenarios of interest

Brief description of the key scenarios of interest identified (see note):

**< Unchanged text omitted >**

(7) Indoor industrial scenarios

(9) Integrated sensing and communication scenarios as described in Clause 7.9.1.

NOTE: The scenarios of interest are based on the plenary email discussion and different from the supported scenarios in clause 7. The indoor industrial scenarios were identified at a later stage in the TSG RAN #81 meeting. The integrated sensing and communication scenarios were identified at a later stage as part of Study on channel modelling for integrated sensing and communications for NR.

**< Unchanged text omitted >**

## 6.4 Modelling objectives

The requirements for channel modelling are as follows.

**< Unchanged text omitted >**

- Support large antenna arrays

- Support integrated sensing and communications

# 7 Channel model(s) for 0.5-100 GHz

**< Unchanged text omitted >**

## 7.9 Channel model(s) for ISAC

### 7.9.0 Introduction

The channel model for ISAC in Clause 7.9 is designed based on the channel model defined in the previous clauses within Clause 7 taking into account the known properties, e.g., location, Radar Cross-Section (RCS), polarization and etc. of one or more physical objects. A physical object is categorized as a sensing target (ST) or an environment object (EO). In the following descriptions in Clause 7.9, only the related details on ST are described, which is also applicable to type-1 EO.

The large scale and small scale parameters of the channel between any two of sensing transmitter (STX), ST and sensing receiver (SRX) in a sensing scenario are obtained from the Technical Reports for the same communication scenario unless updates on the parameter values are specially described. The ST is considered as a receiver or transmitter, respectively, in the determination of a proper channel model for a STX-ST link or a ST-SRX link.

The common framework for the ISAC channel between a pair of STX and SRX is composed of a component for one or multiple target channel(s) and a component for a background channel (described in Clause 7.9.4.3 and 7.9.5.3). One or multiple STs can be modelled in the channel between one pair of STX and SRX. The target channel of ST *k* includes all multipath components impacted by ST *k,* , where *K* is the number of STs. The background channel includes other multipath components not belonging to any of the K target channel(s).

### 7.9.1 Scenarios

Sensing scenario X is defined as a scenario for sensing where STX/SRX are selected among the TRPs and UEs in the corresponding communication scenario X. X can be UMi/UMa/RMa/InH/InF/UMi-AV/UMa-AV/RMa-AV/Urban grid/Highway/High Speed Train (HST). Based on the interested type of ST, the sensing scenarios can be grouped to UAV sensing scenarios (ISAC-UAV), Automotive sensing scenarios (ISAC-Automotive), Human sensing scenarios (ISAC-Human), Automated Guided Vehicles (AGV) sensing scenarios (ISAC-AGV), and Objects creating hazards on roads/railways sensing scenarios (ISAC-Objects creating hazards on roads/railways).

The detailed sensing scenario description in this clause can be used for channel model calibration.

**ISAC-UAV**

In the ISAC-UAV sensing scenarios, the sensing targets are outdoor UAVs below or above the buildings in urban or rural areas. Monostatic or bistatic sensing can be performed using TRPs and/or UEs, including UEs on other UAVs. Details on ISAC-UAV scenarios are listed in Table 7.9.1-1.

Table 7.9.1-1: Evaluation parameters for UAV sensing scenarios

|  |  |  |
| --- | --- | --- |
| **Parameters** | | **Value** |
| Applicable communication scenarios | | UMi, UMa, RMa, SMa  UMi-AV, UMa-AV, RMa-AV [36.777] |
| Sensing transmitters and receivers properties | STX/SRX Locations | STX/SRX locations are selected among the TRPs and UEs locations in the corresponding communication scenarios.  see note 1 |
| Sensing target | LOS/NLOS | LOS and NLOS |
| Outdoor/indoor | Outdoor |
| 3D mobility | Horizontal velocity: uniform distribution between 0 and 180km/h, if horizontal velocity is not fixed to 0.  Vertical velocity: 0km/h, optional {20, 40} km/h  see note 2 and 3 |
| 3D distribution | Horizontal plane:  Option A: *N* targets uniformly distributed within one cell.  Option B: *N* targets uniformly distributed per cell.  Option C: *N* targets uniformly distributed within an area not necessarily determined by cell boundaries.  *N* = {1, 2, 3, 4, 5}  see note 4  Vertical plane:  Option A: Uniform between 1.5m and 300m.  Option B: Fixed height value chosen from {25, 50, 100, 200, 300} m assuming vertical velocity is equal to 0. |
| Orientation | Random in horizontal domain |
| Physical characteristics (e.g., size) | Size:  Option 1: 1.6m x 1.5m x 0.7m  Option 2: 0.3m x 0.4m x 0.2m |
| Minimum 3D distances between pairs of STX/SRX and sensing target | | Min distances based on min TRP/UE distances defined in TR36.777. |
| Minimum 3D distance between sensing targets | | Option 1: At least larger than the physical size of a target  Option 2: 10 meters |
| NOTE 1: This may include aerial UEs for UMi-AV, UMa-AV, RMa-AV communication scenarios. In this case, other STX/SRX properties (e.g. mobility) are also taken from the corresponding communication scenario.  NOTE 2: 3D mobility can be horizontal only or vertical only or a combination for each sensing target  NOTE 3: time-varying velocity may be considered for future evaluations.  NOTE 4: *N*=0 may be considered for the evaluation of false alarm | | |

**ISAC-Automotive**

In the ISAC-Automotive sensing scenarios, the sensing targets are passenger vehicles or trucks and buses traveling on roads and streets in urban and rural areas. Monostatic or bistatic sensing can be performed using TRPs and/or UEs, including UEs on other vehicles and roadside UEs (RSU-type UEs). Details on ISAC-Automotive scenarios are listed in Table 7.9.1-2.

Table 7.9.1-2: Evaluation parameters for Automotive sensing scenarios

|  |  |  |
| --- | --- | --- |
| Parameters | | Values |
| Applicable communication scenarios | | Highway, Urban Grid.  UMi, UMa, RMa, SMa |
| Sensing transmitters and receivers properties | | STX/SRX locations are selected among the TRPs and UEs (e.g., VRU, vehicle, RSU-type UEs) locations in the corresponding communication scenario.  Additional option: ISD between TRPs of Urban Grid is 250m |
| Sensing target | LOS/NLOS | LOS and NLOS (including NLOSv) |
| Outdoor/indoor | Outdoor |
| Mobility (horizontal plane only) | Based on TR37.885 mobility for urban grid or highway scenario |
| Distribution (horizontal) | Based on dropping in TR37.885 per urban grid or highway communication scenario |
| Orientation | Lane direction in horizontal plane |
| Physical characteristics (e.g., size) | Type 1/2 (passenger vehicle)  Type 3 (truck/bus)  Vehicle type distribution per TR 37.885 |
| Minimum 3D distances between pairs of STX/SRX and sensing target | | For Highway, Urban Grid  - Min distances based on min TRP/UE distances defined in TR37.885  For UMi, UMa, RMa, SMa  - Min distances based on min TRP/UE distances defined in TR38.901 |
| Minimum 3D distance between sensing targets | | Option 1: At least larger than the physical size of a sensing target  Option 2: Fixed value, 10 m. |
| Environment Objects, e.g., types, characteristics, mobility, distribution, etc. | | Type-2 EO for Urban Grid  - up to 4 walls modelled as Type-2 EO, per building of size 413m x 230m x 20m. |

**ISAC-Human**

In the ISAC-Human sensing scenarios, the sensing targets are children and adult persons in indoor (room, office, factory) and outdoor (urban, rural) locations. Monostatic or bistatic sensing can be performed using TRPs and/or UEs in the corresponding communication scenarios. Details on ISAC-Human scenarios are listed in Table 7.9.1-3.

Table 7.9.1-3: Evaluation parameters for Human (indoor and outdoor) sensing scenarios

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | | Indoor Values | Outdoor Values |
| Applicable communication scenarios | | Indoor office, indoor factory  Indoor room [TR38.808] | UMi, UMa, RMa, SMa |
| Sensing transmitters and receivers properties | STX/SRX Locations | STX/SRX locations are selected among the TRPs and UE locations in the corresponding communication scenario | STX/SRX locations are selected among the TRPs and UE locations in the corresponding communication scenario |
| STX/SRX Mobility for UEs | Option 1: 0km/h  Option 2: 3km/h  Option 3: Uniform distribution between 0km/h and 3km/hr | Option 1: 0km/h  Option 2: 3km/h  Option 3: Uniform distribution between 0km/h and 10km/hr |
| Sensing target | LOS/NLOS | LOS and NLOS | LOS and NLOS |
| Outdoor/indoor | Indoor | Outdoor |
| 3D mobility | Option 1: 0km/h  Option 2: 3km/h  Option 3: Uniform distribution between 0km/h and 3km/h  (horizontal plane with random direction straight-line trajectory) | Option 1: 0km/h  Option 2: 3km/h  Option 3: Uniform distribution between 0km/h and 10km/h  (horizontal plane with random direction straight-line trajectory) |
| 3D distribution | *N* targets uniformly distributed over the horizontal area of the convex hull of the TRP deployment  see note 1 | Option A: *N* targets uniformly distributed within one cell.  Option B: *N* targets uniformly distributed per cell.  Option C: *N* targets uniformly distributed within an area not necessarily determined by cell boundaries.  see note 1 |
| Orientation | Random over the horizontal area | Random over the horizontal area |
| Physical characteristics (e.g., size) | Size (Length x Width x Height):  Child: 0.2m x 0.3m x 1m  Adult Pedestrian: 0.5m x 0.5m x 1.75m | Size (Length x Width x Height):  Child: 0.2m x 0.3m x 1m  Adult Pedestrian: 0.5m x 0.5m x 1.75m |
| Minimum 3D distances between pairs of STX/SRX and sensing target | | Min distances defined in TR 38.901 | Min distances defined in TR 38.901 |
| Minimum 3D distance between sensing targets | | Option 1: At least larger than the physical size of a sensing target  Option 2: Fixed value, 1m | Option 1: At least larger than the physical size of a sensing target  Option 2: Fixed value, 1m |
| NOTE 1: N=0 may be considered for the evaluation of false alarm | | | |

**ISAC-AGV**

In the ISAC-AGV sensing scenarios, the sensing targets are automated guided vehicles (AGVs) inside a factory. Monostatic or bistatic sensing can be performed using TRPs and/or UEs in the corresponding communication scenario. Details on ISAC-AGV sensing scenarios are listed in Table 7.9.1-4.

Table 7.9.1-4: Evaluation parameters for AGV sensing scenarios

|  |  |  |
| --- | --- | --- |
| Parameters | | Value |
| Applicable communication scenarios | | InF (Table 7.8-7) |
| Sensing transmitters and receivers properties | | STX/SRX location are selected among the TRPs and UEs location in the corresponding communication scenario  STX/SRX Mobility for UEs  Option 1: 0 km/h  Option 2: 3km/h  Option 3: Uniform distribution between 0km/h and 3km/h |
| Sensing target | LOS/NLOS | LOS and NLOS |
| Outdoor/indoor | Indoor |
| 3D mobility | Horizontal velocity with random straight-line trajectory  Option 1: Uniform distribution in the range of up to 30 km/h  Option 2: Fixed velocities {3, 10} km/h |
| 3D distribution | Option A: Uniformly distributed in the convex hull of the horizontal BS deployment  Option B: Uniformly distributed in horizontal plane |
| Orientation | Horizontal plane only |
| Physical characteristics (e.g., size) | Size (L x W x H)  Option 1: 0.5m x 1.0m x 0.5m  Option 2: 1.5 m x 3.0m x 1.5 m |
| Minimum 3D distances between pairs of STX/SRX and sensing target | | Min distances based on min TRP/UE distances defined in TR38.901 |
| Minimum 3D distance between sensing targets | | Option A: At least larger than the physical size of a target  Option B: Fixed value, 5m |

**ISAC-****Objects creating hazards on roads/railways**

In the ISAC-Objects creating hazards on roads/railways sensing scenarios, the sensing targets are adult humans and children and animals in communication scenarios involving vehicles or high-speed trains. Monostatic or bistatic sensing can be performed using TRPs and/or UEs, including UEs on other vehicles and roadside UEs (RSU-type UEs). Details on ISAC- Objects creating hazards on roads/railways sensing scenarios are listed in Table 7.9.1-5.

Table 7.9.1-5: Evaluation parameters for objects creating hazards on roads/railways sensing scenarios

|  |  |  |
| --- | --- | --- |
| Parameters | | Value |
| Applicable communication scenarios | | Highway, Urban grid, HST (High Speed Train, TR 38.802)  UMi, UMa, RMa, SMa |
| Sensing transmitters and receivers properties | STX/SRX Locations | STX/SRX locations are selected among the TRPs and UEs (e.g., VRU, vehicle, RSU-type UEs) locations in the corresponding communication scenarios.  Additional option: ISD between TRPs of Urban Grid is 250 m |
| Sensing target | LOS/NLOS | LOS and NLOS |
| Outdoor/indoor | Outdoor |
| 3D mobility | Horizontal velocity: up to 10 km/h for humans and animals |
| 3D distribution | Uniformly distributed in horizontal plane |
| Orientation | Random distribution in horizontal plane |
| Physical characteristics (e.g., size) | For human/pedestrians: Child: 0.2m x 0.3m x 1m  Adult: 0.5m x 0.5m x 1.75m  For animals: Size: 1.5m x 0.5m x 1 m |
| Minimum 3D distances between pairs of STX/SRX and sensing target | | For Highway, Urban Grid, HST  - Min. distance is based on min TRP/UE distances defined in TR37.885 and TR38.802  For UMi, UMa, RMa, SMa  - Min distances based on min TRP/UE distances defined in TR38.901 |
| Minimum 3D distance between sensing targets | | Option 1: At least larger than the physical size of a sensing target  Option 2: Fixed value, 10 m. |
| Environment objects, e.g., types, characteristics, mobility, distribution, etc. | | Type-2 EO for Urban Grid  - up to 4 walls modelled as Type-2 EO, per building of size 413m x 230m x 20m. |

### 7.9.2 Physical object model

#### 7.9.2.0 Introduction

A ST is modelled with one or multiple scattering points. Each scattering point of a ST (SPST) is used to model the total scattering effects of some adjacent scattering centres at the ST. The impact of a SPST to the channel includes at least two aspects, i.e., the RCS (Radar Cross Section, 7.9.2.1) and the polarization matrix (7.9.2.2).

#### 7.9.2.1 RCS of a sensing target

The RCS of a SPST is a scalar value defined in LCS of the ST and is dependent on both the incident angle and the scattered angle. The RCS values with same incident/scattered angles can be referred as monostatic RCS values.

The RCS related coefficient of a SPST for a pair of incident/scattered angles is composed of a first component which is included in the large-scale parameters (described in Step 15 in Clause 7.9.4.1), and a second component and third component which are both included in the small-scale parameters (described in Step 10 in Clause 7.9.4.1), i.e., . is a deterministic value for the SPST. can be fixed to 1 or can be angular dependent. follows log-normal distribution. The mean and standard deviation used to characterize satisfied a fixed relation.

(7.9.2-1)

A first RCS model is to characterize a ST as single SPST with component of the monostatic RCS values fixed to 1. is the mean of linear monostatic RCS values at the SPST. For UAV of small size and human with RCS model 1, the values/pattern, denoted as , of the RCS for a SPST is deterministic based on the incident angle () and the scattered angle ().

(7.9.2-2)

where,

- . is the bistatic angle between the incident ray and scattering ray within the plane defined by incident angle () and scattering angle ().

- is for the effect of forward scattering and is set to .

The logarithmic values of of the RCS values for the different STs are provided in Table 7.9.2.1-1.

Table 7.9.2.1-1: Parameters on RCS for the STs with angular independent monostatic RCS values

|  |  |  |
| --- | --- | --- |
| Sensing target | (dBsm) | (dB) |
| UAV with small size | -12.81 | 3.74 |
| Human with RCS model 1 | -1.37 | 3.94 |

A second RCS model is to split a ST into single or multiple SPSTs, and adopts an angular dependent component of the monostatic RCS values for each SPST. For UAV with large size and human, single SPST is modelled. While for vehicle and AGV, both models with single and multiple SPSTs are provided. For vehicle and AGV modelled with multiple scattering points, the recommended five scattering points are located at the front, left, back, right and roof side of the vehicle respectively. The orientation of a ST in LCS is provided as follows.

- The face of a human, the front of a vehicle, a UAV with large size or an AGV is facing the direction with azimuth angle and zenith angle . The front of the AGV is the short edge of AGV in horizontal direction.

- The top of the ST is facing the direction with zenith angle .

For UAV of large size with single SPST, human with RCS model 2 with single SPST, vehicle with single/multiple SPSTs, and AGV with single/multiple SPSTs, the values/pattern, denoted as , of the RCS for a SPST is deterministic based on the incident angle () and the scattered angle ().

(7.9.2-3)

With defined by,

where,

- () are zenith angle and azimuth angle of the bisector the incidence and scattered rays, whose zenith angles and azimuths are () and ().

- . is the bistatic angle between the incident ray and scattering ray within the plane defined by incident angle () and scattering angle ().

- for UAV with large size.

- for human with RCS model 2.

- for vehicle with single/multiple SPSTs.

- for AGV with single/multiple SPSTs.

- is for the effect of forward scattering and is set to .

For a ST with single scattering point, sets of parameters , *Range of* and *Range of* are defined. The bisector angle () is used to index one set from the sets of parameters, and determine of the ST consequently. If the ST is split into scattering points, with each scattering point characterized by one of sets of parameters, are respectively determined for each scattering point.

The sets of parameters to define and the parameters of the RCS for the different STs are provided in Table 7.9.2.1-2/3/4/5/6/7.

Table 7.9.2.1-2: Parameters on RCS for UAV with large size

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | (dBsm) | | | | | | | | (dBsm) | (dB) |
| in [°] | in [°] | in [°] | in [°] |  |  | Range of in [°] | Range of in [°] |
| Left | 90 | 7.13 | 90 | 8.68 | 7.43 | 14.30 | [45,135) | [45,135) | -5.85 | 2.50 |
| Back | 180 | 10.09 | 90 | 11.43 | 3.99 | 10.86 | [45,135) | [135,225) |
| Right | 270 | 7.13 | 90 | 8.68 | 7.43 | 14.30 | [45,135) | [225,315) |
| Front | 0 | 14.19 | 90 | 16.53 | 1.02 | 7.89 | [45,135) | [-45,45) |
| Bottom | - | - | 180 | 4.93 | 13.55 | 20.42 | [135,180] | [0,360) |
| Roof | - | - | 0 | 4.93 | 13.55 | 20.42 | [0,45) | [0,360) |
| NOTE: When is in the range [0,45] or [135,180], . | | | | | | | | | | |

Table 7.9.2.1-3: Parameters on RCS for human with RCS model 2

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | (dBsm) | | | | | | | | (dBsm) | (dB) |
| in [°] | in [°] | in [°] | in [°] |  |  | Range of in [°] | Range of in [°] |
| Front | 0 | 216.65 | 90 | 55.7 | 2.14 | 7.7 | [0,180] | [-90, 90) | -1.37 | 3.94 |
| Back | 180 | 216.65 | 90 | 55.7 | 2.14 | 7.7 | [0,180] | [90,270) |

Table 7.9.2.1-4: Parameters on RCS for vehicle with single scattering point

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | (dBsm) | | | | | | | | (dBsm) | (dB) |
| in [°] | in [°] | in [°] | in [°] |  |  | Range of in [°] | Range of in [°] |
| Left | 90 | 26.90 | 79.70 | 44.42 | 20.75 | 13.68 | [30,180] | [45,135) | 11.25 | 3.41 |
| Back | 180 | 36.32 | 79.65 | 36.73 | 14.56 | 7.50 | [30,180] | [135,225) |
| Right | 270 | 26.90 | 79.70 | 44.42 | 20.75 | 13.68 | [30,180] | [225,315) |
| Front | 0 | 40.54 | 71.75 | 29.13 | 15.52 | 8.45 | [30,180] | [-45, 45) |
| Roof | - | - | 0.00 | 18.13 | 21.26 | 14.19 | [0,30) | [0,360) |
| NOTE: When is in the range [0, 30), . | | | | | | | | | | |

Table 7.9.2.1-5: Parameters on RCS for vehicle with multiple scattering points

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | (dBsm) | | | | | | | | (dBsm) | (dB) |
| in [°] | in [°] | in [°] | in [°] |  |  | Range of in [°] | Range of in [°] |
| Left | 90 | 26.90 | 79.70 | 44.42 | 20.60 | 20.52 | [0,180] | [0,360) | 11.25 | 3.41 |
| Back | 180 | 36.32 | 79.65 | 36.73 | 13.90 | 13.82 | [0,180] | [0,360) |
| Right | 270 | 26.90 | 79.70 | 44.42 | 20.60 | 20.52 | [0,180] | [0,360) |
| Front | 0 | 40.54 | 71.75 | 29.13 | 14.99 | 14.91 | [0,180] | [0,360) |
| Roof | - | - | 0.00 | 18.13 | 21.12 | 21.05 | [0,180] | [0,360) |
| NOTE: For the scattering point associated with roof of the vehicle, . | | | | | | | | | | |

Table 7.9.2.1-6: Parameters on RCS for AGV with single scattering point

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | (dBsm) | | | | | | | | (dBsm) | (dB) |
| in [°] | in [°] | in [°] | in [°] |  |  | Range of in [°] | Range of in [°] |
| Front | 0 | 13.68 | 90 | 13.68 | 13.02 | 23.29 | [30,180] | [-45,45) | -4.25 | 2.51 |
| Left | 90 | 15.53 | 75 | 20.03 | 7.33 | 17.60 | [30,180] | [45,135) |
| Back | 180 | 12.49 | 90 | 11.89 | 11.01 | 21.28 | [30,180] | [135,225) |
| Right | 270 | 15.53 | 75 | 20.03 | 7.33 | 17.60 | [30,180] | [225,315) |
| Roof | - | - | 0 | 11.44 | 11.79 | 22.06 | [0,30) | [0,360) |
| NOTE 1: When is in the range [0,30), .  NOTE 2: Measurement is based on AGV option 1 | | | | | | | | | | |

Table 7.9.2.1-7: Parameters on RCS for AGV with multiple scattering points

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | (dBsm) | | | | | | | | (dBsm) | (dB) |
| in [°] | in [°] | in [°] | in [°] |  |  | Range of in [°] | Range of in [°] |
| Front | 0 | 13.68 | 90 | 13.68 | 13.00 | 30.26 | [0,180] | [0,360) | -4.25 | 2.51 |
| Left | 90 | 15.53 | 75 | 20.03 | 7.27 | 24.53 | [0,180] | [0,360) |
| Back | 180 | 12.49 | 90 | 11.89 | 10.98 | 28.24 | [0,180] | [0,360) |
| Right | 270 | 15.53 | 75 | 20.03 | 7.27 | 24.53 | [0,180] | [0,360) |
| Roof | - | - | 0 | 11.44 | 11.77 | 29.03 | [0,180] | [0,360) |
| NOTE 1: For the scattering point associated with roof of the AGV, .  NOTE 2: Measurement is based on AGV option 1 | | | | | | | | | | |

#### 7.9.2.2 Cross-polarization matrix of a sensing target

The cross-polarization matrixof a SPST for a pair of incident/scattered angles is defined in LCS and is generally modelled by amplitude factors and initial random phases , i.e.,

(7.9.2-4)

For UAV, human, vehicle and AGV, , , i.e.,

(7.9.2-5)

where,

- is the XPR of the pair of incident/scattered angles. is randomly generated by log-normal distribution per target type defined in Table 7.9.2.2-1.

- is uniformly distributed within .

Table 7.9.2.2-1: Parameters on XPR (dB) for the targets

|  |  |  |
| --- | --- | --- |
| Target | μXPR | σXPR |
| UAV | 13.75 | 7.07 |
| Human | 19.81 | 4.25 |
| Vehicle | 21.12 | 6.88 |
| AGV | 9.60 | 6.85 |

### 7.9.3 Reference channel models and required updates

A transmitter or receiver in the sensing operation can be TRP, terrestrial UE, vehicle UE, aerial UE, AGV UE or RSU-type UE. The reference TR(s) to generate the channel for each combination of transmitter and receiver for each sensing scenario are provided in Table 7.9.3-1, where the terrestrial UE, AGV are referred as terrestrial UE.

Table 7.9.3-1: Reference TRs to generate channel for ISAC

|  |  |  |  |
| --- | --- | --- | --- |
| Case | Tx/Rx | Rx/Tx | Reference TR to define the channel model |
| 1 | TRP | TRP | For sensing scenario UMi, UMa, RMa, InH, InF, UMi-AV, UMa-AV, and RMa-AV:  - TRP-TRP link of scenario UMi, UMa, InH, and InF following the option based on TR 38.901 defined in Clause A.3 of TR 38.858  - For InF, hUE is changed to the same height as the BS  - TRP-UE link of scenario RMa defined in Clause 7 of TR 38.901 by setting hUE=35m (see note 1)  For sensing scenario Highway  - TRP-UE link of scenario RMa in Clause 7 of TR 38.901 by setting hUE=35m for FR1(see note 1)  - TRP-TRP link of scenario UMa following the option based on TR 38.901 defined in Clause A.3 of TR 38.858  For sensing scenario Urban grid  - TRP-TRP link of scenario UMa following the option based on TR 38.901 defined in Clause A.3 of TR 38.858  For sensing scenario HST  - TRP-UE link of scenario RMa in Clause 7 of TR 38.901 by setting hUE=35m for FR1 (see note 1)  - TRP-TRP link of scenario UMa following the option based on TR 38.901 defined in Clause A.3 of TR 38.858 for FR2 |
| 2 | TRP | terrestrial UE | For sensing scenario UMi, UMa, RMa, InH, InF, UMi-AV, UMa-AV, and RMa-AV  - TRP-UE link of scenario UMi, UMa, RMa, InH, and InF in Clause 7 of TR 38.901  For sensing scenario Highway and Urban grid  - P2B link of scenario Highway and Urban grid in Clause 6 of TR 37.885  For sensing scenario HST  - TRP-UE link of scenario RMa in Clause 7 of TR 38.901 for FR1 and TRP-UE link of scenario UMa in Clause 7 of TR 38.901 for FR2 |
| 3 | TRP | vehicle UE | For sensing scenario Highway and Urban grid  - V2B link of scenario Highway and Urban grid in Clause 6 of TR 37.885  For sensing scenario UMi, UMa, and RMa  - TRP-UE link of scenario UMi, UMa, and RMa in Clause 7 of TR 38.901 |
| 4 | TRP | aerial UE | For sensing scenario UMa-AV, UMi-AV, and RMa-AV  - TRP-aerial UE link of scenario UMa-AV, UMi-AV, and RMa-AV in Clause Annex A and B of TR 36.777 for FR1  - Reuse the channel model of scenario UMa-AV, UMi-AV, and RMa-AV of FR1 for FR2 |
| 5 | terrestrial UE | terrestrial UE | For sensing scenario UMi, UMa, RMa, InH, InF, UMi-AV, UMa-AV, and RMa-AV:  - UE-UE link of scenario UMi, UMa, InH, and InF following the option based on TR 38.901 defined in Clause A.3 of TR 38.858  - TRP-UE link of scenario RMa defined in Clause 7 of TR 38.901 by setting hBS =1.5m (see note 2)  For sensing scenario Highway and Urban grid  - P2P link in Clause 6 of TR 37.885  For sensing scenario HST  - TRP-UE link of scenario RMa in Clause 7 of TR 38.901 for FR1, e.g., hBS=1.5m, - UE-UE link of scenario UMa following the option based on TR 38.901 defined in Clause A.3 of TR 38.858 for FR2 |
| 6 | terrestrial UE | vehicle UE | For sensing scenario UMi, UMa, RMa  - UE-UE link of scenario UMi, UMa following the option based on TR 38.901 defined in Clause A.3 of TR 38.858  - TRP-UE link of scenario RMa defined in Clause 7 of TR 38.901 by setting hBS =1.5m  For sensing scenario Highway and Urban grid  - V2P link in Clause 6 of TR 37.885 |
| 7 | terrestrial UE | aerial UE | For sensing scenario UMi-AV, UMa-AV, and RMa-AV  - TRP-aerial UE link of UMi-AV in Annex A and B of TR 36.777 by setting hBS =1.5m for FR1  - Reuse the channel model of scenario UMa-AV, UMi-AV, and RMa-AV of FR1 for FR2  - The corresponding parameter values in FR2 are used |
| 8 | vehicle UE | vehicle UE | For sensing scenario Highway and Urban grid  - V2V link of scenario Highway and Urban grid in Clause 6 of TR 37.885  For sensing scenario UMi, UMa, and RMa  - UE-UE link of scenario UMi, UMa following the option based on TR 38.901 defined in Clause A.3 of TR 38.858  - TRP-UE link of scenario RMa defined in Clause 7 of TR 38.901 by setting hBS =1.5m |
| 9 | aerial UE | aerial UE | For sensing scenario UMi-AV, UMa-AV, RMa-AV  - TRP-aerial UE link of UMi-AV in Annex A and B of TR 36.777 by setting height of TRP equal to the height of the first aerial UE for FR1  - Reuse the channel model of scenario UMa-AV, UMi-AV, and RMa-AV of FR1 for FR2  - The corresponding parameter values in FR2 are used |
| 10 | TRP | RSU-type UE | Highway and Urban grid  - B2R link in Clause 6 of TR 37.885 |
| 11 | RSU-type UE | normal UE | Highway and Urban grid  - V2V link in Clause 6 of TR 37.885, with antenna height at RSU is 5m |
| 12 | RSU-type UE | RSU-type UE | Highway and Urban grid  - V2V link in Clause 6 of TR 37.885, with antenna height at RSU is 5m |
| 13 | RSU-type UE | vehicle UE | Highway and Urban grid  - V2V link in Clause 6 of TR 37.885, with antenna height at RSU is 5m |
| NOTE 1: ASA and ZSA statistics updated to be the same as ASD and ZSD; ZoD offset = 0  NOTE 2: ASD and ZSD statistics updated to be the same as ASA and ZSA  NOTE 3: Indoor office scenario can be categorized into 5 sub-indoor scenarios defined in TR38.808. | | | |

The large scale and small scale parameters of the STX-ST link and the ST-SRX link for a sensing scenario are determined according to Table 7.9.3-1 assuming the same sensing scenario. The targets of UAV and vehicle are respectively considered as an aerial UE and vehicle UE. Other targets are considered as terrestrial UE. The proper case for each combination of STX/STX and ST are provided in Table 7.9.3-2.

Table 7.9.3-2: Channel model for STX-ST and ST-SRX link

|  |  |  |
| --- | --- | --- |
| STX/SRX | Target | Cases in Table 7.9.3-1 assuming the same sensing scenario |
| TRP | UAV | Case 4: TRP-Aerial UE link |
| Human | Case 2: TRP-normal UE link |
| Vehicle | Case 3: TRP-Vehicle UE link |
| AGV | Case 2: TRP-normal UE link |
| Object (Hazard) | Case 2: TRP-normal UE link |
| Terrestrial UE | UAV | Case 7: normal UE - Aerial UE link |
| Human | Case 5: normal UE-normal UE link |
| Vehicle | Case 6: normal UE - Vehicle UE link |
| AGV | Case 5: normal UE-normal UE link |
| Object (Hazard) | Case 5: normal UE-normal UE link |
| Vehicle UE | Human | Case 6: normal UE - Vehicle UE link |
| Vehicle | Case 8: Vehicle UE - Vehicle UE link |
| Object (Hazard) | Case 6: normal UE - Vehicle UE link |
| Aerial UE | UAV | Case 9: Aerial UE - Aerial UE link |
| AGV UE | AGV | Case 5: normal UE - normal UE link |
| RSU-type UE | Human | Case 11: RSU-type UE - normal UE link |
| Vehicle | Case 13: RSU-type UE - vehicle UE link |

The large scale and small scale parameters of the STX-SRX link, i.e., background channel for a sensing scenario are determined according to Table 7.9-1 assuming the same sensing scenario. The proper case for each combination of STX and SRX are provided in Table 7.9-3. For TRP monostatic sensing mode, a reference point (RP) is considered as a terrestrial UE. For UT monostatic sensing mode, a RP is considered as a TRP and an aerial UE is considered as a terrestrial UE.

Table 7.9.3-3: Channel model for background channel

|  |  |  |
| --- | --- | --- |
| STX/SRX | SRX/STX | Cases in Table 7.9.3-1 assuming the same sensing scenario |
| TRP | TRP | Case 1: TRP-TRP link |
| Terrestrial UE | Case 2: TRP-normal UE link |
| Vehicle UE | Case 3: TRP-Vehicle UE link |
| Aerial UE | Case 4: TRP-Aerial UE link |
| AGV UE | Case 2: TRP-normal UE link |
| RSU-type UE | Case 10: TRP - RSU-type UE link |
| Terrestrial UE | Terrestrial UE | Case 5: normal UE-normal UE link |
| Vehicle UE | Case 6: normal UE - Vehicle UE link |
| Aerial UE | Case 7: normal UE - Aerial UE link |
| AGV UE | Case 5: normal UE -normal UE link |
| RSU-type UE | Case 11: RSU-type UE - normal UE link |
| Vehicle UE | Vehicle UE | Case 8: Vehicle UE - Vehicle UE link |
| RSU-type UE | Case 13: RSU-type UE - vehicle UE link |
| Aerial UE | Aerial UE | Case 9: Aerial UE - Aerial UE link |
| AGV UE | AGV UE | Case 5: normal UE - normal UE link |
| RSU-type UE | RSU-type UE | Case 12: RSU-type UE – RSU-type UE link |

The following updates compared to the reference TRs are identified to generate ISAC channel.

- For human as a sensing target with a single scattering point, the height of the scattering point is 1.5 m.

- For sensing scenario RMa, UMi-AV, UMa-AV and RMa-AV, the height of a scattering point of a target is used to calculate the LOS probability and pathloss, regardless of the lower bound of hUT in the reference TRs that are used to generate ISAC channel.

- For sensing scenario UMi, UMa, the height of a scattering point of a target is used to calculate the LOS probability and pathloss, regardless of the lower bound of hUT in the reference TRs that are used to generate ISAC channel, except that hUT=1.5 m is assumed for breakpoint distance (dBP) calculation.

- For sensing scenario Urban grid, the absolute delay model of scenarios UMa in Table 7.6.9-1 are reused

- For sensing scenario highway and HST, the absolute delay model of scenarios RMa and UMa are reused for FR1 and FR2 respectively

- For sensing scenarios UMi-AV, UMa-AV and RMa-AV,

- For the TRP-TRP link and TRP-terrestrial UE link, the absolute delay model of scenarios UMi, UMa and RMa are respectively reused.

- For the terrestrial UE- terrestrial UE link, the terrestrial UE - aerial UE link and the aerial UE - aerial UE link, the absolute delay model of scenario UMi is reused.

- For the TRP- aerial UE link, the absolute delay model of scenarios UMi, UMa and RMa are respectively reused.

- On Case 7 in Table 7.9.3-1, the LOS probability between an aerial UE and a normal UE is generated by Table 7.9.3-4. is the height of the aerial UE.

- On Case 9 in Table 7.9.3-1, the LOS probability between two aerial UEs is generated by Table 7.9.3-5. are the height of the two aerial UEs.

Table 7.9.3-4: LOS condition determination for Case 7

|  |  |
| --- | --- |
| Reference scenario to determined LOS probability | Applicability range in terms of aerial UE height |
| UMi in Table 7.4.2-1 in TR 38.901 for UMi-AV/UMa-AV/RMa-AV | UMi, UMa:  RMa: |
| UMi-AV in Table B-1 in TR 36.777 for UMi-AV/UMa-AV  RMa-AV in Table B-1 in TR 36.777 for RMa-AV | UMi, UMa:  RMa: |

Table 7.9.3-5: LOS condition determination for Case 9

|  |  |
| --- | --- |
| Reference scenario to determined LOS probability | Applicability range in terms of aerial UE height |
| UMi in Table 7.4.2-1 in TR 38.901 for UMi-AV/UMa-AV/RMa-AV | UMi, UMa:  RMa: |
| UMi-AV in Table B-1 in TR 36.777 for UMi-AV/UMa-AV  RMa-AV in Table B-1 in TR 36.777 for RMa-AV | UMi, UMa: ,  RMa: , |
| UMa-AV in Table B-1 in TR 36.777 for Aerial UE height in range (22.5m, 100m] for UMi-AV/UMa-AV  RMa-AV in Table B-1 in TR 36.777 for or Aerial UE height in range (10m, 40m] for RMa-AV | UMi, UMa:  RMa: 1 |
| LOS probability is 100% | UMi, UMa: ,  RMa: , |

### 7.9.4 Fast fading model

#### 7.9.4.0 Introduction

The ISAC channel between a pair of STX and SRX is composed of the target channel(s) and the background channel. A multipath component in the target channel may include stochastic generated clusters in either of or both the STX-ST link and ST-SRX link. If blockage/forward scattering between sensing targets is not considered, a propagation path from STX to SRX interacting with more than one sensing target is not modelled.

A stepwise procedure illustrated in Figure 7.9.4-1 is used to generate the channel model for ISAC referring to the procedure in Clause 7.5 with parameters derived by Table 7.9.3-2 and 7.9.3-3. Step 1 is commonly executed, followed by the respective steps for target channel (7.9.4.1) and background channel (7.9.4.2). Finally, the target channel and background channel are combined to form the final channel model for ISAC (7.9.4.3).



Figure 7.9.4-1 Channel coefficient generation procedure

Step 1: Set environment, network layout, and antenna array parameters

a) Choose one of the sensing scenarios (ISAC-UAV, ISAC-Automative, ISAC-Human, ISAC-AGV, ISAC-Objects creating hazards on roads/railways) and related communication scenarios (e.g. UMa, UMi-Street Canyon, RMa, InH-Office, Urban grid, Highway, or InF). Choose a global coordinate system and define zenith angle *θ*, azimuth angle *ϕ*, and spherical basis vectors , as shown in Figure 7.5-2.

b) Give number of STX, ST and SRX. Give the number of the SPST(s) of each ST.

c) Give 3D locations of STX and SRX, give 3D locations of SPST(s) of each ST, and determine LOS AOD (*ϕLOS,AOD*), LOS ZOD (*θLOS,ZOD*), LOS AOA (*ϕLOS,AOA*), and LOS ZOA (*θLOS,ZOA*) of each pair of STX and SPST, and each pair of SPST and SRX in the global coordinate system

d) Give STX and SRX antenna field patterns *Frx* and *Ftx* in the global coordinate system and array geometries.

e) Give STX and SRX array orientations with respect to the global coordinate system. STX array orientation is defined by three angles Ω*STX,α* (STX bearing angle), Ω*STX,β* (STX downtilt angle) and Ω*STX,γ* (STX slant angle). SRX array orientation is defined by three angles Ω*SRX,α* (SRX bearing angle), Ω*SRX,β* (SRX downtilt angle) and Ω*SRX,γ* (SRX slant angle). Give the orientation of ST in the global coordinate system. ST orientation is defined by three angles Ω*ST,α* (ST bearing angle), Ω*ST,β* (ST downtilt angle) and Ω*ST,γ* (ST slant angle).

f) Give speed and direction of motion of STX, ST and SRX in the global coordinate system

g) Specify system centre frequency and bandwidth

NOTE: In case wrapping is used, each wrapping copy of a STX or SRX should be treated as a separate STX/SRX considering channel generation.

For monostatic sensing mode, a STX and a corresponding SRX are co-located, and have the same antenna field pattern, array orientations, speed and direction of motion.

#### 7.9.4.1 Target channel

Following Step 1 in Clause 7.9.4.0, the target channels for the one or multiple STs between a pair of STX and SRX is generated using the following procedure with parameters derived by Table 7.9.3-2. It assumes a ST *k* consists of *P* scattering points, . The propagation conditions for different STX-SPST links and SPST-SRX links can be modelled by spatial consistency procedure in Clause 7.9.5.1.

**Large scale parameters:**

Step 2: Assign propagation condition (LOS/NLOS) for each pair of STX and SPST, and each pair of SPST and SRX according to LOS probability equation defined in reference TRs in Clause 7.9.3.

Step 3: Calculate pathloss with formulas defined in reference TRs in Clause 7.9.3 for each STX-SPST link, and each SPST-SRX link.

Step 4: For each STX-SPST link and SPST-SRX link, generate large scale parameters, e.g. delay spread (DS), angular spreads (ASA, ASD, ZSA, ZSD), Ricean K factor (K) and shadow fading (SF) taking into account cross correlation according to Table 7.5-6 and using the procedure described in clause 3.3.1 of [14] with the square root matrix being generated using the Cholesky decomposition and the following order of the large scale parameter vector: **s***M* = [*sSF, sK, sDS, sASD, sASA, sZSD, sZSA*]*T*.

The LSPs for links from co-sited sectors to a STX/SPST/SRX are the same. In addition, these LSPs for the links of STX/SPST/SRX on different floors are uncorrelated.

Limit random RMS azimuth arrival and azimuth departure spread values to 104 degrees, i.e., ASA= min(ASA, 104°), ASD= min(ASD, 104°). Limit random RMS zenith arrival and zenith departure spread values to 52 degrees, i.e., ZSA= min(ZSA, 52°), ZSD= min(ZSD, 52°).

For monostatic sensing mode, the large scale parameters generated in step 2 to Step 4 are identical for a STX-SPST link and the corresponding SPST-SRX link of the same SPST.

**Small scale parameters:**

Step 5: Generate cluster delays

The cluster delays of cluster n in a STX-SPST link are generated using Step 5 of Clause 7.5, i.e.,.

The cluster delays of cluster in the corresponding SPST-SRX link of the same SPST are generated using Step 5 of Clause 7.5 by replacing subscript *n* with *n’*, i.e., .

Step 6: Generate cluster powers.

The cluster power of cluster n in a STX-SPST link are generated using Step 6 of Clause 7.5, i.e., .

The cluster power of cluster in the corresponding SPST-SRX link of the same SPST are generated using Step 6 of Clause 7.5 by replacing subscript *n* with *n’*, i.e., .

Step 7: Generate arrival angles and departure angles for both azimuth and elevation.

The arrival angles and departure angles for both azimuth and elevation of a cluster *n* in a STX-SPST link are generated using Step 7 of Clause 7.5, i.e., , , , .

The arrival angles and departure angles for both azimuth and elevation of a cluster *n’* in the corresponding SPST-SRX link of the same SPST are generated using Step 7 of Clause 7.5 by replacing subscript *n, m* with *n’, m’*, i.e.,, , , .

For monostatic sensing mode, are respectively equal to in Step 5-7, if and if applicable .

Step 8: Coupling of rays within a cluster for both azimuth and elevation.

The rays within a cluster *n* for both azimuth and elevation in a STX-SPST link are coupled using Step 8 of Clause 7.5.

The rays within a cluster *n’* for both azimuth and elevation in the corresponding SPST-SRX link of the same SPST are coupled using Step 8 of Clause 7.5 by replacing subscript *n, m* with *n’, m’*.

For monostatic sensing mode, the same ray-coupling way applies to both the STX-SPST link and the SPST-SRX link.

Step 9: Coupling of rays for a STX-SPST link and the corresponding SPST-SRX link of the same SPST.

In the STX-SPST link, a LOS ray is represented by , while a NLOS ray *m* of a stochastic cluster *n* is represented by . In the SPST-SRX link, a LOS ray is represented by while a NLOS ray *m’* of a stochastic cluster *n’* is represented by . A ray in the STX-SPST link and a ray in the corresponding SPST-SRX link that are coupled to each other construct a path.

The LOS ray (if present) in the STX-SPST link is coupled with the LOS ray (if present) in the SPST-SRX link. The resulting path is never dropped. Further, a set  of paths are generated which include the coupled rays as follows.

- The LOS ray in the STX-SPST link (if present) is coupled with each NLOS ray in the SPST-SRX link.

- Each NLOS ray in the STX-SPST link is coupled with the LOS ray (if present) in the SPST-SRX link.

- The NLOS rays in the STX-SPST link are coupled with the NLOS rays in the SPST-SRX link. Two options for the coupling are recommended with other methods for complexity reduction up to company choice.

- Option 1: Each NLOS ray in the STX-SPST link is coupled with each NLOS ray in the SPST-SRX link.

- Option 2: The NLOS rays in the STX-SPST link are 1-by-1 randomly coupled with the NLOS rays in the ST-SRX link. If the number of rays in the two links M1, M2 are not equal, min(M1, M2) rays are randomly selected in the link with larger number of rays in the coupling operation.

Step 10: Obtain the power for all generated paths

The power of a path () is given by

(7.9.4-1)

where, are the second and third component of RCS at the SPST *p* for a path are derived by the incident angle, i.e., AOA (), ZOA () of the ray in the STX-SPST link and the scattered angle, i.e., AOD (), ZOD () of the ray in the SPST-SRX link, referring to the RCS model defined in Clause 7.9.2.1 for the SPST. is independently determined for each path of a SPST of the same ST and of the different STs. of a path of a SPST keeps unchanged until it is updated.

NOTE: The transformation between GCS and LCS for the incident/scattered angles is necessary to determine the RCS at the SPST p. are respectively the ray power in the SPST-SRX link and the STX-SPST link.

- If the STX-SPST link is in LOS condition,

- for a LOS ray, where is the Ricean K-factor of the STX-SPST link.

- for a NLOS ray *m* of a stochastic cluster *n,*  , where *M* is number of rays per cluster

- If the STX-SPST link is not in LOS condition,

- for a NLOS ray *m* of a stochastic cluster *n*, .

- If the SPST-SRX link is in LOS condition,

- for a LOS ray, . is the Ricean K-factor of the SPST-SRX link.

- for a NLOS ray *m’* of a stochastic cluster *n’*, .

- If the SPST-SRX link is not in LOS condition,

- for a NLOS ray *m’* of a stochastic cluster *n’*, .

A path with power less than X dB compared to the maximum power among all paths in set is dropped. The value of X can be up to -25 and -40 respectively for Option 1 and Option 2 in Step 9. The value X is up to company choice. The set of remaining paths () after path dropping is denoted as set *R*. The path that couples the LOS ray in the STX-SPST link and the LOS ray in the SPST-SRX link, if present, is included in set R.

Step 11: Obtain the absolute delay for each path in set *R*

The absolute delay of a path () is given by

(7.9.4-2)

where, for the LOS ray in the STX-SPST link, if present, . For the LOS ray in the SPST-SRX link, if present, . is the 3D distance between STX and SPST *p*. is the 3D distance between SPST *p* and SRX. values are generated separately for NLOS rays in the SPST-SRX link and the STX-SPST link according to Table 7.6.9-1 in Clause 7.6.9. For the two strongest clusters in each of the STX-SPST link and SPST-SRX link, and of sub-clusters are revised according to equation (7.5-26).

For monostatic sensing mode, is equal to . are set to 0 for the LOS ray, if present, in the SPST-SRX link and the STX-SPST link.

Step 12: Generate the cross polarization power ratios for paths in set *R*.

The cross polarization power ratios for each ray *m* of a cluster *n* in a STX-SPST link is generated using Step 9 of Clause 7.5, i.e., =.

The cross polarization power ratios for each ray *m’* of a cluster *n’* in a SPST-SRX link is generated using Step 9 of Clause 7.5 by replacing subscript *n, m* with *n’, m’*, i.e., .

For monostatic sensing mode, is equal to if and .

Generate the cross polarization power ratios (XPR) for each path in set R at SPST *p*. XPR is log-Normal distributed. Draw XPR values as

, (7.9.4-3)

where is Gaussian distributed with and from Table 7.9.2.2. Note: is independently drawn for each path in set R. is independently determined for each path of a SPST of the same ST and of the different STs. of a path of a SPST keeps unchanged until it is updated.

The outcome of Steps 1-12 shall be identical for all the links from co-sited sectors to a STX/ST/SRX.

**Coefficient generation:**

Step 13: Draw initial random phases for paths in set *R*.

The random initial phases for each ray *m* of a cluster *n* in a STX-ST link is generated using Step 9 of Clause 7.5, i.e.,

The random initial phases for each ray *m’* of a cluster *n’* in a ST-SRX link is generated using Step 9 of Clause 7.5 by replacing subscript *n, m* with *n’, m’*, i.e., .

For monostatic sensing mode, are respectively equal to , if and .

Draw random initial phases for each path in set *R* at SPST *p* and for four different polarisation combinations (θθ, θϕ, ϕθ, ϕϕ). The distribution for initial phases is uniform within (*-π, π*). are independently determined for each path of a SPST of the same ST and of the different STs. of a path of a SPST keeps unchanged until it is updated.

Step 14: Generate channel coefficients for paths in set *R* for each receiver and transmitter element pair *u, s*.

The channel coefficient for a path in set *R* is generated by

(7.9.4-4)

with the Doppler frequency defined as

(7.9.4-5)

where,

- is the polarization matrix of the SPST *p*.

(7.9.4-6)

- is the polarization matrix of the ray in the STX-SPST link.

- for the LOS ray, if present,

- for NLOS ray generated by stochastic cluster,

(7.9.4-7)

- is the polarization matrix of the ray in the SPST-SRX link.

- for the LOS ray, if present,

- for NLOS ray generated by stochastic cluster,

(7.9.4-8)

- are the two elements in the main diagonal of combined matrix

- is the spherical unit vector at receiver for the link from SRX to SPST *p* of ST *k*, given by

(7.9.4-9)

- is the spherical unit vector at transmitter for the link from STX to SPST *p* of ST *k*, given by

(7.9.4-10)

- is the spherical unit vector at the scattering point for the link from SPST *p* of ST *k* to SRX, given by

(7.9.4-11)

- is the spherical unit vector at the scattering point for the link from SPST *p* of ST *k* to STX, given by

(7.9.4-12)

- are respectively the velocity of SRX, STX.

- is the velocity of SPST *p* of ST *k*, , where is the velocity of the ST k, is velocity due to micro motion of SPST p of ST k.

- denotes a reference point in time that defines the initial phase, e.g., .

The channel impulse response of SPST *p* of ST *k* is given by

(7.9.4-13)

Step 15: Apply pathloss, shadowing, the first component of RCS for the channel coefficients.

The target channel for ST *k*, is formed by summing the channel coefficients of the *P* SPST respectively scaled by the pathloss, shadowing and the first component of RCS of the *P* SPST*.*

(7.9.4-14)

where,

- is the pathloss of the STX-SPST link.

- is the pathloss of the SPST-SRX link.

- is the shadow fading of the STX-SPST link.

- is the shadow fading of the SPST-SRX link.

- is the first component of RCS for the SPST *p* of ST *k*, referring to the RCS model defined in Clause 7.9.2.1.

- , *P* is the total number of SPST of the ST *k*.

#### 7.9.4.2 Background channel

For TRP-TRP, TRP-UE, UE-TRP and UE-UE bistatic sensing modes, following Step 1 in Clause 7.9.4.0, the background channel between a pair of STX and SRX is generated using Step 2 to Step12 of Clause 7.5 with parameters derived by Table 7.9.3-3. The absolute time of arrival in clause 7.6.9 is applied. The resulting channel is denoted as .

For TRP monostatic and UE monostatic sensing modes, the background channel between a pair of STX and SRX is generated using the following steps after Step 1 in Clause 7.9.4.0.

Step 2: Generate 3 reference points (RPs) for the STX/SRX.

Draw the 2D distance between the STX/SRX and each RP, the height of each RP respectively from Gamma distribution and defined in Table 7.9.4.2-1/2. With uniform distribution within range , draw the LOS AOD (*ϕLOS,AOD*) between the STX/SRX and the first RP. The LOS AOD is further rotated by and to respectively derive the LOS AOD from the STX/SRX to the second and third RPs. Consequently, the 3D location of each RP can be calculated.

- Determine LOS ZOD (*θLOS,ZOD*) of the STX/SRX and each RP in the global coordinate system.

- Set each RP the same antenna field patterns *Frx* in the global coordinate system and array geometries as the STX/SRX.

- Set each RP the same array orientations with respect to the global coordinate system, i.e., Ω*RP,α* (RP bearing angle), Ω*RP,β* (RP downtilt angle) and Ω*RP,γ* (RP slant angle) as the STX/SRX.

- Set each RP the same velocity as the STX/SRX.

NOTE: Distributions of height and distance of RPs are not subject to geographical constraints on TRP and UT for the corresponding deployment scenario.

Step 3: Assign NLOS propagation condition to the channel between the STX/SRX and each of the 3 RPs.

Step 4: Generate the channel between the STX/SRX and each of the 3 RPs using Step 3 to Step12 of Clause 7.5 and Clause 7.6.10 with parameters derived by Table 7.9.3-3, with updates as follows.

- In Step 7 of Clause 7.5, the arrival angles are respectively equal to the departure angles . The rays in a cluster with less than 50, 80 and 90 degrees respectively for scenario UMi, UMa and RMa are dropped. The dropping is not applicable to other sensing scenarios.

- The absolute time of arrival in clause 7.6.9 is applied with d3D replaced by , where is the height of the STX/SRX. Three are independently generated and respectively applied to the 3 channels between the STX/SRX and the 3 RPs.

NOTE: In the UT monostatic sensing in UMa and UMi scenario, the ZOD offset should be set as 0.

Step 5: Generate the background channel for the STX/SRX

The background channel for the STX/SRX is formed by summing the 3 channels between STX/SRX and the 3 RPs after applying the respective pathloss and shadowing.

(7.9.4-15)

where,

- is the pathloss between the STX/SRX and the RP with index r.

- is the shadow fading between the STX/SRX and the RP with index r.

Table 7.9.4.2-1: Parameters of background channel for TRP monostatic sensing

| Sensing scenarios | | UMi | **UMa /**  **Urban grid /**  **Highway(FR2) /**  HST(FR2) | **RMa /**  **Highway(FR1) /**  HST(FR1) | Indoor office | Indoor Factory |
| --- | --- | --- | --- | --- | --- | --- |
| Distance (m) | αd | 6.1996 | 10.3370 | 6.2025 | 4.236 | 0.039836 |
| βd | 0.1558 | 0.1317 | 0.0391 | 0.19255 | 0.179783 |
| cd | 15.2697 | 68.7778 | 1.2940 | 4.99 | 1.130020 |
| Height (m) | αh | 12.0487 | 16.2253 | 0.0007 | 1.3293 | 0.283447 |
| βh | 2.3261 | 1.9218 | 5.0146 | 0.1442 | 0.435965 |
| ch | 0.0157 | 2.6142 | 0.0522 | -13.19 | -17.043530 |

Table 7.9.4.2-2 Part-1: Parameters of background channel for UT monostatic sensing

| Sensing scenarios | | UMi | **UMa /**  **Urban grid /**  **Highway(FR2) /**  HST(FR2) | **RMa /**  **Highway(FR1) /**  HST(FR1) | Indoor office | Indoor Factory |
| --- | --- | --- | --- | --- | --- | --- |
| Distance (m) | αd | 10.0220 | 2.9072 | 10.2421 | 4.3733 | 0.231418 |
| βd | 1.2522 | 0.1031 | 0.0526 | 0.4457 | 0.128133 |
| cd | 11.0040 | 3.8471 | 3.3131 | 4.6302 | 2.004903 |
| Height (m) | αh | 3.0487 | 1.6640 | 0.3175 | 0.2974 | 0.462968 |
| βh | 1.9128 | 1.6215 | 1.4150 | 0.4103 | 0.281526 |
| ch | 0.1785 | -1.4205 | 1.5906 | 2.9711 | -16.921515 |

Table 7.9.4.2-2 Part-2: Parameters of background channel for UT monostatic sensing

| Sensing scenarios | | UMi-AV | UMa-AV | **RMa-AV** |
| --- | --- | --- | --- | --- |
| Distance (m) | αd |  |  |  |
| βd |  |  |  |
| cd |  |  |  |
| Height (m) | αh |  |  |  |
| βh |  |  |  |
| ch |  |  |  |
| NOTE: is the height of the aerial UE. | | | | |

#### 7.9.4.3 Combining target channel and background channel

The channel model for ISAC for a pair of STX and STX is the sum of the target channel(s) and the background channel generated in Clause 7.9.4.1 and 7.9.4.2, i.e.,

. (7.9.4-16)

### 7.9.5 Additional modelling components

#### 7.9.5.0 Introduction

Similar to Clause 7.6, the additional modelling components in this clause are to support advanced simulations, such as simulations in which spatial consistency is important, simulations that include known type-2 EO, simulations that need adjusting the sum power of the target channel and the background channel, simulations of moving scatterers, simulation with impacts of lower power clusters in the background channels, and simulations of blockage effects of ST.

These extensions are computationally more expensive and might not be required in all evaluation cases.

#### 7.9.5.1 Spatial consistency

The spatial consistency procedure is used to generate the random variables for the STX-SPST links, the SPST-SRX links and the background channels, so that they are spatial consistent.

For sensing scenario UMi-AV, UMa-AV and RMa-AV, the 2D random process (in the horizontal plane) can be extended to a 3D random process within each applicability range in terms of aerial UE height (defined in 36.777). The correlation distance is equal to the horizontal correlation distance defined in the previous clauses within Clause 7. The random coupling of NLOS rays of Option 2 in Step 9 in Clause 7.9.4.1 shall be kept unchanged per simulation drop even if STX/ST/SRX position(s) changes during simulation.

The spatial consistency procedures in Clause 7.6.3 are reused to handle the links between TRPs and STs/UTs. RSU-type UE is considered as a TRP in the spatial consistency procedures. The spatial consistency procedures in Clause 7.6.3 applies to the links between UT and UT/SPSTs (denoted as UT-UT/SPST links), with a new correlation type for the large scale parameter, cluster specific parameters and ray specific parameters of the links.

- Link-correlated: parameters of any two links of UT-UT/SPST links are correlated, subjected to correlation distance.

- All-correlated: all UT-UT/SPST links are correlated.

In Table 7.9.5.1-1, the correlation type for each parameter of the new spatial consistency procedure is clarified.

Table 7.9.5.1-1: Correlation type among UT-UT/SPST links

|  |  |
| --- | --- |
| Parameters | Correlation type |
| Delays | Link-correlated |
| Cluster powers | Link-correlated |
| AOA/ZOA/AOD/ZOD offset | Link-correlated |
| AOA/ZOA/AOD/ZOD sign | Link-correlated |
| Random coupling | Link-correlated |
| XPR | Link-correlated |
| Initial random phase | Link-correlated |
| LOS/NLOS states | Link-correlated |
| Blockage (Model A) | All-correlated |
| O2I penetration loss | All-correlated |
| Indoor distance | All-correlated |
| Indoor states | All-correlated |

Spatial consistency is not modelled among STX-SPST links, the SPST-SRX links and the background channels in the following situations:

- Different link types, e.g., outdoor LOS, outdoor NLOS or O2I, as defined in Table 7.6.3.4-2.

- UE locates on different floors, as defined in Table 7.6.3.4-2.

- Background channel for monostatic sensing mode, and any link (STX-SPST link, SPST-SRX link, background channel) for bistatic sensing mode.

- Links associated with different non-co-located TRPs, e.g. TRP1-ST/UT/TRP and TRP2-ST/UT/TRP.

- Links that are generated referring to channel models with parameter values of different communication scenarios.

- The background channels for UT monostatic sensing across different UTs or across different RPs for the same UT.

- Between TRP-target/UT link and target/UT-UT link for sensing scenario UMi, InH and InF.

- Between TRP-TRP link and any other links for ISAC channel.

- The background channels for TRP monostatic sensing across different TRPs or across different RPs for the same TRP.

The spatial consistency across the links between STX/SRX and multiple SPSTs of a ST are modelled as if the multiple SPSTs are multiple STs.

#### 7.9.5.2 Type-2 environment object

A type-2 EO, e.g., wall, is modelled as a surface with finite size. A ray specularly reflected by a type-2 EO can be modelled in the STX-SPST link, SPST-SRX link and optionally in the background channel, if a specular reflection point can be found within the surface of the type-2 EO.

A general procedure to generated small scale parameters of a type-2 EO, e.g., a wall, is provided assuming the incident ray comes from Tx and the scattered ray arrives at Rx.

Step A: Check whether a ray specularly reflected by a type-2 EO needs to be modelled or not for the pair of Tx and Rx

The type-2 EO can be described by a plane equation perpendicular to the ground.

(7.9.5-1)

is real number. [A, B, 0] is the normal vector of the plane, which points to the same direction as the orientation of the type-2 EO. The location of Tx and Rx is denoted as and .

The location of reflection point is determined as follows.

(7.9.5-2)

(7.9.5-3)

(7.9.5-4)

where, is the location of the reflection image of Tx relative to the plane. . .

If , the reflection point is on the surface of the type-2 EO, otherwise, there is no reflection ray in the Tx-Rx link due to the type-2 EO.

Step B: Generate parameters of the ray specularly reflected by a type-2 EO if the reflection point is only the surface of the type-2 EO

The 3D distance from the Tx to the reflection point then to the Rx is

(7.9.5-5)

The ZoD and AoD from Tx to the reflection point are derived based on the location of Tx and reflection point.

(7.9.5-6)

(7.9.5-7)

The ZoA and AoA from Rx to the reflection point are derived based on the location of Rx and reflection point.

(7.9.5-8)

(7.9.5-9)

The effective polarization matrix of the type-2 EO reflection ray is given by

(7.9.5-10)

where,

- . represents the normal vector of the incident plane. , in which and . represents the spherical basis vector of incident ray in vertical direction. represents the spherical basis vector of incident ray in horizontal direction. .

- . represents the polar basis vector of scattering ray in vertical direction. represents the spherical basis vector of scattering ray in horizontal direction. . .

- The formula 7.6-38 and 7.6-39 of reflection coefficients and in Clause 7.6.8 can be reused with modified incidence angle. The incidence angle is the angle between the incident vector from Tx to the reflected point and the normal vector of the type-2 EO, which is

(7.9.5-11)

The reflection coefficients for parallel and perpendicular polarization are given by

(7.9.5-12)

(7.9.5-13)

When a type-2 EO is deployed in the simulation area, the following modification to the ISAC channel generation in Clause 7.9.4, 7.9.4.1 and 7.9.4.2 can be applied.

1. In Step 1 in Clause 7.9.4.0,

b) Give number of type-2 EO, additionally.

c) Give 3D locations of type-2 EO in the global coordinate system, additionally.

e) Give the orientation of type-2 EO in the global coordinate system, additionally. The type-2 EO orientation is defined by three angles Ω*EO,α* (type-2 EO bearing angle), Ω*EO,β* (type-2 EO downtilt angle) and Ω*EO,γ* (type-2 EO slant angle).

NOTE: In case wrapping is used, each wrapping copy of a type-2 EO should be treated as a separate type-2EO considering channel generation.

1. In Step 2 in Clause 7.9.4.1,

Two options are provided to determine the LOS condition of a STX-SPST link and a SPST-SRX link.

- Option 1: If a type-2 EO blocks the LOS ray of a link, the LOS probability of the link is equal to 0, and otherwise use the LOS probability equation defined in reference TRs in Clause 7.9.3 to determine propagation condition (LOS/NLOS) of the link.

- Option 2: no change to Step 2 in Clause 7.9.4.1.

NOTE: The same option is used to determine the LOS condition of a STX-SPST link, a SPST-SRX link and the background channel.

1. Between Step 8 and 9 in Clause 7.9.4.1, insert one step to generate NLOS rays specularly reflected by type-2 EO, if present.

In a STX-SPST link, the general procedure to model a type-2 EO as described above is executed by substitute Tx with the STX and Rx with the SPST. A NLOS ray specularly reflected by a type-2 EO, if present, is represented by . .

In a SPST-SRX link, the general procedure to model a type-2 EO as described above is executed by substitute Tx with the SPST and Rx with the SRX. A NLOS ray specularly reflected by a type-2 EO, if present, is represented by . .

1. In Step 9 in Clause 7.9.4.1,

The following paths are generated and added to set .

- A NLOS ray specularly reflected by type-2 EO, if present in the SPST-SRX link is coupled with a NLOS ray specularly reflected by type-2 EO, if present in the STX-SPST link

- A NLOS ray specularly reflected by type-2 EO, if present in the SPST-SRX link is coupled with any LOS ray (if present) and NLOS rays of stochastic clusters in the STX-SPST link

- A NLOS ray specularly reflected by type-2 EO, if present in the STX-SPST link is coupled with any LOS ray (if present) and NLOS rays of stochastic clusters in the SPST-SRX link

1. In Step 10 in Clause 7.9.4.1,

for a NLOS ray specularly reflected by a type-2 EO, if present, in the SPST-SRX link and the STX-SPST link is determined as follows.

- If the STX-SPST link is in LOS condition,

- If the STX-SPST link is not in LOS condition, , where is the pathloss of STX-SPST link assuming LOS condition.

- If the SPST-SRX link is in LOS condition,

- If the SPST-SRX link is not in LOS condition, , where is the pathloss of SPST-SRX link assuming LOS condition.

1. In Step 11 in Clause 7.9.4.1,

For a NLOS ray specularly reflected by a type-2 EO in the STX-SPST link, if present, is replaced by , and is set to 0.

For a NLOS ray specularly reflected by a type-2 EO in the SPST-SRX link, if present, is replaced by , and is set to 0.

1. The outcome of Steps 1-12 in Clause 7.9.4.1 shall be identical for all the links from co-sited sectors to a STX/ST/EO/SRX.
2. In Clause 7.9.4.2, if a type-2 EO is modelled in the background channel between a pair of STX and SRX, the general procedure to model a type-2 EO as described above is executed by substitute Tx with the STX and Rx with the SRX.

#### 7.9.5.3 Power normalization across target channel and background channel

To combine the target channel and the background channel, power normalization can be applied to keep the same/similar channel power as the background channel without sensing target.

#### 7.9.5.4 Doppler of mobile scatterers

To support scatterer mobility, the Doppler frequency component in the channel coefficient generation in step 13 in clause 7.9.4.1 should be updated as follows.

(7.9.5-14)

where,

- is a random variable from to , and is the maximum speed of the clutter. is a random variable of Bernoulli distribution with mean if , otherwise . Parameter determines the proportion of mobile scatterers and can thus be selected to appropriately model statistically larger number of mobile scatterers (higher ) or statistically smaller number of mobile scatterers (e.g. in case of a completely static environment: =0 results in all scatterers having zero speed).

- is a random variable from to , and is the maximum speed of the clutter. is a random variable of Bernoulli distribution with mean *p* if , otherwise . Parameter *p* determines the proportion of mobile scatterers and can thus be selected to appropriately model statistically larger number of mobile scatterers (higher *p*) or statistically smaller number of mobile scatterers (e.g. in case of a completely static environment: p=0 results in all scatterers having zero speed).

#### 7.9.5.5 Lower power clusters

In addition to the clusters/rays in background channel generated in Clause 7.9.4.2, more clusters/rays can be generated to simulate the weak rays in the background channel. The following procedure is applicable for bistatic sensing or for monostatic sensing.

Step 1: Generate a first background channel according to Clause 7.9.4.2.

Step 2: Generate a second background channel according to Clause 7.9.4.2 with the following revised parameters: 1) The number of clusters (N in Clause 7.5) is increased to 360; 2) The number of ray per cluster (M in Clause 7.5) is reduced to 1.

Step 3: The power of the clusters/rays in the second background channel is scaled down by , and is added to the first background channel, where, dB,  is the maximum power of the NLOS clusters in the first background channel. The final background channel is

(7.9.5-15)

#### 7.9.5.6 Blockage

The blockage models in Clause 7.6.4 can be reused as an optional feature to model the blocking effects in the ISAC channel including the blockage due to the ST(s). The blockage of ST(s) can be applied to the LOS/NLOS rays in the background channel of the ST(s). The blockage of a first ST can be applied to the LOS/NLOS rays in the STX-ST and ST-SRX link of a second ST. The location, orientation and size of the ST as a blocker is known before applying the blockage models.

### 7.9.6 Channel model calibration

#### 7.9.6.1 Large scale calibration

For the purposes of large scale calibration without fast fading modelling for sensing targets UAV, human, automotive and AGV, the following calibration parameters are respectively provided in Table 7.9.6.1-1/2/3/4. Unspecified parameters in Table 7.9.6.1-2/3/4 are the same as those in Table 7.9.6.1-1. The calibration results based on TR 38.901 V19.0.0 can be found in R1-2504950 .

Table 7.9.6.1-1: Simulation assumptions for large scale calibration for UAV sensing targets

|  |  |
| --- | --- |
| Parameters | Values |
| Scenario | UMa-AV |
| Sensing mode | TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic |
| Target type | UAV of small size (0.3m x 0.4m x 0.2m) |
| Sectorization | Single 360-degree sector can be assumed |
| Carrier Frequency | FR1: 6 GHz  FR2: 30 GHz |
| BS antenna configurations | Single dual-pol isotropic antenna |
| BS Tx power | FR1: 56dBm  FR2: 41dBm |
| Bandwidth | FR1: 100MHz  FR2: 400MHz |
| BS noise figure | FR1: 5dB  FR2: 7dB |
| UT antenna configurations | Single dual-pol isotropic antenna; (M,N,P,Mg,Ng;Mp,Np) = (1,1,2,1,1;1,1) |
| UT noise figure | FR1: 9dB  FR2: 10dB |
| UT height | 1.5m for terrestrial UTs, |
| UT Tx power | 23dBm |
| UT Distribution | - The overall number of UTs is 30 uniformly distributed in the center cell.  - All of the UTs are either terrestrial UTs or aerial UTs, all outdoors.  - Vertical distribution of aerial UE: Fixed height value of 200 m.  - FR1 is assumed for aerial UE. |
| Sensing target distribution | 1 target uniformly distributed (across multiple drops) within the center cell. Vertical distribution: Fixed height value of 200 m. |
| Component A of the RCS for each scattering point | -12.81 dBsm |
| Minimum 3D distances between pairs of STX/SRX and sensing target | 10 m |
| Wrapping Method | No wrapping method is used if interference is not modelled, otherwise geographical distance based wrapping |
| Coupling loss for target channel | power scaling factor (pathloss, shadow fading, and RCS component A included): |
| STX/SRX selection | Best N = 4 STX-SRX pairs to be selected for the target.  see note 1 |
| Metrics | Coupling loss for target channel  Coupling loss for background channel (in case of monostatic sensing, this is the coupling loss between Tx and one reference point)  see note 2 |
| NOTE 1: Based on the STX-SRX pairs with the smallest power scaling factor of the target channel.  NOTE 2: CDFs can be separately generated for target channel, background channel. | |

Table 7.9.6.1-2. Simulation assumptions for large scale calibration for Human sensing targets

|  |  |  |
| --- | --- | --- |
| Parameters | Indoor Values | Outdoor Values |
| Scenario | Indoor office  12 sectors per 120m \* 50m \* 3m  ISD = 20m  InF-SH  Hall size: L=300 x W=150 m  Room height: 10m  18 BSs on a square lattice with spacing D, located D/2 from the walls.  - D=50m | UMa (ISD = 500m), UMi (ISD= 200m) |
| Sensing mode | TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic, UE monostatic | |
| Target type | Adult Pedestrian: 0.5m x 0.5m x 1.75m. See note. | |
| BS Tx power | FR1: 24dBm  FR2: 23dBm | FR1: 56dBm  FR2: 41dBm |
| UT height | 1m | 1.5m |
| UT Distribution | Per Table 7.8-1 Indoor-Office  Number of UTs: 20 | Per Table 7.8-1.  Number of UTs/cell: 10 |
| Sensing target distribution | 100% indoor, 1 target uniformly distributed (across multiple drops) over the convex hull of the TRP deployment | 100% outdoor. 1 target uniformly distributed (across multiple drops) within the center cell. |
| Component A of the RCS for each scattering point | -1.37 dBsm | |
| Minimum 3D distances between pairs of STX/SRX and sensing target | Min distances defined in TR 38.901 and TR36.843 and TR38.859 | |
| Wrapping Method | N/A | No wrapping method is used if interference is not modelled, otherwise geographical distance based wrapping |
| NOTE: Height of scattering point 1.5m | | |

Table 7.9.6.1-3. Simulation assumptions for large scale calibration for Automotive sensing targets

|  |  |
| --- | --- |
| Parameters | Values |
| Scenario | For FR1:  - Urban Grid (ISD=500m, BS height=25m)  - Highway (ISD=1732m, BS height=35m)  For FR2:  - Urban Grid (ISD=250m, BS height=25m)  - Highway (ISD=500m, BS height=25m)  For Urban Grid ISD =250m  - The layout is configured as follows:  - Red triangles: BS with 250m ISD, 18 BSs are located.  A diagram of a road with red arrows  AI-generated content may be incorrect. |
| Sensing mode | TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic, UE monostatic |
| Target type | Vehicle type 2 [TR37.885] |
| UT height | 1.5m for pedestrian type UE  5m for RSU type UE  1.6m for vehicle type UE |
| UT Distribution | For Highway:  - Vehicle Type UT distribution follows vehicle UE dropping as in Table A.1.2-1 from TR36.885.  - RSU-type UTs are uniformly allocated with 100m spacing in the middle of the freeway as per TR36.885.  For Urban grid:  - Vehicle Type UT distribution follows vehicle UE dropping as in Table A.1.2-1 from TR36.885.  - Pedestrian type UT, the dropping using equally spaced along the sidewalk with a fixed inter-pedestrian X m dropped per TR36.885  - Total number of pedestrian UEs is 16 in the centre grid.  - Pedestrian UE is in the middle of the sidewalk  - The inter-pedestrian UE distance (m) (i.e., X) is calculated by ‘A/16’, where ‘A’ is the total length of sidewalk where the pedestrian UEs are dropped under the assumption of ‘N’ road grids (i.e., ‘{(250m – 17m) + (433m – 17m)} \* 2 \* N’). For example, if the pedestrian UEs are dropped in ‘14’ road grids, the inter-pedestrian UE distance (m) is ‘36.344’.  - N=1;  - RSU-type UT: the dropping is at the center of intersection per TR36.885.  see note 1 |
| Sensing target distribution | Per TR37.885: - Option A - Vehicle type distribution: 100% vehicle type 2. - Clustered dropping is not used.  - Highway: one target uniformly distributed (across multiple drops) within the simulation region. Vehicle speed is 140 km/h in all the lanes as baseline.  - Urban Grid: one target is uniformly distributed (across multiple drops) within the center road grid. Vehicle speed is 60 km/h in all the lanes as baseline.  see note 2 |
| Component A of the RCS for each scattering point | 11.25 dBsm |
| Minimum 3D distances between pairs of STX/SRX and sensing target | 10 m |
| Wrapping Method | No wrapping method is used if interference is not modelled, otherwise geographical distance based wrapping.As defined in urban grid/highway scenario |
| NOTE 1: A single UT type is used per calibration, e.g., pedestrian type UT, RSU type UT, or vehicle type UTPer TR37.885  NOTE 2: A vehicle with size L\*W\*H can be dropped with 5 scattering points (front/left/right/back/roof), respectively with locations (L/2,0,H/2), (0,W/2,H/2), (0,-W/2,H/2), (-L/2,0,H/2) and (0,0,H) in LCS. A vehicle with size L\*W\*H can be dropped with 1 scattering point with location (0,0,H/2) in LCS. In the case of vehicle with 5 scattering points, spatial consistency is enabled with the following assumptions:  - The correlation for LOS/NLOS condition of the 5 points is assumed equal to 1. LOS/NLOS condition can be calculated based on the distance of the STX/SRX to the centroid of the ST, then apply the LOS/NLOS condition to each of the 5 points.  - The correlation for stochastic cluster paths of the 5 points is assumed equal to 1. The stochastic cluster paths can be calculated between the STX/SRX and the centroid of the ST, then the stochastic cluster paths are added to each of the 5 points. | |

Table 7.9.6.1-4. Simulation assumptions for large scale calibration for AGV sensing targets

|  |  |
| --- | --- |
| Parameters | Values |
| Scenario | InF: 18 TRPs per the big hall: L = 300 m x W = 150 m  A diagram of a diagram  AI-generated content may be incorrect.  - X-axis is pointing down to the floor  - The antenna array is mounted in the Y-Z plane with boresight along the X-axis  - The X-axis/Y-axis/Z-axis refer to LCS  - 8 m for high BS scenario |
| Sensing mode | TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic, UE monostatic |
| Target type | Option 1: 1.6m x 1.5m x 0.7m |
| BS Tx power | FR1: 24dBm  FR2: 23dBm |
| UT height | 1.5m |
| UT Distribution | Per Table 7.8-7 Indoor Factory.  Number of UTs: 30 |
| Sensing target distribution | 100% indoor, 1 target uniformly distributed (across multiple drops) over the convex hull of the TRP deployment |
| Component A of the RCS for each scattering point | -4.25 dBsm  see note |
| NOTE: For calibration purposes, other value(s) are not precluded, | |

#### 7.9.6.2 Full calibration

For the purpose of full calibration including the fast fading modelling for sensing scenarios UAV, human, automotive and AGV, the calibration parameters are respectively provided in Table 7.9.6.2-1/2/3/4. Unspecified parameters in the tables are the same as those in Table 7.9.6.1-1/2/3/4 for the same sensing target. If still not specified, the parameters in Table 7.9.6.2-1 are used. The calibration results based on TR 38.900 V19.0.0 can be found in R1-2504950.

Table 7.9.6.2-1: Simulation assumptions for full calibration for UAV sensing targets

|  |  |
| --- | --- |
| Parameters | Values |
| Scenario | UMa-AV |
| Sensing mode | TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic |
| Target type | UAV of small size (0.3m x 0.4m x 0.2m) |
| RCS for each scattering point | Component A: -12.81 dBsm  Component B1: 0 dB  Component B2: 3.74 dB for standard deviation  The same values are used for monostatic RCS and bistatic RCS |
| Fast fading model | TR 36.777 Annex B.1.3 |
| (u, std) for XPR of target | Mean 13.75 dB, deviation 7.07 dB |
| The power threshold for path dropping after concatenation for target channel | -40 dB |
| Coupling loss for target channel | By definition, need to consider all direct and indirect paths. The following parameters are included in the calculation:  - power scaling factor (pathloss, shadow fading, and RCS component A included)  - for small scale RCS B1/B2 and power of rays in Tx-target/target-Rx links (), STX/SRX antenna pattern, 3 polarization matrixes, i.e., |
|  |
| Absolute delay | The model of UMa scenario defined in Table 7.6.9-1 is reused for UMa-AV for all sensing modes. |
| Metrics | Coupling loss for target channel  Coupling loss for background channel (in case of monostatic sensing, this is the linear sum of coupling losses between STX/SRX and all reference points)  See note.  CDF of Delay Spread and Angle Spread (ASD, ZSD, ASA, ZSA). For monostatic sensing mode: delay spread and angle spread of the background channel is calculated separately for each reference point.  Definition of Delay Spread is similar to the definition of angle spread in Annex A of TR 25.996,  Definition of Angle Spread can ref to Annex A of TR 25.996. |
| NOTE: CDFs can be separately generated for target channel, background channel | |

Table 7.9.6.2-2: Simulation assumptions for full calibration for Human sensing targets

|  |  |  |
| --- | --- | --- |
| Parameters | Indoor Values | Outdoor Values |
| Scenario | As specified in Table 7.9.6.1-2 | As specified in Table 7.9.6.1-2 |
| Sensing mode | TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic, UE monostatic | |
| Target type | Adult Pedestrian: 0.5m x 0.5m x 1.75m  see note | |
| UT Distribution | Per Table 7.8-2 Indoor-Office  Number of UTs: 20 | Per Table 7.8-2  Number of UTs/cell: 10 |
| RCS for each scattering point | Component A: -1.37 dBsm  Component B1: 0 dB  Component B2: 3.94 dB  The same values are used for monostatic RCS and bistatic RCS | Component A: -1.37 dBsm  Component B1: 0 dB  Component B2: 3.94 dB  The same values are used for monostatic RCS and bistatic RCS |
| Fast fading model | For BS to UE link: Follow the procedure defined in TR38.901 For BS to target link: Follow the procedure defined in TR38.901 for target to UE link: Follow the procedure defined in 38.858 | For BS to UE link: Follow the procedure defined in TR38.901 For BS to target link: Follow the procedure defined in TR38.901 for target to UE link: Follow the procedure defined in 38.858 |
| (u, std) for XPR of target | (19.81, 4.25) dB | (19.81, 4.25) dB |
| Absolute delay | The model of InH, InF-SH scenarios defined in Table 7.6.9-1. | The model of UMa/UMi scenario defined in Table 7.6.9-1. |
| NOTE: Height of scattering point 1.5m | | |

Table 7.9.6.2-3: Simulation assumptions for full calibration for Automotive sensing targets

|  |  |
| --- | --- |
| Parameters | Values |
| Scenario | As specified in Table 7.9.6.1-3 |
| Sensing mode | TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic, UE monostatic |
| Target type | Vehicle type 2 [TR37.885] |
| RCS for each scattering point | Based on the RCS model in Clause 7.9.2.1. |
| Fast fading model (full calibration) | Procedures based on 37.885 |
| (u, std) for XPR of target | (21.12, 6.88) dB. |
| Absolute delay | The model of UMa scenario defined in Table 7.6.9-1 is reused for Highway (FR2)/Urban Grid for all sensing modes.  The model of RMa scenario defined in Table 7.6.9-1 is reused for Highway (1732m ISD) for all sensing modes. |

Table 7.9.6.2-4: Simulation assumptions for full calibration for AGV sensing targets

|  |  |
| --- | --- |
| Parameters | Values |
| Scenario | As specified in Table 7.9.6.1-4 |
| Sensing mode | TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic, UE monostatic |
| Target type | Option 1: 1.6m x 1.5m x 0.7m |
| RCS for each scattering point | The values/pattern of component A\*B1 are generated by Table 7.9.2.1-6  The same values are used for monostatic RCS and bistatic RCS |
| Fast fading model (Full calibration) | For BS to UE link: Follow the procedure defined in TR38.901  For BS to target link: Follow the procedure defined in TR38.901  for target to UE link: Follow the procedure defined in TR 38.858 |
| (u, std) for XPR of target | (9.60, 6.85) dB |
| Absolute delay | The model of InF scenario defined in Table 7.6.9-1 is reused for all sensing modes. |

#### 7.9.6.3 Calibration of additional features

The calibration parameters for the calibration of spatial consistency and type-2 EO can be respectively found in Table 7.9.6.3-1/2. Unspecified parameters in these tables are the same as those in Tables 7.9.6.1-2/3 and Tables 7.9.6.2-2/3. The calibration results based on TR 38.900 V19.0.0 can be found in R1-2504950.

Table 7.9.6.3-1: Simulation assumptions for calibration of spatial consistency

|  |  |
| --- | --- |
| Parameter | Values |
| Scenario | Urban grid, Indoor office |
| Cell layout | Urban grid: ISD = 500m, the same layout with 37.885  Indoor office: Office size (WxLxH): 120mx50mx3m, ISD=20m (refer to TR 38.901) |
| Sensing mode | TRP- pedestrian UE bistatic in urban grid and TRP-UE bistatic in indoor office |
| Polarized antenna model | Model-2 in clause 7.3.2 in TR 38.901 |
| Scattering point | Single point |
| Calibration link and calibration method | - Calibration link: same target associated to different UT as following figure  A diagram of a cell phone  AI-generated content may be incorrect.  - Calibration method  Step1: In single drop simulation, drop one Target and multiple UTs.  Step2: Generate the channel of each link based on Target level spatial consistency method.  Step3: Determine Target-UT groups based on the distance between UTs.  Step4: Bin all the link pairs into certain distance groups, e.g.,  - 0m <= the location distance of link pair < 1m -> 0m group  - 1m <= the location distance of link pair < 2m -> 1m group  - 2m <= the location distance of link pair < 3m -> 2m group  - 3m <= the location distance of link pair < 4m -> 3m group  …  - (N)m <= the location distance of pair < (N+1)m -> (N)m group (see note 2)  Step5: Calculate the correlation coefficient metric of each distance groups.  Step6: Draw the x-y cure, where x=0, …, N, y= correlation coefficient metric related to (x)m group |
| ST and UT distribution | - Urban grid  one target is uniformly dropped within the center grid in the outside lane with length of 433m,  the UT is distributed by a uniform distribution distance of [0,1]m in the walk road where is in the same street with the target.  As following figure.    see note 3    - Indoor office  1 Target is uniform dropped in office region  10 UTs are dropped uniformly per cell, i.e., totally 120 UTs are uniformly dropped in office region. |
| Metrics | Cross-correlation coefficient of delay for the third cluster of channel between link pairs.  Cross-correlation coefficient of AOA (for UT) for the third cluster of channel between link pairs.  Cross-correlation coefficient of LOS/NLOS status of channel between link pairs(only for indoor office scenario). |
| NOTE 1: Other necessary but unspecified parameters in this table are the same as those in the table for urban grid scenario calibration and indoor office scenario calibration.  NOTE 2: N is at least twice the maximum correlation distance associated with the channel parameters in the scenario  NOTE 3: The ST-UT link only consider LOS condition discarding NLOSv condition. | |

Table 7.9.6.3-2: Simulation assumptions for calibration of type-2 EO

|  |  |
| --- | --- |
| Parameter | Values |
| Scenario | Urban grid |
| Cell layout | For FR1: ISD = 500m, the layout is defined as below:  The BSs are placed at the top of buildings at one corner. Specifically, the road grids shall be shifted by () m in horizontal plane, or the BSs are shifted by ()m in horizontal plane equivalently.  A screenshot of a map  AI-generated content may be incorrect.  For FR2 ISD=250m, the cell layout is as that specified in Table 7.9.6.1-3 |
| Sensing mode | TRP- pedestrian UE bistatic  TRP- RSU type UE bistatic  TRP monostatic  TRP-TRP bistatic  RSU type UE - RSU type UE bistatic (optional) |
| EO deployment | 9 buildings with size 413m x 230m x 20m illustrated by the green blocks as in the figure shown in the row of cell layout. |
| ST distribution | one target is uniformly distributed (across multiple drops) within the center of the outside lane of the grid. |
| UT distribution | - For pedestrian UT  - Pedestrian type UE, the dropping using equally spaced along the sidewalk with a fixed inter-pedestrian X m dropped per TR36.885.  - Total number of pedestrian UEs is 16 in the centre grid.  - Pedestrian UE is in the middle of the sidewalk  - The inter-pedestrian UE distance (m) (i.e., X) is calculated by ‘A/16’, where ‘A’ is the total length of sidewalk where the pedestrian UEs are dropped under the assumption of ‘N’ road grids (i.e., ‘{(250m – 17m) + (433m – 17m)} \* 2 \* N’). For example, if the pedestrian UEs are dropped in ‘14’ road grids, the inter-pedestrian UE distance (m) is ‘36.344’.  - N=1;  - For RSU type UT  - The dropping is at the center of intersection per TR36.885. |
| EM-parameters | Refer to the row for concrete in Table 7.6.8-1 |
| Metrics | CDF curves:  - Full coupling loss: calculate the coupling loss for each Tx-EO-ST-LOS-Rx and Tx-LOS-ST-EO-Rx rays.  - CDF of the Delay.  - CDF of the AoA, AoD, ZoA, ZoD.  Additional CDF curves:  - Coupling loss for target channel  - CDF of Delay Spread and Angle Spread (ASD, ZSD, ASA, ZSA). Definition of Delay Spread is similar to the definition of angle spread [TR 25.996, Annex A]. |
| NOTE: Other necessary but unspecified parameters in this table are the same as those in the table for urban grid scenario calibration. | |

# 8 Map-based hybrid channel model (Alternative channel model methodology)

**< Unchanged text omitted >**