



**KEYSIGHT**  
TECHNOLOGIES

# 3GPP 5G NR RAN4 Update and mmWave OTA Test

*R&D Engineer / Keysight Technologies*

*YoungRyoul Kim*

# 5G SUMMIT



# 3GPP 5G NR RAN4 update

# 5G NR RAN4 – 3GPP context

## 5G NR SPECIFICATIONS: CONDUCTED VS RADIATED

According to 3GPP 38.803:



RAN4 UE specs	Spec title
38.101-1	NR; User Equipment (UE) radio transmission and reception Technical Specification for NR <u>range 1</u> for UE RF requirements
38.101-2	NR; User Equipment (UE) radio transmission and reception Technical Specification for NR <u>range 2</u> for UE RF requirements
38.101-3	NR; User Equipment (UE) radio transmission and reception Technical Specification for NR <u>interworking between NR range1 + NR range2</u> and <u>between NR and LTE</u> for UE RF requirements
38.133	NR; Requirements for support of radio resource management
38.101-4	NR; User Equipment (UE) performance requirements
38.133	NR; Requirements for support of radio resource management

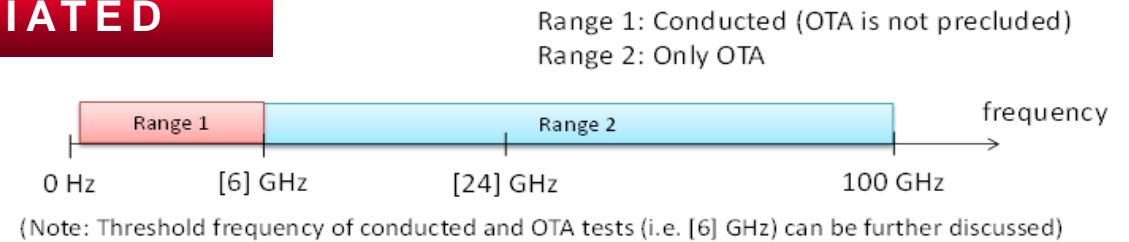


Figure 6.2.1-1: Frequency range 1/2 and the threshold.



Mode	Frequency ranges involved	LTE connections	FR1 connections	FR2 connections
SA	FR1	--	Conducted-calibrated	--
SA	FR2	--	--	Radiated calibrated
SA	FR1 (Pcell) + FR2	--	Radiated -not calibrated (*)	Radiated calibrated
NSA	LTE + FR1	Conducted-calibrated	Conducted-calibrated	--
NSA	LTE + FR2	Radiated --not calibrated (*)	--	Radiated calibrated
NSA	LTE + FR1 (P cell) + FR2	Radiated --not calibrated (*)	Radiated --not calibrated (*)	Radiated calibrated

(\*) When measuring FR2.

No FR1/LTE simultaneous measurements with FR2.

FR1 and LTE tested without FR2

References: [R4-1803261](#), [R4-1801587](#)

# Frequency Bands and Operating Bands

- RAN4 has defined the following two frequency ranges
  - For FR1 (often referred to as sub6), many bands and testing concepts will be re-used from LTE
  - For FR2, new bands had to be defined and new testing concepts had to be developed
- The operating bands defined in **FR1** and **FR2**

Table 5.1-1: Definition of frequency ranges

Frequency range designation	Corresponding frequency range
FR1	450 MHz – 6000 MHz
FR2	24250 MHz – 52600 MHz

Table 5.2-1: NR operating bands in FR1

NR operating band	Uplink (UL) operating band BS receive / UE transmit $F_{UL\_low}$ – $F_{UL\_high}$	Downlink (DL) operating band BS transmit / UE receive $F_{DL\_low}$ – $F_{DL\_high}$	Duplex Mode
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL
n86	1710 MHz – 1780 MHz	N/A	SUL

Table 5.2-1: NR operating bands in FR2

Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	$F_{UL\_low}$ – $F_{UL\_high}$	$F_{DL\_low}$ – $F_{DL\_high}$	
n257	26500 MHz – 29500 MHz	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	24250 MHz – 27500 MHz	TDD
n260	37000 MHz – 40000 MHz	37000 MHz – 40000 MHz	TDD
n261	27500 MHz – 28350 MHz	27500 MHz – 28350 MHz	TDD

# FR1 frequency extension to 7.125 GHz (A.I 6.2)

R4-1902221

- RAN asked RAN4 to confirm the extension of FR1 range to 7.125GHz for newly available unlicensed spectrum above 5.925GHz in the U.S. and Europe (RP-182876) and verify that this extension can be applied in release 15 set of specifications.
- RAN4 concludes it is feasible to **extend the FR1 range to 410MHz - 7.125GHz in Rel-15.**
- Update on FR1 definition or clarification of frequency range needs for below RAN4 specifications: TS38.104, TS38.101-1, TS38.101-2, TS38.101-3, TS38.141-1, TS38.141-2, TS38.113, TS38.124, TR38.817-01
- Core requirement in TS38.104, TS38.101-1 and TS38.101-3
  - FR1 extension has no impact on RF requirements for existing NR bands in Rel-15
  - For operation in the range of 410-450MHz and/or 6-7.125GHz , limits and applicability of core requirements shall be determined in the corresponding WI in Rel-16 or future release (Note).
- Conformance requirement in TS38.141-1 and TS38.141-2
  - FR1 extension has no impact on conformance testing requirements for existing NR bands in Rel-15 including MU and TT.
  - For operation in the range of 410-450MHz and/or 6-7.125GHz , limits and applicability of conformance requirements shall be determined in the corresponding WI in Rel-16 or future release (Note).

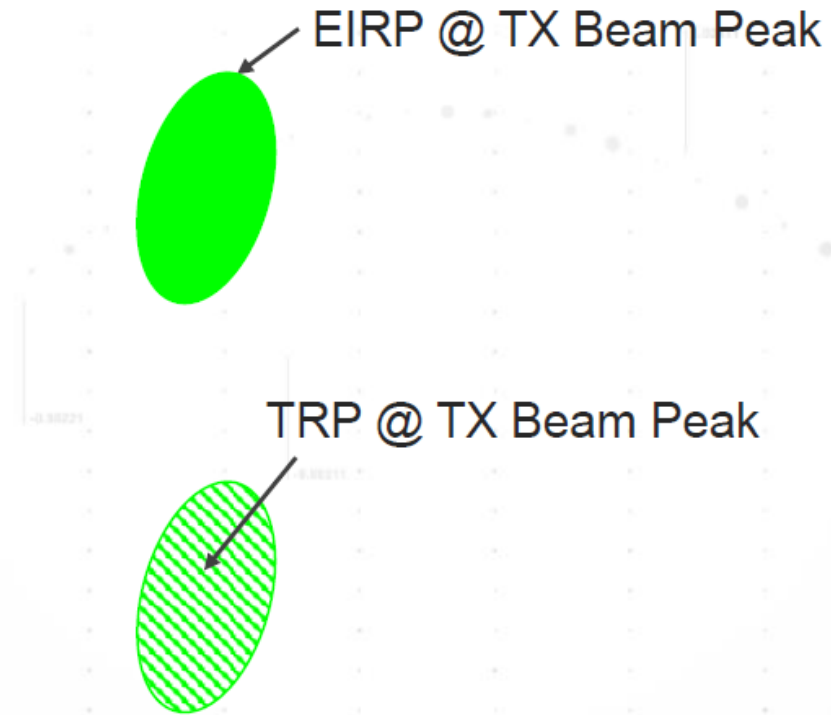
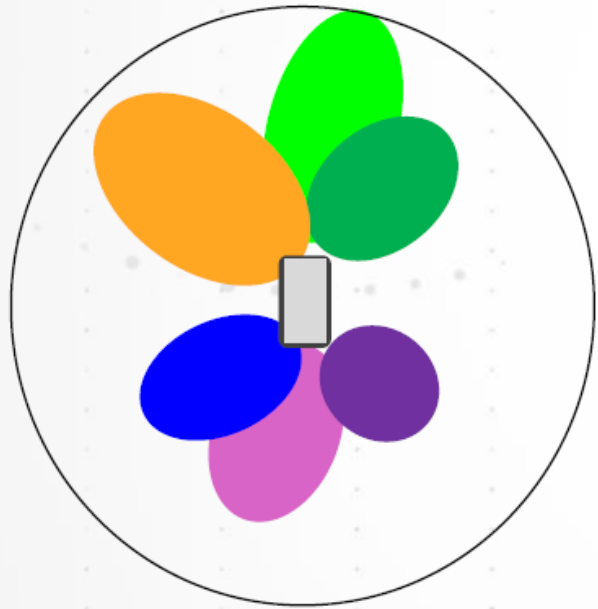
**Table 5.1-1: Definition of frequency ranges**

Frequency range designation	Corresponding frequency range
FR1	450-410 MHz – 6000-7125 MHz
FR2	24250 MHz – 52600 MHz

# Test Metrics

## EIRP, EIS, @BEAM PEAK

- 3GPP requires all EIRP, EIS, TRP measurements to be performed at the respective beam peaks



# UE Beamlock Function (UBF)

- Without UE Beamlock Function (UBF), the UE keeps forming the beam towards the SS
  - Required for Spherical Coverage, TX & RX Beam Peak Searches, EIS, EIRP measurements
- The UBF is intended for making the UE to lock the UE antenna pattern once it has formed a beam towards the base station (SS) direction
  - Required for TRP measurements
  - Recommended to prevent the beam from moving when performing measurements at low SNRs



# 5G NR RAN4 - RF measurement set-up

## OVERVIEW


- 3 types of DUT Antenna configuration defined : 
  - DUT Antenna Configuration can be chosen by an optional declaration from a manufacturer
- 4 permitted testing methodologies agreed so far:
  - Direct Far Field (DFF) → Included in 38.810 v2.0.0
  - Direct Far Field (DFF) simplification for centre of beam measurements → Included in 38.810 v2.0.0
  - Indirect Far Field (IFF – Method 1) – Compact Antenna Test Range → Included in 38.810 v2.0.0
  - Near Field to Far Field Transform (NFTF) → Included in 38.810 v2.1.0
- Attempts to also add Reverberation chamber to these testing methodologies ([R4-1803412](#)). Many concerns → Not approved.
- Attempts to also add Near Field without Far field transform to these testing methodologies (R4-1805896). Many concerns → Not approved.
- Test methods are applicable to test cases based on being less than or equal to a threshold MU.
- The threshold MU for the equivalence framework will be based on DFF for  $D \leq 5\text{cm}$  and for IFF for  $D > 5\text{cm}$
- Test method applicability = f (UE category, D, actual testing distance and resulting calculated MU).
- Applicability of testing methodologies to UE category based on antenna design defined as:

Table 5.3-1: DUT Antenna Configuration

DUT Antenna Configuration	Description
Configuration 1	Maximum one antenna panel with $D \leq 5\text{ cm}$ active at any one time
Configuration 2	More than one antenna panel $D \leq 5\text{ cm}$ without phase coherency between panels active at any one time
Configuration 3	Any phase coherent antenna panel of any size (e.g. sparse array)

Table 5.3-2: Overview of test method applicability for permitted test methods

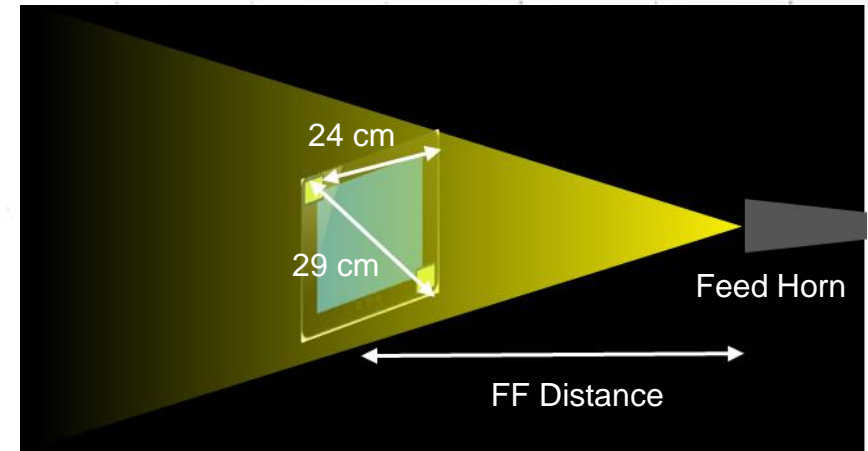
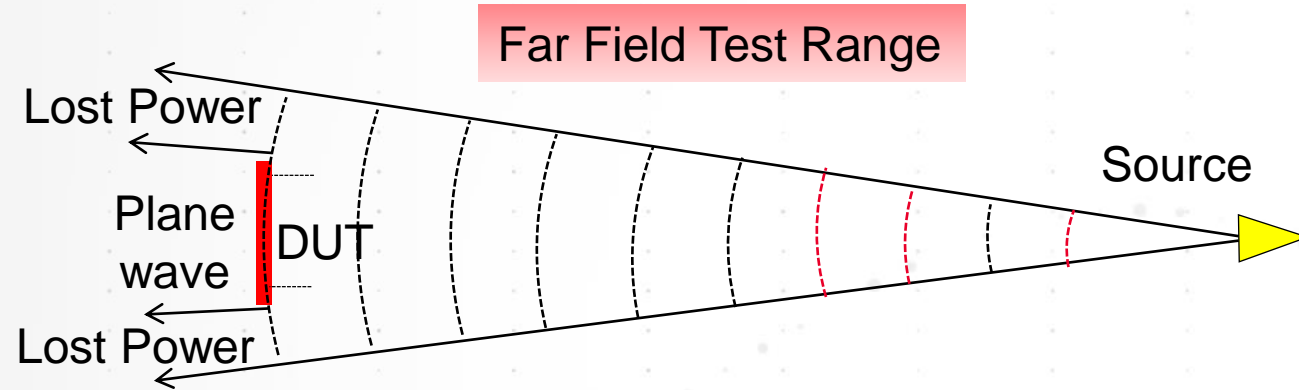
DUT Antenna Configuration	Direct Far Field (DFF)	Indirect Far Field (IFF)	Near Field to far field transform (NFTF)	TBD
Configuration 1	Yes	Yes	Yes	TBD
Configuration 2	Yes	Yes	Yes	TBD
Configuration 3	No	Yes	No	TBD
NOTE: A positive indication means that applicability exists for at least one RF test cases for the given UE Antenna Configuration				



CATR (IFF) covers all UE categories based on antenna design

# Direct Far Field Test Range

CONSIDER DUT HAVING CHARACTERISTIC DIMENSION  $D$

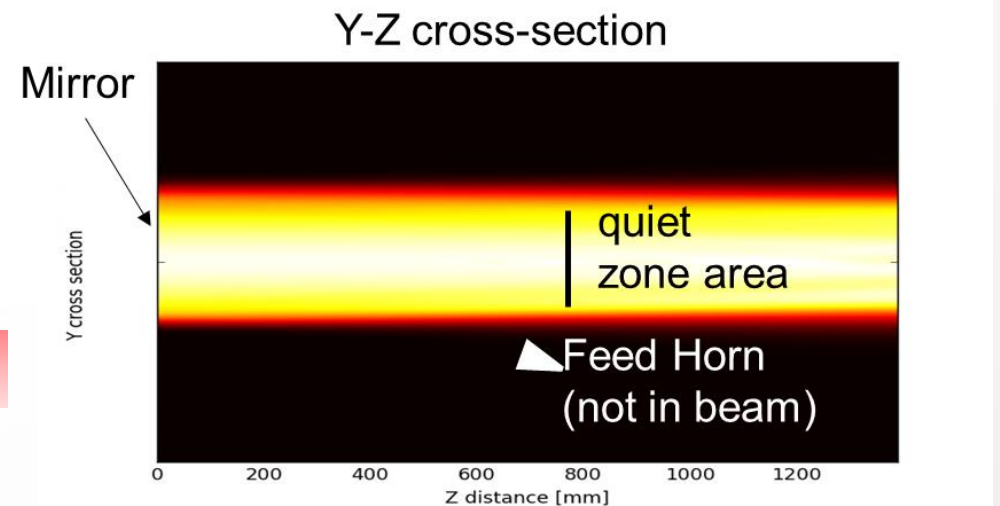
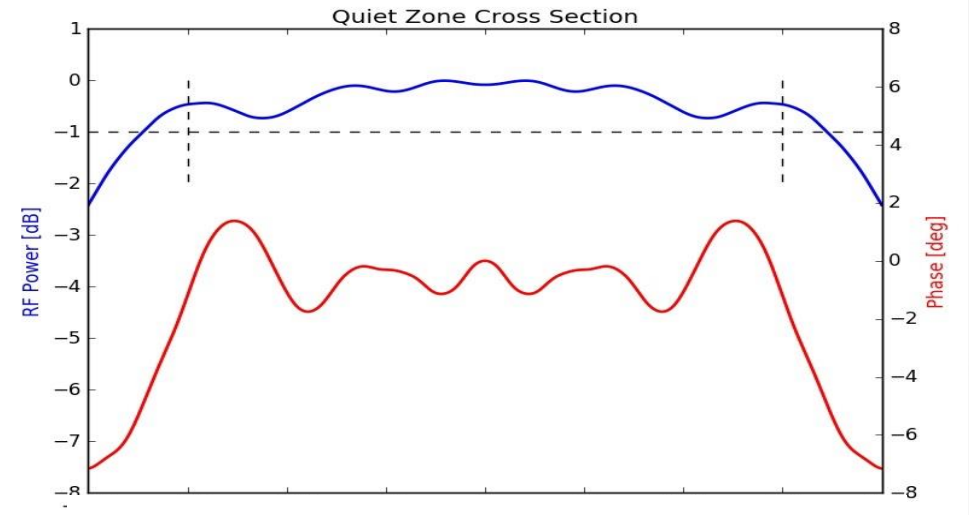
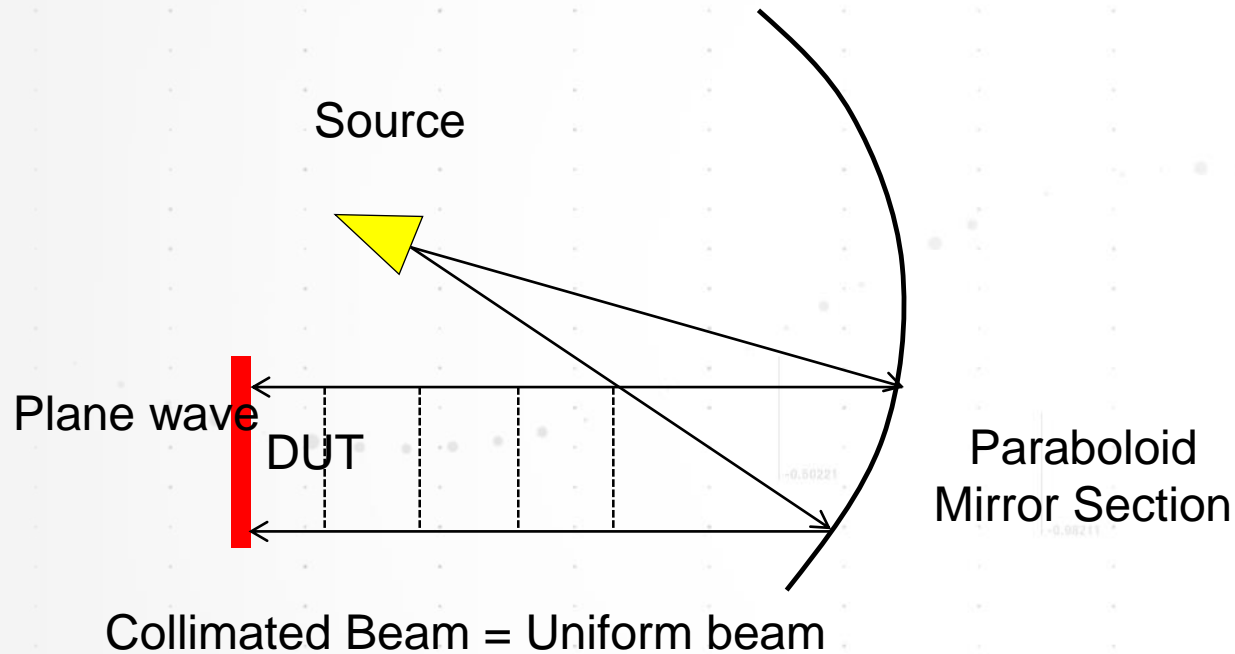


Place DUT at distance of minimum  $2D^2/\lambda$  from Source:

- Phase variation is 22.5°
  - Have to move well beyond minimal  $2D^2/\lambda$  to get phase variation much less than 22.5°
- Power decreases as distance from source increases
- SNR becomes more difficult to achieve

# Compact Antenna Test Range (CATR)

CONSIDER DUT HAVING CHARACTERISTIC DIMENSION  $D$



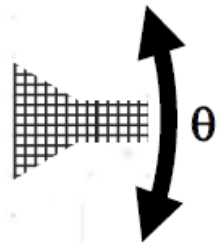
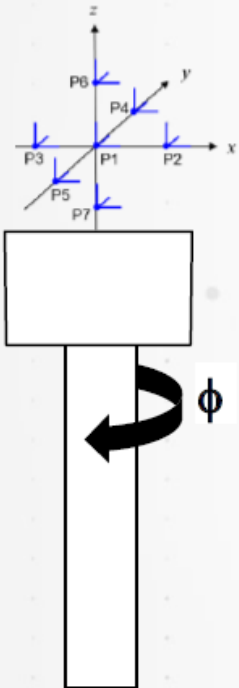
Power does not decrease with distance of DUT from Mirror

# Quality of Quiet Zone

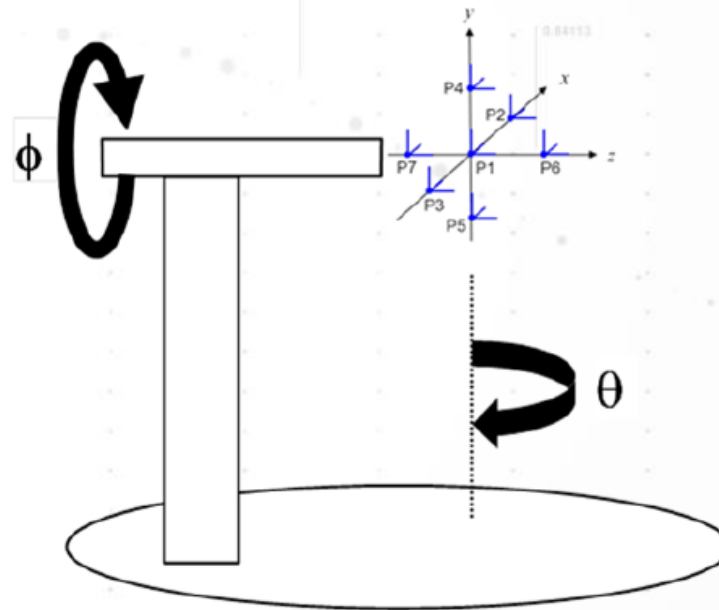
DEFINED IN TR38.810

- The procedure was defined separately for distributed-axes and combined-axes system

## Distributed-axes System



## Combined-axes System

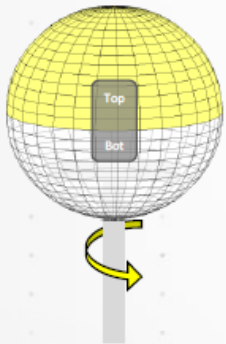


# Re-Positioning Approach

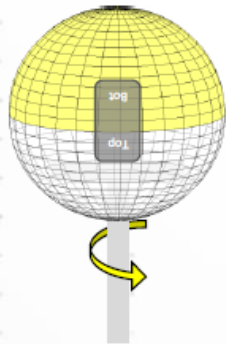
DEFINED IN TR38.810

- Near-field coupling effects between the antenna and the pedestals/positioners/fixtures generally cause increased signal ripples. Re-positioning the DUT by directing the beam peak away from those areas can reduce the effect of signal ripple on EIRP/EIS measurements.
  - DUT orientation 1: the beam peak is directed to the DUT's upper hemisphere
  - DUT orientation 2: the beam peak is directed to the DUT's lower hemisphere

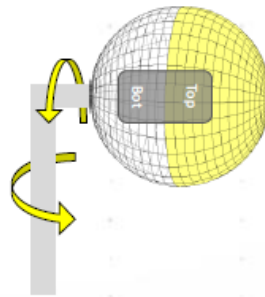
Distributed-Axes System:  
DUT Orientation 1



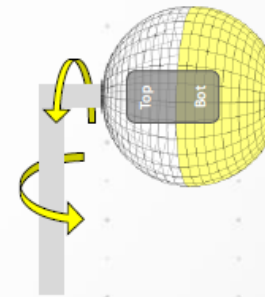
Distributed-Axes System:  
DUT Orientation 2



Combined-Axes System:  
DUT Orientation 1

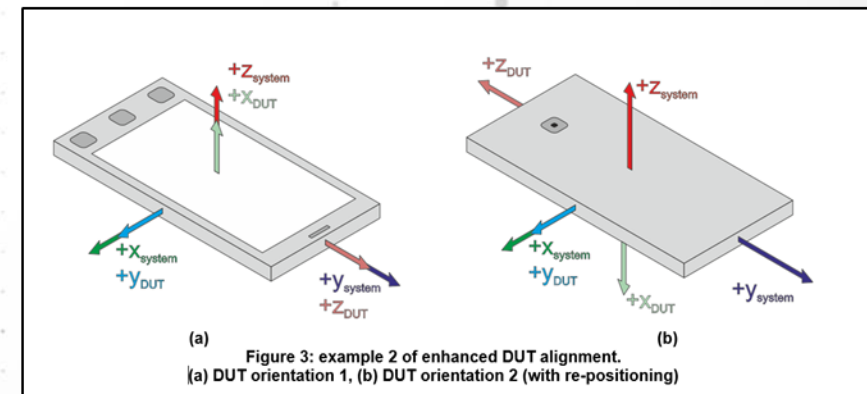
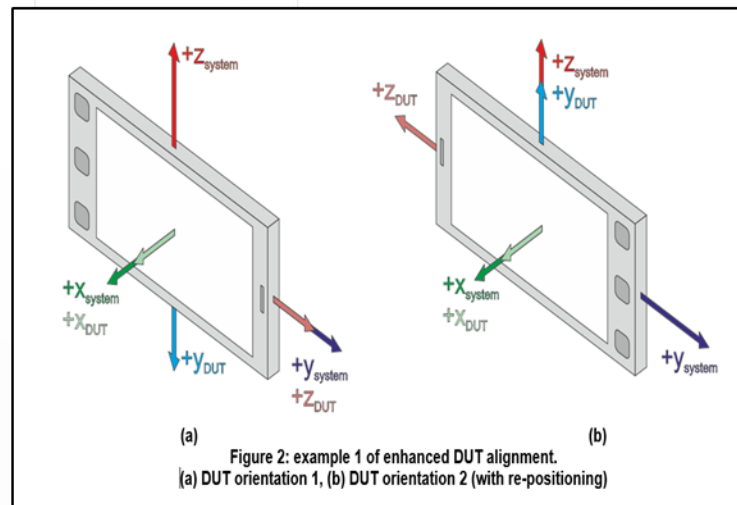
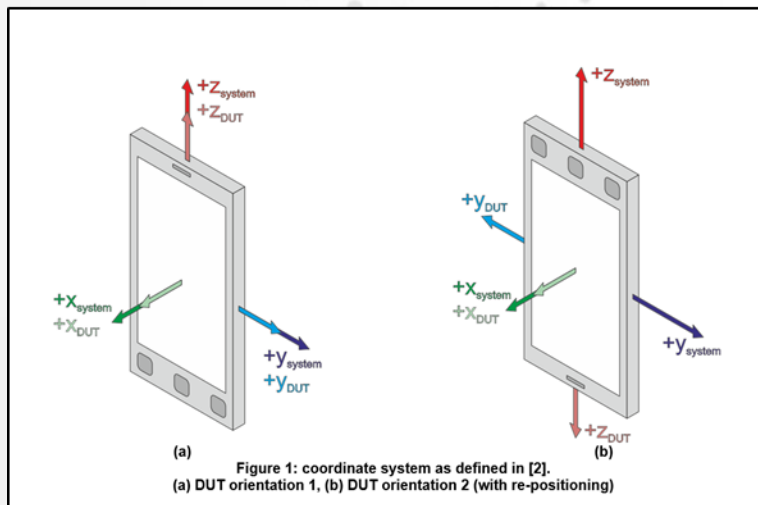


Combined-Axes System:  
DUT Orientation 2



## R4-1901360: ENHANCEMENT OF POSITIONING GUIDELINES

- The reference coordinate system defined for LTE MIMO OTA in [1] was reused in TR 38.810, but many of the challenges for mmWave testing were not considered.
- A clear example for that was the need to introduce the allowance for DUT re-positioning, as detailed in section C.3 in [2], to overcome and/or minimize the near-field coupling effect between the antenna(s) within the DUT and the pedestals/positioners/fixtures.
- Even if this allowance seems sufficient in theory, certain UE implementations may underperform on EIRP/EIS based test cases (e.g. min EIRP, REFSENS, Spatial coverage...) depending on how the UE array(s) are placed with respect to the measurements antenna or how the fixture couples with the actual antenna array placement within the UE. A solution for that could be to introduce some freedom on how the UE axis are aligned with the test system coordinate axis.
- Further discussion is required to decide on the concrete set of allowed alignments, together with other considerations in order to minimize the impact on the traceability between different test systems.
- **Proposal: Consider alternate DUT positioning options in the test system as shown below.**



# Measurement Grid Types

- Two measurement grid types have been studied in more detail
  1. Constant Step Size: the azimuth and elevation angles are uniformly distributed
  2. Constant Density: measurement points are evenly distributed on the surface of the sphere with a constant density

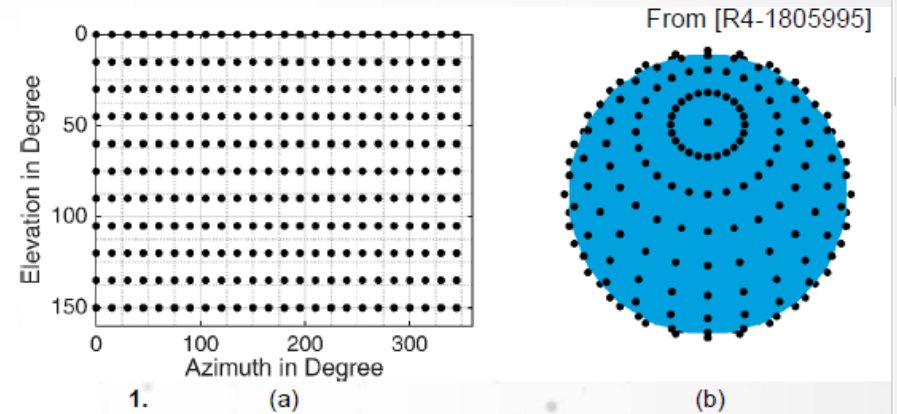


Figure 2: Constant Step Size Measurement Grid as  
(a) Azimuth / Elevation Representation (b) Sphere Representation

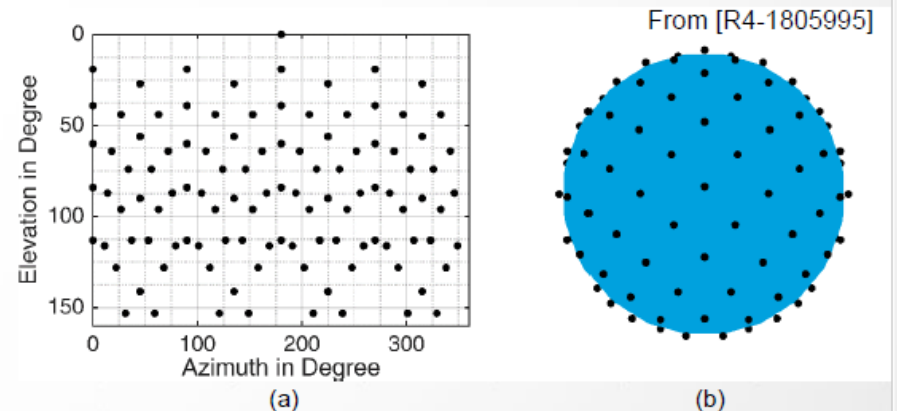
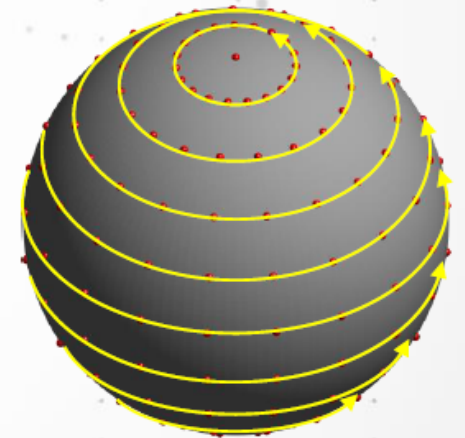
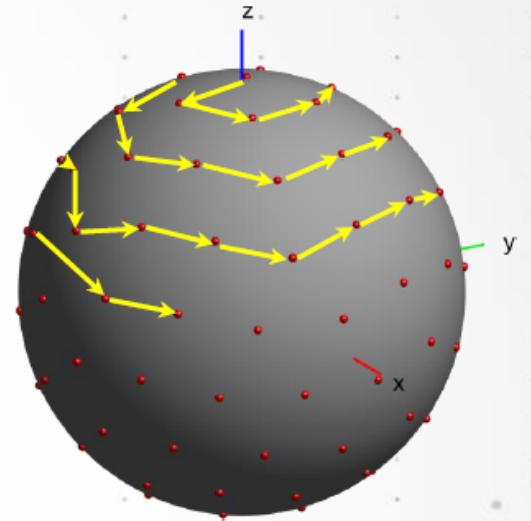


Figure 3: Constant Density Measurement Grid as  
(a) Azimuth / Elevation Representation (b) Sphere Representation

# TRP Measurement Grids

## CONSTANT DENSITY VS CONSTANT STEP SIZE

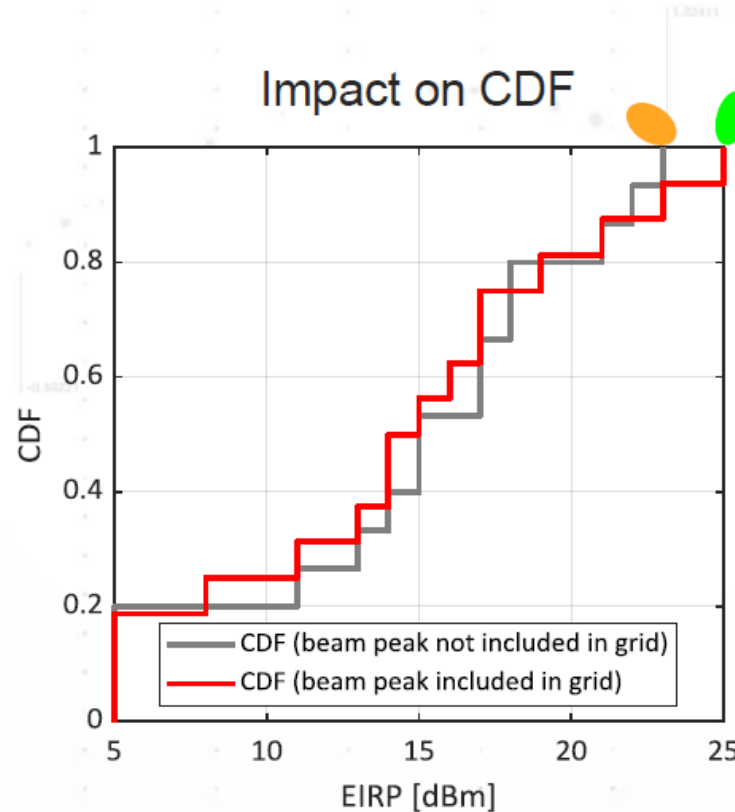
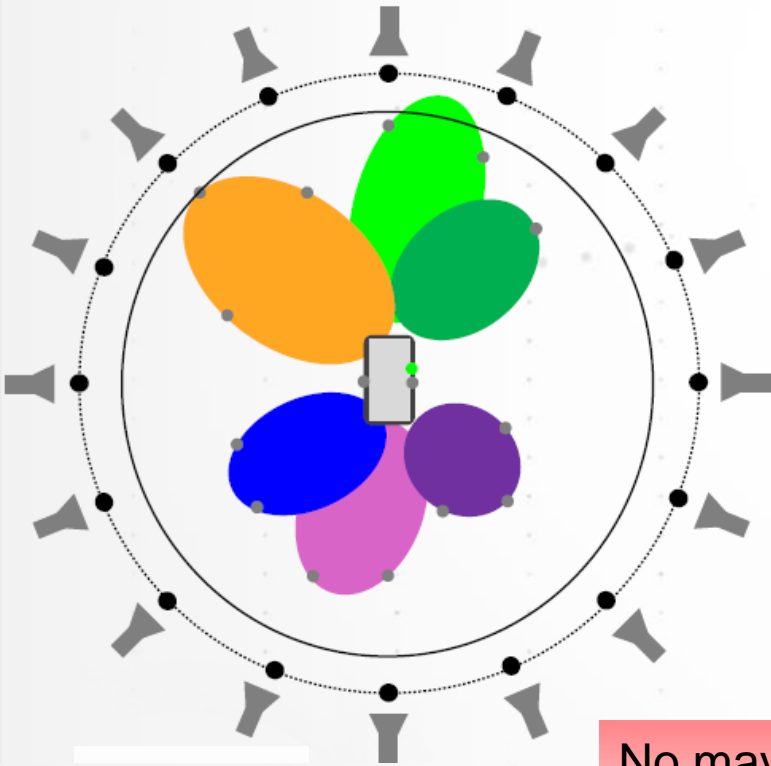
- The main concerns with the constant density
  - The optimum path between the grid points needs to be determined (“traveling sales man”)
  - Both positioners (AZ/EL, Roll/AZ, Theta/Phi) need to move to go from one measurement point to the next, i.e., only step-step measurements are suitable for the constant density grids
- The constant step size grids, on the other hand, allow for a step-continuous sweep measurement approach where one positioner is stepped from one longitude (latitude) to another while the latitude (longitude) can be scanned continuously which allows for a potentially much faster test time even though the min number of test points is larger



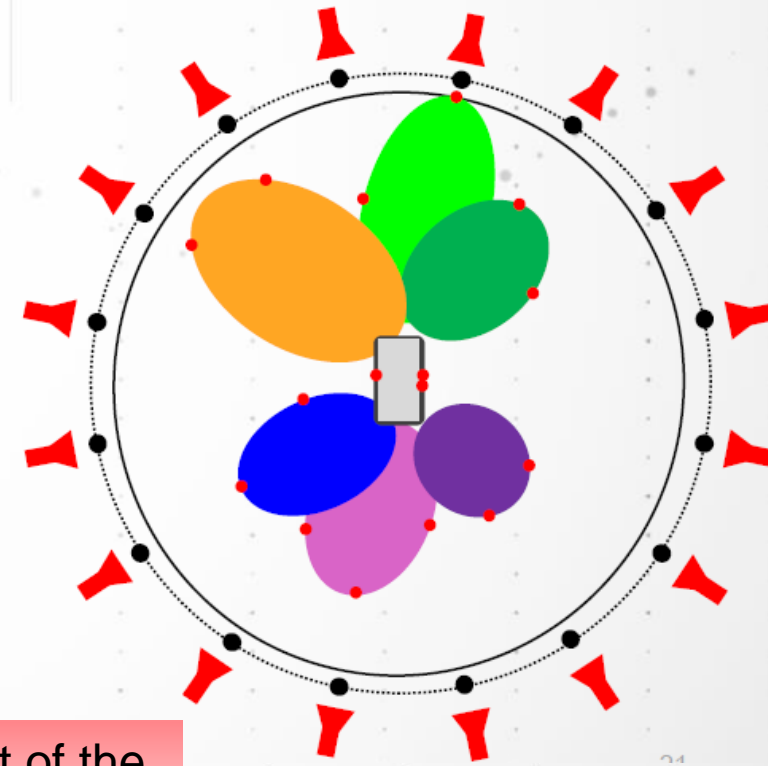
# Test Metrics

## SPHERICAL COVERAGE, CDF

- Beam peak is not included on spherical coverage grid



- Beam peak is included on spherical coverage grid

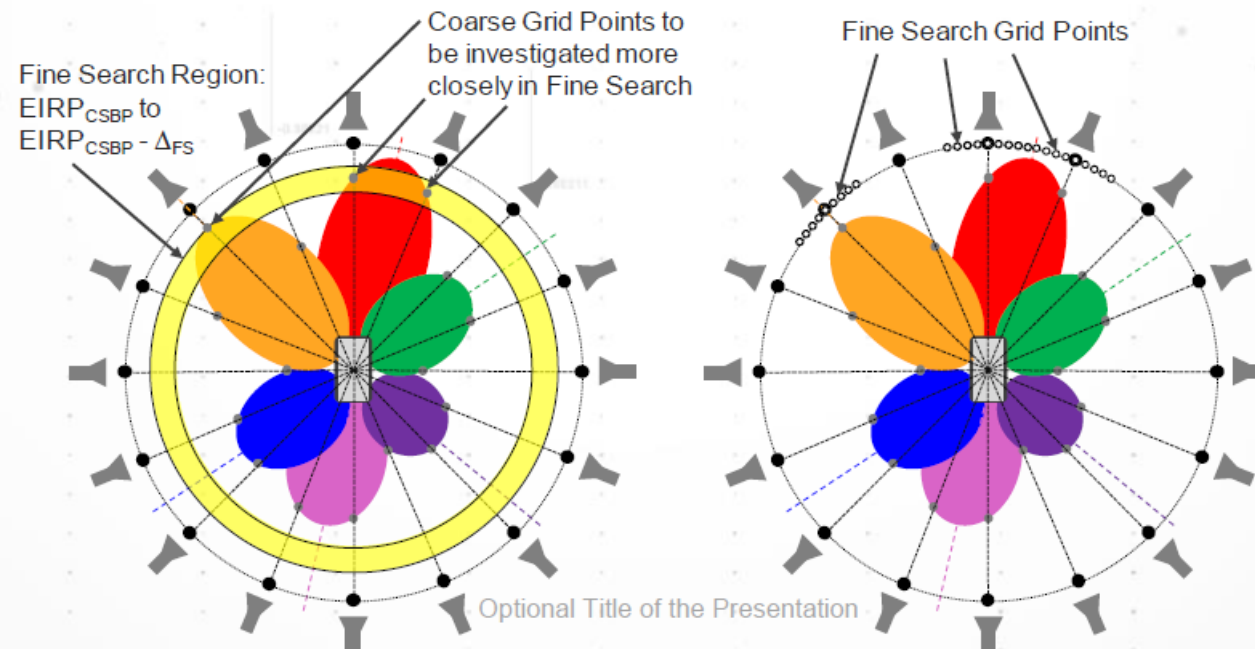


No mayor difference on CDF if beam peak is not part of the spherical coverage grid

# TX Beam Peak Search Grids

DEFINED IN TR38.810

- A coarse & fine grid approach [R4-1811093] for the TX Beam Peak Search was introduced in RAN4#88 in order to reduce the number of test points and thus test time
- The coarse grid might not be suitable for spherical coverage as the beam peak has to be included in the grid. Alternatively, an MU element might be introduced



# EIRP measurement procedure

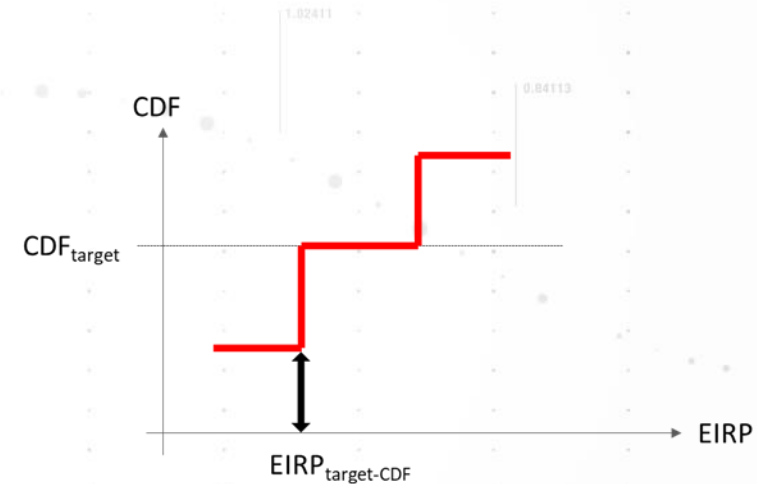
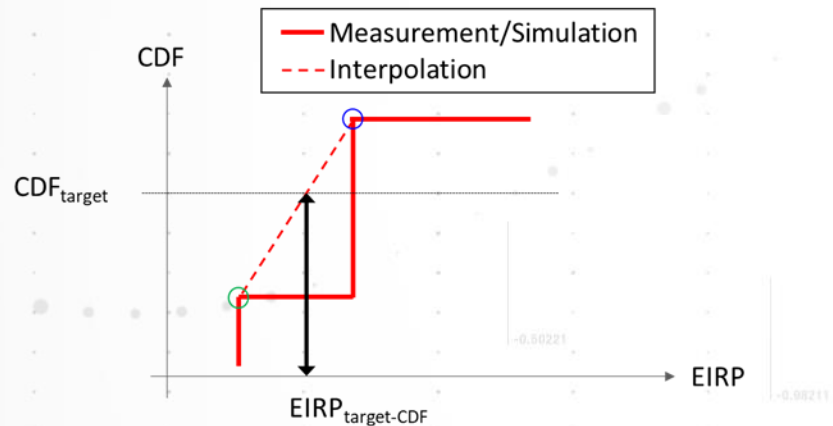
R4-1816260 (INTEL CORPORATION, ROHDE & SCHWARZ, KEYSIGHT, APPLE)

- The following procedure was **updated**:
  - Peak EIRP Measurement Procedure
    1. The TX beam peak direction is where the maximum total component of EIRP is found, including the respective polarization of the measurement antenna used to form the TX beam, according to 5.2.1.3.7.
    2. Connect the SS (System Simulator) with the DUT through the measurement antenna with **polarization reference Pol<sub>Link</sub>** to form the TX beam towards the TX beam peak direction and respective polarization.
    3. Lock the beam toward that direction for the entire duration of the test.
    4. Measure the mean power  $P_{\text{meas}}(\text{Pol}_{\text{Meas}}=\theta, \text{Pol}_{\text{Link}})$  of the modulated signal arriving at the power measurement equipment (such as a spectrum analyser, power meter, or gNB emulator).
    5. Calculate  $\text{EIRP}(\text{Pol}_{\text{Meas}}=\theta, \text{Pol}_{\text{Link}})$  by adding the composite loss of the entire transmission path for utilized signal path,  $L_{\text{EIRP},\theta}$ , and frequency to the measured power  $P_{\text{meas}}(\text{Pol}_{\text{Meas}}=\theta, \text{Pol}_{\text{Link}})$ .
    6. Measure the mean power  $P_{\text{meas}}(\text{Pol}_{\text{Meas}}=\phi, \text{Pol}_{\text{Link}})$  of the modulated signal arriving at the power measurement equipment.
    7. Calculate  $\text{EIRP}(\text{Pol}_{\text{Meas}}=\phi, \text{Pol}_{\text{Link}})$  by adding the composite losses of the entire transmission path for utilized signal path,  $L_{\text{EIRP},\phi}$ , and frequency to the measured power  $P_{\text{meas}}(\text{Pol}_{\text{Meas}}=\phi, \text{Pol}_{\text{Link}})$ .
    8. Calculate total  **$\text{EIRP}(\text{Pol}_{\text{Link}}) = \text{EIRP}(\text{Pol}_{\text{Meas}}=\theta, \text{Pol}_{\text{Link}}) + \text{EIRP}(\text{Pol}_{\text{Meas}}=\phi, \text{Pol}_{\text{Link}})$**

# Definition of EIRP<sub>50%CDF</sub>

R4-1816262 (KEYSIGHT TECHNOLOGIES, ROHDE&SCHWARZ, APPLE, EMITE ING.)

- The definition of the EIRP at the target CDF (for PC3: 50%) was agreed in [R4-1814419] for cases where CDF is flat over EIRP ranges



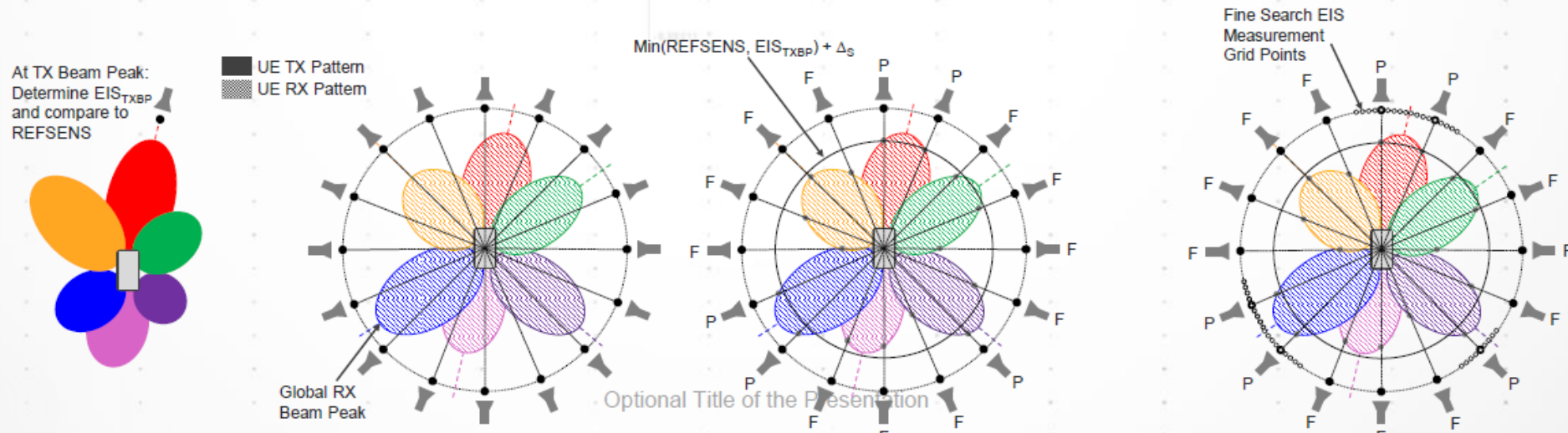
From [R4-1814419]:

**Proposal: For the case when the target CDF is not met with any EIRP values, it is proposed to determine the min. EIRP at the target CDF based on an interpolation of the CDF curve between the raising edges located right above the CDF target and right below the target. For the case where the target CDF is met with one more or EIRP value, define the min. EIRP at the target CDF as the min. EIRP value that meets the CDF target.**

# RX Beam Peak Search Grids & EIS Spherical Coverage

DEFINED IN TR38.810

- In RAN4#88, an EIS spherical coverage requirement was introduced. From the UE RF chairman notes: “RAN4 specifies EIS spherical coverage requirement. How to test the requirement for UE with or without beam correspondence will be further discussed”
- The coarse approach proposed in [R4-1811035] based on TP is not suitable for spherical coverage as the measurement have to be based on EIS (or RSRP with much increased measurement uncertainty)
- Separate spherical coverage and beam peak grids might need to be defined if coarse & fine beam peak search approaches are considered



# EIS measurement procedure

R4-1816260 (INTEL CORPORATION, ROHDE & SCHWARZ, KEYSIGHT, APPLE)

- The following procedure was **updated**:
  - Peak EIS Measurement Procedure
    - The RX beam peak direction is where the minimum EIS is found according to 5.2.1.3.8.
    - 1. Establish a connection between the DUT and the SS with the downlink signal applied to the **Pol<sub>Link</sub> = θ-polarization** of the measurement antenna
    - 2. Position the UE so that the beam is formed towards the measurement antenna in the RX beam peak direction
    - 3. Determine  $EIS(Pol_{Meas}=\theta, Pol_{Link}=\theta)$  for θ-polarization, i.e., the power level for the θ-polarization at which the throughput exceeds the requirements for the specified reference measurement channel
    - 4. Switch the downlink to the **Pol<sub>Link</sub> = φ-polarization** of the measurement antenna
    - 5. Determine  $EIS(Pol_{Meas}=\phi, Pol_{Link}=\phi)$  for φ-polarization, i.e., the power level for the φ-polarization at which the throughput exceeds the requirements for the specified reference measurement channel
    - 6. Calculate the resulting **averaged** EIS as:  
 **$EIS = 2 * [1/EIS(Pol_{Meas}=\theta, Pol_{Link}=\theta) + 1/EIS(Pol_{Meas}=\phi, Pol_{Link}=\phi)]^{-1}$**

# Decisions Made in UE RF related to Testability

## EIS SPHERICAL COVERAGE (CCDF INSTEAD OF CDF)

- FR2 EIS Spherical Coverage Requirements were finally defined in [R4-1816634](#).
- While EIRP spherical is using the CDF metric, EIS is using the CCDF (=1-CDF) metric instead so that the EIS spherical requirement is defined at the same percentile value of EIRP for consistency

Table 7.3.4.1-1: EIS spherical coverage for power class 1

Operating band	EIS at 85 <sup>th</sup> ile CCDF (dBm) / Channel bandwidth			
	50 MHz	100 MHz	200 MHz	400 MHz
n257	[-89.5]	[-86.5]	[-83.5]	[-80.5]
n258	[-89.5]	[-86.5]	[-83.5]	[-80.5]
n260	[-86.5]	[-83.5]	[-80.5]	[-77.5]
n261	[-89.5]	[-86.5]	[-83.5]	[-80.5]

NOTE 1: The transmitter shall be set to P<sub>UMAX</sub> as defined in subclause 6.2.4  
 NOTE 2: The EIS spherical coverage requirements are verified only under normal thermal conditions as defined in Annex E.2.1.

Table 7.3.4.2-1: EIS spherical coverage for power class 2

Operating band	EIS at 60 <sup>th</sup> ile CCDF (dBm) / Channel bandwidth			
	50 MHz	100 MHz	200 MHz	400 MHz
n257	[-83.5]	[-80.5]	[-77.5]	[-74.5]
n258	[-83.5]	[-80.5]	[-77.5]	[-74.5]
n261	[-83.5]	[-80.5]	[-77.5]	[-74.5]

NOTE 1: The transmitter shall be set to P<sub>UMAX</sub> as defined in subclause 6.2.4  
 NOTE 2: The EIS spherical coverage requirements are verified only under normal thermal conditions as defined in Annex E.2.1.

Table 7.3.4.3-1: EIS spherical coverage for power class 3

Operating band	EIS at 50 <sup>th</sup> ile CCDF (dBm) / Channel bandwidth			
	50 MHz	100 MHz	200 MHz	400 MHz
n257	[-77.4]	[-74.4]	[-71.4]	[-68.4]
n258	[-77.4]	[-74.4]	[-71.4]	[-68.4]
n260	[-73.1]	[-70.1]	[-67.1]	[-64.1]
n261	[-77.4]	[-74.4]	[-71.4]	[-68.4]

NOTE 1: The transmitter shall be set to P<sub>UMAX</sub> as defined in subclause 6.2.4  
 NOTE 2: The EIS spherical coverage requirements are verified only under normal thermal conditions as defined in Annex E.2.1.

Table 7.3.4.4-1: EIS spherical coverage for power class 4

Operating band	EIS at 20 <sup>th</sup> ile CCDF (dBm) / Channel bandwidth			
	50 MHz	100 MHz	200 MHz	400 MHz
n257	[-88.0]	[-85.0]	[-82.0]	[-79.0]
n258	[-88.0]	[-85.0]	[-82.0]	[-79.0]
n260	[-83.0]	[-80.0]	[-77.0]	[-74.0]
n261	[-88.0]	[-85.0]	[-82.0]	[-79.0]

NOTE 1: The transmitter shall be set to P<sub>UMAX</sub> as defined in subclause 6.2.4  
 NOTE 2: The EIS spherical coverage requirements are verified only under normal thermal conditions as defined in Annex E.2.1.

# 5G NR RAN4 – UE types in FR2

R4-1805926

- Consider min peak EIRP level, spherical coverage needs as potential distinguishing factors between UE types (other aspects are not precluded)
- The table below captures all the types discussed so far. It will be revised as new contributions are discussed and requirements are clearer

**NR FR2 UE Type summary**

#	Min Peak EIRP (dBm)	Spherical coverage	Maximum allowed EIRP (dBm)	Maximum allowed TRP (dBm)	Power Class	Comments*
1	[22.0-22.4]	Full sphere	43	23	Power Class 3	Handheld UE
2	[26-30]	Half sphere → Full sphere	43	23	Power Class 2	Vehicle mounted UE (fixed on moving platform)
3	[~35]	Full sphere	43	23	Power Class 4	Higher power mobile UE
4	[30-40]	Half sphere or further limited sphere → Full sphere	55	35	Power Class 1	FWA on fixed platform

\*Note: these notes are meant to illustrate examples that have the requirements listed, other examples are not precluded

# FR2 Power class 3 is default power class

R4-1902490

- Adding PC3 as default power class in TS 38.101-2 for single carrier and CA

## 6.2.1 UE maximum output power

### 6.2.1.0 General

NOTE: Power class 1, 2, 3, and 4 are specified based on the assumption of certain UE types with specific device architectures. The UE types can be found in Table 6.2.1.0-1.

Table 6.2.1.0-1: Assumption of UE Types

UE Power class	UE type
1	Fixed wireless access(FWA) UE
2	Vehicular UE
3	Handheld UE
4	High power non-handheld UE

Power class 3 is default power class.

## 6.2A Transmitter power for CA

### 6.2A.1 UE maximum output power for CA

For downlink intra-band contiguous and non-contiguous carrier aggregation with a single uplink component carrier configured in the NR band, the maximum output power is specified in Table 6.2.1-1.

For uplink intra-band contiguous carrier aggregation for any CA bandwidth class, the maximum output power is specified in Table 6.2.1-1

Power class 3 is default power class.

# UL MIMO REQUIREMENTS IN 38.101-2

## UL MIMO

1. UL-MIMO Requirement defined for the following table(PC3)

Table 6.2D.1.3-1: UE minimum peak EIRP for UL-MIMO for power class 3      Table 6.2D.1.3-4: UE spherical coverage for UL-MIMO for power class 3

Operating band	Min peak EIRP (dBm)
n257	22.4
n258	22.4
n260	20.6
n261	22.4

NOTE 1: Minimum peak EIRP is defined as the lower limit without tolerance.  
NOTE 2: Min Peak EIRP refers to the total EIRP for the UL beams peaks.

Operating band	Min EIRP at 50 %-tile CDF (dBm)
n257	11.5
n258	11.5
n260	8
n261	11.5

NOTE 1: Minimum EIRP at 50 %-tile CDF is defined as the lower limit without tolerance  
NOTE 2: The requirements in this table are only applicable for UE which supports single band in FR2

2. For UL MIMO, UE can use either polarized or spatial UL MIMO in implementation. Requirements are same and only need to test one of the UL MIMO. Thus, it is not proper to define requirements with “polarization”, instead we can use “stream”.

### 6.2D.4 Configured transmitted power for UL-MIMO

For UE configured with UL MIMO ~~either in polarization MIMO or in spatial MIMO scheme~~, the configured maximum output power  $P_{\text{CMAX},c}$  for serving cell  $c$  is defined as sum of all streams and is bound by limits set in section 6.2.4.

### 6.4D Transmit signal quality for UL-MIMO

#### 6.4D.0 General

For UE(s) supporting UL-MIMO, the transmit modulation quality requirements in subclause 6.4 apply. The requirements shall be met with the UL-MIMO configurations specified in Table 6.2D.1.3-3. Each [layer polarization shall](#) could be verified separately [in accordance with the test procedure specified in TS 38.521-2](#).

# FR2 Transmit OFF power

## REQUIREMENTS IN 38.101-2

1. The transmit OFF power is defined as the TRP in the channel bandwidth when the transmitter is OFF. The transmitter is considered OFF when the UE is not allowed to transmit or during periods when the UE is not transmitting a sub-frame. During DTX and measurements gaps, the transmitter is not considered OFF
2. The requirement is verified with the test metric of TRP (Link=TX beam peak direction)

Table 6.3.2-1: Transmit OFF power

Operating band	Channel bandwidth / Transmit OFF power (dBm) / measurement bandwidth			
	50 MHz	100 MHz	200 MHz	400 MHz
n257, n258, n260, n261	-35	-35	-35	-35
	47.52 MHz	95.04 MHz	190.08 MHz	380.16 MHz

# FR2 Out of band blocking

R4-1812134: FINALLY REMOVED FROM 38.101-2

< start of changes >

## 7.6.3 ~~Out-of-band blocking~~Void

~~Detailed content of the subclause is TBD.~~

< end of changes >

# FR2 spurious response removal

R4-1901837

RAN4 #90

## 7.7 ~~Spurious response~~Void

~~Detailed content of the subclause is TBD.~~

<End of change>

# Beam correspondence

## R4-1902590: DRAFT CR TO TS 38.101-2: INTRODUCTION OF THE REQUIREMENT ON BEAM CORRESPONDENCE

- Definition:

- *Beam correspondence: the ability of the UE to select a suitable beam for UL transmission based on DL measurements with or without relying on UL beam sweeping.*

- Symbol:

- $\Delta EIRP_{BC}$  → The beam correspondence tolerance, where  $\Delta EIRP_{BC} = EIRP_2 - EIRP_1$
- $EIRP_1$  → The measured total EIRP based on the beam the UE chooses autonomously (corresponding beam) to transmit in the direction of the incoming DL signal, which is based on beam correspondence without relying on UL beam sweeping
- $EIRP_2$  → The measured total EIRP based on the beam yielding highest EIRP in a given direction, which is based on beam correspondence with relying on UL beam sweeping

### 6.6 Beam correspondence

#### 6.6.1 General

Beam correspondence is the ability of the UE to select a suitable beam for UL transmission based on DL measurements with or without relying on UL beam sweeping. The beam correspondence requirement is satisfied assuming the presence of both SSB and CSI-RS signals and Type D QCL is maintained between SSB and CSI-RS.



All Tx test cases as Tx beam peak scan must have SSB and CSI-RS signals and Type D QCL is maintained between SSB and CSI-RS

### 6.6.4 Beam correspondence for PC3

#### 6.6.4.1 General

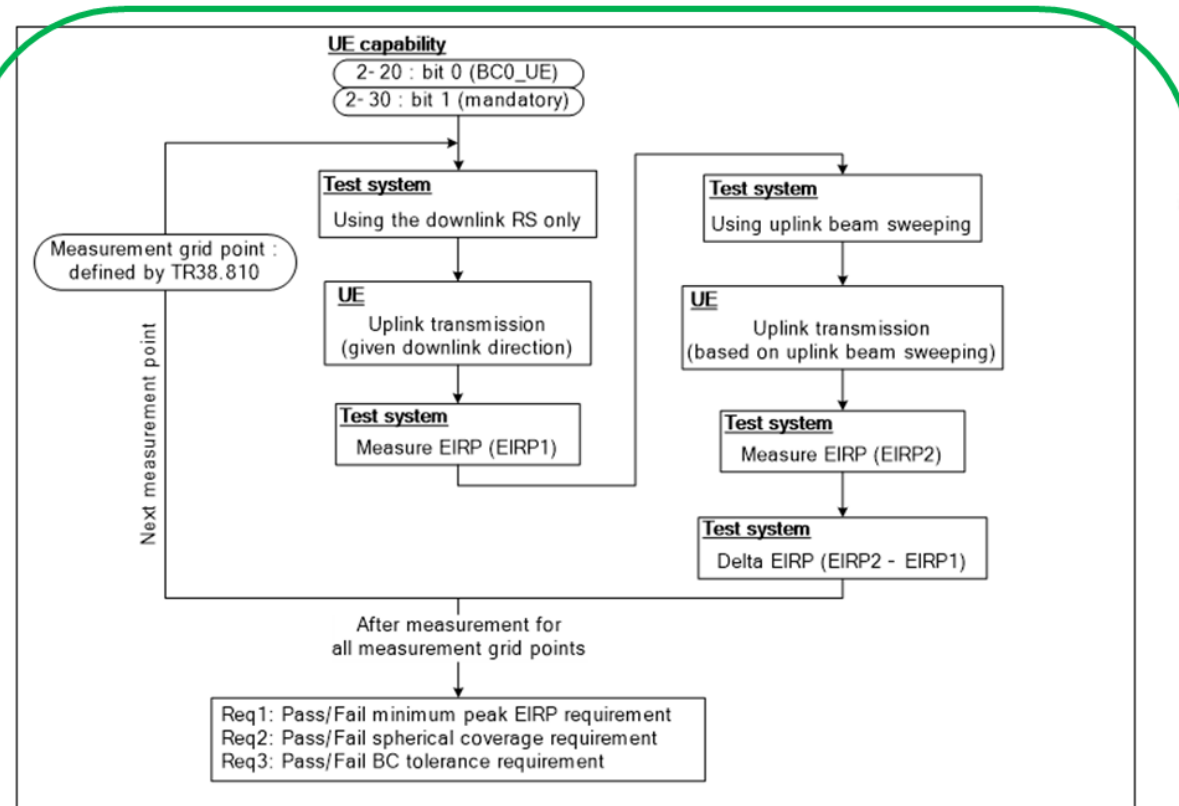
The beam correspondence requirement for PC3 UEs consists of three components: UE minimum peak EIRP (as defined in Clause 6.2.1.3), UE spherical coverage (as defined in Clause 6.2.1.3), and beam correspondence tolerance (as defined in Clause 6.6.4.2). The beam correspondence requirement is fulfilled if the UE satisfies one of the following conditions, depending on the UE's beam correspondence capability, as defined in TS38.306 [14]:

- If [bit-1], the UE shall meet the minimum peak EIRP requirement according to Table 6.2.1.3-1 and spherical coverage requirement according to Table 6.2.1.3-3 with its autonomously chosen UL beams and without uplink beam sweeping. Such a UE is considered to have met the beam correspondence tolerance requirement.
- If [bit-0], the UE shall meet the minimum peak EIRP requirement according to Table 6.2.1.3-1 and spherical coverage requirement according to Table 6.2.1.3-3 with uplink beam sweeping. Such a UE shall meet the beam correspondence tolerance requirement defined in Clause 6.6.4.2 and shall support uplink beam management, as defined in TS38.306 [14].

# Beam correspondence

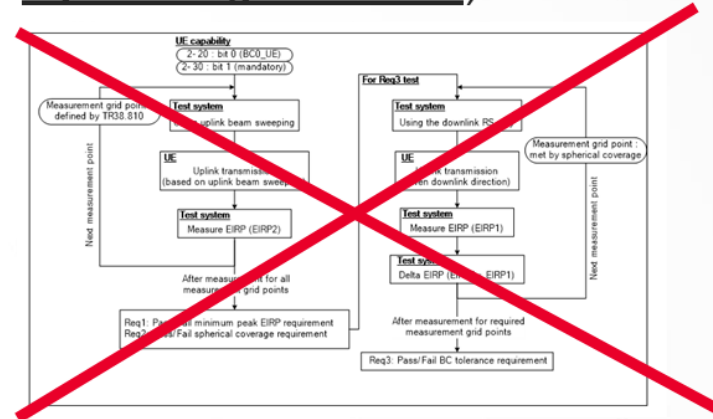
## R4-1902683: TEST PROCEDURE IN 38.810

### Option 3 (baseline)



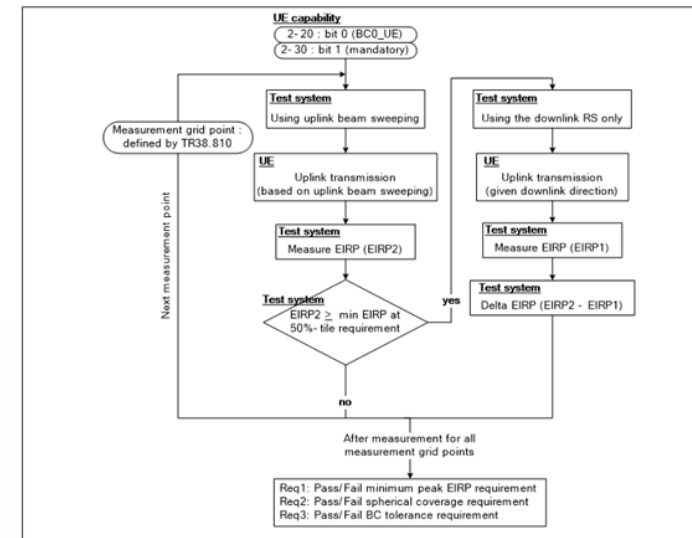
for each test point in sphere, test EIRP1, test EIRP2.

### Option 2 (precluded)



EIRP2 on whole sphere, and then EIRP1 on whole sphere, and CDF on subset of test points.

### Option 1 (test time optimization? TBC)



Per-test point, EIRP 1 performs only if EIRP2 larger than required spherical coverage req.

# Way forward on RF exposure compliance in FR2

R4-1814176

## Background

- Under certain conditions, the amount of power back-off needed for regulatory compliance of FR2 devices will have an impact on performance and may lead to radio link failure [R4-1804127, R4-1813169]
- From network and system perspective, this sudden, drastic and even unpredictable reduction of NR UL power or even drop of NR UL transmission is problematic as the network does not know why this sudden NR UL power drop or complete NR UL transmission drop has happened
- Some actions could help prevent link failure from the UE and system
- Standards and regulations are under discussion

## Way forward

- RAN4 should decide whether to *solely* rely on P-MPR to maintain compliance with RFE limits, or introduce necessary mitigation techniques to prevent the radio link failure and optimize performance
  - Possible options:
    - Introduce a maximum uplink duty cycle restriction as optional
    - UE provides information for the network to avoid UL link failure due to large power back-off
    - Other techniques are *not precluded*, for example:
      - Dynamic uplink duty cycle restriction
      - Beam refinement requests

# Specific Absorption Rate (SAR) Maximum Permissible Exposure (MPE)

## SPECIFIC ABSORPTION RATE (SAR)

- **Tentative Agreements on ranges and default values:**

- The lowest range is 10%
- The highest range is 100%
- The default value is 100%

- **Tentative Agreement on CR:**

- The change in the CR (R4-1900254) is agreed in the AH.
- The evaluation period is changed to 1s

- **LS to RAN2**

- RAN4 has discussed the value of *maxUplinkDutyCycle* which is the UE capability of maximum percentage of uplink transmission time that can be scheduled within 10msec time to ensure compliance with applicable electromagnetic energy absorption requirements provided by regulatory bodies. The value ranges are 20% to 90% with 10% step and default value is 20% for bands n257, n258 and n261 and 40% for n260.

# FR2 Extreme testing conditions

## R4-1900443: CR TO 38.101-2 ON EXTREME TESTING CONDITIONS

- Annex E.2.1 defined that requirements are applicable for temperature range in table. The table however contains two ranges, making it unclear which one is valid.
- RAN4 has discussed if the requirements should be ETC or NTC, and concluded that certain specific requirements shall be specified to be verified under NTC only. Those exclusions are made against the default that the requirement itself is valid under ETC

### E.2.1 Temperature

All RF requirements for UEs operating in FR2 are defined over the air and can only be tested in an OTA chamber.

The UE shall fulfil all the requirements in the temperature range for extreme conditions, as defined in Table E.2.1-1, unless explicitly stated otherwise in any requirement.

Table E.2.1-1: Temperature conditions

+ 25 °C ± 10 °C	For normal (room temperature) conditions with relative humidity of 25% to 75%
-10°C to +55°C	For extreme conditions

Outside this temperature range the UE, if powered on, shall not make ineffective use of the radio frequency spectrum. In no case shall the UE exceed the transmitted levels as defined in clause 6.2 for extreme operation.



# Channel Emulation

# 5G NR RAN4 - Channel emulation

## UE (REL-15), BS (REL-15) AND MIMO OTA(REL-16)

TDoc	Title	Source	Type	Agenda item	Agenda item description
R4-1812177	Discussion on simplified TDL channel models	Intel Corporation	discussion	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1812178	Discussion on channel models for FR2	Intel Corporation	discussion	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1812326	Simplification of FR1 TDL channel models	Huawei Technologies Sweden AB	discussion	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1812327	Simplification of FR2 TDL channel models	Huawei Technologies Sweden AB	discussion	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1812328	TP on channel models for TS38.101-4	Huawei Technologies Sweden AB	pCR	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1812334	TP for introducing propagation conditions (Annex B) of TS 38.101-4	Huawei Technologies Sweden AB	pCR	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1812736	Views on HST scenarios	NTT DOCOMO, INC.	discussion	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1812853	Simplified propagation channel models for FR1 UE demodulation requirements	Ericsson	other	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1812854	Simplified propagation channel models for FR2 UE demodulation requirements	Ericsson	other	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1813572	Impact of tap reduction on TDL models	Keysight Technologies UK Ltd	discussion	7.13.1.5	Channel model [NR_newRAT-Perf]
R4-1812210	Draft CR on FR2 channel models delay quantization grid	Intel Corporation	draftCR	10.1.3	Channel Model [FS_NR_test_methods]
R4-1813242	Channel model for BS demodulation	Keysight Technologies UK Ltd	discussion	7.13.2.5	Channel model [NR_newRAT-Perf]
R4-1812332	NR UE MIMO OTA channel model for FR1 and FR2	Huawei Technologies Sweden AB	discussion	10.4.4	Channel Models [FS_NR_MIMO_OTA_test]
R4-1813602	Channel model and test method considerations for NR radiated requirements	Keysight Technologies UK Ltd	other	10.4.4	Channel Models [FS_NR_MIMO_OTA_test]

### Summary:

- Rel-15 UE Channel model simplification concluded (12 taps,  $\Delta T \leq 5\text{ns}$ , simplification method clarified)
- Rel-15 BS Channel model following UE channel model (TDL, similar simplification method in FR1, defined profiles applicable to each demod test)
- Rel-16 UE Channel model to use TR38.901 CDL models CDL-A, CDL-B, and CDL-C for NR MIMO OTA.as a starting point

# UE Channel emulation – FR2

## DELAY PROFILE

- The delay profiles are simplified from the TR 38.901 [5] TDL models
  - The Maximum number of taps : [12]
  - 5ns quantization grid (200MHz sampling frequency)

Table B.2.1.2-1: Delay profiles for NR channel models

Model	Number of channel taps	Delay spread (r.m.s.)	Maximum excess tap delay (span)	Delay resolution
TDLA30	12	30 ns	290 ns	5 ns
TDLC60	12	60 ns	520 ns	5 ns

Table B.2.1.2-2 TDLA30 (DS = 30 ns)

Tap #	Delay [ns]	Power [dB]	Fading distribution
1	0	-15.5	Rayleigh
2	10	0	Rayleigh
3	15	-5.1	Rayleigh
4	20	-5.1	Rayleigh
5	25	-9.6	Rayleigh
6	50	-8.2	Rayleigh
7	65	-13.1	Rayleigh
8	75	-11.5	Rayleigh
9	105	-11.0	Rayleigh
10	135	-16.2	Rayleigh
11	150	-16.6	Rayleigh
12	290	-26.2	Rayleigh

Table B.2.1.2-3 TDLC60 (DS = 60 ns)

Tap #	Delay [ns]	Power [dB]	Fading distribution
1	0	-7.8	Rayleigh
2	15	-0.3	Rayleigh
3	40	0	Rayleigh
4	50	-8.9	Rayleigh
5	55	-14.5	Rayleigh
6	75	-8.5	Rayleigh
7	80	-10.2	Rayleigh
8	130	-12.1	Rayleigh
9	210	-13.9	Rayleigh
10	300	-15.2	Rayleigh
11	360	-16.9	Rayleigh
12	520	-19.4	Rayleigh

# UE Channel emulation – FR2

## COMBINATIONS OF CHANNEL MODEL PARAMETERS

1. The propagation conditions used for the performance measurements in multi-path fading environment are indicated as a combination of a channel model name and a maximum Doppler frequency

Table B.2.2-2 Channel model parameters for FR2

Combination name	Model	Maximum Doppler frequency
TDLA30-35	TDLA30	35 Hz
TDLA30-75	TDLA30	75 Hz
TDLA30-300	TDLA30	300 Hz
TDLC60-300	TDLC60	300 Hz



# Demod requirements



# Demod requirements

## DEMODO REQUIREMENT

### [Requirements applicable rules]

- Requirements applicable rules for SA and NSA

#### Previous agreements:

For SA/NSA Normal demodulation performance requirements only verified NR carrier requirements, additional EN-DC specific requirements can be further discussed after normal requirements finalized.

For EN-DC Normal demodulation performance requirements and CSI requirements:

- Test applicability in FR2 considering TE achievable SNR limitation
- Requirements applicable rules for FR2 Bands

### [Es, SNR ,Noc and DL power allocation...]

- Noc for multi-band supporting in FR2
- DL Power allocation setting
- PDSCH mapping type, TDD UL/DL configuration, TRS configuration

# NR MIMO OTA SI

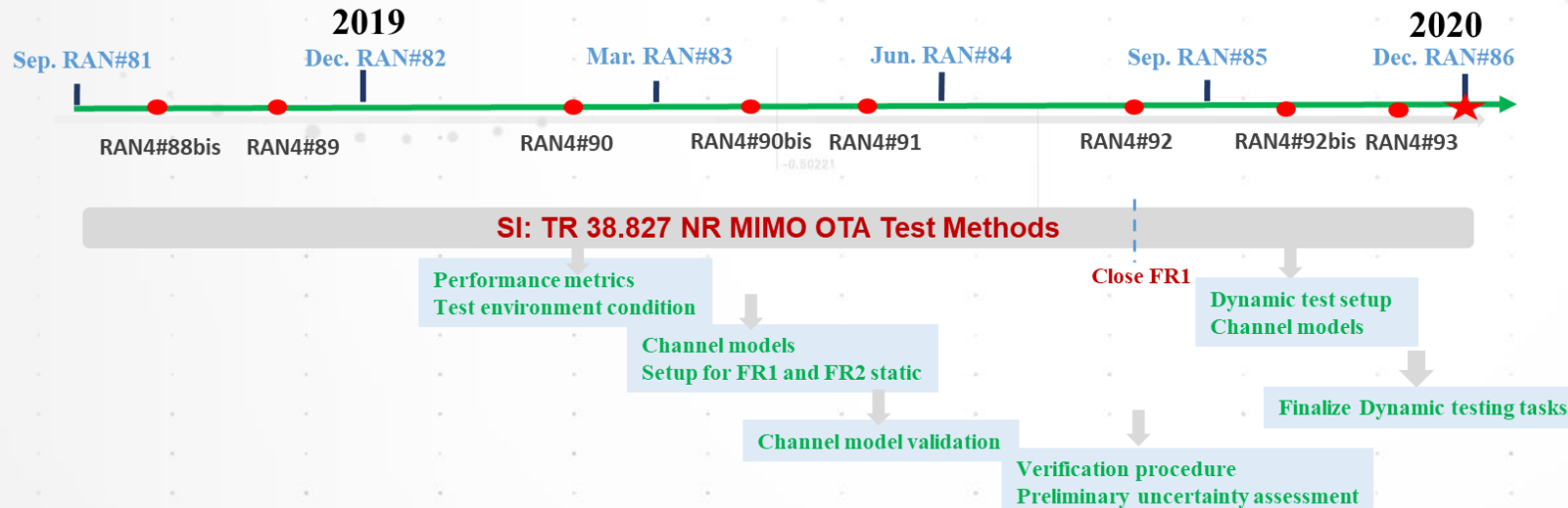
# NR MIMO OTA SI One Column Layout

## WORK PLAN

- **R4-1813563** Work plan for Rel-16 NR MIMO OTA SI – **Approved**

Some concerns on the scope (more details required) and challenges to complete the work in time. So far, approved to be aligned with plenary decisions

### NR MIMO OTA: Key outcomes in each meeting



- For FR2 testing methodologies, approve the two phases approach to finalize the objectives of FR2 NR MIMO OTA (i.e. finalize the static geometry testing and start dynamic testing discussion).

# NR MIMO OTA SI

## PERFORMANCE METRICS

- **Performance metrics scope in SID (RP-181402)**
  - General
    - The study is based on key performance metrics identified by operators, network infrastructure vendors, and UE vendors
    - A study to define the environmental conditions is needed
      - Noise-limited and interference-limited (with spatial interference emulation) scenarios shall be considered
  - FR1
    - Use the performance metric based on the LTE MIMO OTA performance metrics in TS37.144 and CTIA MIMO OTA Test Plan as a starting point such that
      - The DUT configuration, DUT positions (FS DMP, FS DML, FS DMSU), and DUT azimuth positions should be reused where possible
  - FR2
    - MIMO throughput under static geometry environment is the first priority
    - MIMO throughput under dynamic geometry environment is the second priority
    - Noise-limited environmental condition is the first priority
- **Agreements**
  - Issue #1: Performance metrics for NR MIMO OTA (FR1 and FR2 static)
    - Option 1 agreed: Use averaged MIMO OTA throughput as the baseline performance metrics for NR MIMO OTA testing, the definition of MIMO OTA throughput is the same as LTE MIMO
  - Issue #2: environmental conditions for FR1 (noise-limited and interference-limited)
    - Way Forward: encourage operators and UE vendors to provide views on environmental conditions for FR1 and FR2 static.

# Executive Summary

## FR1 & FR2

### [FR1]

- The contribution of some companies showed similar outcome in terms of the sector sizes after the channel models were filtered by the BS antenna pattern and after power scaling
- A lot of companies objected to 3D channel model implementations for FR1 and suggested to re-use the existing MIMO OTA systems
- Various agreements on channel model were made (all captured in the WF), including BS antenna assumptions, selection of just two CDL channel models, etc.

### [FR2]

- There were fewer discussions in this meeting on FR2 when compared to FR1 and little progress was made for FR2 other than some select small channel model assumption agreements
- Feedback on our FR2 contributions included the need to define the UE antenna assumptions and the need to present test zone size for the proposed system



# RRM testing methodology

# WF on RRM Test Methods

R4-1814313

## Way forward

- **Scenarios for RRM test cases** which can be supported by the NR Test Methods
  - Scenario #1: 1 AoA with signal coming from the UE RX beam peak direction
  - Scenario #2: 1 AoA with signal coming from the non UE RX beam peak direction
  - Scenario #3: 2 AoA
    - Signal directions
      - Option 1: One signal comes from the UE RX beam peak direction. The other signal comes from the non RX beam peak direction
      - Option 2: Both signals come from the non-beam peak directions
    - *NOTE 1: Type 1 (UE is using “fine” UE RX beams) and Type 2 (UE is using “rough” UE RX beams) RRM test cases can be used for either scenario*
    - *NOTE 2: it is up to RRM room to decide whether any of the scenarios can be used for RRM test case definition.*
- The following modes of **Side condition emulation** can be supported by the NR Test Methods
  - Mode 1: TE emulates target SNR conditions
    - Scenario 1/2: TE transmits desired signal and artificial noise jointly. The noise power is set to reach target SNR conditions in the reference point
    - Scenario #3: TE can transmit both desired and noise signals from both directions.
      - Option 1: Same noise level can be applied for both tested directions.
      - Option 2: Different noise levels can be applied for different directions.
      - Assumption is that the respective signal and noise levels per AoA at the reference point will be defined in the test description
  - Mode 2: TE emulates desired signal only without artificial noise
    - *NOTE: It is up to RRM room to select applicable mode for each test case*

# Testability RRM

## R4-1902525: WAY FORWARD ON OPEN ISSUE FOR FR2 RRM TESTING

### • Background:

- In RAN4#89 meeting, the following agreements on test methods for FR2 RRM testing were made in [1].
- During RAN4#90 meeting the following issues were discussed on FR2 RRM testing [2-10]:
  - Antenna gain difference between fine and rough beam for 1AoA
  - Antenna gain difference for dual directions within 1 beam for 2AoA
  - Noc setup and SNR/SINR range
  - Test setup
- This document summarizes the way forward on FR2 RRM testing.

### • Antenna gain difference for 1AoA:

The following assumptions on antenna gain difference can be used for 1AoA RRM testing:

- For peak beam direction
  - Antenna gain difference for PC3  $Y=7\text{dB}$ 
    - $Y$  is the antenna gain difference between the fine and rough beams in the RX beam peak direction. ( $Y$  is not band dependent)
- For non-peak beam direction
  - Antenna gain difference for PC3  $Z$  will be further studied in the RAN4#90bis meeting.
    - $Z$  is the antenna gain difference between “fine” and “rough” RX beams within 50% percentile EIS directions ( $Z$  is not band dependent).
    - Companies are encouraged to provide analysis on this, and define  $Z$  at RAN4#90bis meeting.
  - Further evaluate how panel selection may impact the  $Z$  value, e.g., how to share 24 samples for FR2 measurement for PC3 UE
  - Further evaluate the antenna gain difference between the rough and fine beams ( $Y$  and  $Z$  values) for the UE PC 1, 2 and 4.

# Testability RRM

## R4-1902525: WAY FORWARD ON OPEN ISSUE FOR FR2 RRM TESTING

- **Antenna gain difference for 2AoA:**

- Further study antenna gain difference for dual directions within 1 beam for 2AoA
- Companies are encouraged to bring analysis on antenna gain difference for PC3 UE fine/rough beams and assess the gain difference dependency on relative probe spacing.

- **Noc setup for multi-band device:**

- For PC3 multi-band devices, the Noc power level shall increase by multi-band relaxation defined in TS 38.101-2 Table 6.2.1.3-4.
  - AoA from Test cases with peak beam direction:
    - $\text{Noc}_{\text{MB}} = \text{Noc}_{\text{Single}} + \Sigma \text{MB}_P$
  - AoA from Test cases with non-peak beam direction:
    - $\text{Noc}_{\text{MB}} = \text{Noc}_{\text{Single}} + \Sigma \text{MB}_S$
  - $\text{Noc}_{\text{Single}}$  is derived by assuming UE supports single band.

- **Test setup:**

- For 2AoA cases,
  - TDM transmission approach for 2 probes is allowed used.
  - ~~For 2AoA cases,~~ simultaneous transmission approach for 2 probes will be further studied.
- The antenna gain difference defined in this WF can be used to derive the FR2 RRM side condition.

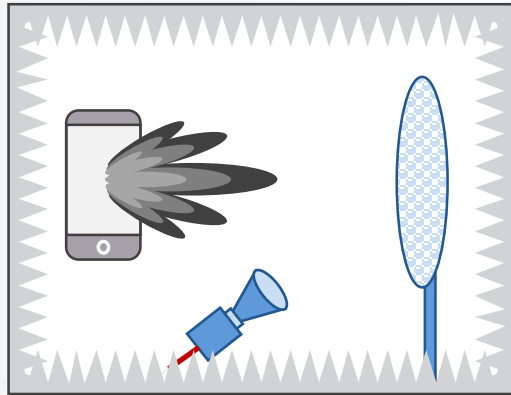


## 5G NR mmWave OTA system solutions

# Industry's Most Complete mmWave OTA Portfolio

VALIDATE MMWAVE 5G DEVICES ACROSS WORKFLOW

## RF/Antenna/RCT

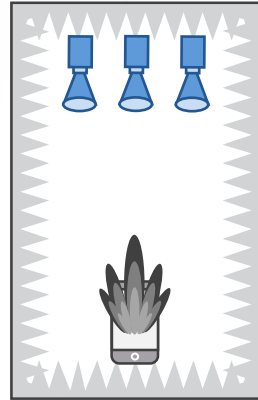


CATR

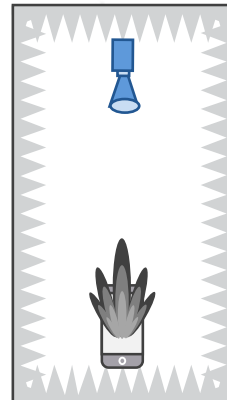


- Indirect far field
- Module to full device testing
- 30 cm device size

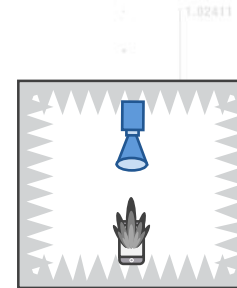
## Protocol/Functional/PCT



2DMPAC



RMTC

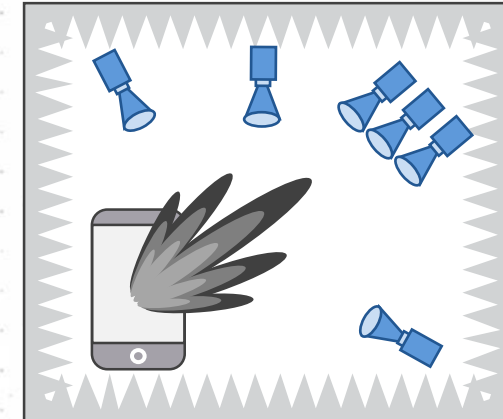


mini-RMTC



- Direct far field
- Module to full device testing
- Light weight and bench top

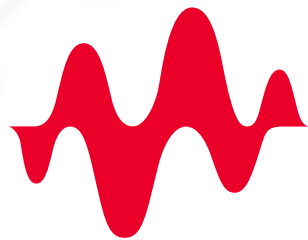
## Mobility and Performance



3D MPAC



- Direct far field
- Module to full device testing
- Supports fading models with Channel Emulator



**KEYSIGHT**  
TECHNOLOGIES

4.50221