Bench and Lab Testing 5G Devices

Where did all the Lab Space Go?

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Concept & Stated Goals

GSMA (consortium) want 5G to

- Allow Gbps connections to end points
- Decrease end-to-end round trip time to 1mS
- Connect at least 10x devices to network
- Provide “perception of” 99.999% availability
- Provide “perception of” 100% coverage
- Decrease network energy usage by 90%
- Enable multi-year battery life for low power, machine-type devices

https://www.gsmaintelligence.com/research/?file=141208-5g.pdf&download

Pointing toward the future (Ericsson CEO, MWC Barcelona)

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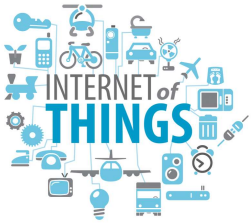
Goals We Can Ignore

Network Energy usage cut 90%

10-100x network connected at low data rate IoT



Availability & coverage

5G "signal bars" limited by business case rather than tech

ARPU – average revenue per user is metric

Battery life dependent on device implementation and use case

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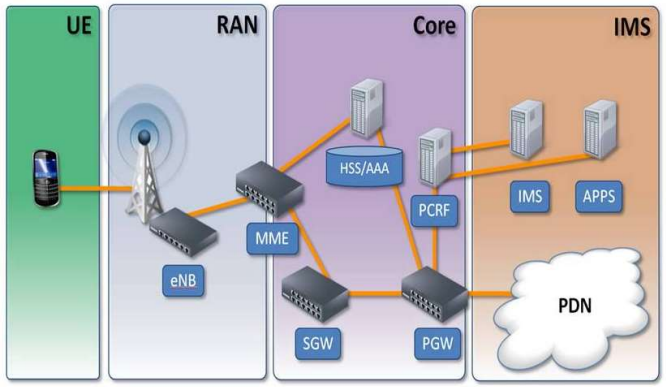
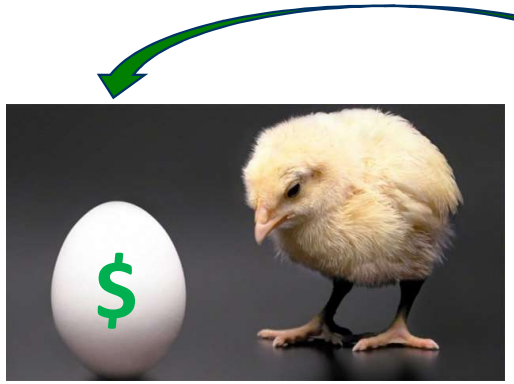
Latency Goal vs Use Case

Decrease **latency** to 1mS

Backhaul adds 40 - 100mS latency





1mS Latency use cases so far

Remote surgery? – You go first

Vehicle to X? - @ 87 mph travel ~1.5 inches in 1mS

AR/VR? – Need killer app to drive APRU much higher

AI? – Not latency dependent unless remote processing

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5G Bandwidth Enables Gbps Connections

Gbps connections to end points

- Shannon capacity limit
- More (C)apacity = change to (B)andwidth, (S)ignal or (N)oise

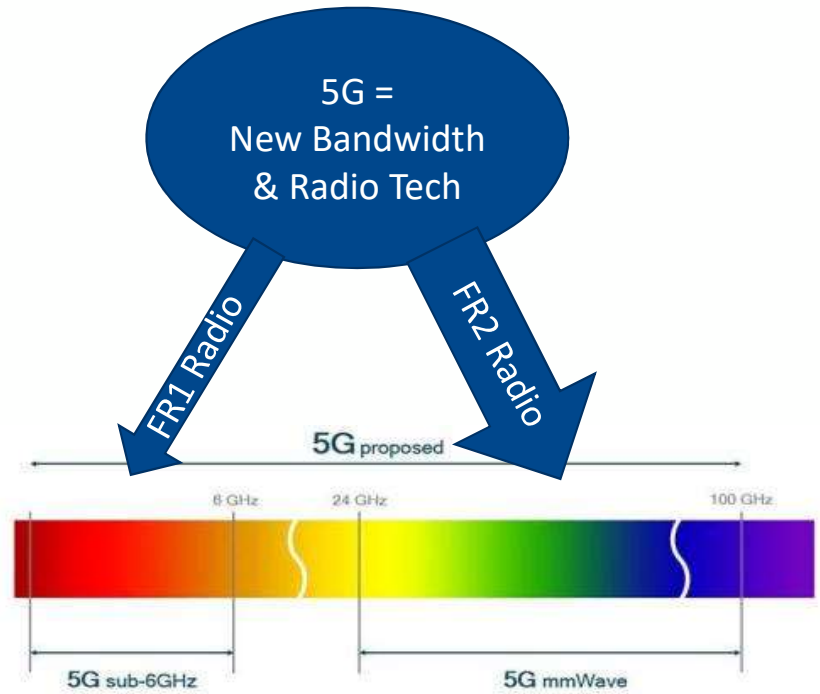
Channel Capacity (bits per second)

Signal Power

$$C = B\log_2\left(1+\frac{S}{N}\right)$$

Bandwidth (kHz)

Noise Power



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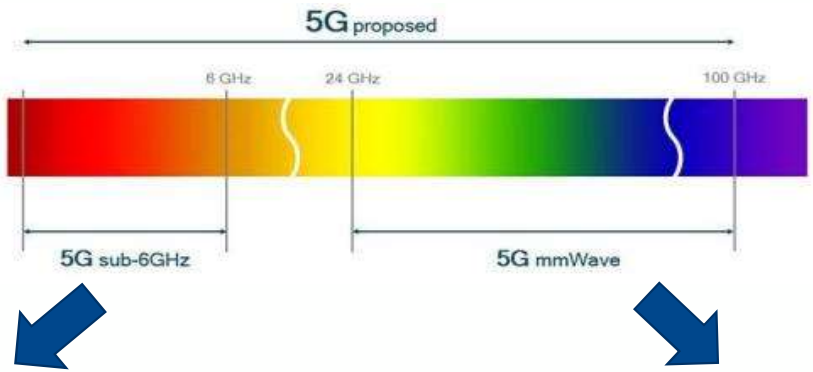
Technology for Gbps Data to End Points



Efficiency Gains in Existing BW

- ✓ Carrier Aggregation
- ✓ Massive MIMO
- ✓ Adaptive resource block size
- ✓ Licensed + Unlicensed spectrum

✓ Beamforming

3 GHz new Bandwidth

NR Operating Bands in FR2

NR FR2 Band	Band Alias	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}	Bandwidth	Duplex Mode
n257	28 GHz	26500 MHz – 29500 MHz	26500 MHz – 29500 MHz	3000 MHz	TDD
n258	26 GHz	24250 MHz – 27500 MHz	24250 MHz – 27500 MHz	3250 MHz	TDD
n260	39 GHz	37000 MHz – 40000 MHz	37000 MHz – 40000 MHz	3000 MHz	TDD

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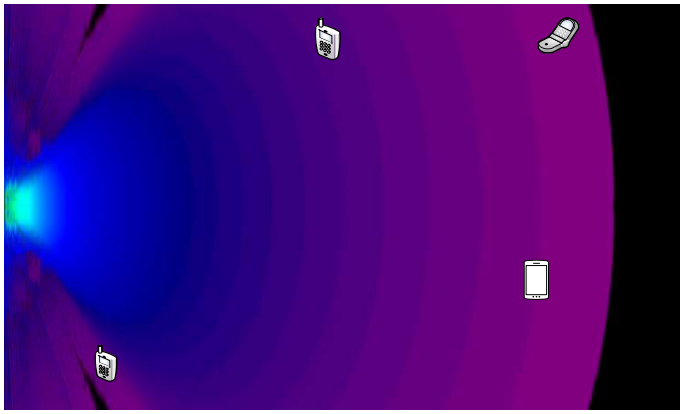
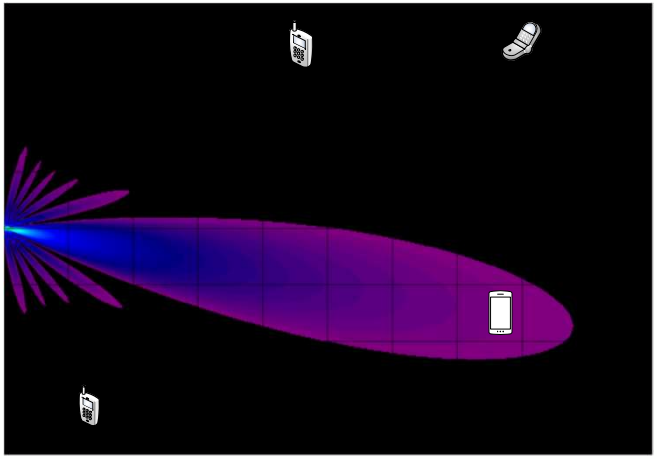
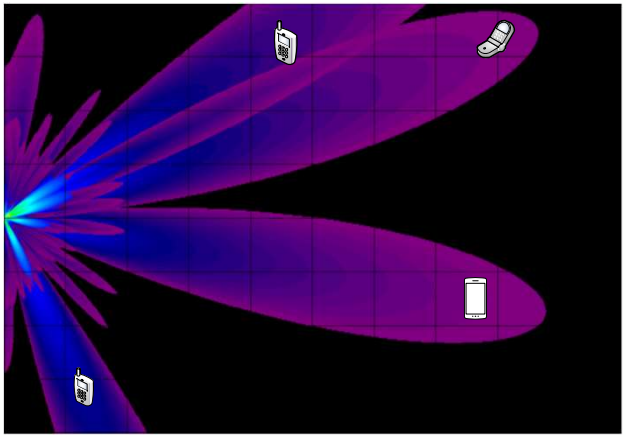
MIMO and Massive MIMO sub 6GHz



MIMO



Massive MIMO



Beamforming allows directional signal per user

- SINR better vs omni per user
- Will require gNB to gNB pointing info for handoff

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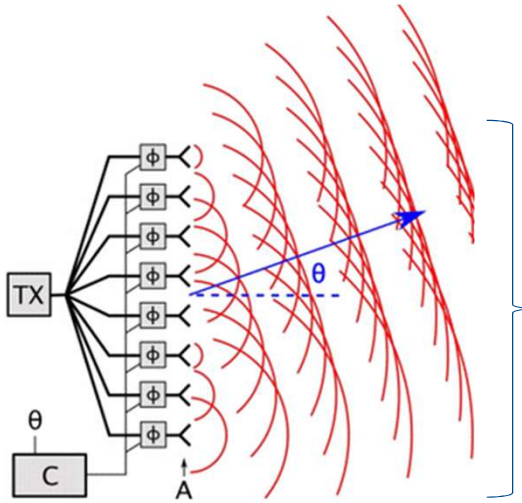
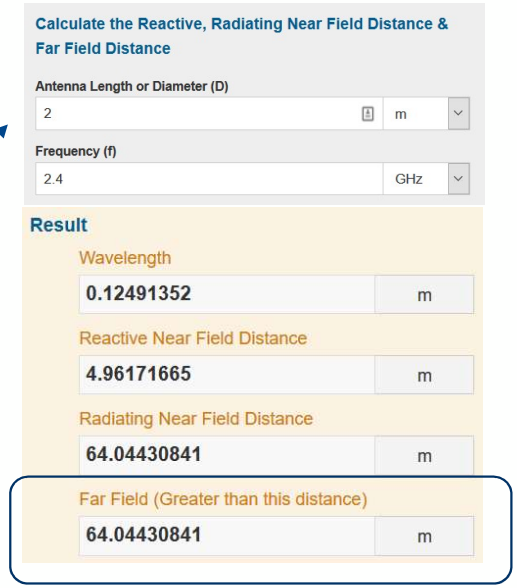
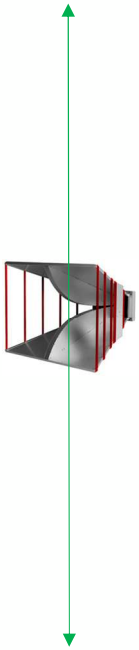
Testing sub 6GHz Antenna Arrays





$$R > \frac{2D^2}{\lambda}$$



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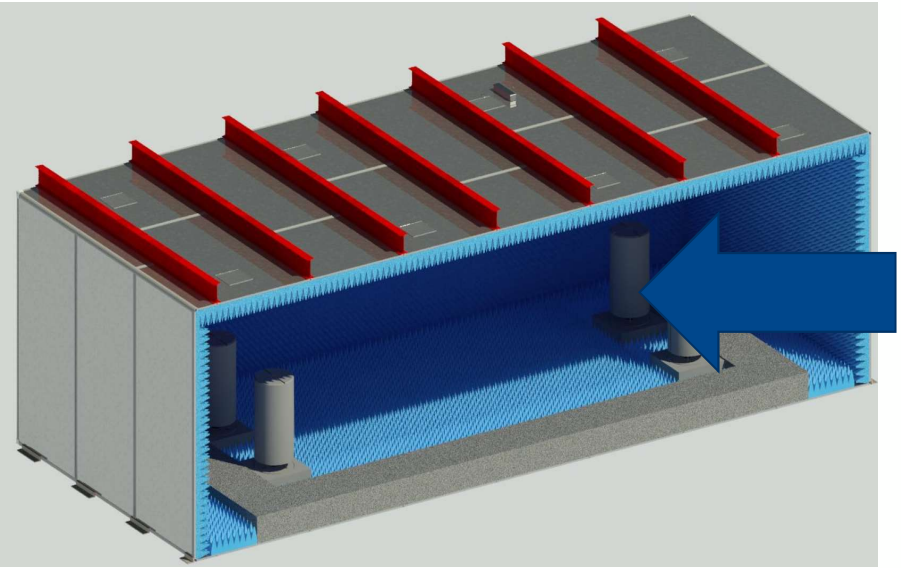
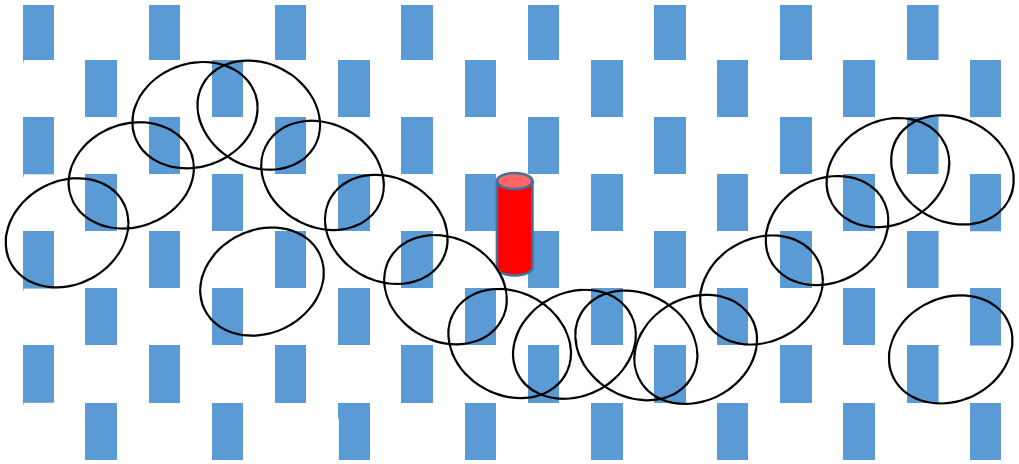
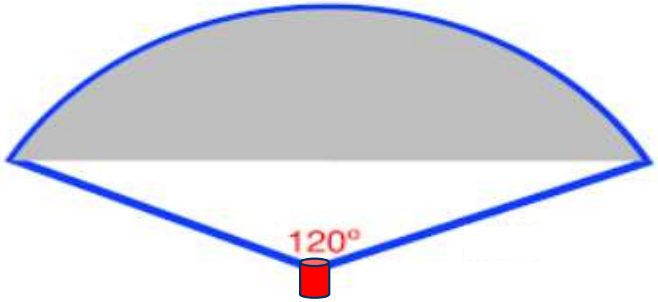
Massive MIMO, Curved Probe Wall







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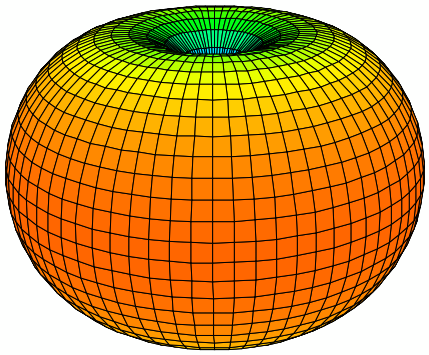
mmWave Antenna (Array) Characteristics



Frequency Range 2 = **FR2**
24.25 to 52.6 GHz
No harmonization – wide country scatter depending on what is available

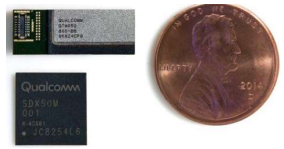
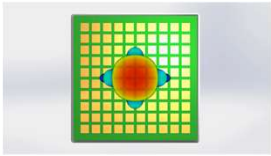


Photo Courtesy of Qualcomm



No cable connections possible

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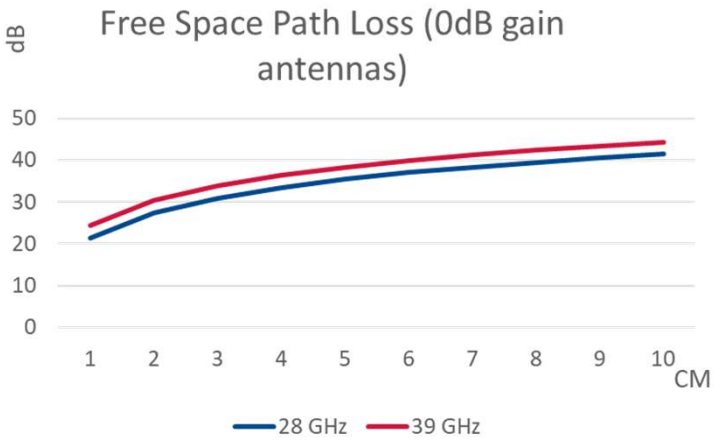
Cable Replacement

R&D Test phase

- Protocol in R&D stage
- RF design validation tests
- Functional KPI testing



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Conformance and Acceptance Tests

Device Acceptance Tests

- Protocol Conformance
- RF/RRM conformance
- Carrier specific acceptance tests
- Benchmarking tests

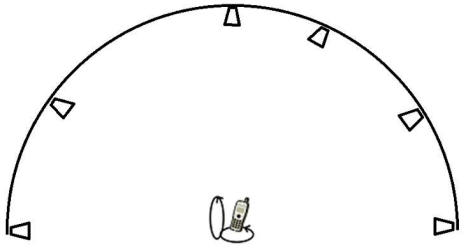

Figure 6.2.1.1-1: Baseline measurement setup of RRM characteristics

Defined by 3GPP TR38.810 RRM

- Two-axis of rotation with Fading
- AoAs: 30°,60°,90°,120°,150° & 180°
- Applies to DUTs array D ≤ 5cm

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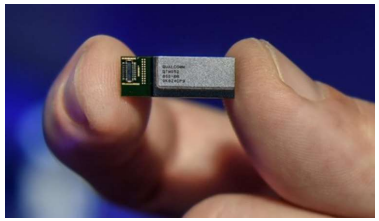
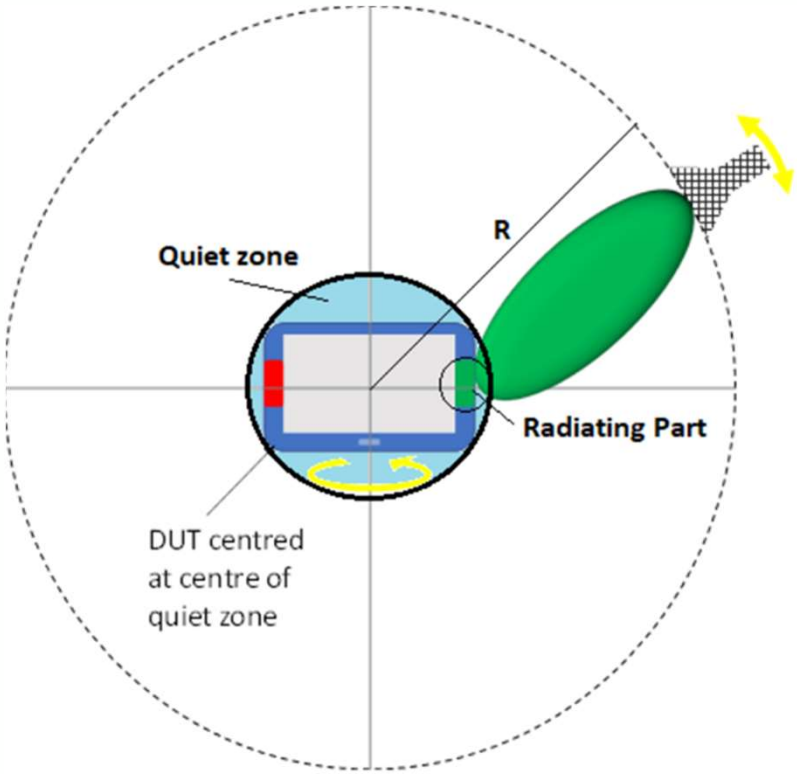
Quiet Zone definition for TR38.810

1. Far-field calculation = radiating part to probe
2. The 3GPP “Quiet zone” is traditionally center of the DUT (larger than the far field “QZ”)
3. Now rotate the DUT
4. This is going to be fun





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Real Life results

28 GHz VzW 5G waveform

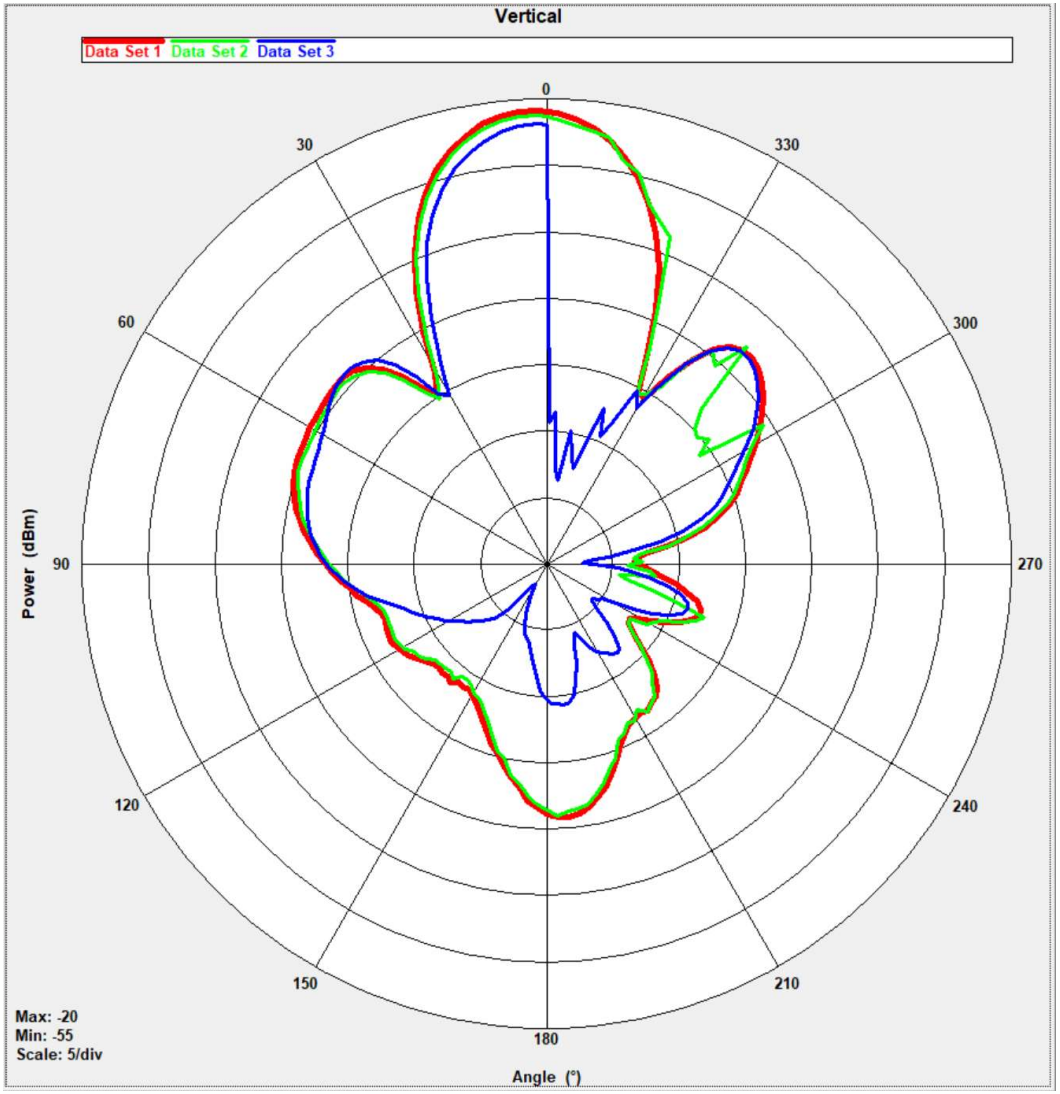
TX = 1x4 Linear antenna array

RX = Directional 15dBi antenna

8x100MHz = 800MHz wide bandwidth

Data

- Red = No interference
- Green = Person, faraway on side
- Blue = Person, between and behind



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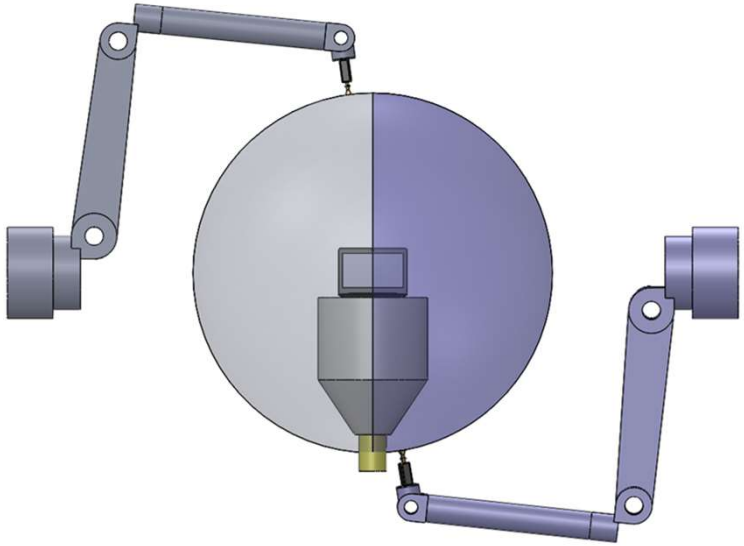
Testing Adaptive Antenna System

Past focus was main beam (EIRP/EIS)

Expect the device to “steer around” signal impediments

Better figure of merit is signal-to-interference ratio (SIR) in the presence of other radios in same channel.

Need multiple probes to evaluate interference from different directions.



Patents Pending

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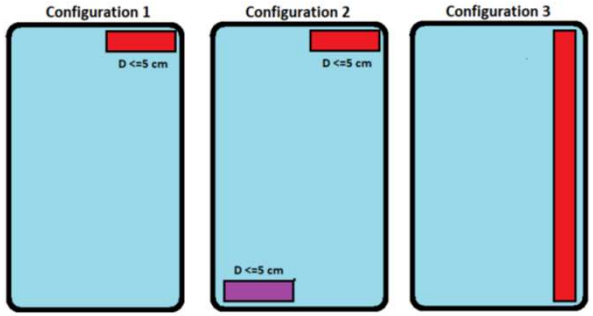
Test Method Applicability

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			



Currently 3 acceptable test methods – drive the test environment

- Direct Far Field
- Indirect Far Field
- Near Field to far field transformation

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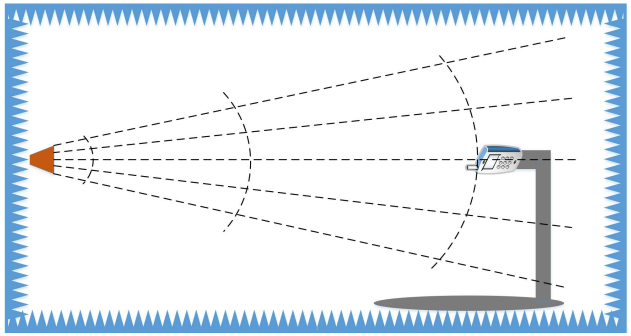
Direct Far Field (DFF) Method

Typical chamber and test method



Far field test distance between TX and RX is dependent on antenna size (D) and wavelength:

$$R > \frac{2D^2}{\lambda}$$

If DUT radiating aperture D=5 cm

R(cm) = 50/1.07

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DFF Pros and cons

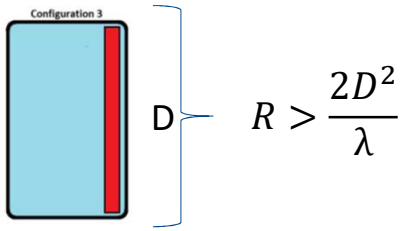
Simple construction without complicated components

Link antenna location stationary

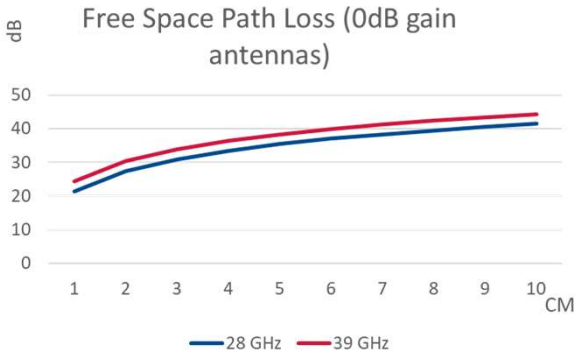
Long path length to fulfill the far field requirement

High free space loss due to path length

Large QZ = large chamber



$$R > \frac{2D^2}{\lambda}$$



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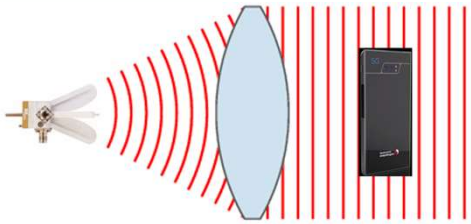
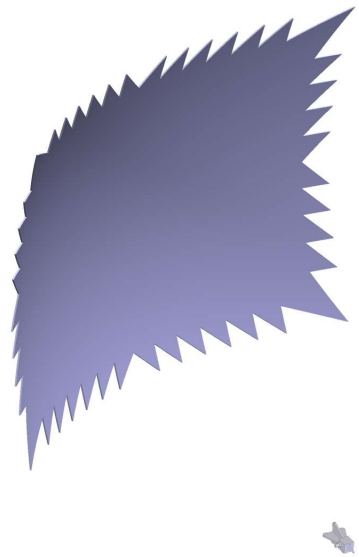
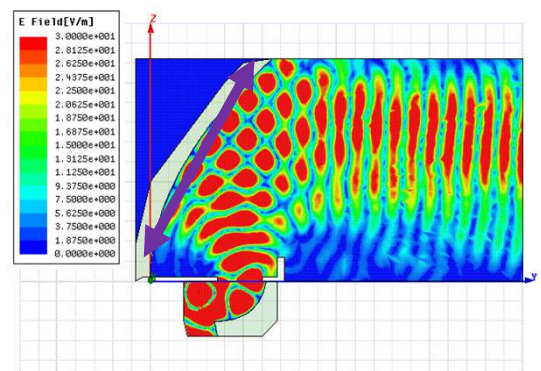
Indirect Far Field (IFF) Method





IFF methods use reflector or lens to adjust wavefront

Creates larger quiet zone in shorter distance that DFF



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IFF pros and cons

Larger QZ in smaller space than DFF

Reduced free space loss

Can move distances between components

Better dynamic range than DFF

Frequency limited reflector / lens

$$$ change frequency band

Link antenna location / movement

Adjustments needed to maintain communication link

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Near Field (NF) Method

Scan amplitude & phase

3λ - 5λ distance

Adjust near field to far field using transformation software

Requires probe characterization and phase reference equipment

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NF Method Pros and Cons

- Large QZ in very small space
- Lower free space loss

- Long test times due to large probing grid, resolution needed
- Requires phase reference for NF to FF transformation
  - UE does not provide that so alternative method needs to be developed
  - Additional equipment over DFF or IFF
- TX Power tests only
  - OK for TRP/EIRP
  - EIS, RSE, blocking tests not accepted by 3GPP

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Conclusions for Your Tests and Labs

5G and IoT device antenna(s) inseparable from RF section

All radio tests complicated by beamforming and mmWave physics

- Functional (production) tests need shield box
- Protocol conformance needs full antenna pattern test system
- Antenna pattern systems must optimize for path loss and quiet zone

Enclosures use significant space and increase complexity of tests

Setup and test time will increase and be less accurate than if cabled

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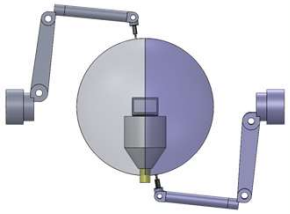
Conclusions for Your Tests and Labs

New production tests are needed to evaluate the array itself

Standards are just forming up, much still to be written

EUT really needs to be tested when AAS system is active



5G has arrived only for the marketing departments

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