July 2020

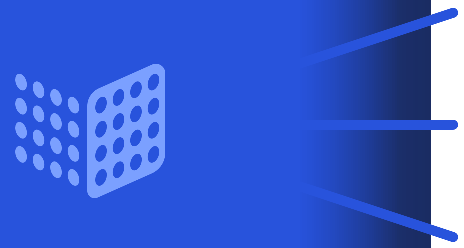
Future Forum

mmWave UE OTA testing

Bin Han

Qualcomm Technologies, Inc.

Breaking the wireless barriers to mobilize 5G NR mmWave



We are overcoming the mobile mmWave challenge

Proving the skeptics wrong about mmWave can never be used for mobile

Limited coverage and too costly

Significant path loss means coverage limited to just a few hundred feet, thus requiring too many small cells

Significant coverage with co-siting

Analog beamforming w/ narrow beam width to overcome path loss. Comprehensive system simulations reusing existing sites.

Works only line-of-sight (LOS)[1]

Blockage from hand, body, walls, foliage, rain etc. severely limits signal propagation

Operating in LOS and NLOS[1]

Pioneered advanced beamforming, beam tracking leveraging path diversity and reflections.

Only viable for fixed use

As proven commercial mmWave deployments are for wireless backhauls and satellites

Supporting robust mobility

Robustness and handoff with adaptive beam steering and switching to overcome blockage from hand, head, body, foliage.

Requiring large formfactor

mmWave is intrinsically more power hungry due to wider bandwidth with thermal challenges in small formfactor

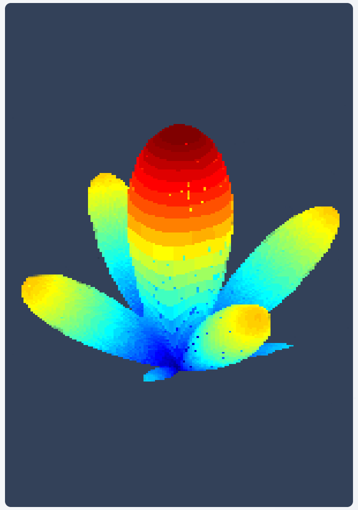
Commercializing smartphone

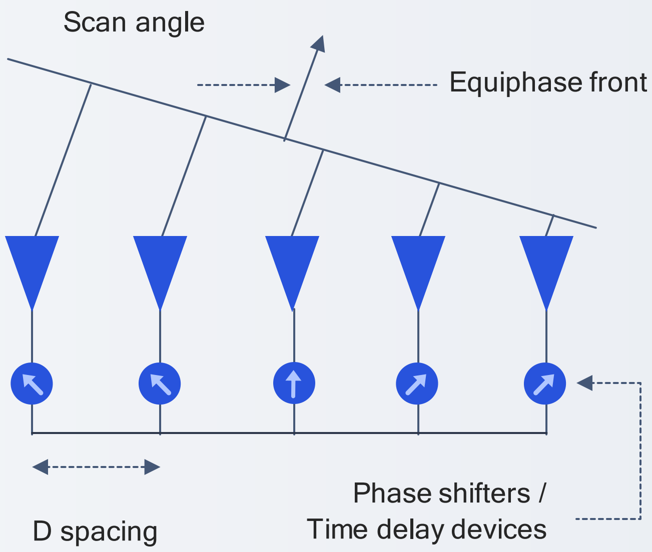
Announced modem, RF, and antenna products to meet formfactor and thermal constraints, plus device innovations.

1 LOS: Line of sight, NLOS: Non-line-of-sight

Addressing mobility challenges with multi-beam techniques

Improves coverage, robustness, and non-line of sight operations

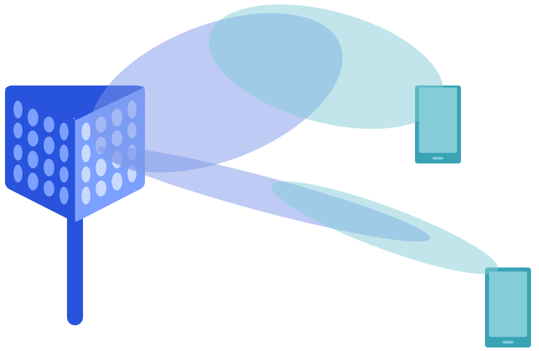




High-gain directional antenna arrays

Analog beamforming with narrow beamwidth to overcome significant path loss in bands above 24 GHz

Required in both base station (~128 to 256+ elements) and mobile device (~4 to 32 elements) for 3D beamforming

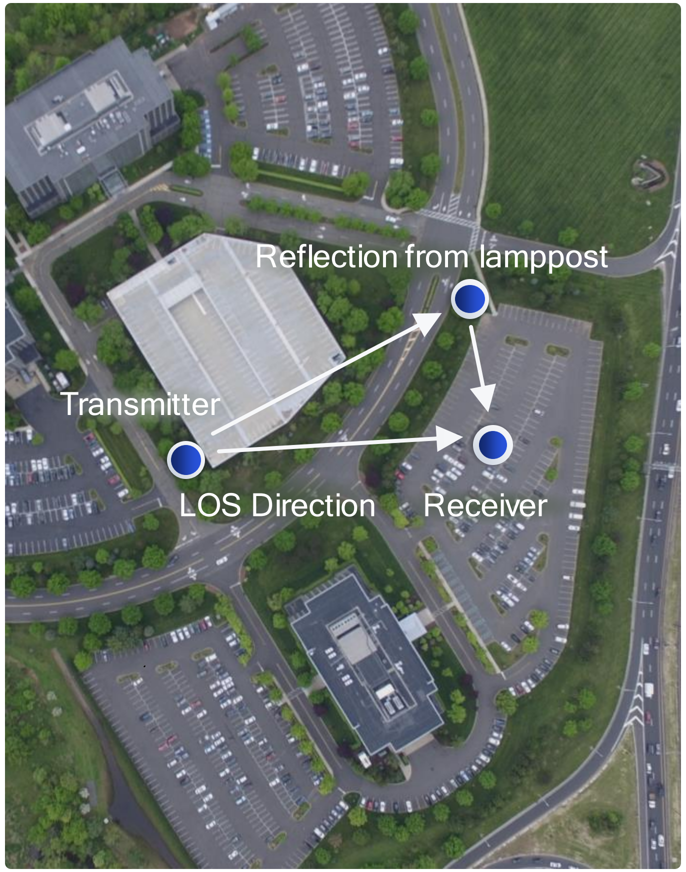


Beam switching — Switches between candidate beams to adapt to changing environment

Beam steering — Changes direction of uplink beams to match the that of incoming beams from gNodeB

Beam tracking — Distinguishes between beams arriving from gNodeB

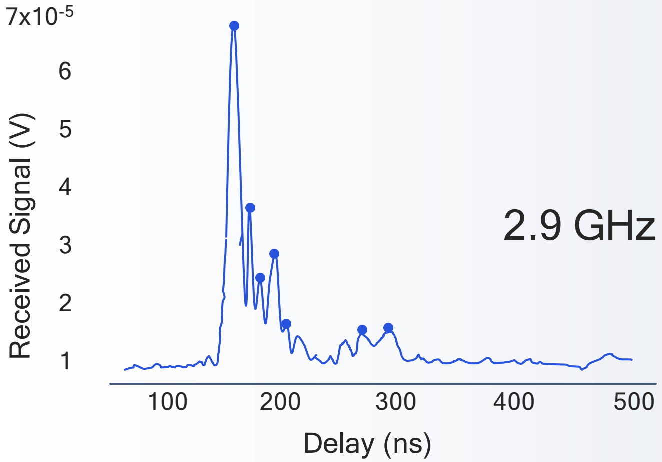
Smart, closed-loop algorithms determine most promising signal paths with fast switching within and across access points



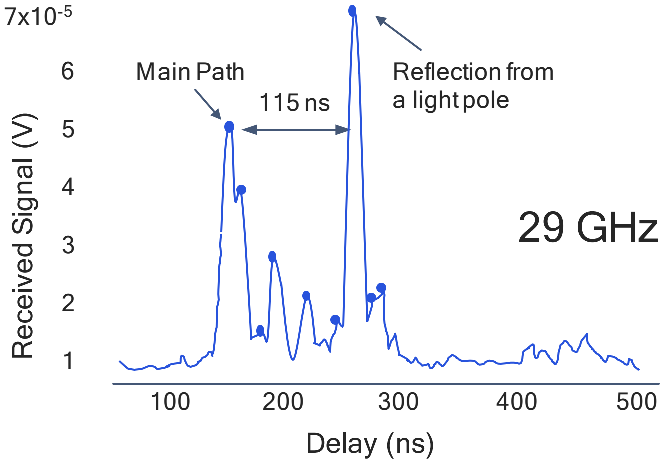
Channel response from omni-directional antennas

(Example measurement)

Operating at sub-6 GHz



Operating above 24 GHz



- Alternative paths in mmWave can have very large receive signal
- Small objects affect mmWave propagation more than sub-6 GHz (e.g., tree branches)

Showcasing reflections provide alternative paths when LOS is blocked – based on our outdoor channel measurements

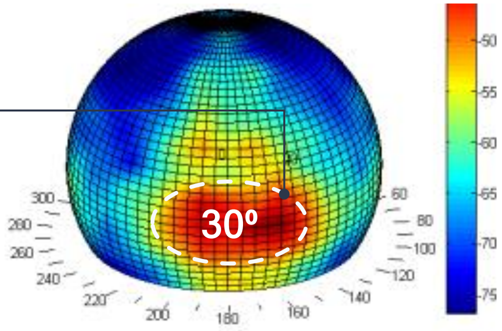
Leveraging path diversity to overcome blockage

Based on our spherical scan measurements

Indoor office

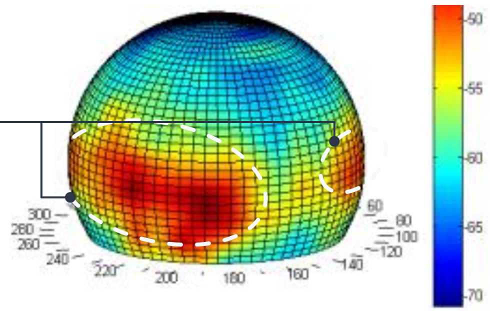
Diversity in elevation

Numerous resolvable paths in elevation



Diversity in Azimuth

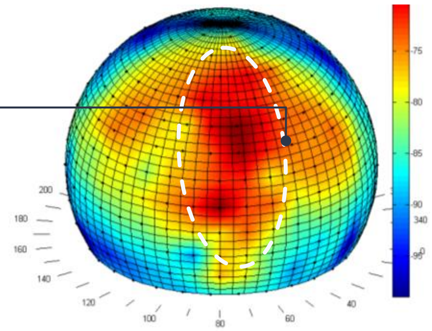
Significant path diversity in azimuth – Ability to withstand blockage events



Outdoor

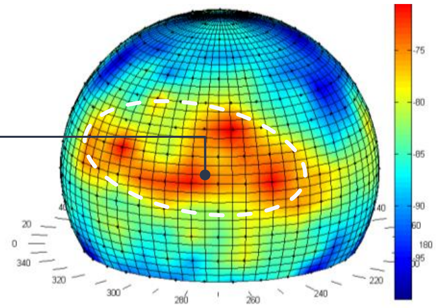
Diversity in elevation

Reflections from tall buildings result in wide elevation spread



Diversity in Azimuth

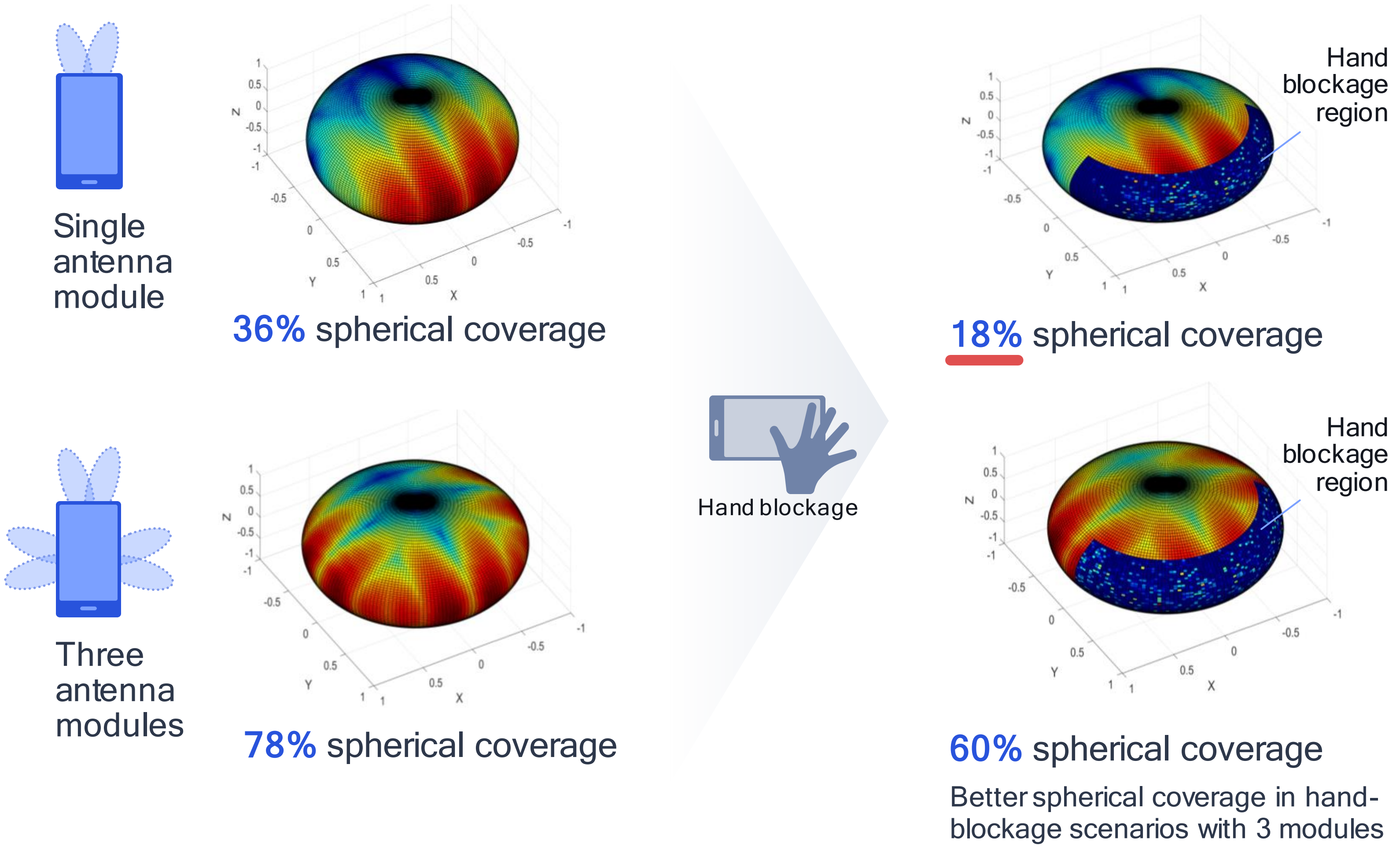
Foliage obstructed diffracted path – energy spread across wide azimuth



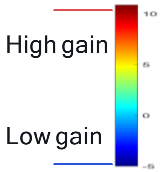
UE antenna module design for coverage

Design objectives

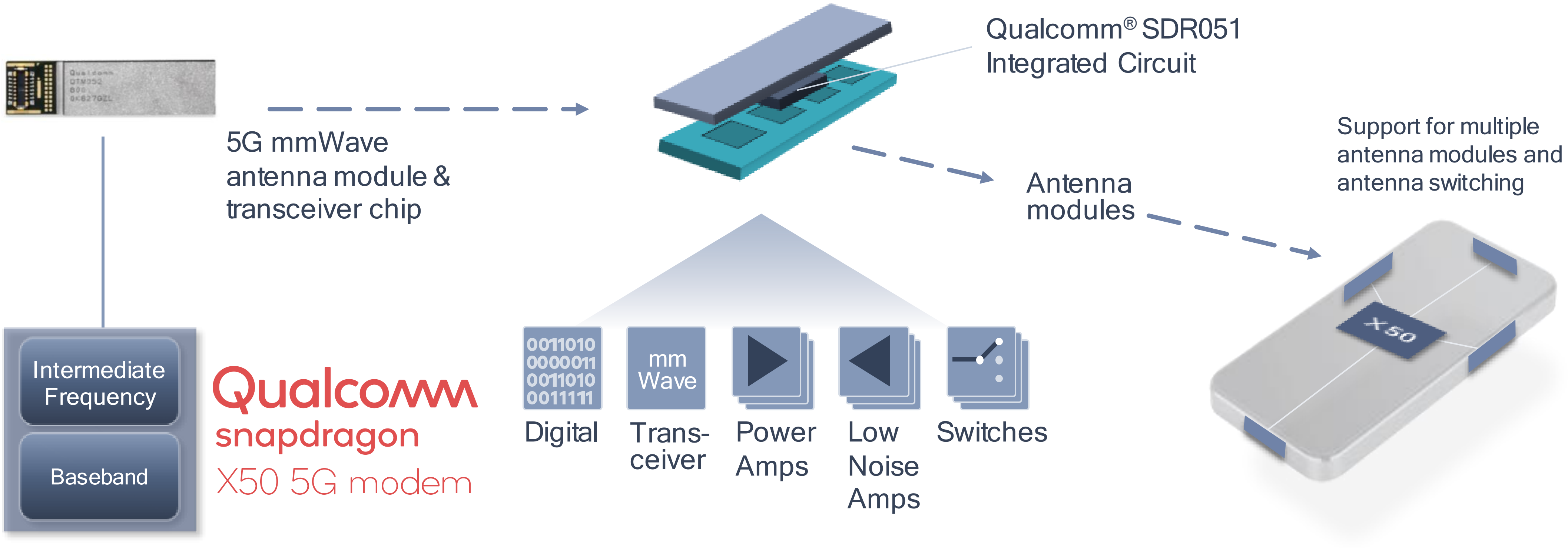
- Uniform performance independent of UE orientation
- Mitigate impact of hand/body blockage



Multiple antenna modules provide nearly spherical coverage for both polarizations



Modem-to-antenna 5G mmWave solution



Snapdragon X50 5G mmWave architecture

Integrated antenna array and RFFE for performance and ease-of-use

Architecture allows flexible placements and multiple modules

Making mmWave successful with OTA testing

mmWave UE OTA testing

3GPP mmWave OTA Standardization Work (SI/WI)

Timelines

Rel-15

Study on test methods for New Radio

- UE RF testing methodology
- UE RRM testing methodology
- UE demodulation testing methodology

Rel-16

Study on enhanced test methods for FR2

- Test methodology for high DL power and low UL power test cases
- Polarization basis mismatch
- FR2+FR2 CA
- Reduce testing time
- …

Radiated metrics and test methodology for the verification of multi-antenna reception performance of NR UEs

- MIMO OTA testing methodology
- Define the test scenario(s)
- MIMO throughput under static geometry environment

Rel-17

Study on enhanced test methods for FR2

- Continue to study the enhanced test methods in Rel-17

WI on Multiple Input Multiple Output (MIMO) Over-the-Air (OTA) performance requirements for NR UEs

- Specify the FR2 MIMO OTA requirements

New proposal on FR2 dynamic testing (Not started yet)

- …

3GPP mmWave 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
  - TRP, EIRP, EIS, Spherical coverage, Beam correspondence, EVM, spurious emissions, etc.
- RRM
  - Cell-level measurements
  - Beam-level measurements
  - Up to 2 AoAs
- Demod/CSI
  - pure baseband performance with TDL channel model
  - radiative near field or in the far field
- MIMO OTA
  - Rank 2 throughput

Test geometries

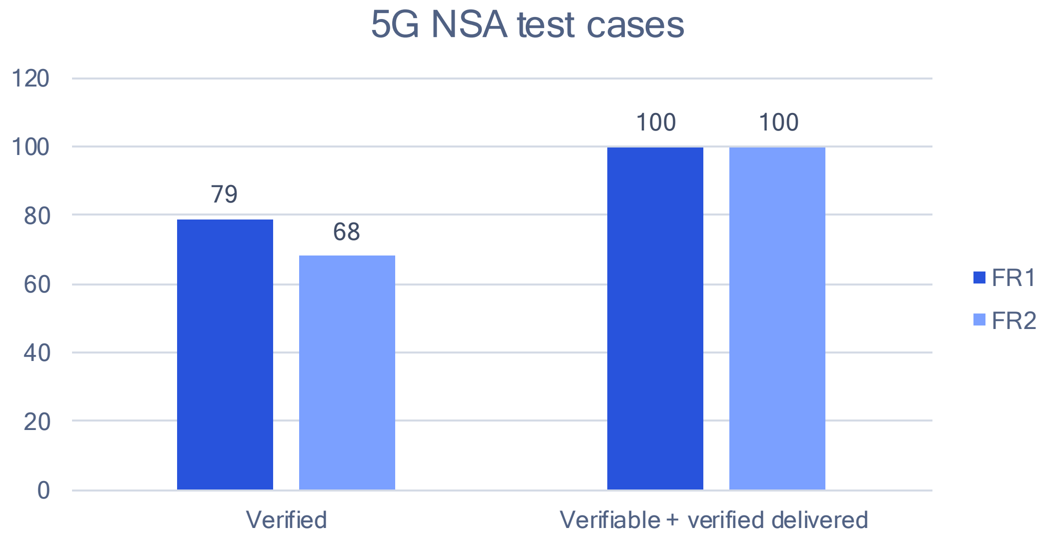
- Static-geometry based
  - Enough beam-dwell time in-between test geometry updates for UE beam requirement
- Dynamic-geometry based
  - None

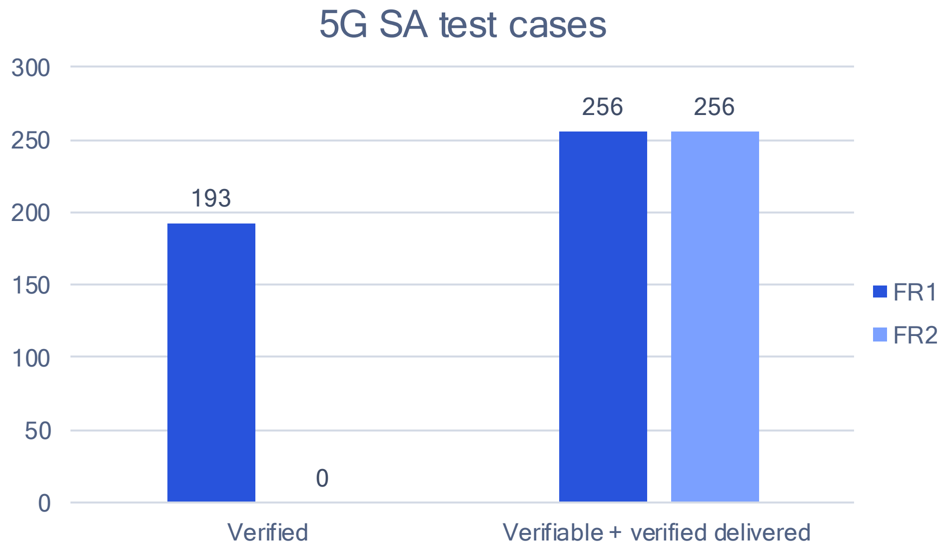
Baseline test method and setup for mmWave commercial deployments are ready!

Summary of TC status

After RAN#88 e-meeting

- 5G Test cases status in 3GPP RAN5





- 68 test cases has been verified for FR2 5G EN-DC while 79 test cases for FR1 EN-DC.
- Completion of FR2 SA test cases is with low priority.

Motivation of Dynamic-geometry based FR2 OTA Test

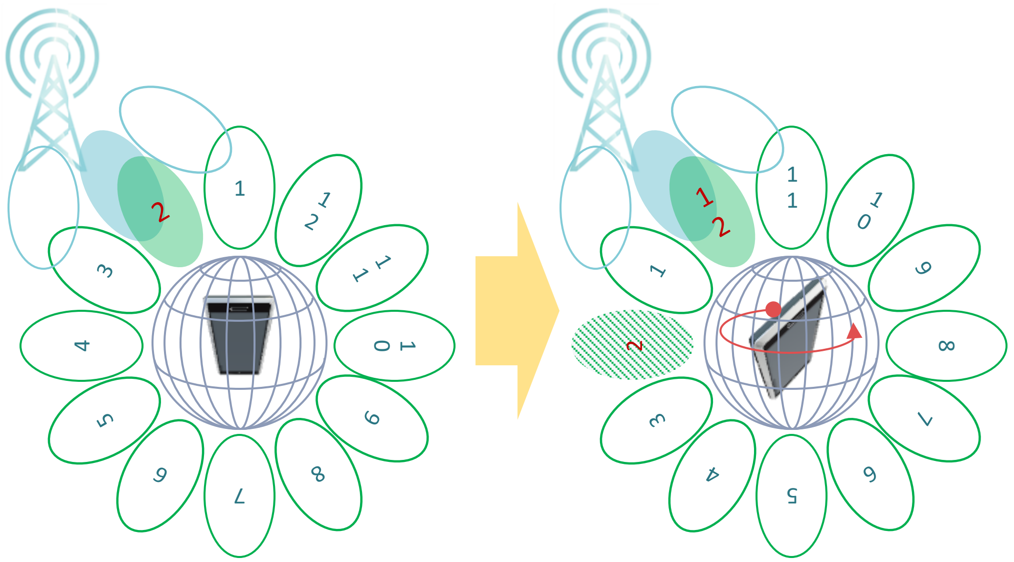
Problem statement and Benefits

- The key enablers of high throughput for FR2 are analog/hybrid beamforming techniques which should be thoroughly verified by corresponding tests. However, the current test mechanisms 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.
- Infra requests additional performance assessment results to see if UE beam related performances are stable when UE position and/or orientation dynamically change.
- With a standardized FR2 OTA test system, the following performance evaluation approaches can be avoided for integrated UE performance assessments
  1. Field test based integrated UE performance assessment
  2. Proprietary Lab solutions based UE performance assessment

Scenarios for Dynamic-geometry based FR2 OTA Test

UE orientation rotation-based Scenario

- Scenario
  - A scenario where the serving gNB DL beam doesn't change but UE Tx/Rx beam needs to be updated to maintain link and continue transmitting and receiving UL/DL signals.
  - Note that such test is not possible under the current static-geometry based OTA Testing.

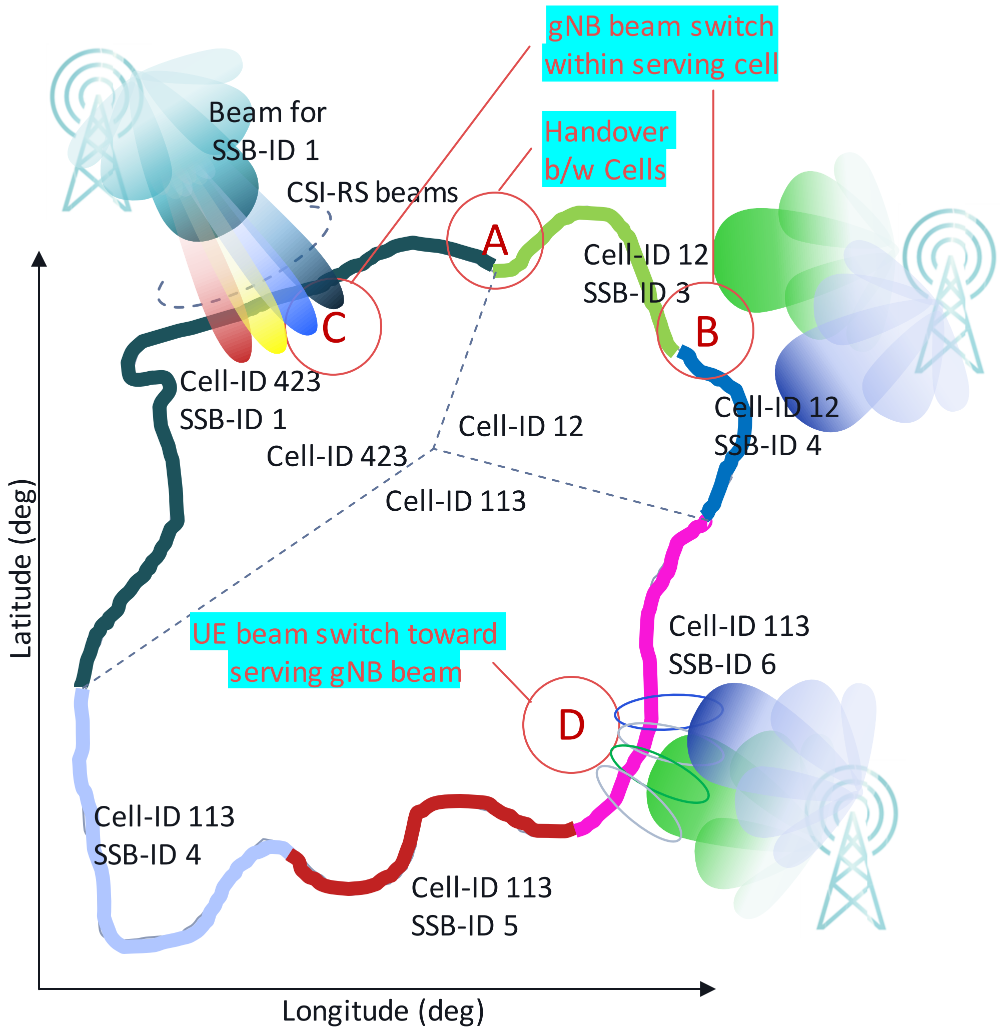


- Examples of potential Figure of Merit
  - Whether UE can maintain the established link without or with very infrequently triggering of "Beam failure detection and Link recovery" procedure
  - Averaged RSRP/RSRP and T-put
  - Performance deviation in terms of
    - SSB and/or CSI-RS based RSRP/RSRQ
    - PDSCH T-put

Scenarios for Dynamic-geometry based FR2 OTA Test

UE travel-based Scenario

- Scenario
  - The current static-geometry based RRM test mechanism roughly covers
    - UE mobility performance in (A) using RRM requirements
    - UE beam management performance in (B) and (C) using SSB-based and CSI-RS based BFD/LR requirements
  - Rel-17 MIMO OTA WI will only partially cover
    - Static T-put performance in (D) using 36 test directions in each of which UE will be given enough time for Tx/Rx beam refinement
  - Note:
    - For (A) - (C), there are at most 2 beams, and there is no test case where UE should deal with concurrently detectable multi-beams.
    - For (A) - (D), there is a moment when gNB serving Tx beam explicitly changes which implicitly signals UE to re-obtain or refine Rx beam.
    - For (A) - (D), enough dwell time (at least 3sec in RAN5) is given to UE for new T/Rx beam re-obtain/refinement which is far from real user scene.



Motivation of downlink 4 layers testing

Advanced features in FR2, e.g. Rank 4 throughput

- In Rel-15 NR testability SI, the test methodology for up to Rank 2 demodulation performance was specified. Then the performance metric and test method for MIMO OTA throughput with Rank 2 was studied in Rel-16 MIMO OTA SI.
- The advanced features, e.g. Downlink 4 layers transmission can further enhance the throughput for FR2, but the enhancement for the current test environment might be needed to support 4 layers testing.
- From the test method and test environment point of view, there are following commonalities as dynamic testing
  - Multiple probes test step is needed
  - Multiple beams are supported from gNB(s)
- In addition, UE multi-panel Tx/Rx need to be considered.

Future work

FR2 OTA Testing enhancement

- Support dynamic testing and downlink 4 layers testing for FR2
- Dynamically varying the following parameters should be considered:
  - The number of beams from gNB(s)
  - (Z)AoD and (Z)AoA
  - UE movement trajectory and orientation relative to downlink signal(s)
  - Large scale pathloss, blocking, Doppler shift in channel model
- The following test cases should be studied for FR2 OTA testing:
  - Verify MIMO throughput with Rank 2/4 transmission under
  - Extend the Rel-15 RRM test cases to dynamic geometry with multiple gNB beams
  - Support Multi-panel Tx/Rx UE in test environment

Thank you!

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