



# Views on UE RF enhancements for Rel-18

---

Apple

# Overview

---

- This contribution outlines a list of prioritized topics which RAN4 should pursue toward enhancing UE RF requirements in Rel-18, as follows:
  - FR1 requirements for UL MIMO with UL CA
  - ETC applicability for FR2 requirements
  - UE antenna scaling for FR2-1 and FR2-2

# FR1 requirements for UL MIMO with UL CA

---

- Background

- Although RAN4 defines requirements for UL MIMO and UL CA in 38.101-1, only the Rel-16/17 UL Tx carrier switching feature combines both under the assumption of a UE architecture with only 2 Tx chains
- RAN4 should develop requirements for the combination of these features under the assumption of a UE architecture with 3 Tx chains
- In the past, proposals have been seen suggesting to develop requirements for all 3 Tx scenarios, which include scope for 3-band UL and non-contiguous UL CA with 3 sub-blocks
  - The 3Tx with 3 non-contiguous CCs (either intra-band or inter-band) creates substantially more inter-modulation products than the 2Tx counterpart where the implication to emission requirements as well as REFSENS impact is not well understood and may not be feasible in the Rel-18 timeframe

- Work objectives [RAN4]

- Enhance the core requirements for UEs supporting both UL MIMO and UL CA under the assumption of a UE architecture with 3 Tx chains
- NOTE: this is identified as Case 2 in the RAN email discussions related to 3 Tx

- Further discuss the feasibility of 3Tx with 3 non-contiguous CCs

- NOTE: this is partially identified as Case 3 in the RAN email discussions related to 3 Tx, although this scenario also includes the case of a single band with 3 non-contiguous sub-blocks

# ETC applicability for FR2 requirements

---

- Background

- During the development of Rel-15 requirements, RAN4 applied exemptions on the verification of the following requirements (to be verified under NTC):
  - Spherical coverage EIRP, spherical coverage EIS, and beam correspondence
- With the Rel-17 study item on FR2 measurement methodology enhancements having concluded the objective related to ETC testability, it is now feasible for test equipment to perform TRP and spherical coverage measurements of FR2 devices under ETC
- RAN4 should re-examine the exemptions from ETC applied to the above requirements, quantify the deltas, and find a solution to enable ETC applicability

- Work objectives [RAN4]

- Study and quantify the deltas in the following core requirements between NTC and ETC:
  - Spherical coverage EIRP, spherical coverage EIS, beam correspondence
- Once these gaps are identified, RAN4 to adopt one of the following approaches for each requirement:
  - Introduce a new requirement with ETC applicability
  - Retain the existing requirement, update its applicability to ETC, and request RAN5 to increase measurement uncertainty and test tolerance to compensate for the determined delta

# UE antenna scaling for FR2-1 and FR2-2

---

- Justification

- Any UE implementation can enable and disable tx/rx chains driving the corresponding FR2 antenna elements transparently to the network, and we do observe this behavior in the field. The motivation for this study is rooted in the observation that when the UE performs this scaling autonomously, there is a delay until the network knows by receiving UE measurement report or PHR report. The cause for performance degradation is how fast the UE can inform the network of its scaling with such reports. Before the network receives such updates, the network would rely on previous reports and there is a mismatch between what the network assumes and what the UE uses, which leads to performance degradation. The major questions here are how much degradation in system performance does transparent antenna scaling involve, and how this degradation can be mitigated.

- Study phase objectives [RAN4]

- Quantify the impact on network performance by the UE performing antenna scaling
  - E.g. UE scales from N elements to 2 elements and from 2 elements to N (where N depends on FR2-x assumptions on antenna array size); other scenarios are not precluded
  - UE may determine different antenna switching points based on Rx signal strength, Rx signal quality, Tx output power level, or Tx power headroom
  - Optimal allocation of the number of UE antenna elements to meet desired downlink and uplink coverage can be different
- Identify potential solutions to mitigate the impact of autonomous UE antenna scaling on NW performance
- Identify the impact of UE antenna scaling on UE RF requirements (e.g. TPC, max input level) and the associated testability

- Work phase objectives [RAN4]

- If the impact on network performance and the potential solutions are found feasible, then specify the related requirements

# Preliminary analysis (1)

## ■ Introduction

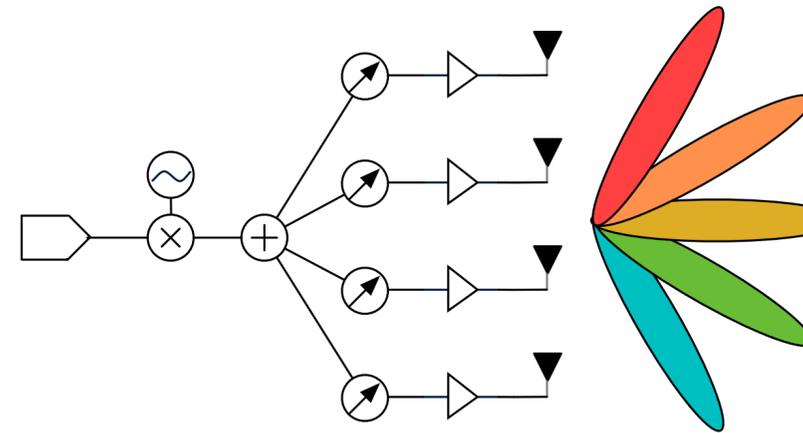
- As a technique to reduce the power consumption of FR2-1 and FR2-2 UEs, a procedure to enable/disable antenna elements with corresponding RF chains can be employed (antenna scaling)
- When the UE scales antenna arrays, its analog beam forming codebook undergoes an instantaneous change
- Antenna scaling can impact NW performance, UE RF requirements on TPC/max input level, and the associated test procedure

## ■ Overview of our proposals

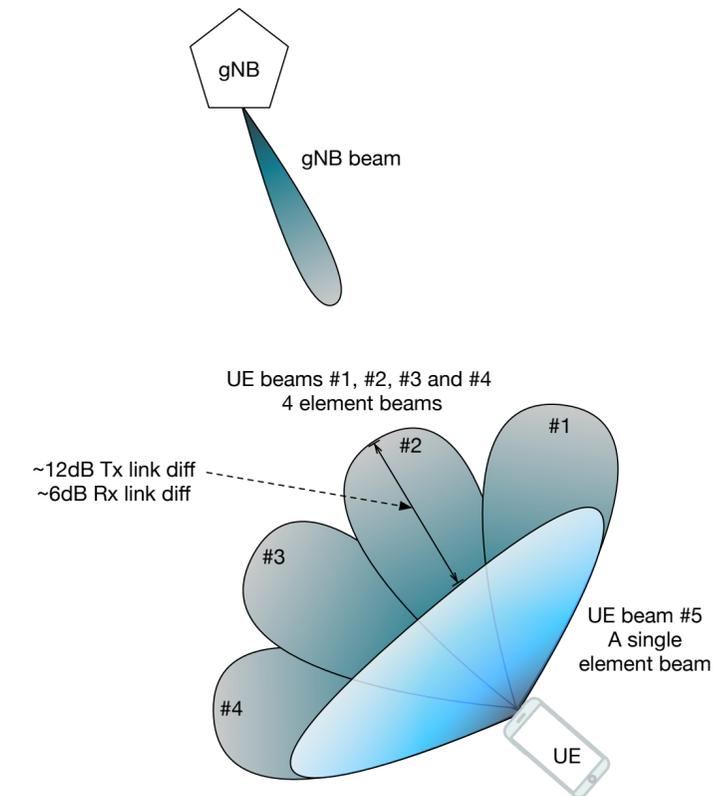
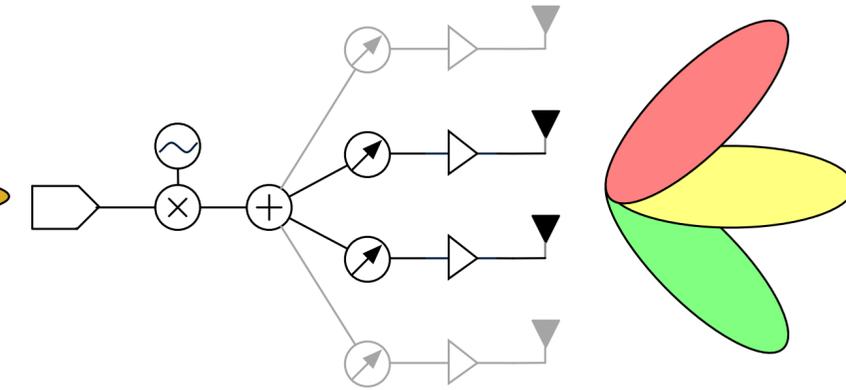
- We propose to study this topic as a Rel-18 FR2-1 and FR2-2 RF study item
- The study should quantify the impact on network performance
  - E.g. UE scales from 4x1 to 2x1 and from 2x1 to 4x1
  - UE may determine different antenna switching points based on Rx signal strength, Rx signal quality, Tx output power level, or Tx power headroom
  - Optimal allocation of the number of UE antenna elements to meet desired downlink and uplink coverage can be different
- The study should identify potential solutions to mitigate impact on NW performance
- The study should also identify the impact of UE antenna scaling on UE RF requirements (e.g. TPC, max input level) and the associated testability

## FR2-x UE antenna element scaling

Example RF architecture with 4 antenna elements



Example RF architecture with 2 antenna elements



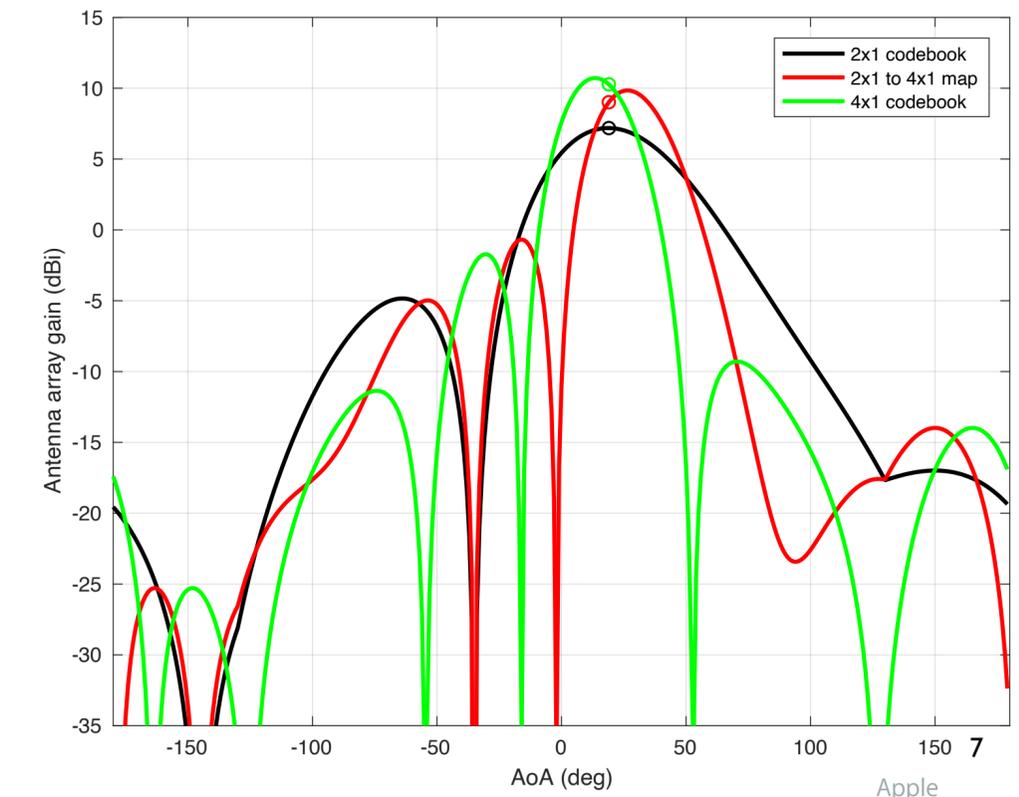
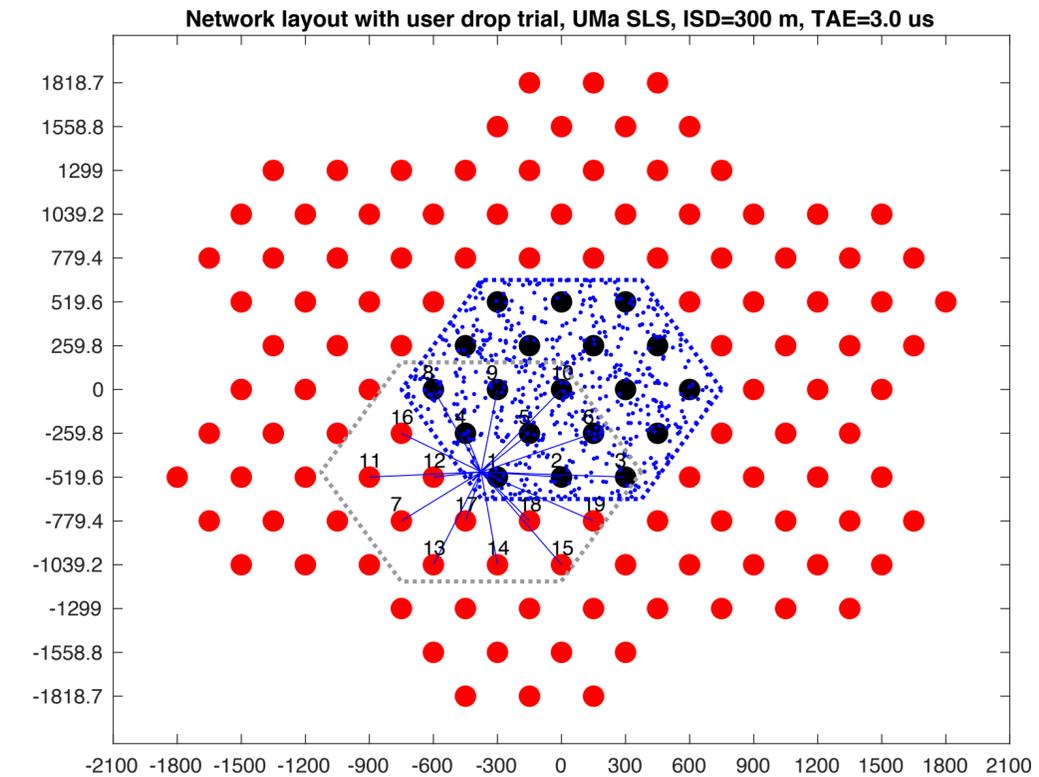
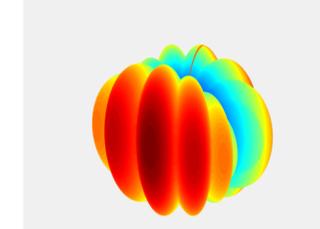
# Preliminary analysis (2)

- Preliminary system level simulations have been performed to quantify impact on NW performance due to UE antenna element scaling
  - SLS setup:
    - 19 sites with Euclidean distance wrap-around; 3 sectors per site (see TR38.803)
    - 10 users per sector => 570 users per trial; 201 trials
    - NW topologies: ISD = 300 m
      - NOTE: more topologies can be evaluated
- Modeling sector-UE coupling loss
  - BS antenna assumptions: 3 sectors per site, 16x8 elements each sector
  - UE antenna assumptions: 2 panels, 4x1 elements each
    - User orientation in azimuth randomized over 360 deg
  - Path loss modeled as UMa-LOS (see TR38.803)
  - $f = 28$  GHz
- Modeling antenna scaling
  - Scenario 1: 4x1 UE scales down to 2x1
  - Scenario 2: 2x1 UE scales up to 4x1
- Analysis:
  - For each UE select best beams according to initial element configuration in each scenario
  - For each UE use a fixed beam mapping table to select the beam after antenna scaling
  - Calculate the difference in user-site coupling gain between fixed beam mapping and further beam refinement after antenna scaling

Coverage pattern, 1 panels, 16x8 elements, impairment IDEAL, f=27925 MHz



Coverage pattern, 2 panels, 4x1 elements, impairment IDEAL, f=27925 MHz



# Preliminary analysis (3)

- Results (gain loss due to fixed beam mapping)

- Gain loss is  $<0.5$  dB for 60% of the users (Scen. 2)
- Gain loss is  $>1.0$  dB for 20% of the users (Scen. 2)
- Gain loss is greater when scaling 2x1 up to 4x1 rather than scaling 4x1 down to 2x1
- Gain loss is greater when user-site association is not optimal (i.e. coupling gain to 2nd strongest site)

- Potential next steps, as part of the proposed study:

- Implement antenna scaling switching points to select only the users where scaling is applicable
- Take DL SNR and UL TPC into account when scaling (i.e. enable/disable Tx and Rx chains) and evaluate UL & DL link budget
- Consider other frequencies (e.g. FR2-2) and antenna arrays with greater number of elements
- Other aspects not precluded

