**3GPP TSG-RAN WG1 Meeting #94 R1-18xxxxx**

**Gothenburg, Sweden, August 20th –24th, 2018**

**Source: CMCC**

**Title:****[94-NR-05] Email discussion on additional simulation assumption for RIM**

**Agenda Item:** **7.2.5**

**Document for:** **Discussion and Decision**

# Overall Description

In 3GPP TSG-RAN WG1 Meeting #94, following agreements have been reached on the simulation evaluation of reference signals in the NR-RIM frameworks.

Agreements:

For simulation evaluation of reference signals in the NR-RIM frameworks

* Following Descriptions of the RS should be provided
	+ *RS sequence*
	+ *Length of RS sequence*
	+ *Time/frequency pattern of RS*

*Time pattern (number of symbols)*

*Frequency pattern*

* Following analytical metrics of the RS should be provided
	+ *The complexity of reference signal detection at gNB*
	+ *Overhead*
	+ *Impact on UEs*
	+ *Others*
* Simulation
	+ *Simulation parameters*

*SCS:* 30 kHz (mandatory) / 15 KHz (optional)

*Simulation bandwidth:* 20 MHz

*gNB MIMO configuration:* 1T1R (mandatory)/1T2R(optional)

*Frequency offset:* 0 Hz

*FFT size:* to be provided

*Length of detection window Lsymbol:* to be provided

*Channel model:*

 Option1: AWGN with random complex phase

 Option2: TDL-E (K-factor = [22] dB, DS = [30] ns, Doppler [0] Hz)

FFS: whether one of the two options or both options are mandatory.

*Delay of received RS:* When multiple RSs arrive in the detection window, the arrival time of the *i*-th RS respect to the start of the detection window, △*i* , is uniformly distributed within [-*Lsymbol*, *Lsymbol*], where *Lsymbol* is the length of UL symbol based on the numerology of RS.

*Power of received RS:*

Option1: Pi of multiple RSs have a power offset with respect to the reference power P0, where the power offset is randomly selected from [-0.5dB, 0.5dB].

 Use option1 as starting point for evaluation, FFS other option(s), e.g., different power offset ranges.

* + *Simulation cases and related metrics*

 *Case 1: Single RS + AWGN (mandatory)*

Metric: the minimum SNR where detection probability of [90%] and a false alarm requirement of [1%]

 FFS: successful detection time, e.g., one-shot.

 *Case 2: Multiple RS + AWGN (mandatory)*

Number of total RSs arrived within one detection window: FFS

Number of base sequences arrived within the detection window: FFS

Metric: FFS.

An email discussion has been assigned to finalize the additional simulation assumptions for RIM till 9/7.

# Discussions on the additional simulation assumptions for NR-RIM reference signal evaluation

## 2.1 Simulation parameters

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| **Simulation parameters** |
| SCS | 30 kHz (mandatory) / 15 KHz (optional) |
| Simulation bandwidth | 20 MHz |
| gNB MIMO configuration | 1T1R (mandatory)/1T2R(optional) |
| Frequency offset | 0 Hz |
| FFT size | to be provided |
| Length of detection window Lsymbol | to be provided |
| Channel model | Option1: AWGN with random complex phase Option2: TDL-E (K-factor = [22] dB, DS = [30] ns, Doppler [0] Hz)FFS: whether one of the two options or both options are mandatory |
| Delay of received RS | When multiple RSs arrive in the detection window, the arrival time of the *i*-th RS respect to the start of the detection window, △*i* , is uniformly distributed within [-*Lsymbol*, *Lsymbol*], where *Lsymbol* is the length of UL symbol based on the numerology of RS.  |
| Power of received RS | Option1: Pi of multiple RSs have a power offset with respect to the reference power P0, where the power offset is randomly selected from [-0.5dB, 0.5dB]. Use option1 as starting point for evaluation, FFS other option(s), e.g., different power offset ranges. |

1. Question 1: channel model
	1. For the two options of channel model, whether one of the two options or both options are mandatory? If only one should be considered as mandatory, which one should it be?
	2. For the TDL-E model, what is the recommended values for K-factor, DS, and Doppler, and what is the reason behind the selections?

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| Company | Option | Comments |
| Ericsson |  1 & 2, or only 2 | As stated during the RAN1#94 discussion, if only mandating a simplistic model (single static tap AWGN) we believe it could have a too large impact on the RS design and evaluation. Using a multi-path channel, one gets, to start with, fading that will cause the target SNR to be more realistic than in pure static conditions. Further, there will be frequency selective fading which could have impact on the RS chosen and also the detector design (not assuming identical channel coefficients across the whole RS). Then the question is if the TDL-E with the parameters above is good enough to represent a multi-path channel. To us, this is of secondary interest and the important point is that it is at least better than using only a static channel tap for our evaluations.a) We are ok with both as mandatory, or only having TDL-E as mandatoryb) To our knowledge, there are limited field trials in the area, but some indications that the delay spread is low, and also that LOS is present. Using the parameters above are fine with us. Maybe one could increase the Doppler slightly to model effects of moving surrounding environment, e.g. 1 Hz as used in the work NB-IoT and eMTC, but this is not expected to have an impact on our performance evaluation. |
| CMCC | Option 1 is mandatoryCompanies are also encouraged to provide results using Option 2 | Option 1 is mandatory for RS comparison. Companies are also encouraged to provide results using Option 2 |
| Huawei, HiSilicon | Option 1 is mandatory | Option 1 is mandatory for RS comparison. Option 2 is up to companies’ interests because we are not sure at current stage how much the chosen parameters of Option 2 reflects the realistic channel characteristics. Additionally, it seems no different simulation results could be expected between assumptions Option 1 and Option 2. DS 30ns is very close to the sampling resolution of 20 MHz RS signal bandwidth. With K-factor 22 dB, only two paths may be observed by a simulator where the LOS path with much higher power over the other path is dominating the results. |
| ZTE | Option 1 is mandatory | Due to lack of field measurement data, we have concern whether the channel model in Option 2 itself and those associated parameters reflect the realistic channel characteristics for NR-RIM scenarios.For the purpose of comparing different RS designs for NR-RIM, we think the channel model of Option 1 is sufficient. |
| Nokia, NSB | Option 1 and 2 | We are fine with two options. Option 1 can be a starting point, but it is necessary to consider practical channels when simulating with UL channels. On the TDL-E parameters, the proposed values are acceptable. K\_factor = 22 dB, DS=30 ns, Doppler 0 Hz |

1. Question 2: Power of received RS
	1. Should other options be considered for the power of received RS within the detection window, and what is the reason behind it?

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| Company | Comments |
| Ericsson | As stated in the RAN1#94 discussions, we do not agree with the reasoning behind [-0.5,0.5] dB (assuming free space propagation ignoring antenna gain), it will though result in getting some sort of worst case performance at least for the case of single RS detection. In case of multi-RS detection and if multiple RSs would have to be detected in the same detection window, a strong power imbalance between them would lead to a more challenging detection. The answer to this question has thus a relation to the multi-RS model and the number of RSs that the gNB should detect (see Q6). In case RAN1 agrees on a single RS detection per detection window, the assumption on [-0.5,0.5] dB seems sufficient (and would represent a worst-case detector scenario).We would though prefer to keep things simple and apply 0 dB instead of the [-0.5,0.5 ] dB distribution. This is more easily motivated (worst case detector assumptions) and would result in the same performance. |
| CMCC | For single RS simulation case, there is only RS arriving within one detection window, thus there is no power offset.For multiple RS simulation case, if the power of received RSs varies much from each other, the RS with lower power may not be regarded as an aggressor. Thus, we believe [-0.5dB, 0.5dB] is sufficient to simulate comparable RS power imbalance due to transmission distance. Compared with 0dB power offset, [-0.5dB, 0.5dB] range is more challenging under our proposed detection probability metric (see our comment to Q4). However, consider reducing simulation load, we may be open to consider 0dB as a simplified assumption. |
| Huawei, HiSilicon | For Case 1, assuming only single RS is sent from single source gNB, only one RS is detectable. For Case 2, two sub-cases can be evaluated:Case 2-1: the same single RS is sent from multiple source gNB, whose combination can be detected by the concerned gNB. Case 2-2: multiple different RS are sent from multiple source gNB, respectively. The number of source gNB may be larger than the number of RS sent, e.g. gNB grouping. Multiple RS candidates are supposed to be detected by the concerned gNB.With the above understanding, and considering that the largest distance between source gNBs within one detection window has been limited by the length of detection window, the fluctuation of RS arrival energy [-0.5: 0.5] dB is not applicable to Case 1, but applicable to both Case 2-1 and Case 2-2 as a starting point. |
| ZTE | For the simulation case of single RS, no power offset is needed as only one RS in the detection window.For the simulation case of multiple RS, we think some variation/randomness in terms of received power of RS would be close to the realistic NR-RIM scenario where the received power of RS is likely to be different due to environment and the corresponding channel between each transmitter and the receiver. It would be good to model this aspect with this [-0.5, 0.5] dB assumption.  |
| Nokia, NSB | The proposed power range of [-0.5, 0.5] dB can be a starting point. However, to reflect practical scenario (including both different channel and gNB transmit power), other options like [-1.5, 1.5] dB can be added. |

## 2.2 Simulation cases and related metrics

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| *Case 1: Single RS + AWGN (mandatory)* |
| Metric | the minimum SNR where detection probability of [90%] and a false alarm requirement of [1%]FFS: successful detection time, e.g., one-shot. |

1. Question 3: Metrics for Case 1: single RS+AWGN
	1. What is recommended values for detection probability, false alarm requirement and the number of detection times (one-shot or multiple-shot)?

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| Company | Comments |
| Ericsson | This has a large dependency on how the detector is designed. For example, do we assume that a missed detection can be corrected in the next opportunity when the RS is sent. The implications of this to the system performance will depend on for example the time period between RSs. Also, for false detection, if the detector takes a decision of a specific RS only after X number of consecutive detections (e.g.) it will have a great impact on the overall false alarm (even if the ‘per detection’ false alarm can be relatively high). We are OK to start with the numbers within brackets to get some results on the table for discussion. What is important to start with is a common baseline and the possibility to compare results between companies. For this reason, we also proposed to use single-shot as baseline, even though actual implementations might use multi-shot detection. However, assuming uncorrelated error events between multiple shots, it should be possible to derive multi-shot performance from single-shot simulations  |
| CMCC | The agreed detection probability of [90%] and a false alarm requirement of [1%] with one-shot detection, can be considered as a starting point for evaluation. Further refinement can be considered when some initial evaluation results are provided.In addition, note that such case is not realistic under the two frameworks, thus such simulation is mainly served for calibration among companies.  |
| Huawei, HiSilicon | The current detection probability and false alarm requirement are starting point only for simulation purpose. Here we can assume that they are targeted for one shot detection and further detector improvement by utilizing the correlation between multi-shot detections for the same RS candidate can be considered. |
| ZTE | Our understanding of this simulation case is more for calibration among companies rather than determination of the actual performance metric. Therefore, it would be okay as long as each company report the required SNR for the same detection probability and false alarm requirement. We also propose to use one shot detection for this case to avoid possible difference due to companies’ implementation of multi-shot detection. |
| Nokia, NSB | Fine with the proposed value of detection probability 90% and FA 1%, and this is pending to the detection algorithm. One shot detection can be the baseline.  |

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| *Case 2: Multiple RS + AWGN (mandatory)* |
| Number of total RSs arrived within one detection window | FFS  |
| Number of base sequences arrived within the detection window | FFS |
| Metric | FFS |

1. Question 4: Metrics for Case 2: *Multiple RS + AWGN*
	1. What is the recommended value for the total RSs arrived within one detection window, and what is the reason behind the selection?
	2. What is the recommended value for the number of base sequences arrived within the detection window, and what is the reason behind the selection?
	3. What metric(s) should be considered for the multiple RS case?

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| Company | Comments |
| Ericsson | There is no doubt that there will be a lot of RSs received in case of duct, the question is how many of them are worth modelling. Having multiple paths using the same RS is important to model as well as having multiple RS sequences. We proposed to split these two into separate multi-RS scenarios as shown in the figures below: The leftmost figure would evaluate the impact of the auto-correlation in the design (as the single RS case but now with multiple temporally separated paths). The rightmost figure would evaluate the impact on cross-correlation of the RS design.The two cases are shown in the table below, assuming here constant power of 0 dB (see Q2).

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| RIM scheme | RS# | Power [dB] | Delay | RS |
| RIM-1 | RS-1 | 0 |  [-Lsymb,Lsymb] | RS-A |
| RS-2 | 0 |  [-Lsymb,Lsymb] | RS-A |
| … | … | … | … |
| RS-5 | 0 |  [-Lsymb,Lsymb] | RS-A |
| RIM-2 | RS-1 | 0 |  [-Lsymb,Lsymb] | RS-A |
| RS-2 | 0 |  [-Lsymb,Lsymb] | RS-B |
| … | … | … | … |
| RS-5 | 0 |  [-Lsymb,Lsymb] | RS-E |

Regarding metrics, the same as in the single RS case can be re-used also here. |
| CMCC | Two cases need to be evaluated.**Case 2-1:** Total number of base sequences in the whole network is 1. Number of total RSs arrived within one detection window is [100]. The performance metric is detection probability, Pd, which is defined as the probability of detecting a sequence that is above the threshold obtained under a false alarm rate smaller than [1%].Note that the meaning of “arrived within one detection window” is the arrival time of the RS is within [-Lsymbol, Lsymbol] with respect to the start of the detection window. **Case 2-2**: Total number of base sequences in the whole network is more than 1. At least for evaluating RS for Framework 2, where it is needed to distinguish gNBs ( or group of gNBs ) based on received RS. Consider number of total RSs arrived within one detection window as *n\*NRS*, where *n* is the number of base sequences that actually arrives within the detection window and *NRS* is the number of RSs sharing the same base sequence. Value of *n* is uniformly distributed between [1, Nseq,max], where Nseq,max= 8 is the number of different base sequences in the whole network. Fix NRS as 1 (for no gNB grouping), and 50 or 100 (for gNB grouping). Two performance metrics are necessary:**Metric-1 Worst detection probability**: $P\_{d}=\min\_{\left|A\right|\in \left\{1,… N\_{seq,max}\right\}} \min\_{i\in A,}P\_{i}$, where $P\_{i,}$ is the probability of correctly detecting the *i*-th base sequence ($i\in A$) when the *i*-th base sequence is actually arrived within the detection window, with $A$ as the set of actually arrived base sequences within the detection window, $\left|A\right|$ as the size of $A$, (i.e., the number of actually arrived base sequences). For example, assume base sequence #1, #2 and #3 are actually arrived within the detection window, while sequence #1, #2 and #4 are detected, then detecting base sequence #1 and #2 is counted as $P\_{i}$, where, *i* = #1, #2, and $A$ = [#1, #2 and #3].**Metric-2: Detection error probability:** $P\_{e}=\max\_{\left|A\right|\in \left\{1,… N\_{seq,max}\right\}}P\_{err,\left|A\right|} $, where $P\_{err,\left|A\right|}$ is the probability of detecting a different base sequence than all the one(s) that actually arrived within the detection window, where $\left|A\right|$ is the number of actually arrived base sequences. For example, when base sequence #1 and #2 arrives in the window, detecting base sequence #3 is counted as an error. Instead, if only sequence #1 are detected, then the error event caused by miss detecting sequence #2 is **NOT** counted as a detection error.Note: Metric-1 is important for frameworks 1 and 2 to avoid the case of the aggressor not applying necessary remote interference mitigation schemes because of total miss detecting RS-1 and RS. It is the lowest detection probability that any one of the sequences should achieve, which should be kept high enough (e.g., higher than [90%]) to suppress the total miss detection risk. Metric-2 is important for framework 2 and should be kept low (e.g., less than [5%]), otherwise, detecting a different base sequence than those actually arrived means a wrong backhaul link will be established which causes high overhead and cost. |
| Huawei, HiSilicon | With the same sub-case definition in our response to Q2, Case 2-1, the number of RS arrivals within the detection window for two separate simulation runs is 10 and 20, respectively. As the number of RS arrivals increases, the trend of their successful detection probabilities can be observed with low simulation workloads. And such trend may be positive proportional. Therefore, the case with a bigger number of RS arrivals for simulations may be covered as well given a fixed thermal noise level.Case 2-2, the number of different RS candidates for the whole network, K, is two, also only K=2 RS candidates arrive at the concerned detection window, with N=10 arrival instances for each RS candidates assuming every 10 source gNBs sending the same RS candidate. The reasons are as follows,1. K=2 is a good starting point to evaluate cross-correlation between different RS candidates.
2. N=10 is based on the same reasoning for Case 2-1.

The same metric for Case 1 may be re-used here for comparison. Other metrics are not precluded. |
| ZTE | First of all, we agree with the above comments from Ericsson, CMCC and Huawei to have separate cases for this multiple RS case. We have a comment on “Number of total RSs arrived within one detection window”. For the case where the same RS is transmitted from multiple gNBs (denoted as Case 2-1 by CMCC and Huawei, illustrated by the left figure in Ericsson’s above comment), the wording “number of total RSs arrived” seems indicating the receiver should differentiate the received RS from each transmitter which may not be always feasible in this case given the exact same RS is transmitted. Thus, we propose to use “Number of total RSs transmitted within one detection window” for Case 2-1. Regarding the actual number, we think N=8 would be reasonable for the gNB set size.Another comment on the term “base sequence”, which we don’t know the definition of it. Assuming it refers to RS sequence, then for the case where different RSs are transmitted from multiple gNBs (denoted as Case 2-2 by CMCC and Huawei, illustrated by the right figure in Ericsson’s above comment), similarly, we propose to use “Number of RS sequences transmitted within one detection window”. Again, we think K=8 would be reasonable to evaluate the cross-correlation of RS sequences. Since the performance of RS sequence in case of gNB grouping has been evaluated in Case 2-1, then no need to have gNB grouping in Case 2-2. The same metric for Case 1 may be re-used here for comparison.  |
| Nokia, NSB | The simulation parameters may be different for framework, algorithms and sequence design.1. For framework-1, the number of RS arrived at the detection window is depending on the size of the gNB group, and how many gNB groups can transmit RIM RS at the same time. The maximum of RS shall fulfil the performance metric requirements.

For framework-2.1 and 2.2, the number of RS can be tested by larger number first, then to reduce the number to fulfil the performance metric requirements, the value 4, 8 can be considered.1. For framework-1, the same base sequence shall be used for gNBs in the same group, base sequence can be different across the group, which is depending on the detailed RIM-RS design, e.g., TMD RIM-RS transmission.

For framework-2.1 and 2.2, base-sequence of each RIM-RS is different, how many RIM-RS can be multiplexing together need to be evaluated.1. The same metric of case 1 can be applied, in addition two-short detection can be considered as well.

It needs to clarify the detection rate in case multiple RS with same base sequence are transmitted. If one path of RIM-RS is detected, consider the RIM-RS detection is successful. |

## 2.3 Others

1. Question 5: Are there any other consideration on the simulation assumption or methodology you would like to share or clarify?

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| Company | Comments |
| Ericsson | See question 6 & 7 |
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1. Question 6: How many RSs should the gNB attempt to detect in each detection window?

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| Company | Comments |
| Ericsson | To simplify our work and avoid complex receivers (e.g. SIC architecture), which also will cause a larger performance spread between companies, we propose **one RS** detected per detection window. The cross-correlation aspects will still be modelled, especially if all RSs are received with relatively equal power (see response to Q2), since sequences with poor cross-correlation would increase the false-alarm rate. Hence, we don’t see a loss in modelling by this simplification, although a gNB in the field might detect multiple RSs in each instance. |
| CMCC | First, it needs to clarify that for the multiple RSs case shown in the rightmost figure (see Ericsson’s comments to Q4), the number of RSs to be detected in each detection window should be **the number of base RS sequences.**Then, we think that in such a case, detecting only one sequence per detection window is NOT sufficient enough. The reason is that the detection probability of detecting one sequence per detection window will be high even if the cross correlation among base sequences is high. With cross-correlation problem, a cross-correlation peak could possibly be treated as an autocorrelation one, which unavoidably increases the detection probability. Therefore, high detection probability obtained by detecting single sequence when there are multiple sequences in the whole network is not sufficient to guarantee good performance. As a result, we need to try multiple sequences during detection, obtain the worst detection probability among all sequences and the detection error probability (see our comments to Q4), to final determine a good sequence design. |
| Huawei, HiSilicon | The number of RS candidates to be detected should be the same as the number of possible RS being sent. For simulation, only the RS detected with the highest energy for each detection window is picked for result output and comparison. This can simplify the simulation and its post-processing. |
| ZTE | See our comment to question 4 above, assuming this question is for Case 2-1 and Case 2-2, then the number of RS sequences to be detected should be the same as the number of RS sequences transmitted. We share the understanding of CMCC, for Case 2-2, the reported minimum SNR for the target detection probability and false alarm rate should be the one corresponding to the detected RS sequence with the lowest energy for each detection window. |

1. Question 7: How should the false detection rate of RS evaluated?

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| Company | Comments |
| Ericsson | By only AWGN input to the receiver, i.e. modelling thermal noise |

# Next Step

The email discussion should be wrapped up before Sept. 7th. Companies are encouraged to feedback their comments regarding the questions in Section 2 before Sept. 5th, and start simulations for RS reference signal evaluation as soon as possible.

# Reference

1. Chairman’s notes, RAN1#94, Gothenburg, Sweden, August 20th – 24th, 2018.