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5G mmWave OTA Testing

Agenda

- mmWave Spectrum
- mmWave Deployment
- mmWave OTA Testing

mmWave Spectrum

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Global mmWave spectrum targets

	24-28GHz	37-40GHz	64-71GHz	>95GHz
	24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz 47.2-48.2GHz	57-64GHz 64-71GHz	>95GHz
	26.5-27.5GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz	57-64GHz 64-71GHz	
	24.5-27.5GHz		57-66GHz	
	26GHz		57-66GHz	
	26GHz		57-66GHz	
	26GHz		57-66GHz	
	26.5-27.5GHz		57-66GHz	
	24.75-27.5GHz	40.5-43.5GHz		
	25.7-26.5GHz 26.5-28.9.5GHz 28.9-29.5GHz	37GHz	57-66GHz	
	26.6-27GHz 27-29.5GHz	39-43.5GHz	57-66GHz	
	27.9-29.5GHz			
	24.25-27.5GHz 27.5-29.5GHz	37-43.5GHz		
	24.25-29.5GHz	39GHz	57-66GHz	

5G NR mmWave spectrum highlights

Ready for deployment in 2020 & beyond

U.S.
Completed three mmWave auctions so far, including 24, 28, 37, 39, and 47 GHz

South Korea
28 GHz auction completed in Jun. 2018; each operator assigned 800 MHz; plan to secure additional spectrum in 2021

Japan
Assigned 28 GHz mmWave spectrum in Apr. 2019; technical rules for additional spectrum (e.g., 26.6-27 GHz and 39.5-43.5 GHz planned for 2021

Taiwan
Auction completed in Feb. 2020 with a total of 1.6 GHz in 28 GHz band awarded to 4 operators

Italy
5G spectrum auction completed in Sep. 2018 with right of use starting January 1st, 2019

Russia
26 GHz auction completed in Q4 2018 to enable 2019+ commercial deployments

Germany
26 GHz spectrum award planned for Q4 2020

Finland, UK have also made mmWave spectrum available

mmWave Deployment

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5G NR mmWave is bringing new waves of opportunities

For outdoor deployments…

- Significantly elevate today's mobile experiences – initially focusing on smartphones
- Deployments predominantly driven by mobile operators – initially focusing on dense urban

For indoor deployments…

- Complementing existing wireless services provided by Wi-Fi–also expanding to new device types
- Bringing superior speeds and virtually unlimited capacity for enhanced experiences

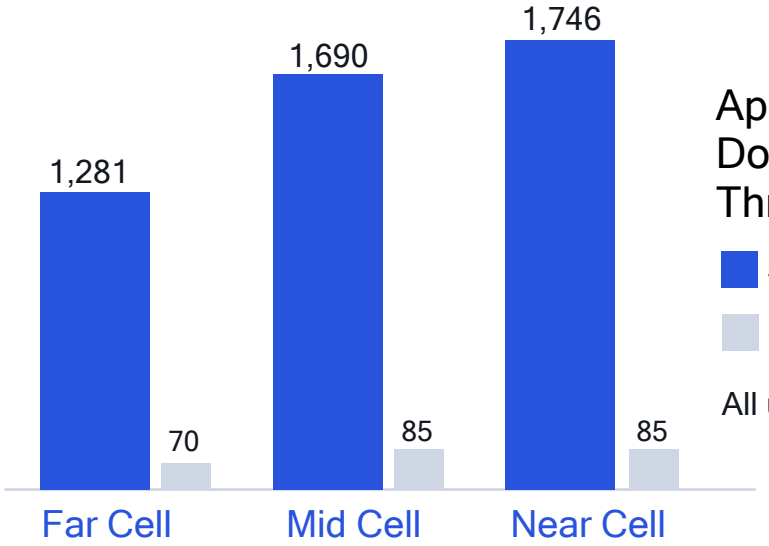
Creating value for the mobile ecosystem

Operators, service providers, venue owners, infra vendors, device OEMs,…

Conducting 5G mmWave performance field tests

Tests in commercial network show 1 Gbps+ downlink sustained throughput in all scenarios

5G mmWave gNodeB



Application layer Downlink Throughput

5G mmWave

LTE

All units in Mbps

Throughput achieved*
1,821 Mbps downlink
96.9 Mbps uplink

Throughput achieved*
1,780 Mbps downlink
73.1 Mbps uplink

*Measured using Ookla SpeedTest

mmWave OTA Testing

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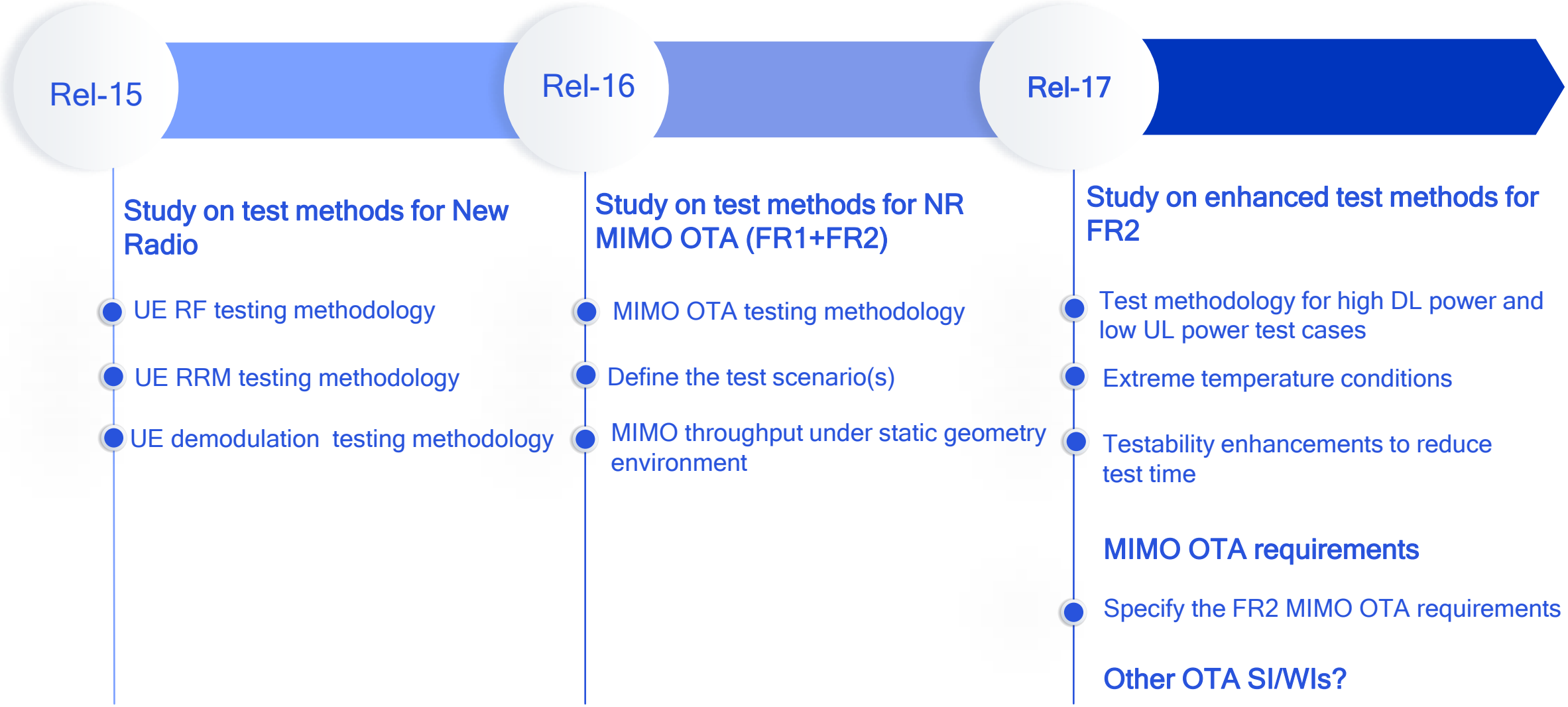
3GPP FR2 RAN4 OTA standardization work (SI/WIs)

Timelines



3GPP FR2 RAN4 OTA standardization work

Brief summary

Test methodologies

- DFF (Direct Far Field)
  - Single AoA, 2 AoAs
- IFF (aka CATR)
  - Single AoA
- NFTF (Near Field to Far Field)
  - not for Rx tests
- 3D MPAC
  - For MIMO OTA
  - CDL based Channel model
- Others
  - Test validation procedures
  - S(I)NR control methods
  - MU analyses

Test figure of merit

- RF (Completed in Rel-15)
  - EIRP on peak direction and spherical coverage requirements
  - TRP for emissions
  - EIS on peak direction and spherical coverage requirements
  - Signal quality measurements (EVM, frequency error, etc.) – measurements to in “beam peak”
- RRM (Completed in Rel-15)
  - Beam switching/tracking capability of UE
  - Up to 2 NR transmission reception points TRxPs are emulated
- Demod (Completed in Rel-15)
  - Demod performance in different channels
  - Test method supports up to MIMO rank 2 transmissions with dual-polarized
- MIMO OTA (Discussed in Rel-16/17)
  - Rank 2 throughput

RAN4 FR2 requirements process

The verification of FR2 UE performance

SI/WI	TR or TS	Test procedure aspects	Requirement aspects
FR2 Testability	TR38.810	Study of Tx/Rx test methodology for FR2	Impacts TS38.101-2, TS38.101-4, TS38.133
FR2 test enhancement	TR38.884	Study on enhanced test methods for FR2	Impacts TS38.101-2, TS38.101-4, TS38.133
NR MIMO OTA	TR38.827	NR MIMO OTA test method for FR1+FR2	Impacts TS38.151
New Radio Access Technology	TS38.101-2	See TR38.810, TR38.831, TR38.884	NR FR2 terminal OTA RF requirements under the conditions defined in TR38.810, TR38.831, TR38.884. Regulatory requirements has been completed.
New Radio Access Technology	TS38.101-4	See TR38.810	NR FR1 and FR2 terminal demodulation requirements; for FR2 test cases, under the conditions defined in TR38.810
New Radio Access Technology	TS38.133	See TR38.810	NR FR1 and FR2 terminal RRM requirements and test cases; for FR2 test cases, under the conditions defined in TR38.810

The verification of FR2 UE performance has been completed in Rel-15, and further enhanced in Rel-16, Rel-17

The advanced testing method such as testability for higher mmW frequency, DL 4 layers transmission, Dynamic testing, etc., should be future investigated.

Dynamic-geometry based mmW OTA Test

Problem statement

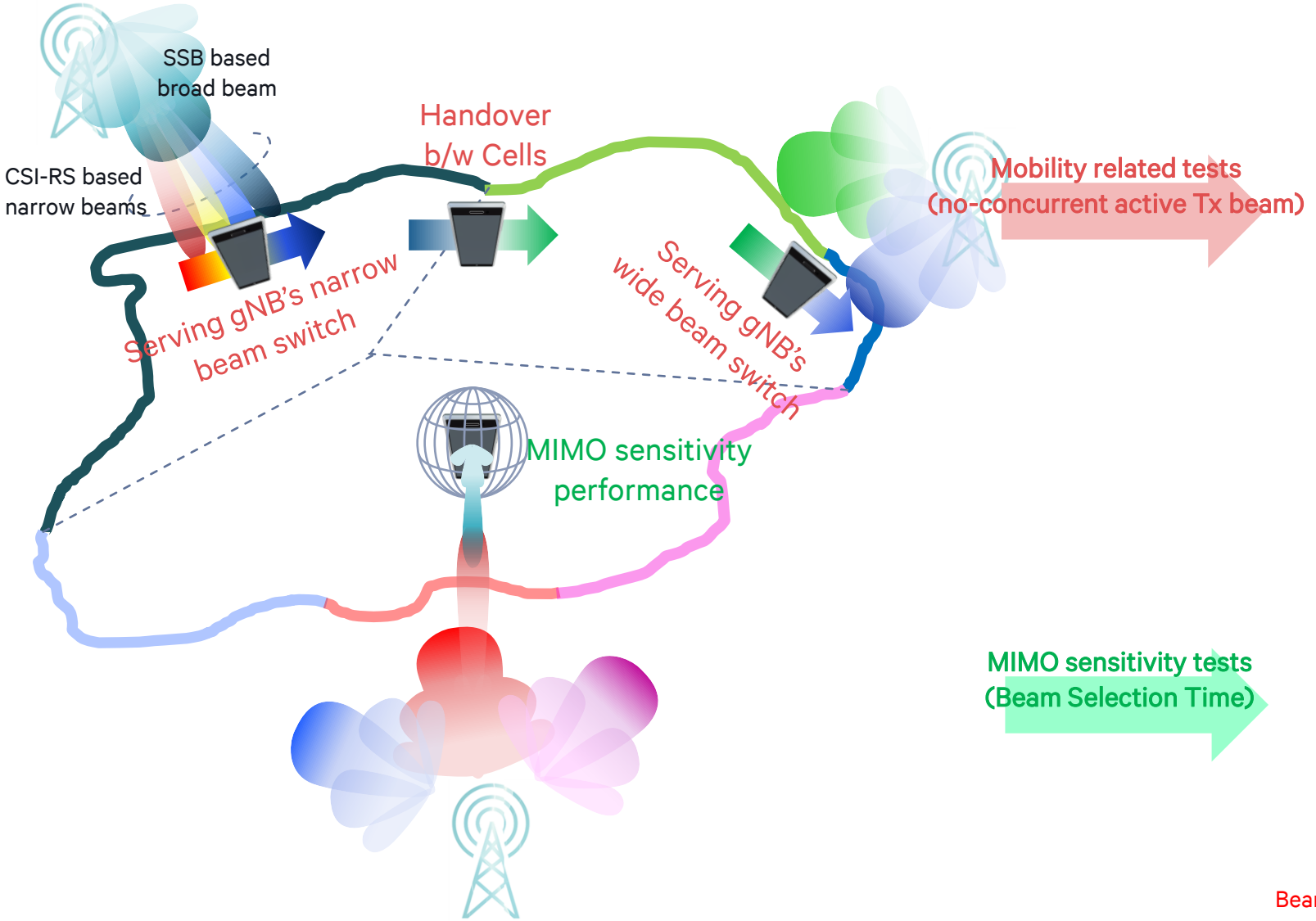
- The key enablers of high throughput for mmW are analog/hybrid beamforming techniques which should be rigorously verified by corresponding tests. However, **the current test mechanisms** defined in 3GPP have the following restrictions:
  - Once UE orientation and test direction are determined before a test, these remain the same during the test
  - Even in cases where performance is measured over multiple test directions, enough beam-dwell time in-between test geometry updates is given for the UE such that Dynamic Beam Management is NOT really tested

  The above restrictions make FR2 test results too optimistic, and hence, these do NOT reflect the real user experience.

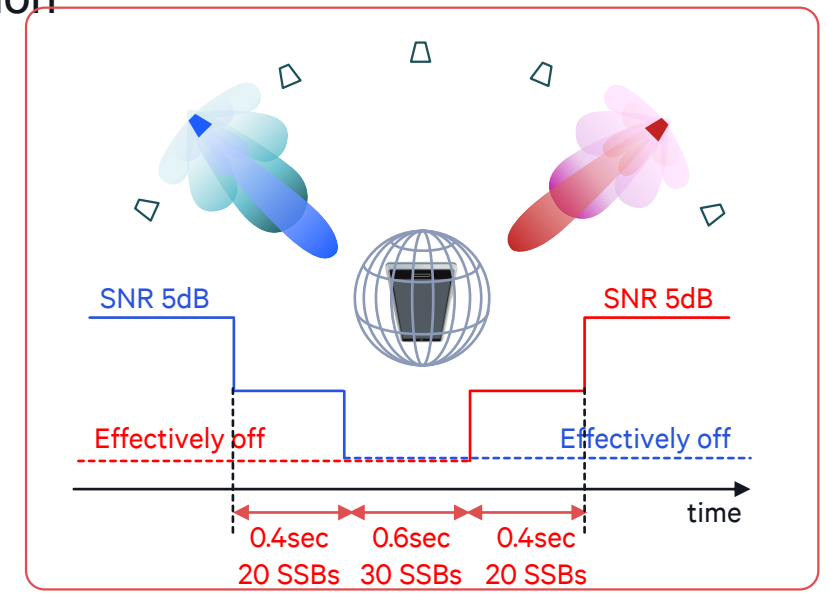
- Besides, considering FR2 UE beam management consumes nonmarginal power and time, there can be UEs reducing beam management frequency and/or a search space size of UE beam codebook to the point where throughput and mobility performance~~s~~ are degraded. However, the performance impact~~s~~ due to the improper Beam Management are NOT accounted for in the current 3GPP FR2 test methodologies.

Test Coverage and Restriction of Current mmW OTA

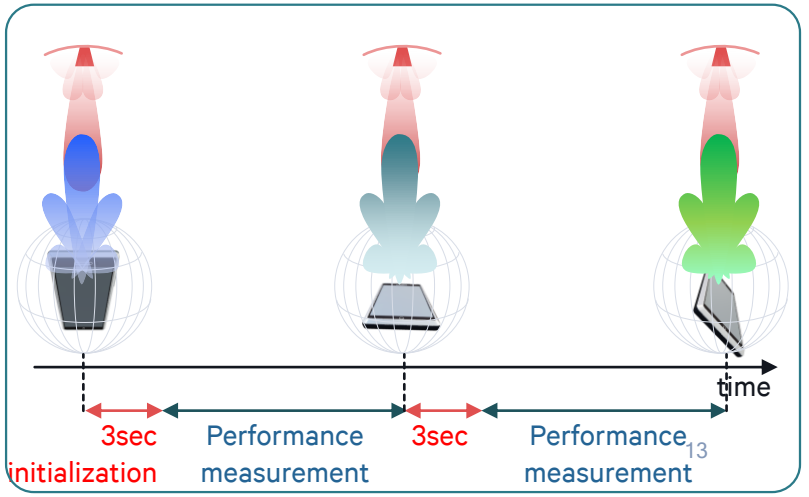
Mobility/Demodulation Performances under Ideal/Deterministic Beam Condition



Mobility related tests
(no-concurrent active Tx beam)

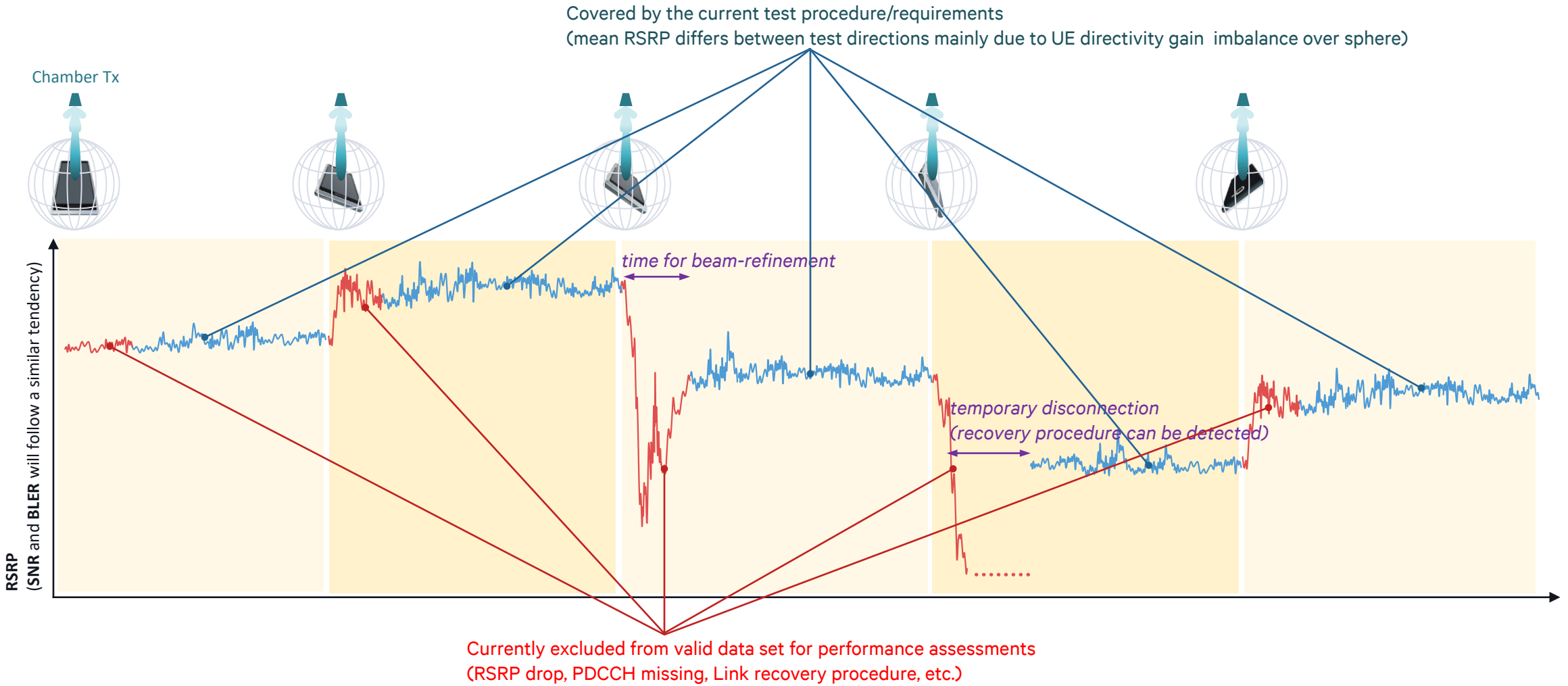


MIMO sensitivity tests
(Beam Selection Time)



Test Coverage and Restriction of Current mmW OTA (cont.)

UE performance in terms of Beam Management is not included in Performance Assessment procedure



Examples of Operator specific Field Requirements focusing on BM

Field Certificate/Compliance Tests

- Graphical analysis (record and plot the following on a geographic map of the drive route)
  - gNB serving beam index
  - SS-RSRP and SS-SINR
  - PDSCH/PUSCH throughput
  - Beam failure and recovery events

- Statistical analysis
  - gNB serving beam dwelling time
  - UE Rx beam dwelling time
  - Number of beam switches
  - Number of beam failure events
  - Beam recovery success rate
  - Beam recovery latency

  Note that the above observation may not be consistent over time, e.g. differ depending on gNB scheduler, gNB beam allocation, scattering environment, etc.

Benefits of Dynamic-geometry based FR2 OTA Test

Benefits

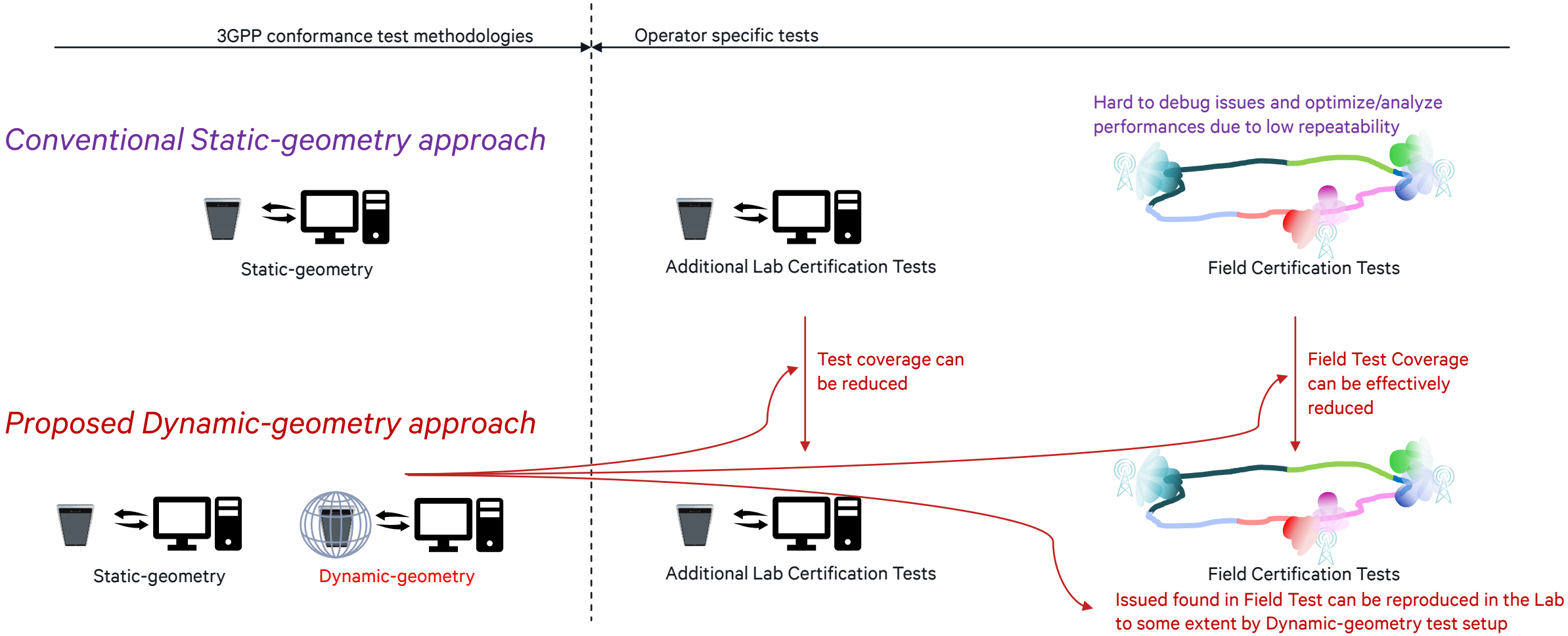
- With a standardized FR2 Dynamic-geometry based OTA test system, the following performance evaluation approaches can be effectively reduced for integrated UE performance assessments
  1. Field test-based integrated UE performance assessment
  2. Proprietary Lab solutions-based UE performance assessment

Note that both above approaches are time and cost prohibitive. In addition, there will be significant uncertainties that make performance analysis and optimization difficult.

	Cost	Repeatability	Comment
Field test-based approach	↑	↓	for analysis, hard to decouple multiple contributors
Proprietary-based approach	↑	↓ (between TEs)	may have reliability issues
3GPP standardized approach	↓	↑	can be easily repurposed for field issue reproduction/R&D/etc

Benefits of Dynamic-geometry based FR2 OTA Test (cont.)

Benefits



Summary

Advanced testing method

- **FR2 UE performance has been completed in Rel-15, and further enhanced in Rel-16, Rel-17.**
- It is very important to address the industry need for **more advanced UE testing** in environments that are closer to field operation
  - Fast changes in signal directions and/or fast channel variation
  - Current tests for RRM/beam management are very simplistic, with most 2 signals coming from different directions and long dwell time(time for UE to acquire signals)
  - Such tests are needed as well during device development.
- The most important part of this item is to develop a standardized test environment and test methodology that benefits everyone
- Multi panel UEs should be considered for forward compatibility of the test setup
  - Multi panel enhancements are part of Rel.17 eMIMO work, currently there is no ongoing work test setup
  - Even if RF requirements are defined, these cannot be verified until a test solution is available

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Thank you!

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