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3rd Generation Partnership Project;

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Further enhancement on NR demodulation performance

(Release 17)

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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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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

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In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# 1 Scope

The present technical report documents the Phase I study outcome on inter-user interference suppression for NR MU-MIMO and techniques to cope with LTE CRS interference for NR UE, with the detailed objectives as follows:

* MMSE-IRC receiver for suppressing intra-cell inter-user interference
	+ - Phase I: Evaluate the performance under practical MU-MIMO interference profile for the candidate reference receiver.
		- Identify practical MU-MIMO interference modelling methodology
		- Reference receiver: MMSE-IRC receiver. Use the DMRS-based interference covariance estimation method as a starting point
		- Prioritize slot-based transmission scenario
		- Phase II: Define the requirements if needed based on the outcome of phase I
		- Target frequency: FR1
		- Rx antenna number: 2Rx and 4Rx for FR1
* Evaluate techniques to cope with CRS interference in scenarios with overlapping spectrum for LTE and NR
	+ - Candidate reference receiver to enable neighboring cell CRS-IM
		- The performance benefit of neighboring cell LTE CRS-IM over the existing rate matching solutions specified in Rel-15 and Rel-16 shall be evaluated.
		- Feasibility of the considered solution regarding NR PDSCH processing timeline need to be checked.
		- Priority will be given to solutions not having RAN1 specification impact.
		- Synchronous network scenario is prioritized. As second priority, RAN4 could evaluate the feasibility and usefulness of the asynchronous network scenario and specify if feasible and useful.
		- 15 kHz SCS for NR is prioritized. RAN4 should evaluate the feasibility and usefulness of 30 kHz SCS for scenarios with LTE and NR deployed in neighboring BSs/areas and specify if feasible and useful.

# 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".

…

 <Text will be added>

# 3 Definitions, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms 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].

Definition format (Normal)

**<defined term>:** <definition>.

**example:** text used to clarify abstract rules by applying them literally.

## 3.2 Symbols

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

Symbol format (EW)

<symbol> <Explanation>

## 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].

Abbreviation format (EW)

<ABBREVIATION> <Expansion>

# 4 Inter-user interference suppression for MU-MIMO

## 4.1 Scenario and interference modelling

*<Text will be added>*

## 4.2 Receiver structure

*<Text will be added>*

## 4.3 Link performance characterization

### 4.3.1 Parameters for link level evaluation

*<Text will be added>*

### 4.3.2 Link level simulation results

*<Text will be added>*

### 4.3.3 Summary of link level evaluation

*<Text will be added>*

# 5 LTE CRS interference handling for NR UE

## 5.1 Scenario and interference modelling

### 5.1.1 Scenario

Dynamic spectrum sharing (DSS) provides a very useful migration path from LTE to NR. To help faster 5G rollout, the network operators can deploy 5G using their existing LTE frequency bands and base stations dynamically share the resources based on the traffic load. As the time and frequency resources are shared between NR UE and LTE UE, the core requirement for DSS is that existing essential channels of LTE, such as CRS (cell-specific reference signal), should be still transmitted for backward compatibility. In DSS scenario (namely scenario 1), serving cell CRS rate matching is assumed to be configured for NR PDSCH, but the always-on CRS signals from interference cells will interfere NR UE.

Another scenario with overlapping spectrum for LTE and NR is that LTE and NR are deployed in neighboring BSs/areas (namely scenario 2), when the refarming progress is different in different areas. In scenario 2, the CRS is not transmitted on the NR serving cell, and the CRS from neighboring LTE cell will cause interference to NR UE in the overlapping spectrum.

To evaluate performance of different CRS interference handling schemes, the two scenarios with overlapping spectrum for LTE and NR are considered below in Figure 1.

* Scenario 1: Serving and interference cells are both operating in DSS (NR+LTE) mode
* Scenario 2: Serving cell is operating in NR mode and interference cell is operating in LTE mode

|  |  |
| --- | --- |
| Scenario 1: | Scenario 2: |
|  |  |
|  |

Figure 5.1.1-1. Scenarios for CRS interference in overlapping spectrum for LTE and NR

For the performance evaluation, 15 kHz SCS and synchronous network with 4 CRS ports are assumed in the first phase.

### 5.1.2 LTE interference model

This subclause provides interference modelling for each explicitly modelled LTE interfering cell in the simulation scenario. The interference modelling methodology and interference profiles from LTE CRS interference mitigation (CRS-IM) for homogenous deployments in [TR 36.863] are reused. INR-*i* (signal level of the *i*-th dominant interference over Noc) is used as the interference power measure, and two dominant interferers are explicitly modelled in the simulation.

In each subframe, each interfering cell shall transmit randomly modulated data over the entire PDSCH region and the full transmission bandwidth according to the probabilities of occurrence. Transmitted physical channels shall include PSS, SSS and PBCH. Probabilities of occurrence of LTE PDSCH in each subframe are as specified in clause 5.3. If the probabilities of occurrence in each subframe are not specified in clause 5.3, as default, they are equal to 1.

For each subframe and each CQI subband as defined in subclause 7.2 of [TS 36.213], a transmission rank shall be randomly determined independently from other CQI subbands as well as other interfering cells. Probabilities of occurrence of each possible transmission rank are as specified in clause 5.3.

For each subframe and CQI subband, a precoding matrix for the number of layers  associated to the selected rank shall be selected randomly from Table 6.3.4.2.3-1 of [TS 36.211]. Note that codebook index 0 shall be excluded from random precoder selection when the number of layers is .

Precoding for spatial multiplexing with CRS for the number of antenna ports in the simulation scenario shall be applied to 16QAM randomly modulated layer symbols, as specified in subclause 6.3.4.2.1 of [TS 36.211] with the selected precoding matrices for each subframe and each CQI subband.

For unallocated REs in the control region, precoding for transmit diversity for the number of antenna ports in the simulation scenario shall be applied to QPSK randomly modulated layer symbols, as specified in subclause 6.3.4.3 of [TS 36.211]. The EPRE ratio for these REs shall be as defined for PDCCH in Annex C.3.2 of [TS 36.101].

The EPRE ratio of LTE CRS of *i*-th dominant interferer to NR SSS of serving cell shall be defined as INR-*i*/SNR, where Noc is same for serving cell and all interfering cells.

## 5.2 Receiver structure

### 5.2.1 General

The baseline reference receiver to evaluate the NR performance in scenarios with overlapping spectrum for LTE and NR is MMSE-IRC, which is used to define the minimum demodulation performance requirements in NR. For CRS interference handling, performance is evaluated with two categories of schemes:

1. LTE CRS interference mitigation (CRS-IM)
2. LTE CRS Rate matching (CRS-RM)

### 5.2.2 Reference receiver of LTE-CRS interference mitigation

For dealing with neighboring LTE CRS interference, two candidate receiver types for CRS-IM are captured in this subclause, and the neighboring cell CRS-IM is used together with LMMSE-IRC for demodulating NR PDSCH.

* CRS interference cancellation (CRS-IC)
	+ Receiver may reconstruct neighboring LTE CRS interference based on detected neighboring LTE cell(s)’ channel estimation and cancel the interference
		- May have iteration for multiple strongest neighboring LTE interference cells
* Log-likelihood ratio (LLR) weighting
	+ Receiver may estimate the power of neighboring LTE CRS interference and apply the weight to the estimated LLRs for REs which occupy with LTE CRS.

In particular, the following CRS-IM receiver assumptions are used for the evaluation:

* Synchronization network deployment is assumed in the first phase.
* Single FFT processing for synchronized network.
* UEs are not restricted to mitigate more than 1 LTE cell’s interference, and this is left up to UE implementation.
* UE with LLR weighting shall meet NR PDSCH processing procedure time requirement defined in TS 38.214 clause 5.3.

### 5.2.3 LTE cell configuration detection

The performance analysis in the technical report is provided under assumption of with and without the knowledge of the interferer cell(s) CRS configuration.

When the information of the dominant interferer cell CRS is not signaled to the UE by RRC signaling, the UE is expected to blindly detect the LTE cells and decode MIB for LTE cell configuration of the interference cells for LTE CRS-IM. Some UEs may not be capable of blindly detecting such information.

## 5.3 Link performance characterization

### 5.3.1 Parameters for link level evaluation

#### 5.3.1.1 General

The link-level simulation assumptions for serving cell PDSCH, interference cells and summary of simulation cases are provided in clause 5.3.1.2, 5.3.1.3 and 5.3.1.4 respectively. Note that these assumptions are used for the performance evaluation in the study phase, and the parameters for performance requirement definition will be discussed separately.

#### 5.3.1.2 Serving cell PDSCH parameters

Simulation assumptions for serving cell PDSCH are captured in Table 5.3.1.2-1.

Table 5.3.1.2-1: Simulation assumptions for NR serving cell PDSCH

|  |  |  |
| --- | --- | --- |
| Parameter | Unit | Value |
| Channel Bandwidth | MHz | 10MHz with full PRB allocation |
| SCS | kHz | 15 |
| Duplex mode |  | FDD |
| MCS |  | 4, 13 |
| Antenna configuration  |  | 4x2, 4x4  |
| HARQ process number |  | 4 |
| Number of layers |  | 1 |
| PDSCH configuration | Mapping type |  | Type A |
| Starting symbol (S)  |  | If Rel-15 or Rel-16 Rate Matching pattern is configured: S = 3, else S =2 |
| Length (L) |  | For scenario 1: 9For scenario 2: L=9, [11] if RM is configured, 12 otherwise.  |
| PRB bundling size |  | 2 |
| PRB bundling type |  | Static |
| Precoding model |  | Random precoding with Single panel Type 1 per PRB bundling size per slot |
| Overhead for TBS determination |  | If Rel-15 or Rel-16 CRS-RM is configured: 18, else 0 |
| PDSCH DMRS configuration | DMRS Type |  | DMRS Type 1 |
| Number of additional DMRS(Note 2) |  | 1 |
| Maximum number of OFDM symbols for DL front loaded DMRS |  | 1 |
| Number of PDSCH DMRS CDM group(s) without data |  | 1 |
| CRS for rate matching for Scenario 1 (Note 1) | LTE carrier centre subcarrier location |  | Same as NR carrier centre subcarrier location |
| LTE carrier BW | MHz | 10 |
| Number of antenna ports |  | 4 |
| v-shift |  | 0 |
| SSB position  |  | First SSB in slot #0 in every 20 ms periodicity that is not scheduled for PDSCH transmission  |
| Propagation conditions and MIMO correlation |  | TDLA30-10 ULA Low |
| Note 1: No MBSFN is configured on LTE carrier Note 2: The additional DMRS is alternated for scenario 2 rate-matching with L=11 |

#### 5.3.1.3 Interference cell parameters

Simulation assumptions for interference cell are captured in Table 5.3.1.3-1.

Table 5.3.1.3-1: Simulation assumptions for interference cells parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Value | Interference Cell #1 | Interference Cell #2 |
| Interference power level | dB | INR1=10.45dB | INR2=4.6dB |
| CRS pattern | LTE carrier centre subcarrier location |  | Same as NR serving carrier centre subcarrier location | Same as NR serving carrier centre subcarrier location |
| LTE carrier BW | MHz | 10 | 10 |
| Number of antenna ports |  | 4 | 4 |
| v-shift |  | 1 | 2 |
| PDSCH loading level |  | 20% probability of occurrence of LTE data transmission in time domain, and full bandwidth allocation in frequency domain. | 20% probability of occurrence of LTE data transmission in time domain, and full bandwidth allocation in frequency domain. |
| Modulation order for interference PDSCH when exists |  | 16 QAM randomly modulated symbols | 16 QAM randomly modulated symbols |
| Time offset | us | 3 | -1 |
| Frequency offset | Hz | 300 | -100 |
| Transmission rank |  | 80% and 20% probability for rank 1 and rank 2 respectively  | 80% and 20% probability for rank 1 and rank 2 respectively |
| Propagation conditions and MIMO configuration (Note 1) |  | TDLA30-10 ULA Low | TDLA30-10 ULA Low |
| Note 1: The channel for interference cells and serving cell are independent. |

#### 5.3.1.4 Summary of simulation cases

Simulation results with assumptions listed in Table 5.3.1.2-1 and Table 5.3.1.3-1 for following cases listed in Table 5.3.1.4-1 are captured in clause 5.3.2.

Table 5.3.1.4-1: Summary of simulation cases

|  |  |  |
| --- | --- | --- |
| Scenario 1 | Reference scheme | Rel-15 serving cell CRS-RM without interference cell CRS handling |
| Scheme #1 | Rel-16 CRS-RM for 1 interference cell (The rate matched CRS is always the first dominant interference) |
| Scheme #2 (Optional) | Rel-16 CRS-RM for 1 interference cell (The rate matched CRS is NOT always the first dominant interference. i.e. 50% probability for rate matching (RM) for the first dominant interference and 50% probability for RM for the second dominant interference) |
| Scheme #3 | Rel-15 RB symbol level CRS-RM for 2 interference cells |
| Scheme #4 | CRS-IC with network assistance |
| Scheme #5 | CRS-IC without network assistance |
| Scheme #6 | LLR weighting with network assistance |
| Scheme #7 | LLR weighting without network assistance |
| Scenario 2 | Reference scheme | Without interference cell CRS handling |
| Scheme #1 | Rel-15 CRS-RM for 1 interference cell (The rate matched CRS is always the first dominant interference) |
| Scheme #2 (Optional) | Rel-15 CRS-RM for 1 interference cell (The rate matched CRS is NOT always the first dominant interference. i.e. 50% probability for RM for the first dominant cell and 50% probability for RM for the second dominant interference) |
| Scheme #3 | Rel-16 CRS-RM for 2 interference cells |
| Scheme #4 | CRS-IC with network assistance |
| Scheme #5 | CRS-IC without network assistance |
| Scheme #6 | LLR weighting with network assistance |
| Scheme #7 | LLR weighting without network assistance |

### 5.3.2 Link level simulation results

#### 5.3.2.1 General

In this clause link level simulation results from different companies are collected for analysis on UE CRS interference handling for NR UE in scenario with overlapping spectrum for LTE and NR. The link level analysis of NR UE PDSCH performance is performed under assumptions from clause5.3.1 and presented in clause5.3.2.1 and 5.3.2.2. Also, this clause contains the analysis from different companies with impact of considered CRS interference handling schemes on LTE UE performance which is presented in clause 5.3.2.3.

The details of NR UE PDSCH performance analysis are presented in the attached file ‘R4-2112151\_ Simulation result collection for CRS interference handling’.

#### 5.3.2.2 NR UE PDSCH performance for Scenario 1

This clause contains the summary of simulation results of link level analysis of NR UE performance for Scenario 1.

Table 5.3.2.1-1 provides the summary of average simulation results from different companies with information about SNR points corresponding to 70% of maximum achievable throughput of Reference scheme. Table 5.3.2.1-2 provides the information about SNR performance difference of different schemes in comparison to Reference scheme for average simulation results.

Table 5.3.2.1-1: Average SNR simulation results for Scenario 1

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MIMO | MCS index | Ref scheme | Scheme #1 | Scheme #2 | Scheme #3 | Scheme #4 | Scheme #5 | Scheme #6 | Scheme #7 |
| 4Tx 2Rx Low | QPSK MCS4 | 3.3 | 1.6 | 3.3 | 1.7 | -0.1 | 0.2 | 0.6 | -0.4 |
| 16QAM MCS13 | 11.2 | 9.9 | 11.7 | 11.2 | 7.8 | 7.7 | 8.9 | 8.3 |
| 4Tx 4Rx Low | QPSK MCS4 | -0.2 | -2.0 | -0.5 | -2.1 | -3.4 | -3.4 | -2.5 | -3.9 |
| 16QAM MCS13 | 7.4 | 5.9 | 7.6 | 7.0 | 3.8 | 3.7 | 5.4 | 4.4 |

Table 5.3.2.1-2: SNR performance difference for Scenario 1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MIMO | MCS index | Scheme #1 | Scheme #2 | Scheme #3 | Scheme #4 | Scheme #5 | Scheme #6 | Scheme #7 |
| 4Tx 2Rx Low | QPSK MCS4 | 1.7 | 0.0 | 1.6 | 3.3 | 3.1 | 2.7 | 3.7 |
| 16QAM MCS13 | 1.3 | -0.5 | 0.0 | 3.4 | 3.4 | 2.3 | 2.9 |
| 4Tx 4Rx Low | QPSK MCS4 | 1.8 | 0.2 | 1.9 | 3.2 | 3.2 | 2.2 | 3.7 |
| 16QAM MCS13 | 1.5 | -0.2 | 0.5 | 3.6 | 3.7 | 2.1 | 3.0 |

#### 5.3.2.3 NR UE PDSCH performance for Scenario 2

This clause contains the summary of simulation results of link level analysis of NR UE performance for Scenario 2.

Table 5.3.2.2-1 provides the summary of simulation results from different companies and average results with information about SNR points corresponding to 70% of maximum achievable throughput of Reference scheme. Table 5.3.2.2-2 provides the information about SNR performance difference of different schemes in comparison to Baseline scheme for average simulation results.

Table 5.3.2.2-1: Average SNR simulation results for Scenario 2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| MIMO | MCS index | Ref scheme | Scheme #4 | Scheme #5 | Scheme #6 | Scheme #7 |
| 4Tx 2Rx Low | QPSK MCS4 | 2.0 | -0.6 | -0.5 | -0.1 | -0.9 |
| 16QAM MCS13 | 9.9 | 7.4 | 7.6 | 8.1 | 7.8 |
| 4Tx 4Rx Low | QPSK MCS4 | -1.7 | -4.0 | -4.1 | -3.3 | -3.6 |
| 16QAM MCS13 | 6.1 | 3.6 | 3.6 | 4.7 | 4.8 |

Table 5.3.2.2-2: SNR performance difference for Scenario 2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| MIMO | MCS index | Scheme #4 | Scheme #5 | Scheme #6 | Scheme #7 |
| 4Tx 2Rx Low | QPSK MCS4 | 2.6 | 2.5 | 2.2 | 2.9 |
| 16QAM MCS13 | 2.5 | 2.3 | 1.8 | 2.1 |
| 4Tx 4Rx Low | QPSK MCS4 | 2.3 | 2.4 | 1.6 | 1.9 |
| 16QAM MCS13 | 2.5 | 2.6 | 1.4 | 1.3 |

For Scenario 2, SNR results and SNR performance difference in comparison to Reference Scheme is not provided for Schemes #1,2 and 3, because per slot TBS values and, as a result, maximum achievable throughput values are different for these schemes.

Table 5.3.2.2-3 provides the information about TBS values for different schemes and different MCSs.

Table 5.3.2.2-3: TBS values for Scenario 2

|  |  |  |
| --- | --- | --- |
| MCS index | Reference Scheme, Scheme #4, 5, 6, 7 | Scheme #1, 2, 3 |
| PDSCH 9 symb | PDSCH 11 symb |
| QPSK MCS4 | 4096 | 2472 | 3240 |
| 16QAM MCS13 | 13064 | 7680 | 10248 |

#### 5.3.2.4 LTE UE performance

This clause provides the observations and analysis from different companies with performance impact of CRS-RM schemes on LTE UE performance:

* Due to RM applied in interference cells, the CRS REs and data REs under LTE cells will observe different interference level with SINR offset.
	+ From companies’ analysis:
		- Based on the INR levels used for RAN4 link-level simulation, for UE at 5% geometry, the delta of SINR observed at CRS RE and data RE is 5.86 dB and 11.75 dB for one dominant interference cell CRS-RM and two interference cell CRS-RM respectively.
	+ From one company result:
		- Based on the system level simulation for ISD of 1000m from one company in R4-2115629, the average delta of SINR observed at CRS RE and data RE is ~2.5 dB to ~4.5 dB for one dominant interference cell CRS-RM and two interference cell CRS-RM respectively.
* The interference mismatch among CRS REs and data REs may bring impact on LTE cells considering the following aspects:
	+ LTE CQI/RI/PMI is computed based on CRS for TM 1-8 and certain configuration of TM9 (when the parameter pmi-RI-Report is not configured by higher layers for TM9).
	+ CRS is used for LTE PDSCH demodulation processing for TMs 1-6.
	+ LTE RSSI is measured only from OFDM symbols containing CRS port 0 of measurement subframes unless indicated otherwise by higher layers, and it can be measured from all OFDM symbols of the DL part of measurement/indicated subframes if indicated by higher layers. LTE RSRQ is calculated based on RSRP and RSSI.

The following NW implementation solutions were provided by one company to address above LTE cell impact and the feasibility of such solutions from network implementation perspective needs further discussion:

* Transmit signal energy in rate-matched REs on top of rate matching. This signal energy could be NZP CSI-RS, random data, copy of PDSCH data or some other signal.

### 5.3.3 Summary of link level evaluation

According to the PDSCH link-level simulation results for 15 kHz SCS and synchronous network in clause 5.3.2, RAN4 initial observations are as follows:

• CRS-IC with the assumption of NW signaling can achieve better performance compared to RM scheme 1.

• CRS-IC without NW assistant signaling achieve similar or lower performance compared to CRS-IC schemes with the assumption of NW signalling.

• LLR weighting with the assumption of NW signaling can achieve better or similar performance compared to RM scheme 1.

• LLR weighting without NW assistant signaling achieve similar or lower performance compared to LLR weighting with the assumption of NW signalling.

• Note: RM scheme 1 is under the assumption that RM always applied for the strongest interference cell.

In addition, due to RM applied in interference cells, the CRS REs and data REs under LTE cells will observe different interference level with SINR offset. The interference mismatch among CRS REs and data REs may bring impact on LTE cells considering the LTE CQI/RI/PMI reporting, PDSCH demodulation and RSSI/RSRQ measurement. NW implementation solutions were provided by one company to address LTE cell impact and the feasibility of such solutions from network implementation perspective needs further discussion.

# 6 Conclusions

*< Editor’s Note: the conclusion on Inter-user interference suppression for MU-MIMO will be added later. >*

This technical report has documented the RAN4 evaluation on techniques to cope with CRS interference in scenarios with overlapping spectrum for LTE and NR. The major work includes the determination of typical network scenarios, interference models and interference profiles, definition of reference receiver structures, and link-level performance evaluations.

Two typical network scenarios, including scenario 1 with LTE/NR DSS and scenario 2 with NR/LTE deployed in neighbouring BSs/areas, are covered. 15 kHz SCS and synchronous network are assumed in the phase I evaluation.

The inter-cell interference modelling methodology and interference profiles from LTE CRS-IM receiver in homogenous deployments are reused. INR-*i* (signal level of the *i*-th dominant interference over Noc) is used as the interference power measure, and two dominant interferers are explicitly modelled in the simulation.

The MMSE-IRC receiver is used to suppress the inter-cell interference for the reference scheme without interference cell CRS handling and the CRS-RM schemes. Three different CRS-RM schemes, including CRS-RM for 1 interference cell always with the strongest interference, CRS-RM for 1 interference cell not always with the strongest interference (optional), and CRS-RM for 2 strongest interference cells, are evaluated.

For CRS-IM schemes, interference cell CRS-IM is used together with MMSE-IRC receiver, and CRS-IC and LLR weighting are considered as two different implementations of CRS-IM.

PDSCH link-level simulations are performed to evaluate the performance gain of CRS-RM and CRS-IM schemes over the reference scheme without interference cell CRS handling. 8 simulation cases with different network scenarios, Rx antenna numbers and MCS levels are included, and 7 CRS interference handling schemes in addition to the reference scheme are evaluated for each simulation case. RAN4 initial observations from link-level evaluation results for 15 kHz SCS and synchronous network:

• CRS-IC with the assumption of NW signaling can achieve better performance compared to RM scheme 1.

• CRS-IC without NW assistant signaling achieve similar or lower performance compared to CRS-IC schemes with the assumption of NW signalling.

• LLR weighting with the assumption of NW signaling can achieve better or similar performance compared to RM scheme 1.

• LLR weighting without NW assistant signaling achieve similar or lower performance compared to LLR weighting with the assumption of NW signalling.

• Note: RM scheme 1 is under the assumption that RM always applied for the strongest interference cell.

In addition, due to RM applied in interference cells, the CRS REs and data REs under LTE cells will observe different interference level with SINR offset. The interference mismatch among CRS REs and data REs may bring impact on LTE cells considering the LTE CQI/RI/PMI reporting, PDSCH demodulation and RSSI/RSRQ measurement. NW implementation solutions were provided by one company to address LTE cell impact and the feasibility of such solutions from network implementation perspective needs further discussion.

Based on these evaluations, it is recommended to define NR PDSCH demodulation requirements for neighbouring cell LTE CRS-IM in scenarios with overlapping spectrum for LTE and NR in Rel-17:

• Use LLR weighting as baseline reference receiver, and further discuss the feasibility of CRS-IC receiver taking into account the UE complexity and PDSCH processing time.

• Synchronous network scenario is prioritized. The asynchronous network scenario will be discussed after RAN #93e meeting.

• 15 kHz SCS for NR is prioritized. The 30 kHz SCS scenario will be discussed after RAN #93e meeting.

• RAN4 will further discuss the necessity of network assistance signaling and UE capability signaling during requirements definition phase.

Annex A:
Change history

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| **Change history** |
| **Date** | **TSG #** | **TSG Doc.** | **CR** | **Rev** | **Subject/Comment** | **Old** | **New** |
| 2021-04 | RAN4 #98e-bis | R4-2104952 |  |  | TR skeleton |  | 0.0.1 |
| 2021-09 | RAN4 #100-e | R4-2112224 |  |  | Implemented the following TPs approved at RAN4 #100-e:R4-2115739, TP to TR 38.833 Scenario for LTE CRS interference handling for NR UE, MediaTekR4-2115742, TP to TR 38.833: Interference Modeling for LTE CRS-IM, QualcommR4-2115737, TP to TR 38.833: Receiver structure for CRS-IM performance, Ericsson R4-2115738, TP: Introduction of simulation assumptions for CRS-IM receiver, Huawei, HiSilicon R4-2115736, TP to TR 38.833: Link level simulation results for LTE CRS interference handling for NR UE, Intel CorporationR4-2115735, TP to TR 38.833: Summary of link level evaluation and conclusion for CRS-IM, China TelecomEditorial modifications | 0.0.1 | 0.1.0 |
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