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Study on evaluation methodology of new Vehicle-to-Everything (V2X) use cases for LTE and NR;

(Release 15)

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# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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# 1 Scope

The present document captures the findings of the study item, "Study on evaluation methodology of new V2X use cases for LTE and NR" [2]. The purpose of this TR is to document the evaluation methodology to be used in evaluating technical solutions to support the full set of 5G V2X use cases as identified in [3] and the full set of 5G RAN requirements in [4].

This document addresses completion of the evaluation methodology in [4] and [5] to compare the performance of different technical options for the new 5G V2X use cases.

This document captures identification of the regulatory requirements and design considerations of potential operation of direct communications between vehicles in spectrum allocated to ITS beyond 6GHz in different regions.

This document is a 'living' document, i.e. it is permanently updated and presented to TSG-RAN meetings.

# 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*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP RP-170837: "New SI proposal: Study on evaluation methodology of new V2X use cases for LTE and NR".

[3] 3GPP TR 22.886: "Study on enhancement of 3GPP Support for 5G V2X Services".

[4] 3GPP TR 38.913: "Study on Scenarios and Requirements for Next Generation Access Technologies".

[5] 3GPP TR 38.802: "Study on New Radio Access Technology; Physical Layer Aspects".

[6] ITU-R M.1452-2 (05/2012): "Millimetre wave vehicular collision avoidance radars and radiocommunication systems for intelligent transport system applications"

[7] ECC/DEC/(09)01: "The harmonised use of the 63-64 GHz frequency band for Intelligent Transport Systems (ITS)"

[8] ETSI TR 102 400 v1.2.1(2006-07): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Intelligent Transport Systems (ITS); Road Traffic and Transport Telematics (RTTT); Technical characteristics for communications equipment in the frequency band from 63 GHz to 64 GHz; System Reference Document".

[9] ETSI EN 302 686 V1.1.1(2011-02): "Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 63 GHz to 64 GHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive"

[10] ERMTG37(17)026012: "ITS in 60GHz proposal, FBConsulting, ETSI ERM-TG37#26"

[11] IEEE 802.18-17/0097: "ITS in 60GHz - An updated proposal discussed in ETSI TC BRAN and TC ITS, Friedbert Berens, Markus Mueck"

[12] Republic of Korea table of frequency allocations, https://spectrum.or.kr:5017/download.php?dnfile=%EC%A3%BC%ED%8C%8C%EC%88%98%EB%B6%84%EB%B0%B0%EB%8F%84%ED%91%9C%282015%EB%85%84+1%EC%9B%94%29.pdf&file=/www/spectrum\_or\_kr/webapp/../upload\_dir/banner/175666235554bdd5483c499.pdf

[13] 3GPP TR 36.885: "Study on LTE-based V2X services".

[14] 3GPP TR 36.873: "Study on 3D channel model for LTE".

[15] 3GPP TR 38.901: "Study on channel model for frequencies from 0.5 to 100 GHz".

[16] 3GPP TR 36.872: "Small cell enhancements for E-UTRA and E-UTRAN - Physical layer aspects".

[17] 3GPP TR 36.814: "Further advancements for E-UTRA physical layer aspects".

[18] 3GPP TR 22.872: "Study on positioning use cases".

[19] F. Gil et al., "A 3-D extrapolation model for base station antenna's radiation patterns" in Proc. IEEE VTC-Fall, Amsterdam, The Netherlands, Sep. 1999, pp. 1341–1345.

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

## 3.2 Symbols

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

<symbol> <Explanation>

## 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].

B2R Base station to road side unit

P2B Pedestrian to base station

P2P Pedestrian to pedestrian

R2R Road side unit to road side unit

RSU Road side unit

V2B Vehicle to base station

V2P Vehicle to pedestrian

V2V Vehicle to vehicle

V2R Vehicle to road side unit

# 4 Introduction

To expand the 3GPP platform to the automotive industry, the initial standard on support of V2V services was completed in September 2016. Further enhancements that focusing on additional V2X operation scenarios leveraging the cellular infrastructure, also for inclusion in Release 14, is targeting completion in March 2017 as 3GPP V2X phase 1.

Currently, SA1 is working on enhancement of 3GPP support for V2X services in FS\_eV2X. SA1 has identified 25 use cases for advanced V2X services and they are categorized into four use case groups: vehicles platooning, extended sensors, advanced driving and remote driving. The detailed description of each use case group is provided as below.

1) Vehicles Platoonning enables the vehicles to dynamically form a platoon travelling together. All the vehicles in the platoon obtain information from the leading vehicle to manage this platoon. These information allow the vehicles to drive closer than normal in a coordinated manner, going to the same direction and travelling together.

2) Extended Sensors enables the exchange of raw or processed data gathered through local sensors or live video images among vehicles, road site units, devices of pedestrian and V2X application servers. The vehicles can increase the perception of their environemnt beyond of what their own sensors can detect and have a more broad and holistic view of the local situation. High data rate is one of the key characteristics.

3) Advanced Driving enables semi-automated or full-automated driving. Each vehicle and/or RSU shares its own perception data obtained from its local sensors with vehicles in proximity and that allows vehicles to synchronize and coordinate their trajectories or manoeuvres. Each vehicle shares its driving intention with vehicles in proximity too.

4) Remote Driving enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive by themselves or remote vehicles located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. High reliability and low latency are the main requirements.

The consolidated requirements for each use case group are captured in TR 22.886. Based on the input from FS\_eV2X, SA1 will generate a set of normative requirements for Release 15. Inline with these requirements, TSG RAN has been defining a set of corresponding 5G RAN requirements within 3GPP TR38.913.

In order to study technical solutions for the new V2X use cases, new evaluation methodology needs to be defined.

# 5 Regulation for ITS operation in frequency band above 6 GHz

## 5.1 International recommendation

ITU-R recommends technical and operational characteristics for millimeter wave radiocommunication systems for ITS applications for V2V and V2I in the frequency band 57.0-66.0 GHz [Annex 2 in 6]. Channel arrangements will be specified by regions or countries separately. ITU-R identifies the transmission parameter requirements for ITS with three types of system bandwidth as follows:

Table 5.1-1 Transmission parameter requirements in [6].

|  |  |  |  |
| --- | --- | --- | --- |
|  | System A | System B | System C |
| System bandwidth | 63-64 GHz | 59-66 GHz | 57-64 GHz |
| E.I.R.P | 40 dBm |  |  |
| Transmit power |  | 10mW | 10mW |
| Antenna Gain | 23 dBi or less | 47 dBi or less | 17 dBi or less |

## 5.2 European regulation

CEPT states that 63-64 GHz frequency bands are allowed for ITS on harmonized use basis and the maximum radiated power should be limited to 40 dBm E.I.R.P [7]. ETSI also indicates that this frequency band can be used for ITS providing traffic safety and traffic efficiency applications (including V2V and V2I) all over Europe, and the following transmission parameters were considered in the analysis in [8, 9]:

- E.I.R.P

- 40 dBm (E.I.R.P. max mean power), 43 dBm (E.I.R.P. max peak power)

- Transmit power

- 27 dBm (max peak conducted power)

- Unwanted emission level

- Less than -30 dBm

- Antenna gain

- RSU : 23 dBi, Vehicle : 21 dBi (for V2V), 14 dBi (for V2I)

The definition of RF output power "the RF output power is the mean equivalent isotropic radiated power (e.i.r.p.) for the equipment during a transmission burst. The mean e.i.r.p. refers to the highest power level of the transmitter power control range during the transmission cycle if the transmitter power control is implemented" in [9] may need to be clarified, e.g., the notion of "transmission burst."

It is noted that there is ongoing discussion in ETSI to adjust ITS spectrum at 63-64 GHz because this spectrum overlaps with two RLAN channels [10, 11]. Based on further progress, ITS frequency allocation above 6 GHz in Europe may be updated, e.g., shift the center frequency of ITS band to 62.64 or 64.80 GHz and enlarge its bandwidth up to 2.16 GHz.

## 5.3 Korean regulation

In Korean regulations, frequency band 57.0-66.0 GHz is currently assigned for the purpose of communications for earth exploration satellite(Passive), fixed and Inter-satellite [12], but no specific use cases are determined yet and the spectrum is being underutilized [Footnote K176C in 12].

## 5.4 Chinese regulation

There is no Chinese regulation for using ITS application in above 6GHz.

# 6 Evaluation methodology

The evaluation methodology in this document is used as a baseline for evaluating technical solutions and can be modified later as necessary.

## 6.1 System level simulation assumptions

### 6.1.1 Evaluation scenarios

For both below and above 6 GHz, the road configuration for urban grid and highway in [4] is used and the details are provided in Annex A.

Parameters regarding evaluation scenarios below 6 GHz are given in the following table:

Table 6.1.1-1: Evaluation scenarios below 6 GHz

|  |  |  |
| --- | --- | --- |
| Parameters | Urban grid for eV2X | Highway for eV2X |
| Carrier frequency | Macro to/from vehicle/pedestrian UE : 4 GHz  Between vehicle/pedestrian UE: 6 GHz  Micro BS to/from vehicle/pedestrian UE : 4 GHz  UE-type-RSU to/from vehicle/pedestrian UE: 6 GHz  Note: Agreed value does not mean non-ITS band is precluded for real deployment for sidelink | Macro to/from vehicle/pedestrian UE : 2 GHz or 4GHz Between vehicle/pedestrian UE: 6 GHz Micro BS to/from vehicle/pedestrian UE : 4 GHz UE-type-RSU to/from vehicle/pedestrian UE: 6 GHz Note: Agreed value does not mean non-ITS band is precluded for real deployment for sidelink |
| Aggregated system bandwidth | Up to 200 MHz (DL+UL)  Up to 100 MHz (SL) | Up to 200 MHz (DL+UL)  Up to 100 MHz (SL) |
| Simulation bandwidth | 20 or 40 MHz (DL+UL)  10 and 20 MHz (baseline for SL)  100 MHz (optional for SL) | 20 or 40 MHz (DL+UL)  10 and 20 MHz (baseline for SL)  100 MHz (optional for SL) |
| BS Tx power | Macro BS: 49dBm PA scaled down proportionally with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm  Micro BS: 24dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 24dBm  Note: 33dBm for RSU is not precluded | Macro BS: 49dBm PA scaled down proportionally with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm Micro BS: 24dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 24dBm  Note: 33dBm for RSU is not precluded |
| UE Tx power | Vehicle/pedestrian UE or UE type RSU: 23dBm  Note: 33dBm is not precluded | Vehicle/pedestrian UE or UE type RSU: 23dBm  Note: 33dBm is not precluded |
| BS receiver noise figure | 5dB | 5dB |
| UE receiver noise figure | 9 dB | |

Note #1: Aggregated sidelink bandwidth of 100 MHz at 6GHz is not available in the current frequency allocations for ITS and its future availability is subject to the progress in the potential additional ITS spectrum allocation.

Note #2: Simulated sidelink bandwidth of 100 MHz is available in licensed spectrum at this moment and not supported in the current ITS spectrum allocation.

Parameters regarding evaluation scenarios above 6 GHz are given in the following table:

Table 6.1.1-2: Evaluation scenarios above 6 GHz

|  |  |  |
| --- | --- | --- |
| Parameters | Urban grid for eV2X | Highway for eV2X |
| Carrier frequency | Macro to/from vehicle/pedestrian UE : 30 GHz  Between vehicle/pedestrian UE: 30 or 63 GHz  Micro BS to/from vehicle/pedestrian UE : 30 GHz  UE-type-RSU to/from vehicle/pedestrian UE: 30 or 63 GHz  Note: Agreed value does not mean non-ITS band is precluded for real deployment for sidelink | Macro to/from vehicle/pedestrian UE : 30 GHz Between vehicle/pedestrian UE: 30 or 63 GHz Micro BS to/from vehicle/pedestrian UE : 30 GHz UE-type-RSU to/from vehicle/pedestrian UE: 30 or 63 GHz Note: Agreed value does not mean non-ITS band is precluded for real deployment for sidelink |
| Aggregated system bandwidth | Up to 1 GHz (DL+UL)  Up to 1 GHz (SL) | Up to 1 GHz (DL+UL)  Up to 1 GHz (SL) |
| Simulation bandwidth | 200 MHz (DL+UL)  200 MHz (SL) | 200 MHz (DL+UL)  200 MHz (SL) |
| BS Tx power | Macro BS: 43dBm PA scaled down proportionally with simulation BW when system BW is higher than simulation BW. Otherwise, 43dBm. EIRP should not exceed 78 dBm and is also subject to appropriate scaling | Macro BS: 43dBm PA scaled down proportionally with simulation BW when system BW is higher than simulation BW. Otherwise, 43dBm. EIRP should not exceed 78 dBm and is also subject to appropriate scaling |
| UE Tx power | Vehicle/pedestrian UE or UE type RSU: 23 dBm for 30 GHz, 21 dB baseline for 63 GHz, 27 dBm optional for 63 GHz. For both 30 and 63 GHz, EIRP should not exceed 43 dBm. | Vehicle/pedestrian UE or UE type RSU: 23 dBm for 30 GHz, 21 dB baseline for 63 GHz, 27 dBm optional for 63 GHz. For both 30 and 63 GHz, EIRP should not exceed 43 dBm. |
| BS receiver noise figure | 7 dB | 7 dB |
| UE receiver noise figure | 13 dB (baseline), 10 dB (optional) | |

Note #1: Further consideration is needed on how to scale the performance of sidelink.

### 6.1.2 UE drop and mobility modeling

Three vehicle types are defined as follows:

- Type 1 (passenger vehicle with lower antenna position): length 5 meters, width 2.0 meters, height 1.6 meters, antenna height 0.75 meters

- Type 2 (passenger vehicle with higher antenna position): length 5 meters, width 2.0 meters, height 1.6 meters, antenna height 1.6 meters

- Type 3 (truck/bus): length 13 meters, width 2.6 meters, height 3 meters, antenna height 3 meters

Vehicles are dropped according to the following process:

- The distance between the rear bumper of a vehicle and the front bumper of the following vehicle in the same lane is max {2 meter, an exponential random variable with the average of the speed \* 2 sec}.

- All the vehicles in the same lane have the same speed.

- Vehicle type distribution is not dependent of the lane.

Clustered vehicle UE dropping is defined as follows:

- A cluster consists of a number vehicle UEs located in the same lane and having the same direction/speed. Two closest UEs belonging to the same cluster are separated with a fixed distance and no other UEs can be located between them.

- The distance between a platoon and a vehicle not belonging to the platoon follows the statistics of the distance between two vehicles not belonging to any platoon.

- Only Type 3 vehicles form a cluster.

- Clustered UE dropping is used only in the highway scenario.

The following UE dropping options are supported for the highway scenario:

- Option A

- Vehicle type distribution: 100% vehicle type 2.

- Clustered dropping is not used.

- Vehicle speed is 140 km/h in all the lanes as baseline and 70 km/h in all the lanes optionally.

- Option B

- Vehicle type distribution: 20% vehicle type 1, 60% vehicle type 2, 20% vehicle type 3.

- Clustered dropping is not used.

- Vehicle speed in each lane is as follows:

- Speed in Lane 1: 80km/h

- Speed in Lane 2: 100km/h

- Speed in Lane 3: 140km/h

- Speed in Lane 4: 40km/h

- Speed in Lane 5: 30km/h

- Speed in Lane 6: 20km/h

- Option C

- Vehicle type distribution: 0% vehicle type 1, 67% vehicle type 2, 33% vehicle type 3.

- Clustered dropping is used. Each cluster consists of 6 Type 3 vehicles with a gap of 2 meters.

- Vehicle speed is 140 km/h in all the lanes.

The following UE dropping options are supported for the urban grid scenario:

- Option A

- Vehicle type distribution: 100% vehicle type 2.

- Clustered dropping is not used.

- Vehicle speed is 60 km/h in all the lanes.

- In the intersection, a UE goes straight, turns left, turns right with the probability of 0.5, 0.25, 0.25, respectively.

- Option B

- Vehicle type distribution: 20% vehicle type 1, 60% vehicle type 2, 20% vehicles type 3.

- Clustered dropping is not used.

- Vehicle speed in each lane is as follows:

- In the East-West direction:

- Speed in Lane 1: 60km/h

- Speed in Lane 2: 50km/h

- Speed in Lane 3: 25km/h

- Speed in Lane 4: 15km/h

- In the North-South direction:

- 0 km/h in all the lanes.

- No vehicles are dropped at the intersections in the North-South direction. Vehicles do not change their direction at the intersection.

Pedestrian UEs are dropped following the procedure in [13].

Cellular UEs are dropped according to the following process:

- Cellular UEs are dropped inside vehicles as follows:

- In each vehicle of type 1 or type 2, the number of cellular UEs inside the vehicle is uniformly random in the range between 1 and 4.

- In each vehicle of type 3, the number of cellular UEs inside the vehicle is uniformly random in the range between 10 and 20.

- The portion of the active cellular UEs is 20, 50, 80%.

- Note that the traffic for the cellular UE is to use licensed spectrum.

### 6.1.3 BS and UE-type RSU deployment

Parameters regarding BS and RSU deployment below 6 GHz are given in the following table:

Table 6.1.3-1: BS and UE-type RSU deployment below 6 GHz

|  |  |  |
| --- | --- | --- |
| Parameters | Urban grid for eV2X | Highway for eV2X |
| Layout | Baseline: Macro only (with the road configuration in Figure 6.1.9-1 in [4] and BS placement as depicted in Figure A.1.3-1 in [13])  Note #1: Out of coverage can be evaluated assuming BS to be disabled.  Note #2: Companies are not precluded to evaluate a scenario with additional micro BS. | Baseline: Macro only (straight line BS placement with Road configuration in [13])  Note #1: Out of coverage can be evaluated assuming BS to be disabled.  Note #2: Companies are not precluded to evaluate a scenario with additional micro BS. |
| Inter-BS distance | Inter Macro: 500m | Inter Macro: 1732m, 500m (optional) |
| UE-type RSU | UE-type RSU deployment as defined in [13]  Note #3: Companies are not precluded to evaluate a scenario with additional UE-type RSU. | UE-type RSU deployment as defined in [13]  Note #3: Companies are not precluded to evaluate a scenario with additional UE-type RSU. |

Parameters regarding BS and RSU deployment above 6 GHz are given in the following table:

Table 6.1.3-2: BS and UE-type RSU deployment above 6 GHz

|  |  |  |
| --- | --- | --- |
| Parameters | Urban grid for eV2X | Highway for eV2X |
| Layout | Baseline: Macro only (with the road configuration in Figure 6.1.9-1 in [4] and BS placement as depicted in Figure A.1.3-1 in [13])  Note #1: Out of coverage can be evaluated assuming BS to be disabled.  Note #2: Companies are not precluded to evaluate a scenario with additional micro BS. | Baseline: Macro only (with BS placement as depicted in Figure A.1.3-3 in [13])  Note #1: Out of coverage can be evaluated assuming BS to be disabled.  Note #2: Companies are not precluded to evaluate a scenario with additional micro BS. |
| Inter-BS distance | Inter Macro: 500m | Inter Macro: 500m |
| UE-type RSU | UE-type RSU deployment as defined in [13]  Note #3: Companies are not precluded to evaluate a scenario with additional UE-type RSU. | UE-type RSU deployment as defined in [13]  Note #3: Companies are not precluded to evaluate a scenario with additional UE-type RSU. |

### 6.1.4 Antenna model

Parameters regarding antenna height are given in the following table:

Table 6.1.4-1: Antenna height

|  |  |  |
| --- | --- | --- |
| Parameters | Urban grid for eV2X | Highway for eV2X |
| BS antenna height | Macro BS: 25m  Micro BS: 5m | Macro BS:  35m for ISD 1732m  25m for ISD 500m  Micro BS: 5m |
| UE antenna height | Vehicle UE: As defined in Subclause 6.1.2  Pedestrian UE, cellular UE: 1.5 m  UE-type-RSU: 5 m | Vehicle UE: As defined in Subclause 6.1.2  Pedestrian UE, cellular UE: 1.5 m  UE-type-RSU: 5 m |

Note #1: The values for UE antenna may be revised after discussions on antenna placement, etc., if any.

Macro BS antenna element pattern and array configuration are given in the following tables:

Table 6.1.4-2: Antenna element pattern for Macro BS

|  |  |  |
| --- | --- | --- |
|  | For 4 GHz | For 30 GHz |
| Antenna element gain vertical pattern |  | |
| Antenna element gain horizontal pattern |  | |
| Pattern combining method for 3D |  | |
| Max direct. gain of the antenna element | 8 dBi | |

Table 6.1.4-3: Antenna array configuration for Macro BS

|  |  |  |
| --- | --- | --- |
|  | For 4 GHz | For 30 GHz |
| TXRU mapping | Up to proponents | Up to proponents |
| Number of antenna elements across all panels | Up to 256 TX/RX antenna elements | Up to 256 Tx /Rx antenna elements |
| Antenna array configuration (M, N, P, Mg, Ng) | (8, 8, 2, 1, 1) | (4, 8, 2, 2, 2) |
| Antenna array spacing (dH,dV,dH,g,dV,g) | (dH, dV) = (0.5, 0.8)λ | (dH, dV) = (0.5, 0.5)λ  (dH,g, dV,g) = (4.0, 2.0)λ |
| Antenna polarization | Declare which polarization model in [15] is used | Declare which polarization model in [15] is used |
| Antenna tilt, deg | 102 degree for 500m ISD, 96 degree for 1732m ISD | 102 degree for 500m ISD, 96 degree for 1732m ISD |
| Others | TXRUs within a panel can be assumed to be synchronized and phase-calibrated (at least to the same level as in LTE) | |

UE-type RSU antenna element pattern and array configuration are given in the following tables:

Table 6.1.4-4: Antenna element pattern for UE-Type RSU

|  |  |
| --- | --- |
| For 6 GHz | |
| Antenna element gain vertical pattern |  |
| Antenna element gain horizontal pattern |  |
| Pattern combining method for 3D |  |
| Max direct. gain of the antenna element | 3 dBi |
| For 30 and 63 GHz | |
| Antenna element gain vertical pattern |  |
| Antenna element gain horizontal pattern |  |
| Pattern combining method for 3D |  |
| Max direct. gain of the antenna element | 5 dBi |

Table 6.1.4-5: Antenna array configuration for UE-Type RSU

|  |  |  |
| --- | --- | --- |
|  | For 6 GHz | For 30 and 63 GHz |
| TXRU mapping | Up to proponents decision | Up to proponents decision |
| Number of antenna elements across all panels | Up to 8 Tx /Rx antenna elements | Up to 32 Tx /Rx antenna elements |
| Antenna array configuration (M, N, P, Mg, Ng) | Baseline: (1, 2, 2, 1, 1)  Optional: (1, 4, 2, 1, 1) | (1, 4, 2, 1, 4)  Panel bearing angle:  Ω0,1=Ω0,0+90°; Ω0,2=Ω0,0+180°; Ω0,3=Ω0,0+270°; |
| Antenna array spacing (dH,dV,dH,g,dV,g) | (dH, dV) = (0.5, 0.8)λ | (dH, dV) = (0.5, 0.5)λ |
| Antenna polarization | Declare which polarization model in [15] is used | Declare which polarization model in [15] is used |
| Antenna tilt, deg | 96 degree | 96 degree |

Pedestrian UE and cellular UE antenna element pattern and array configuration are given in the following tables:

Table 6.1.4-6: Antenna element pattern for pedestrian UE and cellular UE

|  |  |  |
| --- | --- | --- |
|  | Pedestrian UE and cellular UE | |
| For 6 GHz | For 30 and 63 GHz |
| Antenna element gain vertical pattern | Omni-directional |  |
| Antenna element gain horizontal pattern |  |
| Pattern combining method for 3D |  |
| Max direct. gain of the antenna element | 0 dBi | 5 dBi |

Table 6.1.4-7: Antenna array configuration for pedestrian UE and cellular UE

|  |  |  |
| --- | --- | --- |
|  | Pedestrian UE and cellular UE | |
| For 6 GHz | For 30 and 63 GHz |
| TXRU mapping | Up to proponents decision | Up to proponents decision |
| Number of antenna elements across all panels | Up to 8 Tx /Rx antenna elements | Up to 32 Tx /Rx antenna elements |
| Antenna array configuration (M, N, P, Mg, Ng) | (1, 2, 2, 1, 1) | (2, 4, 2, 1, 2)  Panel bearing angle: Ω0,1=Ω0,0+180° |
| Antenna array spacing (dH,dV,dH,g,dV,g) | (dH, dV) = (0.5, 0.5)λ | (dH, dV) = (0.5, 0.5)λ; (dH,g, dV,g) = (0, 0)λ |
| Antenna polarization | Declare which polarization model in [15] is used | Declare which polarization model in [15] is used |
| Antenna tilt, deg | 90 | 90 |

Note: Antenna pattern can be different in different carrier frequencies.

Two options are defined for vehicle UE antenna element pattern and array configuration. Companies are encouraged to provide evaluation results using both options.

- Option 1: Vehicle UE antenna is modelled in Table 6.1.4-8 and 6.1.4-9:

Table 6.1.4-8: Antenna element pattern for vehicle UE in Option 1

|  |  |
| --- | --- |
| For 6 GHz | |
| Antenna element gain vertical pattern |  |
| Antenna element gain horizontal pattern | Vehicle Type 2:    Vehicle Type 1 and Type 3: |
| Pattern combining method for 3D |  |
| Max direct. gain of the antenna element | 3 dBi |
| For 30 and 63 GHz | |
| Antenna element gain vertical pattern |  |
| Antenna element gain horizontal pattern |  |
| Pattern combining method for 3D |  |
| Max direct. gain of the antenna element | 5 dBi |

Table 6.1.4-9: Antenna array configuration for vehicle UE in Option 1

|  |  |  |
| --- | --- | --- |
|  | Vehicle UE | |
| For 6 GHz | For 30 and 63 GHz |
| TXRU mapping | Up to proponents decision | Up to proponents decision |
| Number of antenna elements across all panels | Up to 8 Tx /Rx antenna elements | Up to 32 Tx /Rx antenna elements |
| Antenna array configuration (M, N, P, Mg, Ng) | Vehicle Type 1 and Type 3:  Front and rear antennas:  Baseline: (1, 1, 2, 1, 1) for each location  Optional: (1, 2, 2, 1, 1) for each location  Front antenna array bearing angle: ΩFront = 0°  Rear antenna array bearing angle: ΩRear = 180°  Vehicle Type 2:  Rooftop antenna:  Baseline: (1, 2, 2, 1, 1)  Optional: (1, 4, 2, 1, 1) | Vehicle Type 1 and 3:  Front and rear antennas:  (2, 4, 2, 1, 1) for each location  Front antenna array bearing angle: ΩFront = 0°  Rear antenna array bearing angle: ΩRear = 180°  Vehicle Type 2:  Multi-panel at rooftop:  (1, 4, 2, 1, 4)  Panel bearing angle:  Ω0,1=Ω0,0+90°; Ω0,2=Ω0,0+180°; Ω0,3=Ω0,0+270° |
| Antenna array spacing (dH,dV,dH,g,dV,g) | (dH, dV) = (0.5, 0.5)λ | (dH, dV) = (0.5, 0.5)λ |
| Antenna polarization | Declare which polarization model in [15] is used | Declare which polarization model in [15] is used |
| Antenna tilt, deg | 90 | 90 |

- Option 2: Two panels are placed in the vehicle as follows and the antenna pattern for each location is given by Tables 6.1.4-10 and, 6.1.4-11. The antenna array configuration is given by Table 6.1.4-12.

- For vehicle type 1, one panel at the front bumper and one panel at the rear bumper

- For vehicle type 2, one panel at the front rooftop and one panel at the rear rooftop

- For vehicle type 3, one panel at the front rooftop and one panel at the rear rooftop

Table 6.1.4-10A: Front bumper antenna element pattern for vehicle UE in Option 2 for 6 GHz

|  |  |
| --- | --- |
| Front bumper | |
| Antenna element gain vertical pattern | |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 27.855 | 0.9281 | -1.3062 | | 2 | 31.967 | 2.7336 | 1.4674 | | 3 | 23.665 | 3.0514 | -1.8167 | | 4 | 1.8441 | 7.7354 | -0.6126 |  |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 146.47 | 1.095 | -1.6043 | | 2 | 131.87 | 1.192 | 1.4566 | | 3 | 5.2383 | 3.9996 | -0.8389 | | 4 | 1.9429 | 9.0248 | 1.6705 | |
| Antenna element gain horizontal pattern | |  |  |  | | --- | --- | --- | | k |  |  | | 0 | -20.793 | - | | 1 | -3.4026 | 0.0721 | | 2 | 1.3366 | 0.1213 | | 3 | 2.1764 | -0.0595 | | 4 | 0.5881 | 0.0102 | | 5 | -2.4068 | 0.0675 | | 6 | 1.7561 | -0.1513 | | 7 | 0.7899 | -0.0133 | | 8 | -1.0144 | 0.0177 | |
| Pattern combining method for 3D | The 3D radiation power pattern shall be generated according to [19], i.e.  for , and , , , are defined as  ,  ,  where and , and is given by  Note that points to the front of the car, while points to the back of the car. |
| Max direct. gain of the antenna element | 13 dBi |

Table 6.1.4-10B: Front rooftop antenna element pattern for vehicle UE in Option 2 for 6 GHz

|  |  |
| --- | --- |
| Front rooftop | |
| Antenna element gain vertical pattern | |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 27.156 | 0.8354 | -0.9866 | | 2 | 10.637 | 1.2651 | 1.9323 | | 3 | 2.1018 | 3.7081 | -1.6452 | | 4 | 0.9267 | 12.057 | -2.9006 | | 5 | 0.8573 | 8.5269 | 3.5787 | | 6 | 0.7456 | 15.27 | -2.9591 |  |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 18.648 | 1.0206 | -0.9611 | | 2 | 11.099 | 2.2755 | 1.7808 | | 3 | 213.68 | 3.7367 | -1.6448 | | 4 | 208.11 | 3.7558 | 1.492 | |
| Antenna element gain horizontal pattern | |  |  |  | | --- | --- | --- | | k |  |  | | 0 | -11.719 | - | | 1 | -2.4504 | 0.0053 | | 2 | -0.9825 | -0.0508 | | 3 | -0.0419 | -0.0225 | | 4 | 0.2384 | 0.0065 | | 5 | 0.2406 | -0.0023 | | 6 | 0.1532 | 0.006 | | 7 | 0.1285 | 0.0062 | | 8 | 0.1407 | 0.0038 | |
| Pattern combining method for 3D | Same method as in Table 6.1.4-10A. |
| Max direct. gain of the antenna element | 3 dBi |

Table 6.1.4-10C: Rear rooftop antenna element pattern for vehicle UE in Option 2 for 6 GHz

|  |  |
| --- | --- |
| Rear rooftop | |
| Antenna element gain vertical pattern | |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 21.785 | 0.7541 | -2.5975 | | 2 | 122 | 2.0393 | -0.3421 | | 3 | 4.5185 | 4.4006 | 2.4657 | | 4 | 25.257 | 3.2885 | -0.6558 | | 5 | 125.16 | 2.3309 | 2.7194 |  |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 89.841 | 0.5245 | -0.2707 | | 2 | 64.942 | 0.6058 | 2.9391 | | 3 | 2.4779 | 4.1726 | -1.4849 | | 4 | 1.097 | 7.9882 | -1.7998 | |
| Antenna element gain horizontal pattern | |  |  |  | | --- | --- | --- | | k |  |  | | 0 | -12.399 | - | | 1 | -0.6788 | -0.0034 | | 2 | -1.025 | -0.0364 | | 3 | -0.0755 | -0.0404 | | 4 | 0.4216 | 0.014 | | 5 | -0.6139 | -0.0053 | | 6 | 0.2297 | 0.0063 | | 7 | -0.4418 | -0.0038 | | 8 | 0.0055 | -0.0141 | |
| Pattern combining method for 3D | Same method as in Table 6.1.4-10A. |
| Max direct. gain of the antenna element | 3 dBi |

Table 6.1.4-10D: Rear bumper antenna element pattern for vehicle UE in Option 2 for 6 GHz

|  |  |
| --- | --- |
| Rear bumper | |
| Antenna element gain vertical pattern | |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 28.64 | 0.6822 | -1.6819 | | 2 | 17.941 | 1.0841 | 0.8466 | | 3 | 10.034 | 4.5559 | -2.317 | | 4 | 9.9931 | 4.9505 | 0.8248 | | 5 | 103.05 | 9.2847 | 0.5153 | | 6 | 102.49 | 9.3113 | -2.6065 |  |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 29.045 | 0.2614 | -0.7172 | | 2 | 7.9836 | 2.8649 | 2.965 | | 3 | 5.1881 | 3.3343 | -0.1509 | | 4 | 0.4384 | 7.4621 | 1.8565 | | 5 | 1.0833 | 47.882 | 2.0727 | | 6 | 1.131 | 35.828 | -0.901 | | 7 | 1.0114 | 33.576 | -0.1873 | | 8 | 1.0014 | 39.562 | -1.0305 | |
| Antenna element gain horizontal pattern | |  |  |  | | --- | --- | --- | | k |  |  | | 0 | -17.964 | - | | 1 | 4.1952 | 0.0073 | | 2 | -0.3746 | -0.0202 | | 3 | 1.2325 | 0.005 | | 4 | 0.2862 | -0.0764 | | 5 | -0.2796 | 0.0252 | | 6 | -0.063 | -0.0114 | | 7 | -1.0205 | 0.0298 | | 8 | -0.2964 | 0.0095 | |
| Pattern combining method for 3D | Same method as in Table 6.1.4-10A. |
| Max direct. gain of the antenna element | 11 dBi |

Table 6.1.4-11A: Front bumper antenna element pattern for vehicle UE in Option 2 for 30 and 63 GHz

|  |  |
| --- | --- |
| Front bumper | |
| Antenna element gain vertical pattern | |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 103.4 | 1.2756 | -1.4588 | | 2 | 93.054 | 1.4402 | 1.6919 | | 3 | 1.2433 | 16.391 | -0.2701 |  |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 97.485 | 1.2777 | -1.5428 | | 2 | 88.914 | 1.4458 | 1.5626 | | 3 | 1.6315 | 6.6824 | -1.4228 | |
| Antenna element gain horizontal pattern | |  |  |  | | --- | --- | --- | | k |  |  | | 0 | -14.712 | - | | 1 | -0.814 | -0.0126 | | 2 | 4.5025 | -0.4615 | | 3 | 0.6572 | -0.0404 | | 4 | 0.3252 | 0.5985 | | 5 | -2.0187 | 0.0372 | | 6 | -1.6555 | 0.2589 | | 7 | -0.843 | 0.6858 | | 8 | -0.2954 | -0.2211 | |
| Pattern combining method for 3D | Same method as in Table 6.1.4-10A. |
| Max direct. gain of the antenna element | 16.6 dBi |

Table 6.1.4-11B: Front rooftop antenna element pattern for vehicle UE in Option 2 for 30 and 63 GHz

|  |  |
| --- | --- |
| Front rooftop | |
| Antenna element gain vertical pattern | |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 53.19 | 1.0466 | -0.9824 | | 2 | 171.45 | 2.3513 | 2.2593 | | 3 | 154.83 | 2.4609 | -0.8176 | | 4 | 2.166 | 6.2024 | 0.5122 | | 5 | 1.2277 | 9.599 | 0.5604 | | 6 | 1.1363 | 14.311 | -0.4448 |  |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 34.284 | 1.0869 | -1.1043 | | 2 | 36.721 | 2.2823 | 1.4488 | | 3 | 4.2902 | 5.2423 | 1.1692 | | 4 | 1.7681 | 7.7706 | -3.641 | | 5 | 14.094 | 2.7398 | -1.5731 | | 6 | 1.2267 | 10.465 | 2.0934 | | 7 | 1.0796 | 14.285 | 2.8759 | | 8 | 0.8846 | 31.578 | -1.1871 | |
| Antenna element gain horizontal pattern | |  |  |  | | --- | --- | --- | | k |  |  | | 0 | -16.085 | - | | 1 | -7.903 | 0.1101 | | 2 | -0.2972 | -1.4639 | | 3 | 0.4083 | -0.0866 | | 4 | 0.6706 | 1.0598 | | 5 | -0.9804 | -2.5714 | | 6 | -0.9085 | 0.1326 | | 7 | 0.1433 | -0.1372 | | 8 | -0.1282 | -0.2697 | |
| Pattern combining method for 3D | Same method as in Table 6.1.4-10A. |
| Max direct. gain of the antenna element | 11.5 dBi |

Table 6.1.4-11C: Rear rooftop antenna element pattern for vehicle UE in Option 2 for 30 and 63 GHz

|  |  |
| --- | --- |
| Rear rooftop | |
| Antenna element gain vertical pattern | |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 55.839 | 1.0927 | -1.1273 | | 2 | 95.402 | 2.0245 | 2.1133 | | 3 | 2.9533 | 6.0111 | 1.5482 | | 4 | 1.5696 | 12.462 | 3.2683 | | 5 | 1.2073 | 10.016 | 2.2276 | | 6 | 70.244 | 2.1361 | -0.8181 | | 7 | 1.4093 | 13.127 | 0.6659 |  |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 42.818 | 0.9167 | -0.9757 | | 2 | 18.065 | 1.895 | 1.5513 | | 3 | 8.8444 | 3.6653 | -0.1862 | | 4 | 9.5301 | 7.6263 | 0.1674 | | 5 | 15.018 | 9.0456 | 0.2995 | | 6 | 20.098 | 8.565 | -2.8308 | | 7 | 1.5077 | 12.14 | -1.3725 | |
| Antenna element gain horizontal pattern | |  |  |  | | --- | --- | --- | | k |  |  | | 0 | -18.471 | - | | 1 | 3.6106 | -0.1824 | | 2 | -1.4888 | 1.3614 | | 3 | 0.5772 | 0.5331 | | 4 | 1.7125 | 1.3205 | | 5 | -0.0573 | -2.5904 | | 6 | 0.0628 | -1.0024 | | 7 | -1.0526 | -1.2366 | | 8 | 0.0433 | -0.1443 | |
| Pattern combining method for 3D | Same method as in Table 6.1.4-10A. |
| Max direct. gain of the antenna element | 12.5 dBi |

Table 6.1.4-11D: Rear bumper antenna element pattern for vehicle UE in Option 2 for 30 and 63 GHz

|  |  |
| --- | --- |
| Rear bumper | |
| Antenna element gain vertical pattern | |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 87.458 | 0.0103 | -2.9955 | | 2 | 4.1908 | 2.1185 | 1.8618 | | 3 | 1.0935 | 127.65 | 2.3653 | | 4 | 1.2773 | 16.837 | 1.1214 |  |  |  |  |  | | --- | --- | --- | --- | | k |  |  |  | | 1 | 17.631 | 0.823 | -1.5005 | | 2 | 12.155 | 1.9599 | 1.2643 | | 3 | 15.226 | 5.6698 | 2.2669 | | 4 | 15.495 | 5.7995 | -0.9411 | | 5 | 0.3371 | 10.294 | -3.8515 | | 6 | 0.5965 | 11.41 | 0.4383 | |
| Antenna element gain horizontal pattern | |  |  |  | | --- | --- | --- | | k |  |  | | 0 | -12.742 | - | | 1 | -1.2007 | 0.2451 | | 2 | 4.1916 | -0.5651 | | 3 | 0.1901 | 0.453 | | 4 | 0.4235 | 0.6884 | | 5 | -1.3848 | -0.4145 | | 6 | -0.2381 | 0.2875 | | 7 | 0.4488 | 0.5441 | | 8 | 0.1606 | -0.2555 | |
| Pattern combining method for 3D | Same method as in Table 6.1.4-10A. |
| Max direct. gain of the antenna element | 13.6 dBi |

Table 6.1.4-12: Antenna array configuration for vehicle UE in Option 2

|  |  |  |
| --- | --- | --- |
|  | Vehicle UE | |
| For 6 GHz | For 30 and 63 GHz |
| TXRU mapping | Up to proponents decision | Up to proponents decision |
| Number of antenna elements across all panels | Up to 8 Tx /Rx antenna elements | Up to 32 Tx /Rx antenna elements |
| Antenna array configuration (M, N, P, Mg, Ng) | (1, 1, 2, 1, 1) for each location | (2, 4, 2, 1, 1) for each location |
| Antenna array spacing (dH,dV,dH,g,dV,g) | (dH, dV) = (0.5, 0.5)λ | (dH, dV) = (0.5, 0.5)λ |
| Antenna polarization | Declare which polarization model in [15] is used | Declare which polarization model in [15] is used |
| Antenna tilt, deg | 0 | 0 |

Determination between LOS and NLOSv states is decided per vehicle pair. Note that self-blockage effect is captured Option 2 in the antenna pattern. Self-blockage effect in Option 1 can be further discussed later if necessary.

### 6.1.5 Traffic model

The following options are supported for the traffic model:

- Periodic traffic

- Model 1 (low traffic intensity)

- Inter-packet arrival time: 100 ms

- Packet size: Pattern of {300 bytes, 190 bytes, 190 bytes, 190 bytes, 190 bytes} with random starting point for each UE

- Latency requirement: 100 ms

- Model 2 (medium traffic intensity)

- Inter-packet arrival time: 10 ms

- Other value(s) are not precluded, e.g., 100ms

- Packet size: 1200 bytes with probability of 0.2 and 800 bytes with probability of 0.8

- Latency requirement: 10 ms

- Model 3 (high traffic intensity)

- Inter-packet arrival time: 30 ms

- Packet size: Uniformly random in the range between 30000 bytes and 60000 bytes with the quantization step of 10000 bytes

- Latency requirement: 30 ms

- Aperiodic traffic

- Model 1 (medium traffic intensity)

- Inter-packet arrival time: 50 ms + an exponential random variable with the mean of 50 ms

- Packet size: Uniformly random in the range between 200 bytes and 2000 bytes with the quantization step of 200 bytes

- Latency requirement: 50 ms

- Model 2 (high traffic intensity)

- Inter-packet arrival time: 10 ms + an exponential random variable with the mean of 10 ms

- Packet size: Uniformly random in the range between 10000 bytes and 30000 bytes with the quantization step of 4000 bytes

- Latency requirement: 10 ms

- For evaluations of UE-network relaying or coexistence of sidelink and Uu in licensed spectrum, cellular UEs generate packets using FTP model 3 [16].

Baseline is to evaluate unicast, groupcast, and broadcast in separate simulations. It is noted that, in evaluating technical solutions, scenarios such as mixture of unicast, groupcast, and broadcast, mixture of periodic and aperiodic traffic, etc., may be discussed.

In evaluating broadcast, the baseline is all the vehicles generate messages.

For each transmitter for unicast, the target receiver is randomly selected among the UEs within X meters.

- For the clustered vehicle dropping, the target receiver should be in the same cluster as the transmitter.

- X is to be discussed as a part of technical solutions.

- This transmitter-receiver association assumption can be revisited if an issue is identified.

For each transmitter for groupcast, the target receivers are all the UEs within Y meters.

- For the clustered vehicle dropping, the target receivers should be in the same cluster as the transmitter.

- Y is to be discussed as a part of technical solutions.

### 6.1.6 Performance metric

Packet reception ratio (PRR) has two types and is defined as follows:

- PRR type 1: For one Tx packet, the PRR is calculated by X/Y, where Y is the number of UE/vehicles that located in the range (a, b) from the TX, and X is the number of UE/vehicles with successful reception among Y. CDF of PRR and the following average PRR are used in evaluation

- CDF of PRR with a = 0, b = baseline of 320 meters for highway and 150 meters for urban. Optionally, b = 50 meters for urban with 15 km/h vehicle speed.

- Average PRR, calculated as (X1+X2+X3….+Xn)/(Y1+Y2+Y3…+Yn) where n denotes the number of generated messages in simulation. with a = i\*20 meters, b = (i+1)\*20 meters for i=0, 1, …, 25

- PRR type 2: For one Tx packet, the PRR is calculated by S/Z, where Z is the number of UEs in the intended set of receivers, and S is the number of UE with successful reception among Z.

- Unicast is the special case where Z includes a single UE, where the PRR is average of packets of the unicast link

PRR type 1 is included as a performance metric at least for the broadcast-type use cases.

PRR type 2 is supported and can be used as performance metric in scenarios such as groupcast/unicast or to see the performance of links in a certain condition (e.g., links blocked by a building). When used, the company needs to clarify how the intended set of receivers is determined and what the motivation is.

Packet Inter-Reception (PIR) is defined as follows and used as an additional metric for persistent collision at least for the use cases requiring reliability higher than that of LTE V2X:

- PIR type 1: For a given distance D, PIR is the time Ti elapsed between two successive successful receptions of two different packets transmitted from node A to node B for the same application, if the distances at the two packets' receiving time between node A and node B is within the range of (0,D].

- Average PIR within given distance D, calculated as (T1+T2+T3+…+Tn)/n where n denotes the number of collected PIR in simulation.

- CDF of PIR with given distance D.

- PIR type 2: PIR is the time Ti elapsed between two successive successful receptions of two different packets transmitted from node A to node B for the same application, if the node B is one of the intended set of receivers of the node A.

- Average PIR with intended set of receives, calculated as (T1+T2+T3+…+Tn)/n where n denotes the number of collected PIR in simulation.

- CDF of PIR with intended set of receives.

PIR type 1 is included as a performance metric at least for the broadcast-type use cases.

PIR type 2 is supported and can be used as performance metric in scenarios such as groupcast/unicast or to see the performance of links in a certain condition (e.g., links blocked by a building) or links in a specific area (e.g., lanes with high congestion in highway scenario). When used, the company needs to clarify how the intended set of receivers is determined and what the motivation is.

Packet throughput defined in [17] is used as a performance metric.

## 6.2 Channel model

The V2V sidelink channel is modeled according to the following three states:

- LOS:

- A V2V link is in LOS state if the two vehicles are in the same street and the LOS path is not blocked by vehicles.

- NLOS: LOS path blocked by buildings

- A V2V link is in NLOS state if the two vehicles are in different streets.

- NLOSv: LOS path blocked by vehicles

- A V2V link is in NLOSv state if the two vehicles are in the same street and the LOS path is blocked by vehicles.

A link between two vehicles in the same street is either in LOS state or NLOSv state. The probability of LOS and NLOSv is given by Table 6.2-1. Baseline is the state is not updated between LOS and NLOSv, and evaluation with state update between LOS and NLOSv is not precluded.

Table 6.2-1: Probability of LOS and NLOSv states (d denotes the distance between transmit and receive UEs).

|  |  |
| --- | --- |
| Highway | |
| LOS | If ,  where ,  If , |
| NLOSv |  |
| Urban | |
| LOS |  |
| NLOSv |  |

Vehicle UE location is updated every 100 ms. State transition between LOS/NLOSv and NLOS is checked for each link at each location update during the SLS runtime. At each state, each link uses pathloss, shadowing, and fast fading parameters corresponding to the state as described in the subsequent subsections.

For the channel model between vehicle UE acting as relay and cellular UE, baseline is to use V2P channel model. 3 meters are assumed for the link between antenna of a cellular UE inside a vehicle and the antenna of the same vehicle UE.

### 6.2.1 Pathloss model

Pathloss model for V2V links is given in the following table:

Table 6.2.1-1: Pathloss for V2V links

|  |  |  |
| --- | --- | --- |
| LOS/NLOS/NLOSv | Pathloss [dB] | Shadow fading std [dB]2 |
| LOS, NLOSv | For Highway case,  PL = 32.4 + 20 log10(d3D) + 20 log10(fc)  For Urban case,  PL= 38.77 + 16.7 log10(d3D) + 18.2 log10(fc) | σSF = 3 |
| NLOS | PL= 36.85 + 30 log10(d3D) + 18.9 log10(fc) | σSF = 4 |
| Note 1: fc denotes the center frequency in GHz and d3D denotes the Euclidean distance between TX and RX in 3D space in meters.  Note 2: The model for spatial correlation of shadow fading defined in [13] applies. | | |

When a V2V link is in NLOSv, additional vehicle blockage loss is added as follows:

- The blocker height is the vehicle height which is randomly selected out of the three vehicle types according to the portion of the vehicle types in the simulated scenario.

- The additional blockage loss is max {0 dB, a log-normal random variable}.

- Case 1: Minimum antenna height value of TX and RX > Blocker height

- No additional blockage loss

- Case 2: Maximum antenna height value of TX and RX < Blocker height

- Mean: 9 + max(0, 15\*log10(d)-41) dB, standard deviation: 4.5 dB

- Case 3: Otherwise

- Mean: 5 dB + max(0, 15\*log10(d)-41), standard deviation: 4 dB

Pathloss equation of V2V is reused for that of V2P, P2P, V2R, R2R.

Pathloss in V2B, P2B, B2R link is given as follows:

- LOS propagation type is used for V2B and B2R links in the highway scenario.

- LOS/NLOS propagation types are used for V2B, P2B and B2R links in the urban scenario and spatial consistency is maintained following procedure in Subclause 7.6.3.3 in [15].

- Derive propagation type based on probability formula

- The effective environment height hE to 0.25m.

Table 6.2.1-2: Pathloss for V2B, P2B, B2R links

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Below 6 GHz | | Above 6 GHz | |
| LOS | NLOS | LOS | NLOS |
| V2B  P2B  B2R | Urban:  TR 38.901 UMa LOS  Highway:  TR 38.901 RMa LOS | Urban:  TR 38.901 UMa NLOS  Highway:  N/A | Urban:  TR 38.901 UMa LOS  Highway:  TR 38.901 UMa LOS | Urban:  TR 38.901 UMa NLOS  Highway:  N/A |

For above 6 GHz, oxygen absorption is modelled by introducing additional loss which is derived based on [15].

### 6.2.2 Shadowing model

For V2V, V2P, P2P, V2R, R2R links, the shadowing model in [13] is used. The LOS shadowing model in [13] applies to NLOSv.

For B2V, B2P, B2R links, the shadowing model associated with the used pathloss model in [15] is used.

### 6.2.3 Fast fading model

For sidelink in the urban and highway scenarios, the fast fading parameters are given in the following table:

Table 6.2.3-1: Fast fading parameters for V2V link

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Scenarios | | Urban | | | Highway | |
| LOS | NLOS | NLOSv | LOS | NLOSv |
| Delay spread (DS)  lgDS=log10(DS/1s) | **lgDS | -0.2 log10(1+ fc) – 7.5 | -0.3log10(1+ fc) – 7 | -0.4 log10(1+ fc) – 7 | -8.3 | -8.3 |
| **lgDS | 0.1 | 0.28 | 0.1 | 0.2 | 0.3 |
| AOD spread (ASD)  lgASD=log10(ASD/1°) | **lgASD | -0.1 log10(1+ fc) + 1.6 | -0.08 log10(1+ fc) + 1.81 | -0.1 log10(1+ fc) + 1.7 | 1.4 | 1.5 |
| **lgASD | 0.1 | 0.05 log10(1+ fc) + 0.3 | 0.1 | 0.1 | 0.1 |
| AOA spread (ASA)  lgASA=log10(ASA/1°) | **lgASA | -0.1 log10(1+ fc) + 1.6 | -0.08 log10(1+ fc) + 1.81 | -0.1 log10(1+ fc) + 1.7 | 1.4 | 1.5 |
| **lgASA | 0.1 | 0.05 log10(1+ fc) + 0.3 | 0.1 | 0.1 | 0.1 |
| ZOA spread (ZSA)  lgZSA=log10(ZSA/1°) | **lgZSA | -0.1 log10(1+ *fc*) + 0.73 | -0.04 log10(1+ *fc*) + 0.92 | -0.04 log10(1+ *fc*) + 0.92 | -0.1 log10(1+ *fc*) + 0.73 | -0.04 log10(1+ *fc*) + 0.92 |
| **lgZSA | -0.04 log10(1+ *fc*) + 0.34 | -0.07 log10(1+ *fc*) + 0.41 | -0.07 log10(1+ *fc*) + 0.41 | -0.04 log10(1+ *fc*) + 0.34 | -0.07 log10(1+ *fc*) + 0.41 |
| ZOD spread (ZSD)  lgZSD=log10(ZSD/1°) | **lgZSD | -0.1 log10(1+ *fc*) + 0.73 | -0.04 log10(1+ *fc*) + 0.92 | -0.04 log10(1+ *fc*) + 0.92 | -0.1 log10(1+ *fc*) + 0.73 | -0.04 log10(1+ *fc*) + 0.92 |
| **lgZSD | -0.04 log10(1+ *fc*) + 0.34 | -0.07 log10(1+ *fc*) + 0.41 | -0.07 log10(1+ *fc*) + 0.41 | -0.04 log10(1+ *fc*) + 0.34 | -0.07 log10(1+ *fc*) + 0.41 |
| K-factor (*K*) [dB] | *K* | 3.48 | N/A | 0 | 9 | 0 |
| *K* | 2 | N/A | 4.5 | 3.5 | 4.5 |
| Cross-Correlations | *ASD* vs *DS* | 0.5 | 0 | 0.5 | 0.5 | 0.5 |
| *ASA* vs *DS* | 0.8 | 0.4 | 0.8 | 0.8 | 0.8 |
| *ASA* vs *SF* | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 |
| *ASD* vs *SF* | -0.5 | 0 | -0.5 | -0.5 | -0.5 |
| *DS* vs *SF* | -0.4 | -0.7 | -0.4 | -0.4 | -0.4 |
| *ASD*vs *ASA* | 0.4 | 0 | 0.4 | 0.4 | 0.4 |
| *ASD* vs ** | -0.2 | N/A | -0.2 | -0.2 | -0.2 |
| *ASA* vs ** | -0.3 | N/A | -0.3 | -0.3 | -0.3 |
| *DS* vs ** | -0.7 | N/A | -0.7 | -0.7 | -0.7 |
| *SF* vs ** | 0.5 | N/A | 0.5 | 0.5 | 0.5 |
| Cross-Correlations | *ZSD* vs *SF* | 0 | 0 | 0 | 0 | 0 |
| *ZSA* vs *SF* | 0 | 0 | 0 | 0 | 0 |
| *ZSD* vs *K* | 0 | N/A | 0 | 0 | 0 |
| *ZSA* vs *K* | 0 | N/A | 0 | 0 | 0 |
| *ZSD* vs *DS* | 0 | -0.5 | 0 | 0 | 0 |
| *ZSA*vs *DS* | 0.2 | 0 | 0.2 | 0.2 | 0.2 |
| *ZSD* vs *ASD* | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| *ZSA* vs *ASD* | 0.3 | 0.5 | 0.3 | 0.3 | 0.3 |
| *ZSD* vs *ASA* | 0 | 0 | 0 | 0 | 0 |
| *ZSA* vs *ASA* | 0 | 0.2 | 0 | 0 | 0 |
| *ZSD* vs *ZSA* | 0 | 0 | 0 | 0 | 0 |
| Delay scaling parameter *rτ* | | 3 | 2.1 | 2.1 | 3 | 2.1 |
| XPR[dB] | **XPR | 9 | 8.0 | 8.0 | 9 | 8.0 |
| **XPR | 3 | 3 | 3 | 3 | 3 |
| Number of clusters | | 12 | 19 | 19 | 12 | 19 |
| Number of rays per cluster | | 20 | 20 | 20 | 20 | 20 |
| Cluster *DS* () in [ns] | | 5 | 11 | 11 | 5 | 11 |
| Cluster *ASD* () in [deg] | | 17 | 22 | 22 | 17 | 22 |
| Cluster *ASA* () in [deg] | | 17 | 22 | 22 | 17 | 22 |
| Cluster *ZSA* () in [deg] | | 7 | 7 | 7 | 7 | 7 |
| Cluster *ZSD* () in [deg] | | 7 | 7 | 7 | 7 | 7 |
| Per cluster shadowing std  [dB] | | 4 | 4 | 4 | 4 | 4 |
| Correlation distance in the horizontal plane [m] | *DS* | 7 | 10 | 10 | 7 | 10 |
| *ASD* | 8 | 10 | 10 | 8 | 10 |
| *ASA* | 8 | 9 | 9 | 8 | 9 |
| *SF* | 10 | 13 | 13 | 10 | 13 |
| ** | 15 | N/A | N/A | 15 | N/A |
| *ZSA* | 12 | 10 | 10 | 12 | 10 |
| *ZSD* | 12 | 10 | 10 | 12 | 10 |
| *fc* is carrier frequency in GHz. Procedure for generating both ZOA and ZOD is the same and based on the ZOA procedure in 3GPP TR38.901. | | | | | | |

Channel generation procedure of NLOSv state follows the procedure defined for LOS state in [15].

For B2V, B2P, B2R links, the fast fading parameters associated with the used pathloss model in [15] is used.

For sidelink, dual mobility is modeled as follows with the parameters defined in [15]:

- Doppler for the LOS path:

,





- Doppler for the delayed paths:

where is a random variable with uniform distribution from to , is the maximum speed of the vehicle in the layout, and () is a random variable with uniform distribution. Evaluation using other distribution for is not precluded.

#### 6.2.3.1 CDL Models for Link Simulations

The parameters represent a CDL model derived from the V2X SCM channel model in Section 6.2.3. The procedure for generating the channel using the CDL model is the same as defined in [15].

Table 6.2.3.1-1, 6.2.3.1-2, 6.2.3.1-3, 6.2.3.1-4 and 6.2.3.1-5 show the CDL models for Urban LOS, Urban NLOS, Urban NLOSv and Highway LOS and NLOSv channels.

Table 6.2.3.1-1: CDL model for Urban LOS V2X channel

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cluster #** | **Delay [ns]** | | **Power in [dB]** | | **AOD in [°]** | | **AOA in [°]** | | **ZOD in [°]** | | **ZOA in [°]** |
| 1 | 0.0000 | | -0.12 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 0.0000 | | -15.52 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 2 | 6.4000 | | -17.7 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 3 | 12.8000 | | -19.5 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 4 | 11.0793 | | -15.9 | | 93.2 | | -51.8 | | 75.1 | | 57.8 |
| 5 | 21.9085 | | -14.6 | | 85.4 | | -51.9 | | 76.6 | | 119.7 |
| 6 | 29.6768 | | -9.1 | | -49.9 | | 96.8 | | 84.8 | | 100.0 |
| 7 | 36.0768 | | -11.3 | | -49.9 | | 96.8 | | 84.8 | | 100.0 |
| 8 | 42.4768 | | -13.1 | | -49.9 | | 96.8 | | 84.8 | | 100.0 |
| 9 | 68.4085 | | -19.3 | | -97.1 | | -37.5 | | 107.3 | | 130.3 |
| 10 | 82.2944 | | -20.0 | | 108.5 | | -45.7 | | 107.7 | | 130.3 |
| 11 | 115.4173 | | -16.3 | | -90.7 | | 57.3 | | 104.0 | | 58.1 |
| 12 | 143.2963 | | -17.9 | | 105.5 | | -42.1 | | 107.0 | | 52.5 |
| 13 | 146.4136 | | -25.4 | | 127.1 | | -17.6 | | 68.4 | | 36.9 |
| 14 | 183.1925 | | -26.9 | | 127.0 | | 18.6 | | 67.2 | | 145.1 |
| 15 | 214.1501 | | -22.9 | | -101.5 | | 20.6 | | 69.4 | | 42.8 |
| 16 | 326.7825 | | -25.3 | | 125.2 | | -19.1 | | 112.0 | | 141.6 |
| **Per-Cluster Parameters** | | | | | | | | | | | |
| **Parameter** | | *c*ASD in [°] | | *c*ASA in [°] | | *c*ZSD in [°] | | *c*ZSA in [°] | | XPR in [dB] | |
| **Value** | | 3 | | 17 | | 7 | | 7 | | 9 | |

Table 6.2.3.1-2: CDL model for Urban NLOS V2X channel

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Delay (ns) | | Power in [dB] | | AOD in [°] | | AOA in [°] | | ZOD in [°] | | ZOA in [°] |
| 1 | 0.0000 | | -4.8 | | -53 | | -36 | | 79.7 | | 12.5 |
| 2 | 6.466311 | | -0.8 | | -2.7 | | -162.5 | | 89.3 | | 73.3 |
| 3 | 11.6926 | | -3 | | -2.7 | | -162.5 | | 89.3 | | 73.3 |
| 4 | 16.91889 | | -4.8 | | -2.7 | | -162.5 | | 89.3 | | 73.3 |
| 5 | 19.49782 | | 0 | | -30.3 | | -87 | | 93.6 | | 73.7 |
| 6 | 20.64838 | | -0.8 | | -28 | | -79.7 | | 85.3 | | 121.2 |
| 7 | 38.74579 | | -0.9 | | 28.3 | | -88.6 | | 96 | | 119.6 |
| 8 | 48.75469 | | -0.8 | | 0.5 | | 143.6 | | 91.3 | | 92.9 |
| 9 | 53.98099 | | -3 | | 0.5 | | 143.6 | | 91.3 | | 92.9 |
| 10 | 59.20728 | | -4.8 | | 0.5 | | 143.6 | | 91.3 | | 92.9 |
| 11 | 62.18983 | | -6.3 | | -80 | | 6.3 | | 79.8 | | 175.1 |
| 12 | 68.71579 | | -4 | | 60 | | -58.2 | | 81.1 | | 29.4 |
| 13 | 70.33887 | | -8.1 | | -75.7 | | -19.9 | | 102.9 | | 159 |
| 14 | 74.461 | | -8 | | -76.8 | | 23 | | 103.2 | | 168.3 |
| 15 | 105.954 | | -7 | | 59.4 | | -28.7 | | 77.5 | | 6.9 |
| 16 | 117.9043 | | -8.3 | | 72.6 | | -5.4 | | 77.2 | | 168 |
| 17 | 137.072 | | -1.7 | | 42.3 | | -82.8 | | 95.5 | | 134.6 |
| 18 | 210.5223 | | -7.6 | | 57.3 | | -22.4 | | 100.5 | | 21.4 |
| 19 | 218.8232 | | -16.2 | | -93.9 | | 56.2 | | 111.2 | | 84.2 |
| 20 | 232.2158 | | -4.2 | | -37.8 | | 32.9 | | 80 | | 171 |
| 21 | 289.6542 | | -18.2 | | 106.7 | | -57 | | 64.3 | | 110.2 |
| 22 | 357.7905 | | -21.8 | | 107.5 | | -103.3 | | 119.9 | | 39.6 |
| 23 | 380.2389 | | -19.9 | | -95 | | 68.4 | | 117 | | 127.9 |
| **Per-Cluster Parameters** | | | | | | | | | | | |
| **Parameter** | | *c*ASD in [°] | | *c*ASA in [°] | | *c*ZSD in [°] | | *c*ZSA in [°] | | XPR in [dB] | |
| **Value** | | 10 | | 22 | | 7 | | 7 | | 8 | |

Table 6.2.3.1-3: CDL model for Urban NLOSv V2X channel

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Delay [ns] | | Power in [dB] | | AOD in [°] | | AOA in [°] | | ZOD in [°] | | ZOA in [°] |
| 1 | 0.0000 | | -0.14 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 0.0000 | | -14.93 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 2 | 20.1752 | | -8.9 | | 36.0 | | 138.4 | | 84.1 | | 81.1 |
| 3 | 34.2552 | | -11.2 | | 36.0 | | 138.4 | | 84.1 | | 81.1 |
| 4 | 48.3352 | | -12.9 | | 36.0 | | 138.4 | | 84.1 | | 81.1 |
| 5 | 34.3633 | | -17.9 | | -45.7 | | -79.9 | | 74.2 | | 118.1 |
| 6 | 37.1866 | | -14.8 | | 60.7 | | -85.1 | | 76.4 | | 117.3 |
| 7 | 52.1209 | | -11.9 | | 53.6 | | -100.6 | | 77.3 | | 71.3 |
| 8 | 52.7982 | | -10.2 | | -34.5 | | -119.5 | | 97.4 | | 103.0 |
| 9 | 66.8782 | | -12.5 | | -34.5 | | -119.5 | | 97.4 | | 103.0 |
| 10 | 80.9582 | | -14.2 | | -34.5 | | -119.5 | | 97.4 | | 103.0 |
| 11 | 53.2168 | | -11.1 | | 48.4 | | -103.5 | | 99.7 | | 108.7 |
| 12 | 53.2285 | | -15.5 | | -45.8 | | 92.5 | | 105.6 | | 63.7 |
| 13 | 55.2847 | | -13.8 | | 56.0 | | 80.7 | | 76.6 | | 67.0 |
| 14 | 65.8409 | | -12.5 | | 55.7 | | 100.7 | | 76.9 | | 109.3 |
| 15 | 79.0272 | | -20.2 | | -48.9 | | -69.4 | | 71.3 | | 125.9 |
| 16 | 90.9391 | | -11.7 | | 51.1 | | 101.2 | | 77.9 | | 108.3 |
| 17 | 91.0347 | | -19.0 | | 62.7 | | 69 | | 71.6 | | 58.4 |
| 18 | 105.4760 | | -17.1 | | -43.0 | | 86.5 | | 73.9 | | 119.8 |
| 19 | 118.7946 | | -17.5 | | 62.4 | | 91.5 | | 72.4 | | 119.9 |
| 20 | 166.1280 | | -18.1 | | -50.6 | | -76.6 | | 72.7 | | 120.3 |
| 21 | 253.7053 | | -22.2 | | -57.0 | | -68.1 | | 110.7 | | 54.1 |
| 22 | 293.5444 | | -16.4 | | -43.1 | | 82.7 | | 104.6 | | 62.1 |
| 23 | 471.3768 | | -19.8 | | -50.1 | | -61.8 | | 108.6 | | 56.4 |
| **Per-Cluster Parameters** | | | | | | | | | | | |
| **Parameter** | | *c*ASD in [°] | | *c*ASA in [°] | | *c*ZSD in [°] | | *c*ZSA in [°] | | XPR in [dB] | |
| **Value** | | 10 | | 22 | | 7 | | 7 | | 8 | |

Table 6.2.3.1-4: CDL model for Highway LOS V2X channel

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Delay [ns] | | Power in [dB] | | AOD in [°] | | AOA in [°] | | ZOD in [°] | | ZOA in [°] |
| 1 | 0.0000 | | -0.07 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 0.0000 | | -18.08 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 2 | 2.1109 | | -19.9 | | 63.4 | | -80.2 | | 83.8 | | 75.0 |
| 3 | 2.9528 | | -13.9 | | 50.0 | | 98.6 | | 86.9 | | 98.4 |
| 4 | 17.0328 | | -16.2 | | 50.0 | | 98.6 | | 86.9 | | 98.4 |
| 5 | 31.1128 | | -17.9 | | 50.0 | | 98.6 | | 86.9 | | 98.4 |
| 6 | 9.1629 | | -14.5 | | 55.2 | | 73.1 | | 85.1 | | 78.1 |
| 7 | 10.6761 | | -21.3 | | -62.6 | | -64.3 | | 97.3 | | 73.7 |
| 8 | 11.0257 | | -18.7 | | 56.0 | | 65.7 | | 96.3 | | 105.4 |
| 9 | 18.5723 | | -14.9 | | 53.3 | | -90.9 | | 85.3 | | 79.1 |
| 10 | 19.8875 | | -16.2 | | -51.1 | | 84.5 | | 94.4 | | 79.4 |
| 11 | 33.9675 | | -18.5 | | -51.1 | | 84.5 | | 94.4 | | 79.4 |
| 12 | 48.0475 | | -20.2 | | -51.1 | | 84.5 | | 94.4 | | 79.4 |
| 13 | 25.7370 | | -17.1 | | -56.1 | | 71.3 | | 95.5 | | 77.4 |
| 14 | 36.2683 | | -13.8 | | 58.4 | | -81.5 | | 86.2 | | 80.4 |
| 15 | 66.7093 | | -28.4 | | 74.7 | | 41.4 | | 81.1 | | 68.1 |
| 16 | 139.9695 | | -27.4 | | -71.5 | | -42.6 | | 99.4 | | 111.8 |
| **Per-Cluster Parameters** | | | | | | | | | | | |
| **Parameter** | | *c*ASD in [°] | | *c*ASA in [°] | | *c*ZSD in [°] | | *c*ZSA in [°] | | XPR in [dB] | |
| **Value** | | 3 | | 17 | | 7 | | 7 | | 9 | |

Table 6.2.3.1-5: CDL model for Highway NLOSv V2X channel

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cluster # | Delay [ns] | | Power in [dB] | | AOD in [°] | | AOA in [°] | | ZOD in [°] | | ZOA in [°] |
| 1 | 0.0000 | | -0.2927 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 0.0000 | | -11.8594 | | 0.0 | | -180 | | 90.0 | | 90.0 |
| 2 | 5.5956 | | -12.5090 | | -52.3 | | -120 | | 99.2 | | 61.5 |
| 3 | 19.6756 | | -14.7274 | | -52.3 | | -120 | | 99.2 | | 61.5 |
| 4 | 33.7556 | | -16.4884 | | -52.3 | | -120 | | 99.2 | | 61.5 |
| 5 | 21.7591 | | -11.8681 | | 66.4 | | -114.6 | | 77.2 | | 54.8 |
| 6 | 21.8113 | | -11.3289 | | -46.7 | | 96.5 | | 78.6 | | 56.1 |
| 7 | 27.2207 | | -17.8834 | | 89.8 | | 77 | | 106.8 | | 34.8 |
| 8 | 39.3242 | | -9.9943 | | -56.8 | | -124.7 | | 81.2 | | 120.7 |
| 9 | 51.0232 | | -12.7302 | | 75.9 | | 93.1 | | 102.1 | | 119.9 |
| 10 | 51.4828 | | -13.9120 | | 85.4 | | 88.2 | | 103.7 | | 48.7 |
| 11 | 53.3659 | | -16.8781 | | 88.9 | | 80.7 | | 74.0 | | 136.9 |
| 12 | 65.1775 | | -12.9647 | | -46.2 | | 94.4 | | 100.0 | | 56.9 |
| 13 | 79.2575 | | -15.1832 | | -46.2 | | 94.4 | | 100.0 | | 56.9 |
| 14 | 93.3375 | | -16.9441 | | -46.2 | | 94.4 | | 100.0 | | 56.9 |
| 15 | 67.9841 | | -10.7858 | | -50.9 | | 98.1 | | 100.2 | | 121.1 |
| 16 | 70.7561 | | -12.3875 | | -54.3 | | -99.3 | | 77.7 | | 121.6 |
| 17 | 73.9980 | | -17.3827 | | 88.3 | | 66.8 | | 73.8 | | 141.6 |
| 18 | 75.8665 | | -14.7254 | | 78.0 | | 91.5 | | 103.8 | | 131.1 |
| 19 | 84.3678 | | -13.5863 | | 73.5 | | -108.4 | | 104.8 | | 51.1 |
| 20 | 90.1654 | | -20.9080 | | -69.7 | | -89.6 | | 69.4 | | 147.1 |
| 21 | 91.6154 | | -15.5653 | | -62.1 | | 84.4 | | 103.2 | | 46.7 |
| 22 | 142.9312 | | -19.7098 | | -70.3 | | -81.8 | | 109.1 | | 32.2 |
| 23 | 158.4339 | | -24.7824 | | -84.5 | | -69.6 | | 113.8 | | 157.3 |
| **Per-Cluster Parameters** | | | | | | | | | | | |
| **Parameter** | | *c*ASD in [°] | | *c*ASA in [°] | | *c*ZSD in [°] | | *c*ZSA in [°] | | XPR in [dB] | |
| **Value** | | 10 | | 22 | | 7 | | 7 | | 8 | |

## 6.3 Link level simulation assumptions

The assumption for system level simulation is used for link level simulation if available.

The parameters related to solutions need to be clarified by each company. At least the following parameters are the list needs to be clarified.

- Carrier frequency

- Channel model (e.g. fast fading model)

- PHY packet size

- Channel codes (for control and data channels)

- Modulation and code rates (for control and data channels)

- Signal waveform (for control and data channels)

- Subcarrier Spacing

- CP length

- Frequency synchronization error

- Time synchronization error

- Channel estimation (e.g. DMRS pattern and symbol location)

- Number of retransmission and combining (if applied)

- Number of antennas (at UE and BS)

- Transmission diversity scheme (if applied)

- UE receiver algorithm

- AGC settling time and guard period

- EVM (at TX and RX)

## 6.4 Additional assumptions to evaluate vehicle positioning

The simulation assumptions for "vehicle positioning" reuse those defined in Subclauses 6.1, 6.2, and 6.3.

Performance metrics are defined as follows:

- Absolute and relative UE poisoning error in meter

- For the additional performance metric for latency, those in [18] can be used as a starting point when necessary.

Annex A:  
Road configuration for urban grid and highway

Parameters regarding the road configuration for urban grid and highway are given in the following table:

Table A-1: Road configuration for urban grid and highway

|  |  |  |
| --- | --- | --- |
| Parameter | Urban case | Highway case |
| Number of lanes | 2 in each direction (4 lanes in total in each street) | 3 in each direction (6 lanes in total in the highway) |
| Lane width | 3.5 m | 4 m |
| Road grid size by the distance between intersections | 433 m \* 250 m. NOTE1 | N/A |
| Simulation area size | Minimum 1299 m \* 750 m NOTE2 | Highway length >= 2000 m. Wrap around should be applied to the simulation area. |
| NOTE1: 3 m is reserved for sidewalk per direction (i.e., no vehicle or building in this reserved space).  NOTE2: This value is tentative and could be modified after SA1'further input. | | |

Figure A-1 and A-2 show illustrative diagrams of urban grid and highway, respectively.



Figure A-1: Road configuration for urban grid



Figure A-2: Road configuration for highway scenario

Annex B: Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2018-02 | RAN1#92 | R1-1803309 |  |  |  | Skeleton TR | 0.0.1 |
| 2018-04 | RAN1#92bis | R1-1804589 |  |  |  | Inclusion of RAN1#92 agreements and the text in RP-172401. | 0.1.0 |
| 2018-05 | RAN1#93 | R1-1806178 |  |  |  | Inclusion of RAN1#92bis agreements | 0.2.0 |
| 2018-05 | RAN1#93 | R1-1807837 |  |  |  | Inclusion of RAN1#93 agreements | 0.3.0 |
| 2018-05 | RAN1#93 | R1-1807869 |  |  |  | Agreed version for one-step approval as version 1.0.0 | 1.0.0 |
| 2018-06 | RAN#80 |  |  |  |  | Spec under change control further to RAN approval decision | 15.0.0 |
| 2018-09 | RAN#81 | RP-181801 | 0001 | 2 | F | Correction of optional antenna element patterns for vehicular UEs | 15.1.0 |
| 2018-09 | RAN#81 | RP-181801 | 0002 | 1 | F | Correction and confirmation of some evaluation assumption parameters | 15.1.0 |
| 2018-12 | RAN#82 | RP-182530 | 0003 | - | F | Correction on the groupcast terminology | 15.2.0 |
| 2018-12 | RAN#82 | RP-182530 | 0004 | - | F | Correction on vehicle blockage loss in NLOSv | 15.2.0 |
| 2018-12 | RAN#82 | RP-182530 | 0005 | - | F | Introduction of CDL models | 15.2.0 |
| 2019-06 | RAN#84 | RP-191274 | 0006 | - | F | V2X antenna model and pathloss correction | 15.3.0 |