3GPP TSG-RAN WG4 Meeting #109 **R4-2318688**
Chicago, US, November 13 – 17, 2023

Agenda item: **8.7.1.1**
Source: **Apple**
Title: **TP on Annex <A>:Simulation results**
Document for: **Approval**

1 Introduction

At the last meeting, there was a TP agreed to capture the previous simulation results [1]. We commented that we would like to understand the necessary to capture such results, as some of the intermediate results or proposals should not be captured as they did not receive wide support during the discussion in RAN4.

In this TP, we aim to re-organize the results and hence send a clear and coherent message. If the results are helpful to the RAN4 understanding and development of the requirement concept, they are kept; otherwise, they are removed.

2 Text Proposal

Annex <A>:
Simulation results

A.1 General

This Annex intends to capture the simulation results and analysis during FR2 multi-Rx DL reception discussion that are helpful in understanding the development of the RF requirement.

Deleted: Even though not all efforts are directly reflected in the evaluation of the final requirements, they are still very meaningful in terms of identifying the right way to build the requirements and may serve as inspiration for other Work Item.

A.2 AoA offset distribution with system simulation

Background

As the RF requirement serves as a metric for UE's two-AoA spherical coverage performance, it is helpful to know how the AoA offset between two AoAs is distributed in real network in different scenarios, which can provide guidance on whether the range of AoA offset can be narrowed down and the requirement can be targeted for some common AoA offsets.

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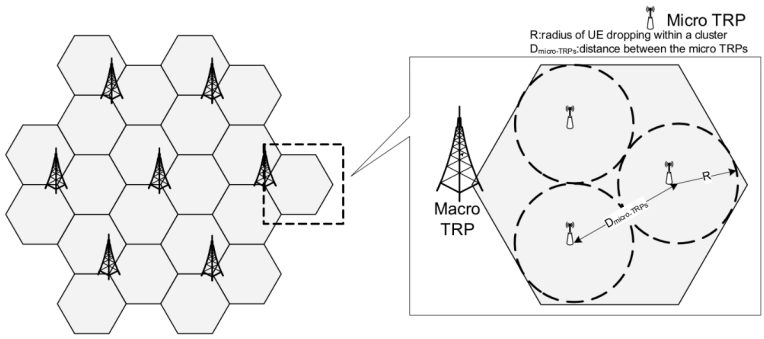
R4-2218166

To understand if the angular difference between the two AoAs observed in a typical multi-TRP deployment scenario exhibits any pattern, we conduct simulation based on the system simulation assumptions in A.2 in TR 38.802. We simulate the following mTRP scenario as shown below. In particular, the inter-macro TRP distance is 200m, in each cell (hexagon), three micro TRPs are randomly dropped within each dashed circle (i.e., cluster) around the center of the circle (within 20m), following some minimum distance rules (such as the minimum distance between two micro TRPs is 40m, the minimum distance between a micro TRP to a macro TRP is 10m, etc.). UEs are randomly dropped in the cluster (R = 50m). UE is assumed to have two back-to-back panels (pointing to opposite directions), with 4x1 antenna elements each. Details of other simulation parameters such as power can be found in Table A.2.1-1 in TR 38.802 corresponding to the Dense urban scenario.



NOTE: Micro TRPs refers to micro TRP centers

Figure A.2.1-3: Cell layout for dense urban (3 Micro TRPs per Macro TRP)

The analysis methodology for these simulations is as follows:

1. Assume each site (macro & micro TRP), in the modeled network is a potential point for the mTRP connection
2. Calculate RSRP between each site, taking into account BS gain in the link direction, UE gain in the link direction, and path loss
3. Associate TRP1 and TRP2 according to max. RSRP and also according to one of the following panel mapping assumptions:
   - No restriction on panel mapping (i.e., two beams with best RSRP can be mapped to the same panel)

   OR
   - Best panel mapping (i.e., one AoA is mapped to the best beam/panel, and the other AoA is mapped to the best beam from the remaining panel)
4. Calculate AoA1 and AoA2 to these TRPs from the UE perspective
5. Evaluate the distribution of AoA1 - AoA2 (ΔAoA)

Results are shown in Figures 1 and 2 below.

- It can be seen from Fig. A.1-1 that with unrestricted panel mapping, the distribution of ΔAoA is nearly uniform. In other words, it takes values from 0 to 180 degrees with equal probability.
- In Fig. A.1-2, with best panel mapping restriction, it can be observed that for 95% of the UEs, ΔAoA > 60 degrees.
- We note the results depend in general on the UE antenna panel assumptions as well as the power levels of the macro and micro nodes. We welcome other companies to share results for comparison.

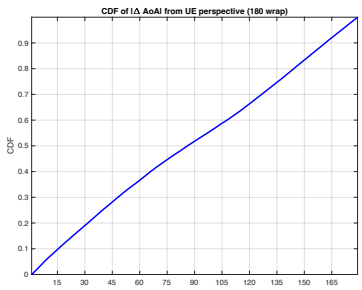


Figure A.1-1: Distribution of ΔAoA with unrestricted panel mapping

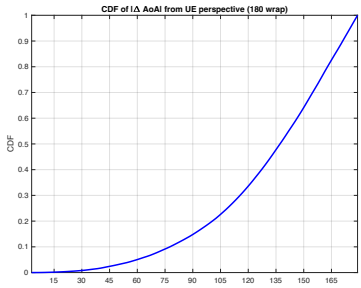


Figure A.1-2: Distribution of ΔAoA with best panel mapping restriction

R4-2301573

To further figure out the AoA separation distribution in the dedicated deployment, we perform a simulation and 2 deployments are considered, as shown in Figure A.1-3:

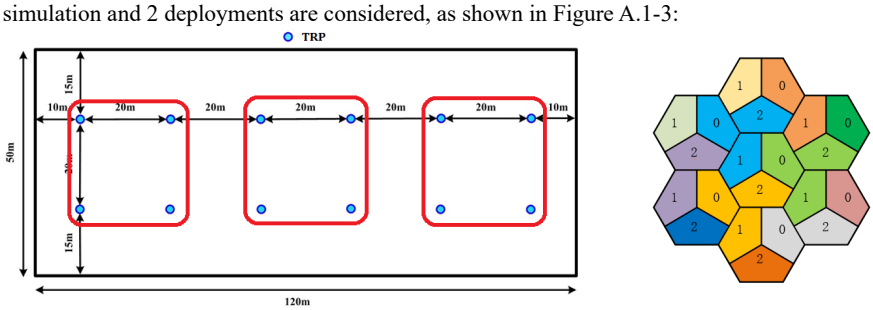


Figure A.1-3 Indoor and Dense Urban (Macro only) deployment

For indoor scenario, 4 TRPs within the red circle are combined as a cluster, and UE can access any two of them. For Dense Urban, the TRPs with the same color can collaborate. Other simulation assumptions are mainly from TR38.802, and the results are shown in Figure A.1-4.

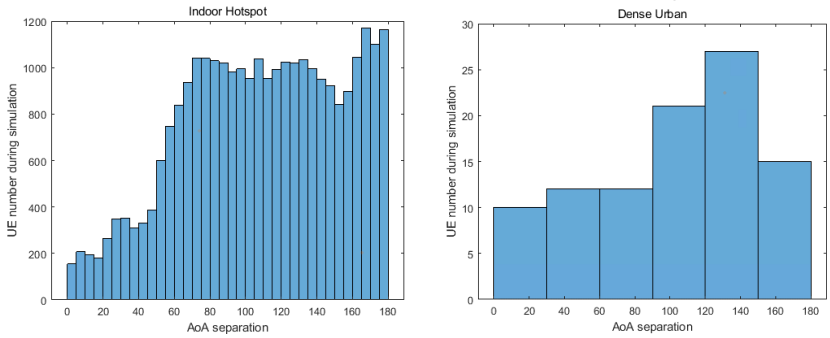


Figure A.1-4 AoA separation distribution in indoor and Dense urban

Unfortunately, it is hard to further narrow down the AoA separation range based on the results, as we have already mentioned in the previous meeting, UE can access the TRP if the channel condition is acceptable and the AoA separation varies due to the UE location, channel condition changes, and we cannot get a so-called minimum or maximum threshold based on the simulation results.

A.3 Requirement applicability for sDCI and mDCI

Background

It is preferrable to define a single set of requirements for both sDCI and mDCI. The following part provides the analysis of whether it is feasible under functionality-based requirement.

R4-2308232

When both AoAs use the same fixed DL power level, due to the antenna gain and inter-beam interference being different for the signal from 2 AoA, the SINR at baseband for 2 layers are different, which means using the same fixed DL power will bring power imbalance artificially.

For multi-DCI UE, each layer can be decoded separately and we can get the throughput of each layer, so the power imbalance doesn't matter and the -1 dB criterion above to judge each test point from a pair of AoA is still reasonable. However, things become different for sDCI UE because the 2 layers of sDCI UE share one transmission block and we can only get a total throughput of 2-layer MIMO, and there is no doubt that the power imbalance will affect this total throughput, and simply using -1dB as the criterion for each test point does not make sense anymore. Figure A.3-1 shows that how power imbalance will affect the throughput of sDCI UE.

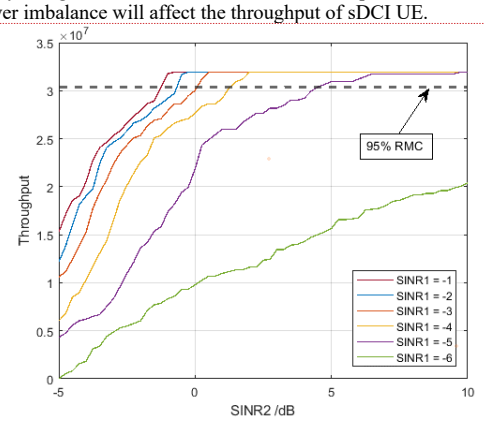


Figure A.3-1 impact of power imbalance for sDCI UE

In the simulation, the SINR1 and SINR2 represent the SINR value from 2AoA. Obviously, due to the power imbalance, even though one of SINRs is less than -1 dB, the total throughput still can achieve 95% RMC and pass the test.

Can raising or lowering the power of one of the AoA help with this problem? The answer is NO. Simply changing the power level cannot remove the power imbalance, and the only way to solve this issue is for each test point, the DL power should be changed, but this scheme is too complicated from both the verification and evaluation perspectives.

As a compromise, we can only focus on that whether the sDCI UE can pass the same requirement as mDCI under power imbalance. In Figure 1, the simulation shows that when both SINRs is larger than -1 dB, the total throughput still can be larger than 95% RMC, which means the -1 dB in simulation still can ensure the AoA pair can pass the test. The only omission here is that cases where either SINR1 or SINR2 is less than -1dB and UE can still pass the test are not accounted for in the requirement. As we mention above, even though we realize this omission, it is hard to be verified or evaluated. So we think it is enough to confirm the same requirement can be applied to both sDCI and mDCI UEs under the current evaluation method.

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Background¶
For EIS-based requirement, one problem was raised which is how to assess that multi-Rx has sufficient gain compared to 1AoA operation, and the following part is a possible way.¶
R4-2218042¶
A legacy UE's efficiency based FOM may be defined as the effective sensitivity derived from the spatial average of the directional efficiencies. For simplicity in explaining the concept, we have assumed a uniform spatial grid of 'N' points rather than a lat-long grid, to enable dropping the compensation terms (sine weighting) for non-uniform distribution of gid points. We use '$Tput_{DL}$' as the throughput criterion for the legacy EIS requirement. For the legacy case, this FOM takes the form:¶
$\frac{Tput_{DL}}{FOM_{BL}} = \frac{1}{N}\sum_{k=directions}\frac{Tput_{DL}}{EIS_k}$¶
which can be simplified to:¶
$\frac{1}{FOM_{BL}} = \frac{1}{N}\sum_{k=directions}\frac{1}{EIS_k}$¶
This type of spatial averaging has strong precedent in the derivation of the TIS metric by CTIA (Annex 'E' of 'Test Plan for Wireless Device Over-the-Air Performance') and 3GPP's own metrics like the FR2 MIMO averaged spatial sensitivity and FR1 TRS. ¶
The FOM can be extended to the 2AoA case be recognizing that the UE has two concurrent links, one for each TRP. For each TRP_n: ¶
$\frac{1}{FOM_n} = \frac{1}{N}\sum_{k=directions}\frac{1}{S_{AoAn,k}}$¶
This formulation highlights the first important consideration: the AoA pairs must be selected so that the underlying directions for each TRP are also uniformly distributed in space, otherwise spatial bias will be introduced. If there is non-uniform distribution, de-weighting must be used to remove bias. Also, the TRP must have full spatial coverage, it is impossible to get an unbiased picture with incomplete coverage for the TRP.¶
The figures of merit for each TRP in the 2AoA case can be treated individually or be combined for an 'overall goodness' of the UE, it is mostly a matter of convenience. ¶
¶ ... [1]

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Background¶
EIS-based requirement was a possible way during the ... [2]

A.4 Impact of UE orientation

Background

As mentioned in Clause 6.3.4, it is identified that UE has different performance under different UE orientation due to the test system constrains. The following part captures the evaluations.

R4-2304824

Our simulation results shown in section 2.1.3 gather simulation data for all angular separation values, for 3 typical UE orientations, for 3 different panel placement implementations, respectively. Those data are visualized in Figure A.4-1 for convenience of comparison. From the figure, it can be observed that different panel placement implementations show obvious different trend in angular separation preference, thus it is not proper to specify requirements for both small angular separation and large angular separation.

Different UE orientations also impact performance a lot. From Figure A.4-1 (a) and (c), it can be observed that there is even orientation showing bad performance for every angular separation from 30° to 180°, thus it is not proper to specify requirements for all UE orientations.

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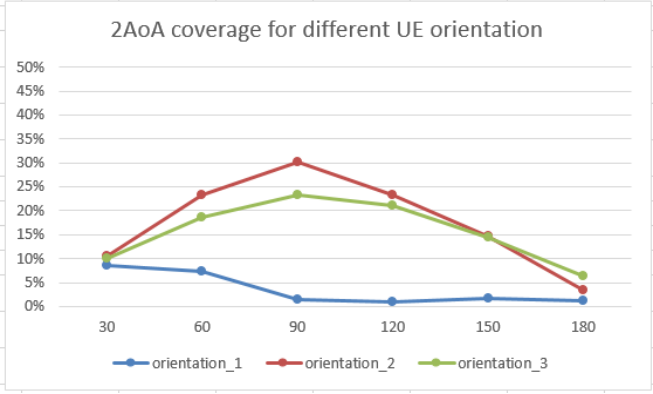
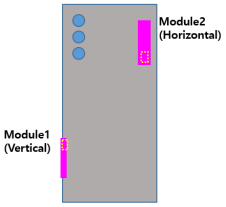
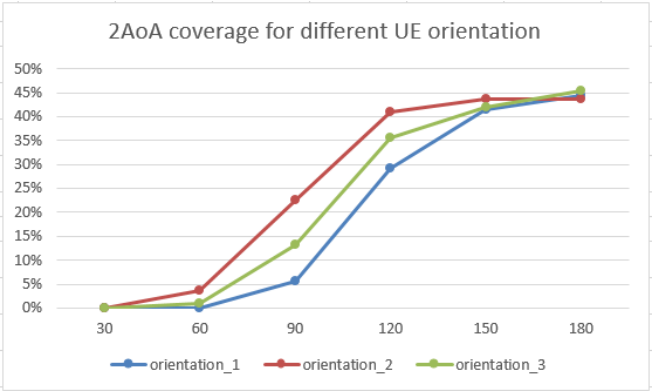
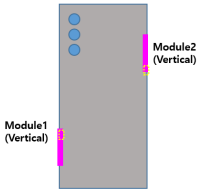


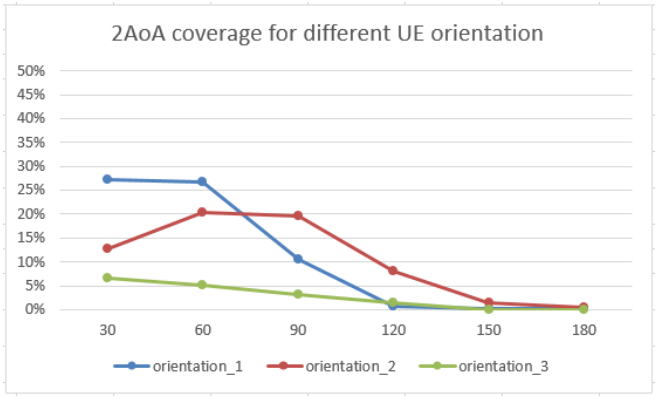


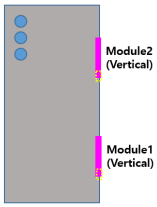
(a) **simulation results of Right + Back panel placement**





(b) simulation results of Left + Right panel placement





(c) **simulation results of Left + Left panel placement**

Figure A.~~4~~-1 Visualization of our simulation results

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The simulation results for different UE orientations are shown in Figure A.~~4~~-2 and the post-processing rules that mentioned in previous part are used.

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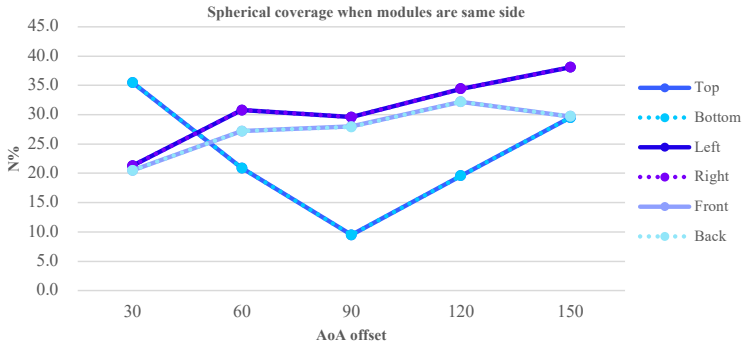

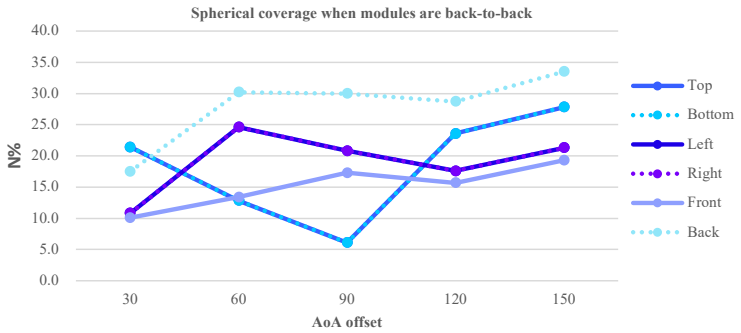

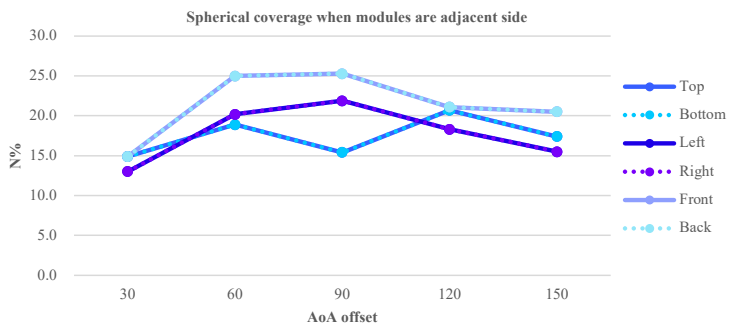

Figure A.4-2 N% for different orientations

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Some curves are totally overlapped is because the model itself has symmetry. When metal blockage exists, the EM field will be scattered due to the reflection, and it is hard to summarize a rule between N% and AoA offset. The UE orientation also led to different results although the AoA offset is same, and the reason here is that the relative position between AoA pair and UE will be changed under different UE orientation.

R4-2304603

To evaluate the impact of different choices on module orientations relative to the UE reference coordinate system, a UE with 2 identical modules housed in adjacent faces was used. Each module comprised a 4x1 dual polarized element array. The coverage pattern is shown in figure A.4-3. Annex C has details on the module orientation in the UE reference coordinate system. Module locations were grouped into two categories.

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1. In the first category, one module pattern covered the polar region of the reference coordinate system. Examples: Front+Bottom, Front+Top, Front+Right
2. In the second category, both modules cover equatorial regions (away from polar regions). Examples: Top+Left, Top+Right

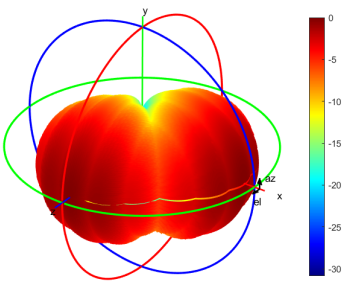

Figure A.4-3: Coverage pattern of example UE with modules on adjacent faces

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The list in each category is not exhaustive but deemed sufficient to capture characteristic trends. Figures A.6-4 and A.6-5 shows a comparison of overall probability to support 2TRP DL for the example UE chosen for the UE positioning study. Category 1 orientations are captured in cool colors (blues and greens), and category 2 orientations are captured in warm colors (reds).

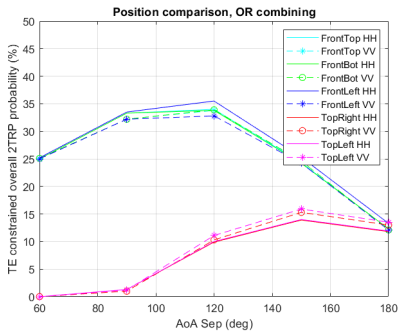

Figure A.6-4: OR combining method

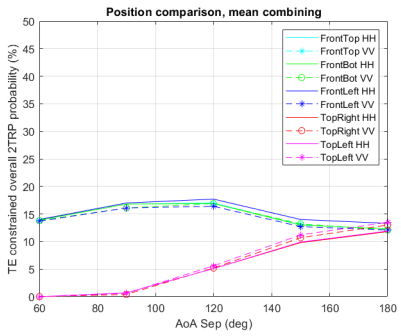

Figure A.6-5: mean combining

Here too, the dashed and solid trends for any one color track closely. This suggests that module orientation (H-scanning or V-scanning) seems to make a relatively small difference in the projected overall probability result for a UE with modules on adjacent faces.

A.5 Impact of gain imbalance between antenna modules

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Background

For a real UE, the performance of panels may not be exactly same. The following part shows how the gain imbalance impacts the functionality-based requirement.

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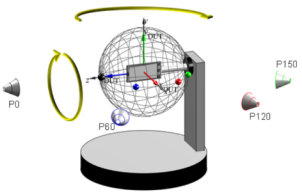
R4-2307482

The simulation of the pass ratio over the whole sphere is performed by considering different antenna module performances, different UE orientations, and different antenna module combinations.

- Antenna module performance
  - Case 1: antenna module#1 and antenna module#2 are assumed to have the same performance gain
  - Case 2: antenna module#1 is assumed to have a 3dB lower performance gain than antenna module#2
  - Case 3: antenna module#2 is assumed to have a 3dB lower performance gain than antenna module#1
- UE orientation
  - Z-axis oriented
  - Y-axis oriented
  - X-axis oriented
    - Probes are located in the xz plane in [2]



- Antenna module combination
  - left-side & right-side combination
  - left-side & top-side combination

Figure A.5-1, Figure A.5-2, and Figure A.5-3 show the results of the pass ratio of both OR combining and averaging for Case1, Case2, and Case3, respectively.

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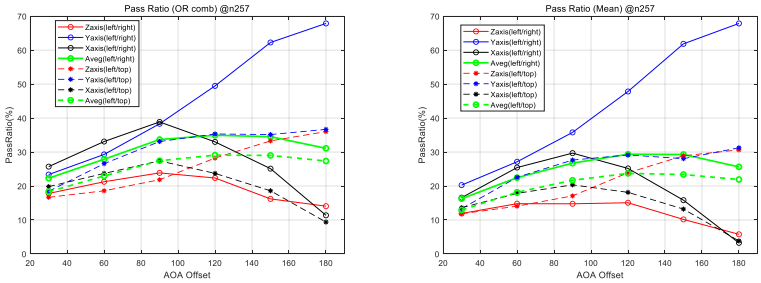

(a). OR combining (b) Averaging

Figure A.5-1: Pass Ratio of both 'OR combining' and 'averaging' for Case 1.

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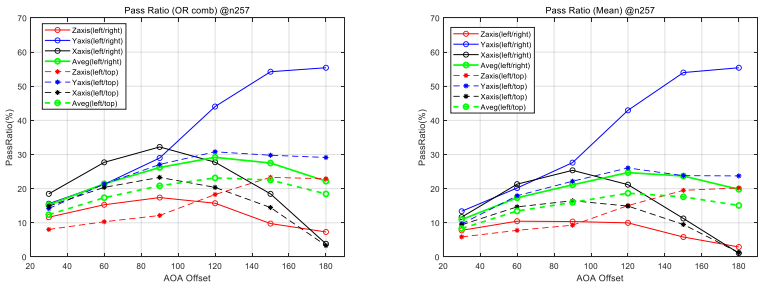

(a). OR combining (b) Averaging

Figure A.5-2: Pass Ratio of both 'OR combining' and 'averaging' for Case 2.

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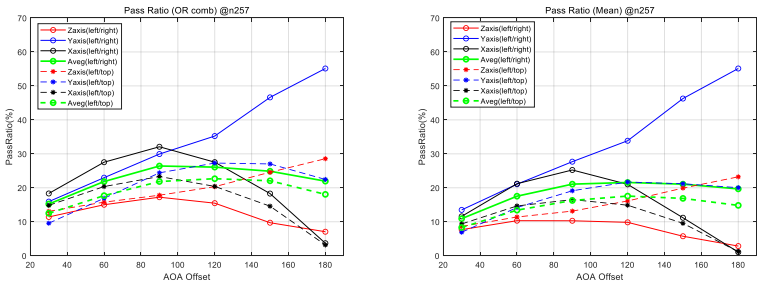

(a). OR combining (b) Averaging

Figure A.5-3: Pass Ratio of both 'OR combining' and 'averaging' for Case 3.

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R4-2309284

Sometimes it is preferable to use actual module coverage data, but in conjunction with the spherical coverage calibration condition, we may end up with an over-specified set of boundary conditions. (i.e cannot meet both REFSENS and spherical coverage gain drop at the same time.). In these cases,

the baseline assumption in a previous WF suggests to ‘scale antenna gain’, see excerpt below

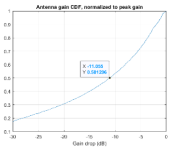
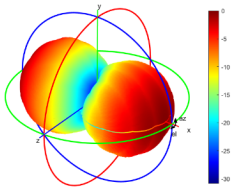
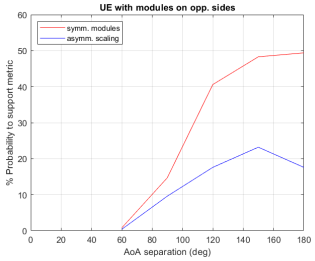
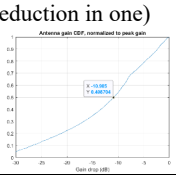
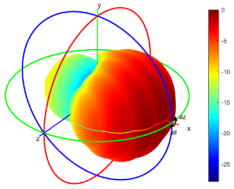
2.6 UE implementations to study for requirement derivation

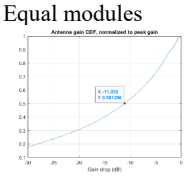
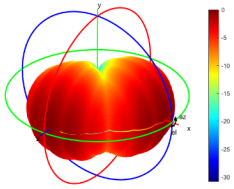
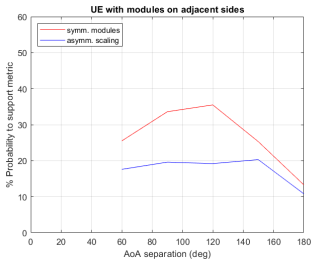
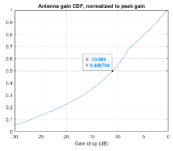
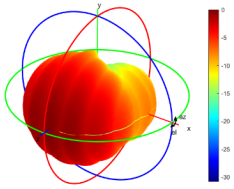
Simulation guidelines for UEs that dot not align with both peak EIS and spherical coverage in current spec:

Option 1: Adjust the beam shape or scale the antenna gain to make UE align with both peak EIS and spherical coverage.

(**figure 2.4-1**).

There are several ways to achieve this scaling: the first method would apply to both modules equally (symmetric scaling of gains in way to ‘tune’ the spherical coverage gain drop), and the second method would reduce the gain of one of the modules relative to the other (asymmetric scaling). Asymmetric scaling makes the sensitivity worse for one module over the other, so it can impact the probability metric significantly, see tables below.

Left and Right modules, legacy antenna gain	Module coverage relative to positioner centric grid (*)	Probability to support 2 TRP DL (option 1 metric [1]+ OR combining)
Equal modules 		
Asymm. scaled modules (9.0 dB reduction in one) 		

Left and Front modules, legacy antenna gain	Module coverage relative to positioner centric grid (*)	Probability to support 2 TRP DL (option 1 metric [1]+ OR combining)
Equal modules 		
Asymm. scaled modules (7.5 dB reduction in one) 		

Note that all the UEs above are calibrated to legacy spherical coverage, but the probability metrics can be vastly different between UEs with equal modules and UEs with asymmetric modules. This difference may be tolerable for small differences (2 dB or less) across modules, but this type of implementation is not suitable for 2 TRP reception if the asymmetric gain split is larger across the modules. Larger gain splits become necessary if the individual module.

A.6 Test time estimates

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Background

Test time is an important aspect to be considered in search of the proper requirement concept. The following part provides the estimation for EIS-based requirement and functionality-based requirement.

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In the previous sections it was shown that the test time for the multi-AoA DL spherical test depends on various aspects, e.g.,

- number of AoA2 probes
- number of polarization combinations ($AoA1_q$, $AoA2_q$), ($AoA1_q$, $AoA2_f$), ($AoA1_f$, $AoA2_q$), ($AoA1_f$, $AoA2_f$)
- single-DCI vs multi-DCI schemes
- parametric vs non-parametric test approach

The summary of test time estimates is tabulated in Table A.6-1. Big differences in terms of test time/test efforts can be observed; as expected, the non-parametric test approach yields the lowest test time.

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Table A.6-1: Overview of Approximate Test Times

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Power Class	Grid Type		Minimum	Number of Polarization	Number of	Effort/Test Time for	Notes

		Test Approach	Number of Spherical Coverage Test Points *N*	Combinations *P*	AoA2 Probes *M*	multi-AoA DL spherical coverage test [min]		
						Min	**Max**	
PC1/PC3	constant-step size	Parametric single-DCI	312	4	4	1331	1799	Min/Max test time depends on Joint 2 AoA Sensitivity approach
					3	1248	1716	
					2	1165	1633	
				2	4	666	900	
					3	624	858	
					2	582	816	
PC1/PC3	constant-step size	Parametric multi-DCI	312	any	4	666		N/A
					3	624		
					2	582		
PC1/PC3	constant-step size	Non-Parametric single-DCI or multi-DCI	312	4	4	21	333	Min/Max depends on early Pass
					3	21	250	
					2	21	166	
				2	4	21	166	
					3	21	125	
					2	21	83	

Given the large difference in test time, feedback from industry is requested whether the test approach for multi-AoA spherical coverage should be based on a parametric test (as legacy spherical coverage test case) or on a non-parametric test.

3 References

[1] R4-2317592, "TP to 38.751 on collection of simultion results," vivo

[2] TR 38.751, " User Equipment (UE) RF requirements for NR frequency range 2 (FR2) multi-Rx chain DL reception," v1.1.0

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