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NR Sidelink enhancement;

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(Release 17)

** 

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***3GPP***

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis

Valbonne - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

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# Foreword

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

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# 1 Scope

The present document is a technical report for NR sidelink enhancement services in Rel-17. The purpose is to specify radio solutions that are necessary for NR to support sidelink enhancement services based on the study outcome captured in TR 38.840 and TR 37.885. Based on merged motivations from interested companies, the following justification and objectives of this work item decided in session 4.1 and session 4.2.

# 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 TR 30.007: "Guideline on WI/SI for new Operating Bands".

[3] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".

[4] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone".

[5] 3GPP TS 38.101-3: "NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios".

[6] RP-202846: “WID revision: NR sidelink enhancement”.

# 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] and the following 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:

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP 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 3GPP TR 21.905 [1].

ACLR Adjacent Channel Leakage Ratio

ACS Adjacent Channel Selectivity

AGC Automatic Gain Control

A-MPR Additional Maximum Power Reduction

BLER BLock Error Rate

BS Base Station

CBW Channel Bandwidth

CDF Cumulative Distribution Function

CP-OFDM Cyclic Prefix-OFDM

DMRS Demodulation Reference Signal

DSRC Dedicated Short-Range Communications

EIRP Equivalent Isotropically Radiated Power

EVM Error Vector Magnitude

FDD Frequency Division Duplex

FDM Frequency Division Multiplexing

FR1 Frequency Range 1

FR2 Frequency Range 2

ITS Intelligent Transportation System

LDPC Low Density Parity Check

LTE Long Term Evolution

LOS Line-Of-Sight

MPR Maximum Power Reduction

NF Noise Figure

NLOS Non-Line-Of-Sight

NR New Radio

OLPC Open Loop Power Control

PC Power Control

PRB Physical Resource Block

PRR Package Reception Ratio

ProSe Proximity-based Services

PSCCH Physical Sidelink Control CHannel

PSSCH Physical Sidelink Shared CHannel

REFSENS Reference Sensitivity

RF Radio Frequency

SCS Sub-Carrier Spacing

SINR Signal to Interference plus Noise Ratio

SL Sidelink

SNR Signal-to-Noise Ratio

TDD Time Division Duplex

TDM Time Division Multiplexing

UE User Equipment

UL Uplink

V2V Vehicle to Vehicle

V2X Vehicle to Everything

# 4 Background

## 4.1 Justification

3GPP has been developing standards for sidelink as a tool for UE to UE direct communication required in various use cases since LTE. The first standard for NR sidelink enhancement is to be completed in Rel-16 by the work item “5G V2X with NR sidelink” where solutions including NR sidelink are being specified mainly for vehicle-to-everything (V2X) while they can also be used for public safety when the service requirement can be met.

Meanwhile, the necessity of NR sidelink enhancement has been identified. For V2X and public safety, the service requirements and operation scenarios are not fully supported in Rel-16 due to the time limitation, and SA works are ongoing on some enhancement in Rel-17 such as architecture enhancements for 3GPP support of advanced V2X services – Phase 2 (FS\_eV2XARC\_Ph2) and System enhancement for Proximity based Services in 5GS (FS\_5G\_ProSe). In addition, other commercial use cases related to NR sidelink are being considered in SA WGs via several work/study items such as Network Controlled Interactive Service (NCIS), Gap Analysis for Railways (MONASTERYEND), Enhanced Relays for Energy eFficiency and Extensive Coverage (REFEC), Audio-Visual Service Production (AVPROD). In order to provide a wider coverage of NR sidelink for these use cases and be able to provide the radio solutions in accordance with the progress in SA WGs, it is necessary to specify enhancements to NR sidelink in TSG RAN.

The following significant interest has been observed based on the several motivations for SL enhancements.

* **Power saving** enables UEs with battery constraint to perform sidelink operations in a power efficient manner. Rel-16 NR sidelink is designed based on the assumption of “always-on” when UE operates sidelink, e.g., only focusing on UEs installed in vehicles with sufficient battery capacity. Solutions for power saving in Rel-17 are required for vulnerable road users (VRUs) in V2X use cases and for UEs in public safety and commercial use cases where power consumption in the UEs needs to be minimized.
* **Enhanced reliability and reduced latency** allow the support of URLLC-type sidelink use cases in wider operation scenarios. The system level reliability and latency performance of sidelink is affected by the communication conditions such as the wireless channel status and the offered load, and Rel-16 NR sidelink is expected to have limitation in achieving high reliability and low latency in some conditions, e.g., when the channel is relatively busy. Solutions that can enhance reliability and reduce latency are required in order to keep providing the use cases requiring low latency and high reliability under such communication conditions.

While several work areas have been identified in the discussion, some important principles were also discussed regarding the 3GPP evolution for NR sidelink. In dealing with different use cases in the evolution of NR sidelink, WGs should strive to achieve maximum commonality between commercial, V2X, and Critical Communication usage of sidelink in order to avoid duplicated solutions and maximize the economy of scale. In addition, enhancements introduced in Rel-17 should be based on the functionalities specified in Rel-16, instead of designing the fundamental NR sidelink functionality again in Rel-17.

## 4.2 Objective

The objective of this work item is to specify radio solutions that are necessary for NR sidelink enhancement to support advanced V2X services, public safety services and other commercial use cases related to NR sidelink. In the following objectives, RAN4 should focus on the objective 4 and 6 in the approved WID [1] as below

1. Sidelink evaluation methodology update: Define evaluation assumption and performance metric for power saving by reusing TR 36.843 and/or TR 38.840 (to be completed by RAN#89) [RAN1]

* Note: TR 37.885 is reused for the other evaluation assumption and performance metric. Vehicle dropping model B and antenna option 2 shall be a more realistic baseline for highway and urban grid scenarios.

2. Resource allocation enhancement:

* Specify resource allocation to reduce power consumption of the UEs [RAN1, RAN2]
  + Baseline is to introduce the principle of Rel-14 LTE sidelink random resource selection and partial sensing to Rel-16 NR sidelink resource allocation mode 2.
  + Note: Taking Rel-14 as the baseline does not preclude introducing a new solution to reduce power consumption for the cases where the baseline cannot work properly.
  + This work should consider the impact of sidelink DRX, if any.
* Study the feasibility and benefit of solution(s) on the enhancement(s) in mode 2 for enhanced reliability and reduced latency in consideration of both PRR and PIR defined in TR37.885 (by RAN#91), and specify the identified solution(s) if deemed feasible and beneficial [RAN1, RAN2]
  + Inter-UE coordination with the following.
    - A set of resources is determined at UE-A. This set is sent to UE-B in mode 2, and UE-B takes this into account in the resource selection for its own transmission.
  + Note: The solution should be able to operate in-coverage, partial coverage, and out-of-coverage and to address consecutive packet loss in all coverage scenarios.
  + Note: RAN2 work will start after RAN#89.

3. Sidelink DRX for broadcast, groupcast, and unicast [RAN2]

* Define on- and off-durations in sidelink and specify the corresponding UE procedure
* Specify mechanism aiming to align sidelink DRX wake-up time among the UEs communicating with each other
* Specify mechanism aiming to align sidelink DRX wake-up time with Uu DRX wake-up time in an in-coverage UE

**4. Support of new sidelink frequency bands for single-carrier operations [RAN4]**

* Support of new sidelink frequency bands should ensure coexistence between sidelink and Uu interface in the same and adjacent channels in licensed spectrum.
* The exact frequency bands are to be determined based on company input during the WI, considering both licensed and ITS-dedicated spectrum in both FR1 and FR2.

5. Define mechanism to ensure sidelink operation can be confined to a predetermined geographic area(s) for a given frequency range within non-ITS bands [RAN2].

* This applies areas where there is no network coverage.

**6. UE Tx and Rx RF requirement for the new features introduced in this WI [RAN4]**

7. UE RRM core requirement for the new features introduced in this WI [RAN4]

Enhancements introduced in Rel-17 should be based on the functionalities specified in Rel-16, and Rel-17 sidelink should be able to coexist with Rel-16 sidelink in the same resource pool. This does not preclude the possibility of operating Rel-17 sidelink in a dedicated resource pool.

The solutions should cover both the operating scenario where the carrier(s) is/are dedicated to ITS and the operating scenario where the carrier(s) is/are licensed spectrum and also used for NR Uu/LTE Uu operation.

The solutions should support the network control of NR sidelink as in Rel-16, i.e., NR Uu controls NR sidelink using Layer 1 and Layer 2 signalling and LTE Uu controls NR sidelink using Layer 2 signalling.

In ITS carriers, it is assumed that any co-channel coexistence requirements and mechanisms of NR sidelink with non-3GPP technologies will not be defined by 3GPP.

Also, RAN4 agreed to specify additional V2X RF requirements as following

* Left over issue in Rel-16:
  + Supporting PC2 NR SL UE RF requirements (PC2 single at n47, PC2 SL-MIMO at n47, PC2 inter-band con-current operation)
  + Partial used SL operation in a carrier including n79 and other interesting bands
    - Cover the Frequency separation issues and timing alignment issue

## 4.3 NR sidelink enhancement operating scenarios

### 4.3.1 General description

The NR Sidelink enhancement operating scenarios will be decribed to support advanced V2X services, public safety services and other commercial use cases based on agreed WID. RAN4 needs to enhance RF core requirements based on operating scenarios in Rel-16 NR V2X service and the Proximity service (ProSe) in TR 36.877.

Specifically, RAN4 did not complete some open issues in Rel-16 NR V2X, which include:

* TxD for NR V2X
* PC2 HPUE for NR V2X
* Intra-band V2X operation for TDD band, e.g. band n79k
* Intra-band con-current V2X operation for TDD band, e.g. band n79

The left over items will be further studied and specified into the related RF requirements in this TR.

From RAN4 RF perspective, it is necessary to study coexistence before introducing the new frequency NR band to support NR sidelink enhancement operating at a frequency adjacent to NR Uu service for advanced V2X services, public safety services and other commercial use cases in licensed spectrum.

In RAN4 #98-e meeting, RAN4 agreed not to introduce a new band for NR sidelink in FR2 since no operator proposed a FR2 NR operating band for NR sidelink.

Hence, RAN4 need to study and specify the RF core requirements for NR sidelink enhancement only in FR1 in Rel-17.

### 4.3.2 Operation Aspects

Operating scenarios for NR sidelink enhancement WI are as follows:

* **(Aspect 1) SL services and Operating band perspectives**
  + Case 1: Public Safety Service
    - Case 1A: Dedicated public safety licensed band such as NR Band 14
      * Public safety UE only operated in out-of NW coverage.
    - Case 1B: Dedicated public safety licensed band in other licensed bands (depends on inputs from operators)
      * Public safety UE operated in both in-NW coverage and out-of-NW coverage.
  + Case 2: NR V2X service
    - Case 2A: V2X UE in ITS spectrum (e.g. 5.9GHz (n47))
      * RAN4 already evaluated in ITS spectrum in Rel-16 NR V2X WI
    - Case 2B: V2X UE in FR1 licensed bands (e.g. 4.5GHz(TDD), 2GHz(FDD))
      * TDD coexistence evaluated in Rel-16 NR V2X WI
      * FDD coexistence need to evaluated to protect legacy system (depends on inputs on operating band from operators)
  + Case 3: Other commercial use cases (depends on inputs from operators and other WGs)
    - Basic operation can be performed in existing NR SL operating bands.
    - If specific operating band is requested, need to add a new operating band in suffix E in TS38.101-1.
* **(Aspect 2) gNB deployment including network control possibility**
  + Case 1: Public safety Service
    - Case 1A: gNB is not deployed since only public safety UE operated in out-of-coverage in licensed band such as n14
    - Case 1B: gNB is deployed to support both legacy NR UE and public safety UE
      * Public safety UE needs to protect the legacy NR system
  + Case 2: NR V2X service
    - Case 2A: No gNB deployment scenarios based on semi-statically network-configured/pre-configured radio parameters
      * Support UE autonomous resource allocation, at least mode 2.
    - Case 2B: gNB deployment scenarios
      * Providing more UE specific or/and more dynamic resource allocation including Mode 1.
  + Case 3: Other commercial use cases
    - Basic NR sidelink operation can support both in-coverage network and out-of-coverage NW scenarios.
    - If identified, RAN4 need to add new operating scenarios

RAN4 shall consider exact deployment scenarios and operating band planning for public saftety service, NR V2X service and other commercial SL operation.

### 4.3.3 Synchronization reference source

It was agreed in RAN4 to follow the existing RAN1 design on sync reference source. The agreements by RAN1 are listed below:

* *Whether GNSS-based synchronization or gNB/eNB-based synchronization is used is (pre)-configured.* 
  + *The following table is a working assumption*

|  |  |
| --- | --- |
| **GNSS-based synchronization** | **gNB/eNB-based synchronization** |
| * P0: GNSS * P1: the following UE has the same priority: * UE directly synchronized to GNSS * P2: the following UE has the same priority: * UE indirectly synchronized to GNSS * P3: the remaining UEs have the lowest priority. | * P0: gNB/eNB * P1’: UE directly synchronized to gNB/eNB * P2’: UE indirectly synchronized to gNB/eNB * P3’: GNSS * P4’: UE directly synchronized to GNSS * P5’: UE indirectly synchronized to GNSS * P6’: the remaining UEs have the lowest priority. |

* *For confirmation of the working assumption of synchronization priority rules, eNB/gNB should be included into the priority order of GNSS-based synchronization.*

|  |  |
| --- | --- |
| **GNSS-based synchronization** | **gNB/eNB-based synchronization** |
| • P0: GNSS  • P1: UE directly synchronized to GNSS  • P2: UE indirectly synchronized to GNSS  • P3: gNB/eNB  • P4: UE directly synchronized to gNB/eNB  • P5: UE indirectly synchronized to gNB/eNB  • P6: the remaining UEs have the lowest priority. | • P0’: gNB/eNB  • P1’: UE directly synchronized to gNB/eNB  • P2’: UE indirectly synchronized to gNB/eNB  • P3’: GNSS  • P4’: UE directly synchronized to GNSS  • P5’: UE indirectly synchronized to GNSS  • P6’: the remaining UEs have the lowest priority. |

Based on RAN2 specification in TS 38.331：

|  |
| --- |
| 5.8.12 DFN derivation from GNSS When the UE selects GNSS as the synchronization reference source, the DFN, the subframe number within a frame and slot number within a frame used for NR sidelink communication are derived from the current UTC time, by the following formulae:  *DFN*= Floor (0.1\*(*Tcurrent* –*Tref–OffsetDFN*)) mod 1024  *SubframeNumber*= Floor (*Tcurrent* –*Tref–OffsetDFN*) mod 10  *SlotNumber*= Floor ((*Tcurrent* –Tref–*OffsetDFN*)\*2μ) mod (10\*2μ)  Where:  ***Tcurrent*** is the current UTC time that obtained from GNSS. This value is expressed in milliseconds;  ***Tref*** is the reference UTC time 00:00:00 on Gregorian calendar date 1 January, 1900 (midnight between Thursday, December 31, 1899 and Friday, January 1, 1900). This value is expressed in milliseconds;  ***OffsetDFN*** is the value *sl-OffsetDFN* if configured, otherwise it is zero. This value is expressed in milliseconds. |

And according to RAN1 agreements, there are two standalone lists for synchronization priority as GNSS-based synchronization or gNB/eNB-based synchronization. When a UE is (pre)-configured with GNSS-based synchronization, the UE would prefer GNSS as synchronization resource. When a UE is (pre)-configured with gNB/eNB -based synchronization, the UE would prefer network as synchronization resource. Also based on RAN1 agreement, it is up to (pre)-configuration whether GNSS-based synchronization or gNB/eNB-based synchronization is used.

When SL and Uu operate in the same licensed band, it is up to network configuration to determine GNSS-based synchronization or gNB/eNB-based synchronization is used. On the one hand, it is natural that a UE can be configured by network with the network based synchronization for intra-band con-current V2X operating bands. On the other hand, when GNSS is known by network, it is still reasonable that a UE is (pre)-configured with GNSS-based synchronization for intra-band con-current V2X operating bands, because there is an ‘*OffsetDFN*’ defined in TS 38.331 which is indicated by network to make sure that there is a common understanding for SL and Uu about which slot is used for SL transmission. Then it is up to network implementation to determine the synchronization list configuration for a SL UE, no more specification impact is needed.

# 5 Leftover RF requirements

## 5.1 Power class 2 sidelink UE

### 5.1.1 Coexistence evaluation for PC2 SL UE in licensed band

In this section, the adjacent channel system coexistence evaluation for PC2 NR V2X operation was studied for NR V2X services. The operating scenarios include the case where the carrier is deployed for NR V2X service in licensed spectrum. For the licensed carrier, the coexistence evaluation include LTE or NR Uu on the adjacent carrier of NR V2X.

#### 5.1.1.1 Coexistence evaluation scenarios

The adjacent channel coexistence evaluation scenarios for PC2 NR V2X service are shown in Table 5.1.1.1-1

Table 5.1.1.1-1: The adjacent channel coexistence scenarios for PC2 NR V2X service

|  |  |  |
| --- | --- | --- |
| NR V2X operating frequency | | Deployment scenarios  (Aggressor-to-Victim) |
| FR1 | Scenario A: V2X service at licensed band where only NR SL is supported. (TDD: 2.6GHz)  (2nd priority) | * Case1: PC2 NR V2X UE-to- PC2 NR V2X UE * Case2: PC2 NR V2X UE-to- PC3 NR V2X UE |
| Scenario B: V2X service at licensed bands where NR SL and NR Uu are supported. (TDD: 2.6GHz)  (1st priority) | * Case3: : PC2 NR V2X UE-to-NR Uu BS * Case4: NR Uu UE-to- PC2 NR V2X UE |

Basic simulation parameters are below

* Deployment scenarios: Urban Manhattan grid model
* Simulation Block Size :
  + Urban : Manhattan grid model: 3\*433m, 3\*250m
* RAN1 dependent parameter
  + For licensed band, NR SL operation in Uplink band in FDD, UL opportunity in TDD is considered.
  + For SINR calculation in partial overlapping between aggressor and victim, worst case SINR should be considered.

The details of the deployment scenarios are presented in the following clauses.

#### 5.1.1.2 Coexistence simulations assumptions

##### 5.1.1.2.1 Layout model

RAN4 reuse the Manhattan Grid model based on the network layout model for licensed band as shown in section 5.2.1 and section 5.2.2 in TR38.886.

##### 5.1.1.2.2 Simulation parameters

In Table 5.1.1.2.2-1 and Table 5.1.1.2.2-2, RAN4 provide detail simulation parameters for PC2 coexistence evaluation in licensed band.

Table 5.1.1.2.2-1: Simulation parameters in licensed band for scenarios A

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | |
| NR V2X UE (Aggressor) | NR V2X UE (Victim) |
| Tx power | 26dBm | 23dBm or 26dBm |
| Channel Bandwidth | 20MHz | 20MHz |
| Packet size | 1) 14 PRB (190 byte packet) for 15kHz SCS  2) Other options are not precluded | 1) 14 PRB (190 byte packet) for 15kHz SCS  2)Other options are not precluded |
| Traffic model | 1 transmission every 100ms   * 100ms message generation period * Time instance of message generation is randomized among vehicles | |
| Noise figure | 9dB | 9dB |
| Antenna pattern | Omni-directional with gain of 0 dBi | |
| Sidelink Power control | The worst case of no power control is used | |
| SINR-to-BLER mapping | As per link level performance model in TR 38.xxx  Table A-x for 2.6GHz | As per link level performance model in TR 38.xxx  Table A-x for 2.6GHz |

Table 5.1.1.2.2-2: Simulation parameters in licensed band for scenarios B

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Value** | | |
| NR UE | NR BS | NR V2X UE |
| Max Tx power | 23dBm or 26dBm | NA | 26dBm |
| Channel Bandwidth | 20MHz | 20MHz | 20MHz |
| Packet size | 1) [32] PRB for 15kHz SCS  2) Other options are not precluded |  | 1) 14 PRB (190 byte packet) for 15kHz SCS  2) Other options are not precluded |
| Traffic model | Full buffer | Full buffer | Reference table 5.2.1.2-1 |
| Noise figure | N/A | 5dB | 9dB |
| Antenna pattern | Omni-directional with gain of 0 dBi | Antenna pattern for FR1 Macro BS from TR 38.828 | Omni-directional with gain of 0 dBi |
| SINR-to-BLER mapping for NR V2X | NA | NA | As per link level performance model in TR 38.xxx  Table A-x for 2.6GHz |
| SINR-to-rate mapping for NR | NA | As per link level performance model in TR 36.942 (Table A.2). α, attenuation = 0.4, SNIRMIN, dB = -10, SNIRMAX, dB = 22 (subclause 5.2.3.6 from TR 38.828). | NA |

##### ACLR and ACS

RAN4 only consider 1step ACLR/ACS model to derive the PC2 coxistence evaluation in licensed band

Table 5.1.1.2.3-1: ACLR and ACS in licensed band for scenarios A

| **Parameter** | **Value** | |
| --- | --- | --- |
| PC2 NR V2X UE (Aggressor) | NR V2X UE (Victim PC3/PC2) |
| ACLR | 31+XdB | 30 + X dB  31 + X dB |
| ACS | 27+XdB | 27+ X dB |

Table 5.1.1.2.3-2: ACLR and ACS in licensed band for scenarios B

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Value** | | |
| NR UE (PC3/PC2) | NR BS | NR V2X UE (PC2) |
| ACLR | 30 dB/31 dB | NA | 31 + X dB |
| ACS | NA | 46 dB | 27 + X dB |

##### Power control

For V2X operating scenarios A, RAN4 make consensus to reuse the OLPC in TR36.786 or no power control is considered.

For V2X operating scenarios B, the power control mechanism which was specified in clause 5.2.3.4 in TR38.886 for FR1 TDD band can be reused.

#### 5.1.1.3 Coexistence results

5.1.1.3.1 Scenario A

In this subsection, the evaluation results in scenario A are provided. According to the detail simulation assumption, the final evaluation results in broadcast, groupcast and unicast can be obtained from Figure 1 to Figure 3. The HARQ feedback option 2 scheme is used in groupcast scenario. Additionally, the performance of sidelink UE in scenario A is evaluated without power control. The vehicle speed is fixed of 60km/h and the number of the UE working in each channel is approximate.

|  |  |
| --- | --- |
|  |  |
| Figure 1 Average PRR of SL UE in broadcast scenario without power control | Figure 2 Average PRR of SL UE in groupcast scenario without power control |
|  | |
| Figure 3 Average PRR of SL UE in unicast scenario without power control | |

5.1.1.3.2 Scenario B

In this subsection, the evaluation results in scenario B are provided. According to the detail simulation assumptions, the final evaluation results in broadcast, groupcast and unicast can be obtained from Figure 4 to Figure 12. The HARQ feedback option 2 scheme is used in groupcast scenario. Additionally, the performance of NR UE in scenario B is evaluated with power control, while the sidelink UE in scenario B is evaluated without power control. The TDD configuration used in the simulation is DDSUUDDSUU.

|  |  |
| --- | --- |
|  |  |
| Figure 4 Average PRR of NR SL UE in broadcast scenario | Figure 5 SINR of NR Uu UE in broadcast scenario |
|  | |
| Figure 6 Throughput of Uu UE in broadcast scenario | |
|  |  |
| Figure 7 Average PRR of NR SL UE in groupcast scenario | Figure 8 SINR of NR Uu UE in groupcast scenario |
|  | |
| Figure 9 Throughput of NR Uu UE in groupcast scenario | |
|  |  |
| Figure 10 Average PRR of NR SL UE in unicast scenario | Figure 11 SINR of NR Uu UE in unicast scenario |
|  | |
| Figure 12 Throughput of NR Uu UE in unicast scenario with power control | |

The PRR loss for scenario A based on broadcast, groupcast, unicast are summarized in Table 1.

Table 1 Average PRR loss for Scenario A considering Broadcast, Groupcast, Unicast

|  |  |  |  |
| --- | --- | --- | --- |
| **PRR loss (190Byte)** | **At 150m range for 60km/h** | | |
| **Broadcast** | **Groupcast** | **Unicast** |
| **Case1:PC2 V-UE** | **0.15%** | **0.12%** | **0.09%** |
| **Case2:PC2 V-UE** | **0.4%** | **0.36%** | **0.07%** |

It can be observed from Table 1, for victim PC2 V-UE in Case 1 for Scenario A, the average PRR losses for broadcast, groupcast, unicast are 0.15%, 0.12%, 0.09%, respectively; for victim PC3 V-UE in Case 2 for Scenario A, the average PRR losses for broadcast, groupcast, unicast are 0.4%, 0.36%, 0.07%. respectively.

The PRR loss and throughput loss for scenario B based on broadcast, groupcast, unicast are summarized in Table 2.

**Table 2 Average PRR loss and throughput loss for Scenario B considering Broadcast, Groupcast, Unicast**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Average throughput loss** | **Broadcast** | | **Groupcast** | | **Unicast** |
| **Case3:NR BS**  **(PC2 Uu-UE)** | **1.33%** | | **1.75%** | | **0.68%** |
| **Case3:NR BS**  **(PC3 Uu-UE)** | **2.62%** | | **2.27%** | | **1.61%** |
| **PRR loss (190Byte)** | **At 150m range for 60km/h** | | | | |
| **Broadcast** | **Groupcast** | | **Unicast** | |
| **Case4:PC2 V-UE** | **0.4%** | **0.05%** | | **0.07%** | |

It can be observed from Table 2, with the interference from PC2 V-UE to PC2 Uu-UE, the throughput losses for NR Uu BS for Broadcast, Groupcast, Unicast are 1.33%, 1.75%, 0.68%, respectively; with the interference from PC2 V-UE to PC3 Uu-UE, the throughput losses for NR Uu BS for Broadcast, Groupcast, Unicast are 2.62%, 2.27%, 1.61%, respectively. With the interference from Uu-UE to PC2 V-UE, the total PRR losses for PC2 V-UE are 0.4%, 0.05%, 0.07%, respectively.

#### 5.1.1.4 Conclusion of Coexistence evaluations

### 5.1.2 PC2 NR V2X UE RF requirements for single carrier

#### 5.1.2.1 Maximum output power for NR V2X UE

The following V2X UE Power Classes define the maximum output power for any transmission bandwidth within the channel bandwidth. The period of measurement shall be at least one sub frame (1ms).

Table 8.1-1: V2X UE Power Class

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NR band | Class 1 (dBm) | Tolerance (dB) | Class 2 (dBm) | Tolerance (dB) | Class 3 (dBm) | Tolerance (dB) | Class 4 (dBm) | Tolerance (dB) |
| … |  |  |  |  |  |  |  |  |
| n47 |  |  | 26 | ±2 | 23 | ±2 |  |  |
| NOTE 1: NR Band n47 is used for NR V2X Service.  NOTE 2: PPowerClass is the maximum UE power specified without taking into account the tolerance | | | | | | | | |

#### 5.1.2.2 UE maximum output power reduction

The following assumption can serve as a starting point for MPR simulation assumptions as shown in Table 5.1.2.2-1 and Table 5.1.2.2-2.

Table 5.1.2.2-1: MPR simulation assumption for PC2 NR V2X

|  |  |
| --- | --- |
| **parameter** | **Assumption** |
| **center frequency** | **5.9GHz** |
| **Bandwidth** | **10/20/30/40MHz** |
| **Maximum output power** | **26 dBm** |
| **numerology** | **15 kHz/30kHz/60kHz** |
| **Modulation** | **QPSK/16QAM/64QAM/256QAM** |
| **Waveform** | **CP-OFDM** |
| **Carrier leakage** | **25dBc** |
| **IQ image** | **25dBc** |
| **CIM3** | **45dBc or 60dBc** |
| **PA calibration** | PA calibrated to deliver [31dBc] ACLR for a fully allocated RBs in 20MHz QPSK DFT- S-OFDM waveform at 1 dB MPR.  This is based to share PA between LTE V2X and NR V2X at 5.9GHz as worst case. |

For PC2 NR V2X, simultaneous transmission of PSCCH and PSSCH in the same sub-frame is supported. The following constraints in Table 5.1.2.2-2 can be assumed based on current RAN1’s agreement.

Table 5.1.2.2-2: PC2 V2X UE’ MPR simulation assumptions

|  |  |
| --- | --- |
| **Items** | **Assumption** |
| Allowed sub-channel sizes | **• Support {10, 12, 15, 20, 25, 50, 75, 100} PRBs for possible sub-channel size.** |
| Allowed LCRB allocation | 10,12,15,20,24,25,30,36,40,45,48,50,60,70,72,75,80,84,90,96,100,105,108,110,120,130,132,135,140,144,150,156,160,165,168,170,175,180,190,192,195,200,204,210,216 |
| Regarding PSCCH / PSSCH multiplexing |  |
| PSCCH size | **10RB\*3 Symbols** |
| PSD offset of X dB between PSCCH and PSSCH | **0dB** |

For simultaneous transmission of PSFCH transmission for PC2 V2X UE, RAN4 assumed as follow

Table 5.1.2.2-3: PC2 V2X UE’ MPR simulation assumptions for PSFCH transmission

|  |  |
| --- | --- |
| **Items** | **Assumption** |
| **Modulation for PSSCH** | QPSK |
| **PSFCH** | ZC sequence |
| **Structure of Slot** | Baseline is follow RAN1 agreements |
| **RB allocation** | * 1 RB per user * All users have the same power per RB * Total power of all users equals 26dBm for PC2 * Both Non-contiguous PSFCH RB allocation and contiguous PSFCH allocation are allowed   + MPR will be derived by non-contiguous PSFCH RB allocation (N>1) * At least, the worst cases with possible RBstart and Ngap need to be checked. ( Ngap = RBend – RBstart )   + For example: The worst case N gap is (106-1 =105\*15kHz\*12=) 18.9MHz for 20MHz, 15kHz SCS * IMD problem by dual PSFCH in SEM/SE region shall be considered to derive MPR level according to all supporting CBW and SCS. * N (Number of users) is up to 5 and RBs except for RBstart and RBend can be inserted between RBstart and RBend randomly. * Assumption of N in RAN4 is only for MPR simulation purpose, the final number is up to RAN1 decision. |

For S-SSB transmission for PC2 V2X UE, RAN4 assumed as follow

Table 5.1.2.2-4: PC2 V2X UE’ MPR simulation assumptions for S-SSB transmission

|  |  |
| --- | --- |
| **Items** | **Assumption** |
| **Modulation for PSBCH** | QPSK |
| **S-PSS** | M-sequence |
| **S-SSS** | Golden-sequence |
| **S-SSB structure** |  |
| **RB allocation** | RBstart: All the possible cases  LCRB: 11 RB |

### 5.1.3 PC2 NR V2X UE RF requirements SL-MIMO

### 5.1.4 PC2 NR V2X inter-band con-current UE RF requirements

## 5.2 Intra-band V2X operation in a licensed band

### 5.2.1 Intra-band V2X operation scenarios and basic assumptions

For the intra-band V2X operation in licensed band, RAN4 agreed the prioritization on operating scenarios including TDM and FDM and baseline RF architecture as follow.

* 1st priority: TDM (Single RF chain for Tx as baseline)
  + RAN4 allow TDM operation between spectrally partially used PC5 SL and Uu UL/DL operation in a licensed TDD band regardless of adjacent/ non-adjacent carrier
* 2nd priority: FDM with adjacent carrier (Separate RF chain as baseline)
* 3rd priority: FDM with non-adjacent carrier (Separate RF chain as baseline)

### 5.2.2 Coexistence evaluation

#### 5.2.2.1 Coexistence evaluation scenarios

#### 5.2.2.2 Coexistence simulations assumptions

#### 5.2.2.3 Coexistence results

#### 5.2.2.4 Conclusion of Coexistence evaluations

### 5.2.3 Intra-band V2X UE RF requirements for TDM operation

For the intra-band V2X service for TDM operation, the existing TS38.101-1 RF requirements in suffix E for single carrier V2X UE are considered.

#### 5.2.3.1 Intra-band V2X operating bands

Intra-band NR V2X operation is designed to operate with NR Uu operation in TDM mode on the operating bands combinations listed in Table 5.2.3.1-1.

Table 5.2.3.1-1: Intra-band V2X operating bands

|  |  |  |
| --- | --- | --- |
| Intra-band V2X operating band Combination | NR Band | Interface |
| V2X\_n79-n791 | n79 | Uu |
|  | n79 | PC5 |
| NOTE 1: Only single switched sidelink or NR uplink/downlink is supported. | | |

#### 5.2.3.2 Additional Tx requirements for TDM operation

For the TDM operation in same carrier and different carrier, transmit ON/OFF time mask are FFS.

### 5.2.4 Intra-band V2X con-current UE RF requirements with adjacent channel for FDM operation

#### 5.2.4.1 Intra-band V2X con-current operating bands

Intra-band NR V2X con-current operation is designed to operate concurrent with NR uplink/downlink on the operating bands combinations listed in Table 5.2.4.1-1.

Table 5.2.4.1-1: Intra-band V2X con-current operating bands

|  |  |  |
| --- | --- | --- |
| Intra-band V2X con-current operating band Combination | NR Band | Interface |
| V2X\_n79-n79 | n79 | Uu |
|  | n79 | PC5 |

#### 5.2.4.2 Tx requirements for NR intra-band V2X con-current operation with adjacent channel

##### 5.2.4.2.1 Maximum output power

The following NR intra-band V2X con-current operating UE’ Power Classes define the maximum output power for any transmission bandwidth within the channel bandwidth. The period of measurement shall be at least one sub frame (1ms).

Table 5.2.4.2.1-1: intra-band V2X contiguous con-current V2X UE Power Class

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NR band | Class 1 (dBm) | Tolerance (dB) | Class 2 (dBm) | Tolerance (dB) | Class 3 (dBm) | Tolerance (dB) | Class 4 (dBm) | Tolerance (dB) |
| … |  |  |  |  |  |  |  |  |
| V2X\_n79B |  |  |  |  | 23 | ±2 |  |  |
| V2X\_n79C |  |  |  |  | 23 | ±2 |  |  |
| NOTE 1: the intra-band contiguous con-current NR V2X operating band is used for NR V2X and NR Uu Service.  NOTE 2: PPowerClass is the maximum UE power specified without taking into account the tolerance | | | | | | | | |

##### 5.2.4.2.2 UE maximum output power reduction

The following assumption can serve as a starting point for MPR simulation assumptions as shown in Table 5.2.4.2.2-1 and Table 5.2.4.2.2-2.

Table 5.2.4.2.2-1: MPR simulation assumption for NR V2X intra-band contiguous con-current operation

|  |  |
| --- | --- |
| **parameter** | **Assumption** |
| **center frequency** | **4.5GHz (n79)** |
| **Bandwidth** | **10/20/30/40MHz for NR SL**  **10/20/40/60/80MHz for NR Uu** |
| **Maximum output power** | **26 dBm** |
| **numerology** | **15 kHz/30kHz/60kHz** |
| **Modulation** | **QPSK/16QAM/64QAM/256QAM** |
| **Waveform** | **CP-OFDM for NR SL**  **CP-OFDM or DFT-S-OFDM for NR Uu** |
| **Carrier leakage** | **25dBc** |
| **IQ image** | **25dBc** |
| **CIM3** | **45dBc or 60dBc** |
| **PA calibration** | PA calibrated to deliver 30dBc ACLR for a fully allocated RBs in 20MHz QPSK DFT- S-OFDM waveform at 1 dB MPR. |

For NR V2X intra-band contiguous con-current operation, simultaneous transmission of PUSCH/PUCCH and NR V2X’s PSCCH and PSSCH in the same sub-frame is supported. The following constraints in Table 5.2.4.2.2-2 can be assumed based on current RAN1’s agreement.

Table 5.2.4.2.2-2: NR V2X intra-band contiguous con-current operation UE’ MPR simulation assumptions

|  |  |
| --- | --- |
| **Items** | **Assumption** |
| Allowed sub-channel sizes for NR SL | **• Support {10, 12, 15, 20, 25, 50, 75, 100} PRBs for possible sub-channel size.** |
| Allowed LCRB allocation for NR SL | 10,12,15,20,24,25,30,36,40,45,48,50,60,70,72,75,80,84,90,96,100,105,108,110,120,130,132,135,140,144,150,156,160,165,168,170,175,180,190,192,195,200,204,210,216.  **No restriction of LCRB for NR Uu** |
| Regarding PSCCH / PSSCH multiplexing for NR SL |  |
| PSCCH size for NR SL | **10RB\*3 Symbols** |
| PSD offset of X dB between PSCCH and PSSCH for NR SL | **0dB** |
| NOTE 1: If there is not indicate the detail parameters, then follow TR38.886 for NR SL operation. Also follow TS38.211/TS38.212/TS38.101-1 for NR Uu operation. | |

For simultaneous transmission of PSFCH transmission for V2X UE and PUSCH/PUCCH for NR Uu, RAN4 need further discussion how to apply the MPR requirements.

For simultaneous transmission of S-SSB transmission for V2X UE and PUSCH/PUCCH for NR Uu, RAN4 need further discussion how to apply the MPR requirements.

##### 5.2.4.2.3 UE maximum output power with additional requirements

*[It will be further discussed based on regional regulatory requirements]*

##### 5.2.4.2.4 Configured transmitted power for intra-band con-current V2X operation

When a UE is configured for simultaneous NR V2X sidelink and NR uplink transmissions for intra-band con-current operation, the UE is allowed to set its configured maximum output power PCMAX,*c*,*NR*and PCMAX,*c*,*V2X*for the configured NR uplink carrier and the configured NR V2X carrier, respectively, and its total configured maximum output power PCMAX,c forserving cell *c.*

The configured maximum output power PCMAX *c*,*NR(p)* in slot *p* for the configured NR uplink carrier shall be set within the bounds:

PCMAX\_L,*c,NR* (*p*) ≤ PCMAX,*c,NR* (*p*) ≤ PCMAX\_H,*c,NR* (*p*)

where PCMAX\_L,*c,NR* andPCMAX\_H,*c,NR* are the limits for a serving cell c as specified in clause 6.2.4.

The configured maximum output power PCMAX *c*,*V2X (q)* in slot *q* for the configured NR V2X carrier shall be set within the bounds:

PCMAX,*c,V2X* (*q*) ≤ PCMAX\_H,*c,V2X* (*q*)

where PCMAX\_H,*c,V2X* is the limit as specified in clause 6.2E.4.

The total UE configured maximum output power PCMAX (*p,q*) in a slot *p* of NR uplink carrier and a slot *q* of NR V2X sidelink that overlap in time shall be set within the following bounds for synchronous and asynchronous operation unless stated otherwise:

PCMAX\_L (*p,q*) ≤ PCMAX (*p,q*) ≤ PCMAX\_H (*p,q*)

with

PCMAX\_L (*p,q*) = PCMAX\_L,*c,NR* (*p*)

PCMAX\_H (*p,q*) = MIN{10 log10 [pCMAX\_H,*c,NR*(*p*) + pCMAX\_H,*c,V2X*(*q*)],PPowerClass,V2X}

where

* pCMAX\_H*,c,V2X* and pCMAX\_H,*c,NR*are the limits PCMAX\_H,*c,V2X* (*q*) and PCMAX\_H,*c,NR* (*p*) expressed in linear scale;
* PPowerClass, V2X is the maximum intra-band V2X con-current UE power specified in Table 5.2.4.2.1-1 without taking into account the tolerance;

If the transmissions from NR uplink and NR sidelink do not overlap, then the complete clauses for configured transmitted power for NR uplink and NR sidelink respectively from their own specifications apply with the modifications specified above.

The measured total maximum output power PUMAX over both the NR uplink and NR V2X carriers is

PUMAX = 10 log10 [pUMAX,*c,NR* + pUMAX,*c,V2X*],

where pUMAX,*c,NR*  denotes the measured output power of serving cell *c* for the configured NR uplink carrier, and pUMAX,*c,V2X* denotes the measured output power for the configured NR V2X carrier expressed in linear scale.

When an UL subframe of NR transmission *p* overlap with a physical channel *q* from the NR sidelink*,* then for PUMAX evaluation, the NR subframe *p* is takenas reference period TREF and always considered as the reference measurement duration and the following rules are applicable.

PCMAX\_L(*p, q*)  – TLOW (PCMAX\_L(*p, q*)) ≤ PUMAX  ≤ PCMAX\_H(*p, q*) + THIGH (PCMAX\_H(*p, q*))

where PCMAX\_L (*p,q*) and PCMAX\_H (*p,q*) are the limits for the pair (*p,q*) and with the tolerances TLOW(PCMAX) and THIGH(PCMAX) for applicable values of PCMAX specified in Table 6.2E.4.1-1 in TS38.101-1. PCMAX\_L may be modified for any overlapping portion of slots *(p, q)* and *(p +1, q+1).*

##### 5.2.4.2.5 Minimum output power for intra-band con-current V2X operation

For intra-band con-current V2X operation UE, the minimum output power is defined per RAT and the requirement for NR uplink is specified in clause 6.3.1 in TS38.101-1 and the requirement for NR sidelink is specified in clause 6.3E.1 in TS38.101-1, respectively.

##### 5.2.4.2.6 Transmit OFF power for intra-band con-current V2X operation

For intra-band con-current V2X operation UE, the minimum output power is defined per RAT when the transmitter is OFF on all component carriers. The requirement for NR uplink is specified in clause 6.3.2 in TS38.101-1 and the requirement for NR sidelink is specified in clause 6.3E.2 in TS38.101-1, respectively.

##### 5.2.4.2.7 ON/OFF time mask for intra-band con-current V2X operation

For intra-band con-current V2X operation UE, the minimum output power is defined per RAT during the ON power period and the transient periods. The ON/OFF time mask specified in clause 6.3.3.1 in TS38.101-1 is applicable for NR uplink and the ON/OFF time mask in 6.3E.3.1 in TS38.101-1 is applicable for NR sidelink. The OFF period as specified in clause 6.3.3.1 in TS38.101-1 shall only be applicable for each component carrier when all the component carriers are OFF.

##### 5.2.4.2.8 Power control for intra-band con-current V2X operation

###### 5.2.4.2.8.1 Absolute power tolerance

The absolute power tolerance is the ability of the UE transmitter to set its initial output power to a specific value for the first sub-frame at the start of a contiguous transmission or non-contiguous transmission with a transmission gap on each active component carriers larger than 20ms. The requirement can be tested by time aligning any transmission gaps on the component carriers.

Minimum requirements

For intra-band con-current V2X operation, the absolute power control tolerance per RAT. The requirements in 6.3.4.2 in TS38.101-1 is applcable for NR uplink and the requirements in 6.3E.4.2 in TS38.101-1 is applicable for NR sidelink.

###### 5.2.4.2.8.2 Relative power tolerance

Minimum requirements

For intra-band con-current V2X operation, the requirements specified in clause 6.3.4.1.2 in TS38.101-1 shall apply for the uplink in licensed band. There was no relative power tolerance for NR sidelink.

###### 5.2.4.2.8.3 Aggregate power control tolerance

For intra-band V2X operation, the requirements specified in clause 6.3.4.1.3 in TS38.101-1 shall apply for the uplink in licensed band. There was no aggregated power tolerance for NR sidelink.

##### 5.2.4.2.9 Transmit signal quality for intra-band con-current V2X operation

###### 5.2.4.2.9.1 Frequecny error

For intra-band V2X operation, the UE modulated carrier frequencies per band shall be accurate to within ±0.1 PPM observed over a period of one timeslot compared to the carrier frequency of primary component carrier received in the corresponding band.

###### 5.2.4.2.9.2 EVM

For the intra-band V2X operation, the Error Vector Magnitude requirement should be defined for RAT. Requirements only apply with PRB allocation in one of the component carriers. The requirements in 6.4A.2.1.1 in TS38.101-1 is applicable for both NR uplink and NR sidelink.

###### 5.2.4.2.9.3 In-band emission

For intra-band V2X operation, the requirements in Table 6.4A.2.1.2-1 and 6.4A.2.1.2-2 in TS38.101-1 apply within the aggregated transmission bandwidth configuration with both component carrier (s) active and one single contiguous PRB allocation of bandwidth  at the edge of the aggregated transmission bandwidth configuration.

###### 5.2.4.2.9.4 Carrier leakage

For intra-band V2X operation, the requirements in Table 6.4A.2.1.3-1 in TS38.101-1 applied with applicable frequencies dependent on parameter *txDirectCurrentLocation* in *UplinkTxDirectCurrent* IE indicated in active uplink carrier(s).

###### 5.2.4.2.9.5 EVM equalizer spectrum flatness

For intra-band V2X operation, the EVM equalizer spectrum flatness is applied for RAT. The requirement in 6.4.2.4 in TS38.101-1 is applicable for NR uplink and requirement in 6.4E.2.5 in TS38.101-1 is applicable for NR sidelink.

##### 5.2.4.2.10 Spectrum emission mask for intra-band con-current V2X operation

###### 5.2.4.2.10.1 SEM for intra-band contiguous class C

For intra-band V2X operation, the spectrum emission mask of the UE applies to frequencies (ΔfOOB) starting from the ± edge of the aggregated channel bandwidth. The power of any UE emission shall not exceed the levels specified in Table 6.5A.2.2.1-1 in TS38.101-1.

##### 5.2.4.2.11 ACLR requirements for intra-band con-current V2X operation

For intra-band V2X operation, the Adjacent Channel Leakage power Ratio is the ratio of the filtered mean power centred on the aggregated channel bandwidth to the filtered mean power centred on an adjacent aggregated channel bandwidth at nominal channel spacing. The assigned aggregated channel bandwidth power and adjacent aggregated channel bandwidth power are measured with rectangular filters with measurement bandwidths specified in Table 6.5A.2.4.1.1-1 in TS38.101-1. If the measured adjacent channel power is greater than –50dBm then the NRACLR shall be higher than the value specified in Table 6.5A.2.4.1.1-1 in TS38.101-1.

##### 5.2.4.2.12 Spurious emission for intra-band con-current V2X operation

For intra-band V2X operation, the spurious emission limits apply for the frequency ranges that are more than FOOB (MHz) in Table 6.5A.3.1-1 in TS38.101-1 from the edge of the aggregated channel bandwidth. For frequencies ΔfOOB greater than FOOB as specified in Table 6.5A.3.1-1 in TS38.101-1 the spurious emission requirements in Table 6.5.3.1-2 in TS38.101-1 are applicable.

##### 5.2.4.2.13 Spurious emission band UE co-existence for intra-band con-current V2X operation

For intra-band V2X operation, the spurious emission band UE co-existence requirements in Table 6.5A.3.2.1-1 in TS38.101-1 are applicable.

##### 5.2.4.2.14 Transmit intermodulation for intra-band con-current V2X operation

For intra-band V2Xoperation, the requirement of transmitting intermodulation is specified in Table 6.5A.4.2.1-1 in TS38.101-1.

#### 5.2.4.3 Rx requirements for NR intra-band V2X con-current operation with adjacent channel

##### 5.2.4.3.1 Reference sensitivity power level

For the intra-band V2X operation, the reference sensitivity power level is applied per RAT. The requirements in Table 5.2.4.3.1-1 is applicable for both NR downlink and NR sidelink.NR V2X sidelink throughput for the carrier shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annexes A.7.2 in TS38.101-1. Also the NR downlink throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annexes A.3 in TS38.101-1.

Table 5.2.4.3.1-1: Reference sensitivity for intra-band con-current V2X operating Band

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intra-band con-current V2X Band | | NR Operating band / SCS / Channel bandwidth / Duplex-mode | | | | | | | | | | |
| NR V2X Band (PC5) | NR Band (Uu) | NR Band | SCS  kHz | 10MHz  (dBm) | 20MHz  (dBm) | 30MHz  (dBm) | 40MHz  (dBm) | 50MHz  (dBm) | 60MHz  (dBm) | 80MHz  (dBm) | 100MHz  (dBm) | Duplex Mode |
| n79 | n79 | n79 | 15 | N/A | N/A | N/A | -89.6 | -88.6 | N/A | N/A | N/A | TDD (Uu) |
| 30 | N/A | N/A | N/A | -89.7 | -88.7 | -87.9 | -86.6 | -85.6 |
| 60 | N/A | N/A | N/A | -89.9 | -88.8 | -88.0 | -86.7 | -85.7 |
| n79 | 15 | -95.5 | -92.2 | -90.4 | -89.1 | N/A | N/A | N/A | N/A | HD (PC5) |
| 30 | -95.1 | -92.4 | -90.7 | -89.2 | N/A | N/A | N/A | N/A |
| 60 | -95.9 | -92.1 | -90.9 | -89.4 | N/A | N/A | N/A | N/A |

Table 5.2.4.3.1-2: UL configuration for REFSENS for intra-band con-current V2X operating Band (PC5)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intra-band con-current V2X Band | | | NR operating Band / SCS/ Channel bandwidth / NRB / Duplex mode | | | | | | | | | | | |
| NR V2X Band (PC5) | NR band (Uu) | UL band (Uu) | | SCS (kHz) | 10 MHz (dBm) | 20 MHz (dBm) | 30 MHz (dBm) | 40 MHz (dBm) | 50MHz  (dBm) | 60MHz  (dBm) | 80MHz  (dBm) | 100MHz  (dBm) | Duplex Mode |
| n79 | n79 | n79 | | 15 | N/A | N/A | N/A | 216 | 270 | N/A | N/A | N/A | TDD (Uu) |
| 30 | N/A | N/A | N/A | 100 | 128 | 162 | 216 | 270 |
| 60 | N/A | N/A | N/A | 50 | 64 | 75 | 100 | 135 |

Table 5.2.4.3.1-3: SL Tx configuration for REFSENS for intra-band con-current V2X operating Band (Uu)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intra-band con-current V2X Band | | NR operating Band / SCS/ Channel bandwidth / NRB / Duplex mode | | | | | | | | | | | |
| NR V2X Band (PC5) | NR band (Uu) | V2X band (PC5) | SCS (kHz) | 10 MHz (dBm) | 20 MHz (dBm) | 30 MHz (dBm) | 40 MHz (dBm) | 50MHz  (dBm) | 60MHz  (dBm) | 80MHz  (dBm) | 100MHz  (dBm) | Duplex Mode |
| n79 | n79 | n79 | 15 | 50 | 105 | 160 | 216 | N/A | N/A | N/A | N/A | HD (PC5) | |
| 30 | 24 | 50 | 75 | 105 | N/A | N/A | N/A | N/A |
| 60 | 10 | 24 | 36 | 50 | N/A | N/A | N/A | N/A |

##### 5.2.4.3.2 Maximum input level

For intra-band V2X operation, the maximum input level in Table 7.4A.1-1 in TS38.101-1 is applied which is defined as the maximum mean power received at the UE antenna port, over the Transmission bandwidth configuration of each CC.

##### 5.2.4.3.3 Adjacent channel selectivity

For intra-band V2X operation, SL carrier is configured with nominal channel spacing to the NR downlink carrier. The minimum requirement specified in Table 7.5A.1-1 and 7.5A.1-1a in TS38.101-1 is applicable to intra-band V2X operation.

##### 5.2.4.3.4 Blocking characteristics

###### 5.2.4.3.4.1 In-band blocking requirements

For intra-band V2X operation, SL carrier is configured with nominal channel spacing to the NR downlink carrier. The minimum requirement specified in Table 7.6A.2.1-1 and 7.6A.2.1-1a in TS38.101-1 is applicable to intra-band V2X operation.

###### 5.2.4.3.4.2 Out-of-band blocking requirements

For intra-band V2X operation, SL carrier is configured with nominal channel spacing to the NR downlink carrier. The minimum requirement specified in Table 7.6A.3-1 in TS38.101-1 is applicable to intra-band V2X operation.

###### 5.2.4.3.4.3 Narrow band blocking requirements

For intra-band V2X operation, SL carrier is configured with nominal channel spacing to the NR downlink carrier. The minimum requirement specified in Table 7.6A.4.1-1 in TS38.101-1 is applicable to intra-band V2X operation in NR band n1,n41,n66, n71, n48 abd n40. Other band are not applicable for narrow band blocking requirements.

##### 5.2.4.3.5 Spurious response

For intra-band V2X operation, SL carrier is configured with nominal channel spacing to the NR downlink carrier. The minimum requirement specified in Table 7.7A-1 and Table 7.7A-2 in TS38.101-1 are applicable to intra-band V2X operation.

##### 5.2.4.3.6 Wide band intermodulation

For intra-band V2X operation, SL carrier is configured with nominal channel spacing to the NR downlink carrier. The minimum requirement specified in Table 7.8A.2.1-1 and Table 7.8A-2.1-2 in TS38.101-1 are applicable to intra-band V2X operation.

### 5.2.5 NR intra-band V2X con-current UE RF requirements with non-adjacent channel for FDM operation

#### 5.2.5.1 Tx NR intra-band V2X con-current operation with non-adjacent channel

#### 5.2.5.2 Rx NR intra-band V2X con-current operation with non-adjacent channel

# 6 Sidelink enhancement for advanced V2X service, public safety and other commercial use cases

## 6.1 Coexistence evaluation

### 6.1.1 Coexistence evaluation scenarios

### 6.1.2 Coexistence simulations assumptions

### 6.1.3 Coexistence results

### 6.1.4 Conclusion of Coexistence evaluations

## 6.2 RAN4 RF impact analysis for other WG’s sidelink enhancement

# 7 Operating bands and channel arrangement for SL enhancement

## 7.1 Operating bands

### 7.1.1 Operating bands

NR SL enhancement is designed to operate in the operating bands in FR1 defined in Table 7.1.1-1.

Table 7.1.1-1 Operating bands in FR1 for NR SL enhancement

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| V2X Operating Band | Sidelink (SL) Transmission operating band | | | Sidelink (SL) Reception operating band | | | Duplex Mode | Interface |
| FUL\_low – FUL\_high | | | FDL\_low – FDL\_high | | |
| n141 | 788 MHz | - | 798 MHz | 788 MHz | - | 798 MHz | HD | PC5 |
| n792 | 4400 MHz | - | 5000 MHz | 4400 MHz | - | 5000 MHz | TDD | PC5 |
| Note 1: When this band is used for public safety service, the NR band is operated with both in-coverage scenarios and out-of-coverage scenarios.  Note 2: NR V2X service is partially operated in this band with NR Uu. | | | | | | | | |

### 7.1.2 Operating bands for inter-band con-current operation in FR1

## 7.2 Channel bandwidth

### 7.2.1 Channel bandwidth

The operating bands and channel bandwidth for NR SL enhancement in FR1 are shown in Table 7.2.1-1. The same (symmetrical) channel bandwidth is specified for both the TX and RX path. The maximum channel bandwidth for SL operation for NR SL enhancement in licensed band is 40MHz.

Table 7.2.1-1 Channel Bandwidth for NR SL enhancement

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| V2X band / SCS/ V2X channel bandwidth | | | | | | | | | | | |
| V2X Operating Band | SCS kHz | 5 MHz | 10 MHz | 20 MHz | 30 MHz | 40 MHz | 50 MHz | 60 MHz | 80 MHz | 90 MHz | 100 MHz |
| n14 | 15 | Yes | Yes |  |  |  |  |  |  |  |  |
| 30 |  | Yes |  |  |  |  |  |  |  |  |
| 60 |  |  |  |  |  |  |  |  |  |  |
| n79 | 15 |  | Yes | Yes | Yes | Yes |  |  |  |  |  |
| 30 |  | Yes | Yes | Yes | Yes |  |  |  |  |  |
| 60 |  | Yes | Yes | Yes | Yes |  |  |  |  |  |

### 7.2.2 Channel bandwidth for inter-band con-current operation

## 7.3 Channel arrangement enhancement

### 7.3.1 Channel raster

#### 7.3.1.1 NR-ARFCN and channel raster

The NR-ARFCN and channel raster defined in subclause 5.4.2.1 in TS38.101-1 are applied to each licensed operating band for NR SL enhancement.

#### 7.3.1.2 Channel raster to resource element mapping

Channel raster to resource element mapping defined in subclause 5.4.2.2 in TS38.101-1 are applied to each licensed operating band for NR SL enhancement.

#### 7.3.1.3 Channel raster entries for each operating band

The channel raster entries defined in subclause 5.4.2.3 in TS38.101-1 are applied to each licensed operating band for NR SL enhancement.

### 7.3.2 Synchronization raster

There is no synchronization raster definition for each licensed operating band for NR SL enhancement.

# 8 Transmitter/Receiver characteristics for SL enhancement

## 8.1 SL enhancement UE Tx requirements

## 8.2 SL enhancement UE Rx requirements

### 8.2.1 Reference sensitivity power level

The reference sensitivity power level REFSENS is the minimum mean power applied to the UE antenna connector at which the throughput shall meet or exceed 95% of the maximum throughput of the reference measurement channels.

The SL enhancement UE REFSENS is defined by the following equation:

REFSENSV2X=*kTB* + SNRV2X +10log10(LCRB\*SCS\*12/RX\_BW) +( NFV2X+ IM) – Diversity gain

Where

*- kTB:* Thermal noise level is [-174dBm(kT) + 10\*log10(RX BW)]dBm.

*-* NF: Noise figure. 13 dB is used for LAA and can be reused for NR V2X requirements. Assumed NF is 9dB < 3GHz, NF is 10dB>= 3GHz (e.g B42, n77, n78, n79…) at licensed bands at FR1.

*-* IM: 2.5 dB is assumed. When the number of RB size is equal to or less than 24RBs, 0.5dB additional relaxation is allowed.

- Target SNR: -0.5 dB

- Diversity gain: 3dB

The REFSENS requirements for NR SL enhancement are specified in Table 8.2.1-1.

Table 8.2.1-1: Reference sensitivity for NR SL enhancement (PC5)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **NR Operating band / SCS / Channel bandwidth / Duplex-mode** | | | | | | | |
| **V2X Band** | **SCS**  **kHz** | **5MHz**  **(dBm)** | **10MHz**  **(dBm)** | **20MHz**  **(dBm)** | **30MHz**  **(dBm)** | **40MHz**  **(dBm)** | **Duplex Mode** |
| n14 | 15 | [ ] | [ ] |  |  |  | FDD |
| 30 |  | [ ] |  |  |  |
| 60 |  |  |  |  |  |

Table 8.2.1-2: Sidelink TX configuration for reference sensitivity for NR SL enhancement (PC5)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR operating Band / SCS/ Channel bandwidth / NRB / Duplex mode | | | | | | | |
| V2X Band | SCS (kHz) | 5 MHz (dBm) | 10 MHz (dBm) | 20 MHz (dBm) | 30 MHz (dBm) | 40 MHz (dBm) | Duplex Mode |
| n14 | 15 | 25 | 50 |  |  |  | FDD |
| 30 |  | 24 |  |  |  |
| 60 |  |  |  |  |  |

### 8.2.2 Maximum input level

Maximum input level is defined as the maximum mean power received at the UE antenna port, at which the specified relative throughput shall meet or exceed the minimum requirements for the specified reference measurement channel. The maximum input levels for NR SL enhancement are specified in Table 8.2.2-1.

Table 8.2.2-1: Maximum input level for NR SL enhancement

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Rx Parameter | Units | Channel bandwidth | | | | |
|  |  | 5 MHz | 10 MHz | 20 MHz | 30 MHz | 40 MHz |
| Power in Transmission Bandwidth Configuration | dBm | -251 | -251 |  |  |  |
|  |  | -272 | -272 |  |  |  |
| NOTE 1: Reference measurement channel is A.x for 64QAM.  NOTE 2: Reference measurement channel is A.x for 256QAM. | | | | | | |

### 8.2.3 Adjacent Channel Selectivity (ACS)

Adjacent Channel Selectivity (ACS) is a measure of a receiver's ability to receive an NR signal at its assigned channel frequency in the presence of an adjacent channel signal at a given frequency offset from the centre frequency of the assigned channel.

Table 8.2.3-1: Adjacent channel selectivity for NR SL enhancement

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Channel bandwidth | | | | | |
| RX parameters | Units | 5 MHz | 10 MHz | 20 MHz | 30 MHz | 40 MHz |
| ACS | dB | 33.0 | 33.0 |  |  |  |

Table 8.2.3-2: Test parameters for Adjacent channel selectivity for NR SL enhancement, Case 1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Rx Parameter | Units | Channel bandwidth | | | | |
| 5 MHz | 10 MHz | 20 MHz | 30 MHz | 40 MHz |
| Power in Transmission Bandwidth Configuration | dBm | PREFSENS\_V2X + 14 dB | | | | |
| PInterferer | dBm | REFSENS +45.5dB | REFSENS +45.5dB |  |  |  |
| BWInterferer | MHz | 5 | 5 |  |  |  |
| FInterferer (offset) | MHz | 5.0 / -5.0 | 7.5 / -7.5 |  |  |  |
| NOTE 1: The interferer is QPSK modulated PSSCH containing data and reference symbols. Normal cyclic prefix is used.  NOTE 2: The absolute value of the interferer offset Finterferer (offset) shall be further adjusted to MHz with SCS the sub-carrier spacing of the wanted signal in MHz. The interferer is an NR signal with 15 kHz SCS. | | | | | | |

Table 8.2.3-3: Test parameters for Adjacent channel selectivity for NR SL enhancement, Case 2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Rx Parameter | Units | Channel bandwidth | | | | |
| 5 MHz | 10 MHz | 20 MHz | 30 MHz | 40 MHz |
| Power in Transmission Bandwidth Configuration | dBm | -56.5 | -56.5 |  |  |  |
| PInterferer | dBm | -25 | | | | |
| BWInterferer | MHz | 5 | 5 |  |  |  |
| FInterferer (offset) | MHz | 5.0  /  -5.0 | 7.5  /  -7.5 |  |  |  |
| NOTE 1: The interferer is QPSK modulated PSSCH containing data and reference symbols. Normal cyclic prefix is used.  NOTE 2: The absolute value of the interferer offset Finterferer (offset) shall be further adjusted to MHz with SCS the sub-carrier spacing of the wanted signal in MHz. The interferer is an NR signal with 15 kHz SCS. | | | | | | |

### 8.2.4 Blocking characteristics

#### 8.2.4.1 In-band blocking

For NR SL enhancement, RAN4 reuse the in-band blocking requirements for NR Uu as shown in Table 8.2.4.1-1 and Table 8.2.4.1-2.

Table 8.2.4.1-1: In band blocking parameters for NR SL enhancement

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| RX parameter | Units | Channel bandwidth | | | | |
|  |  | 5 MHz | 10 MHz | 20 MHz | 30 MHz | 40 MHz |
| Power in transmission bandwidth configuration | dBm | PREFSENS\_V2X + channel bandwidth specific value below | | | | |
| dB | 6 | 6 |  |  |  |
| BWinterferer | MHz | 5 | | | | |
| FIoffset, case 1 | MHz | 7.5 | | | | |
| FIoffset, case 2 | MHz | 12.5 | | | | |
| NOTE 1: The interferer is QPSK modulated PSSCH containing data and reference symbols. Normal cyclic prefix is used. | | | | | | |

Table 8.2.4.1-2: In-band blocking for NR SL enhancement

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NR  band | Parameter | Unit | | Case 1 | Case 2 |
| n14 | PInterferer | dBm | -56 | | -44 |
| FInterferer (offset) | MHz | -BW/2 – FIoffset,case 1  &  BW/2 + FIoffset,case 1 | | ≤-BW/2 – FIoffset,case 2  &  ≥BW/2 + FIoffset,case 2 |
| FInterferer | MHz | | NOTE 2 | FDL\_low – 15  to  FDL\_high + 15 |
| NOTE 1: For certain bands, the unwanted modulated interfering signal may not fall inside the UE receive band, but within the first 15 MHz below or above the UE receive band.  NOTE 2: For each carrier frequency the requirement is valid for two frequencies:  a. the carrier frequency -BW/2 - FIoffset, case 1 and  b. the carrier frequency +BW/2 + FIoffset, case 1  NOTE 3: FInterferer range values for unwanted modulated interfering signal are interferer center frequencies  NOTE 4: The absolute value of the interferer offset Finterferer (offset) shall be further adjusted to MHz with SCS the sub-carrier spacing of the wanted signal in MHz. The interferer is an NR signal with 15 kHz SCS. | | | | | |

#### 8.2.4.2 Out-of-band blocking

Out-of-band band blocking in existing specification for licensed bands is defined for an unwanted CW interfering signal falling more than 30 MHz below or above the UE receive band. For the first 15 MHz below or above the UE receive band the appropriate in-band blocking or adjacent channel selectivity shall be applied.

For NR SL enhancement, RAN4 reuse the out-of-band blocking requirements for NR Uu as shown in Table 8.2.4.2-1 and Table 8.2.4.2-2.

Table 8.2.4.2-1: Out-of-band blocking parameters for NR SL enhancement

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| RX parameter | Units | Channel bandwidth | | | | |
|  |  | 5 MHz | 10 MHz | 20 MHz | 30 MHz | 40 MHz |
| Power in transmission bandwidth configuration | dBm | PREFSENS\_V2X + channel bandwidth specific value below | | | | |
|  | dB | 6 | 6 |  |  |  |
| NOTE: Reference measurement channel is A.x.x. | | | | | | |

Table 8.2.4.2-2: Out of band blocking for NR SL enhancement

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NR band | Parameter | Units | Range 1 | Range 2 | Range 3 |
| n14 | Pinterferer | dBm | -44 | -30 | -15 |
|  | Finterferer (CW) | MHz | -60 < f – FDL\_low < -15  or  15 < f – FDL\_high < 60 | -85 < f – FDL\_low ≤ -60  or  60 ≤ f – FDL\_high < 85 | 1 ≤ f ≤ FDL\_low – 85  or  FDL\_high + 85 ≤ f  ≤ 12750 |
| NOTE 1: The power level of the interferer (PInterferer) for Range 3 shall be modified to -20 dBm for FInterferer > 4400 MHz. | | | | | |

### 8.2.5 Spurious response

Spurious response is a measure of the receiver's ability to receive a wanted signal on its assigned channel frequency without exceeding a given degradation due to the presence of an unwanted CW interfering signal at any other frequency at which a response is obtained.

For NR SL enhancement, RAN4 reuse the spurious response for NR Uu as shown in Table 8.2.5-1 and Table 8.2.5-2.

Table 8.2.5-1: Spurious response parameters for NR SL enhancement

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| RX parameter | Units | Channel bandwidth | | | | |
|  |  | 5 MHz | 10 MHz | 20 MHz | 30 MHz | 40 MHz |
| Power in transmission bandwidth configuration | dBm | PREFSENS\_V2X + channel bandwidth specific value below | | | | |
|  | dB | 6 | 6 |  |  |  |
| NOTE 1: Reference measurement channel is A.x.x | | | | | | |

Table 8.2.5-2: Spurious response for NR SL enhancement

|  |  |  |
| --- | --- | --- |
| Parameter | Unit | Level |
| PInterferer (CW) | dBm | -44 |
| FInterferer | MHz | Spurious response frequencies |

### 8.2.6 Intermodulation characteristics

Intermodulation response rejection is a measure of the capability of the receiver to receive a wanted signal on its assigned channel frequency in the presence of two or more interfering signals which have a specific frequency relationship to the wanted signal. The wide band intermodulation requirement is defined using modulated NR carrier and CW signal as interferer.

For NR SL enhancement, RAN4 reuse the intermodulation characteristics for NR Uu as shown in Table 8.2.6-1.

Table 8.2.6-1: Wide band intermodulation for NR SL enhancement

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR band | Rx parameter | Units | Channel bandwidth | | | | |
|  |  |  | 5 MHz | 10 MHz | 20 MHz | 30 MHz | 40 MHz |
| n14 | Power in Transmission Bandwidth Configuration | dBm | PREFSENS\_V2X + channel bandwidth specific value below | | | | |
|  | 6 | 6 |  |  |  |
|  | PInterferer 1 (CW) | dBm | -46 | | | | |
|  | PInterferer 2 (Modulated) | dBm | -46 | | | | |
|  | BWInterferer 2 | MHz | 5MHz | | | | |
|  | FInterferer 1 (Offset) | MHz | -BW/2 – 7.5  /  +BW/2 + 7.5 | | | | |
|  | FInterferer 2 (Offset) | MHz | 2 \* FInterferer 1 | | | | |
| NOTE 1: Reference measurement channel is A.x.x.  NOTE 2: The interferer is QPSK modulated PSSCH containing data and reference symbols. Normal cyclic prefix is used. | | | | | | | |

# 9 Conclusion and recommendations

# Annex A

# Annex B: Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2021-01 | RAN4 #98e | R4-2103243 |  |  |  | TR38.xxx v0.0.1: TR skeleton for SL enhancement | 0.0.1 |
| 2021-04 | RAN4 #98BIS-e | R4-2104969 |  |  |  | TR38.785 v0.1.0: TR Update for SL enhancement in Rel-17 | 0.1.0 |
| R4-2104775 |  |  |  | TP on system parameters for newly introduced SL bands |  |
| R4-2104971 |  |  |  | TP on operating scenarios |  |
| R4-2104972 |  |  |  | TP on MPR/coexistence simulation assumptions for leftover issues |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| 2012-05 | RAN4 #99-e | R4-2109921 |  |  |  | TR38.785 v0.2.0: TR Update for SL enhancement in Rel-17 | 0.2.0 |
| R4-2107865 |  |  |  | TP on UE Rx RF requirement for NR SL enhancement |  |
| R4-2107866 |  |  |  | TP on channel bandwidth for newly introduced SL bands |  |
| R4-2107871 |  |  |  | TP on RF requirements for intra-band con-current V2X operation in licensed band |  |
| R4-2107874 |  |  |  | TP on coexistence evaluation for PC2 SL UE in licensed band n38 |  |
| R4-2111431 |  |  |  | TP for 38.785: synchronization reference source for SL enhancements |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |