5G Over-the-Air Test Implications and Solutions

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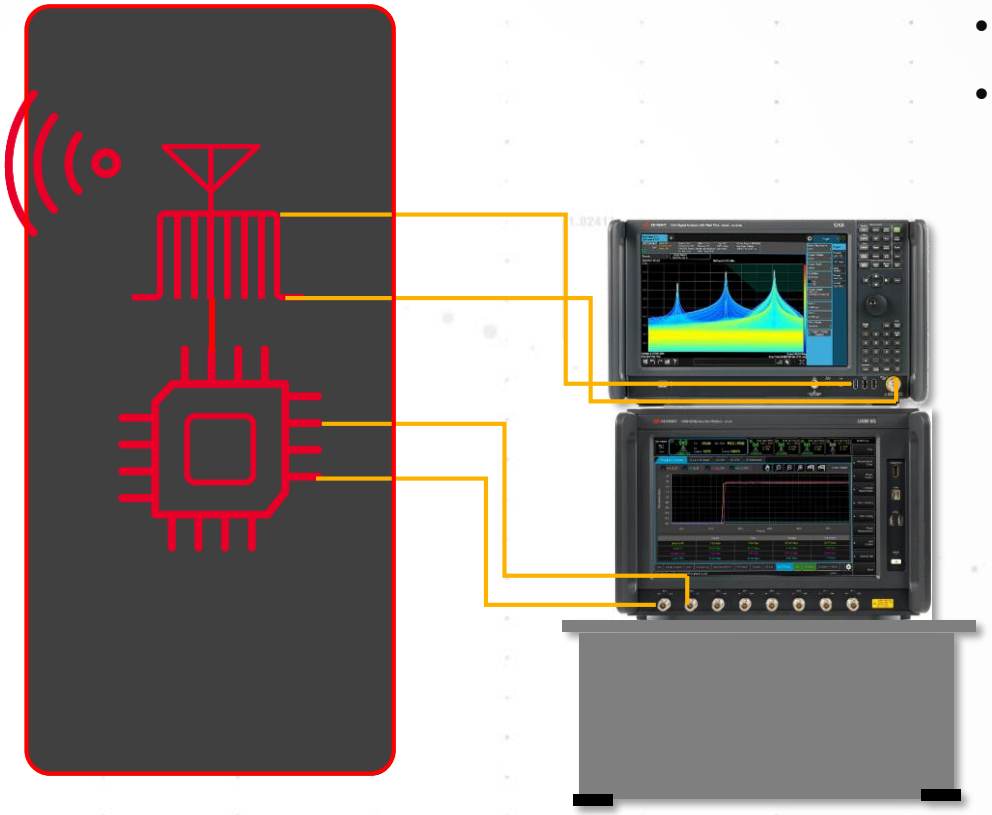
Let’s Build a Device Together

COMPASS FOR THE UNKNOWN

5G OTA – What Changed

Device Development Work Flow

TEST AND MEASUREMENT PERSPECTIVE



How Good is my Antenna?

- Antenna performance OTA tests
- KPI: Antenna Gain, Correlation

Do I have a working device?

- Functional Verification
- KPI: Throughput,

  Battery Drain

Is my RF working?

- RF Verification and Test
- KPI: Output power,

  Spurious emission, EVM

Is my chipset working?

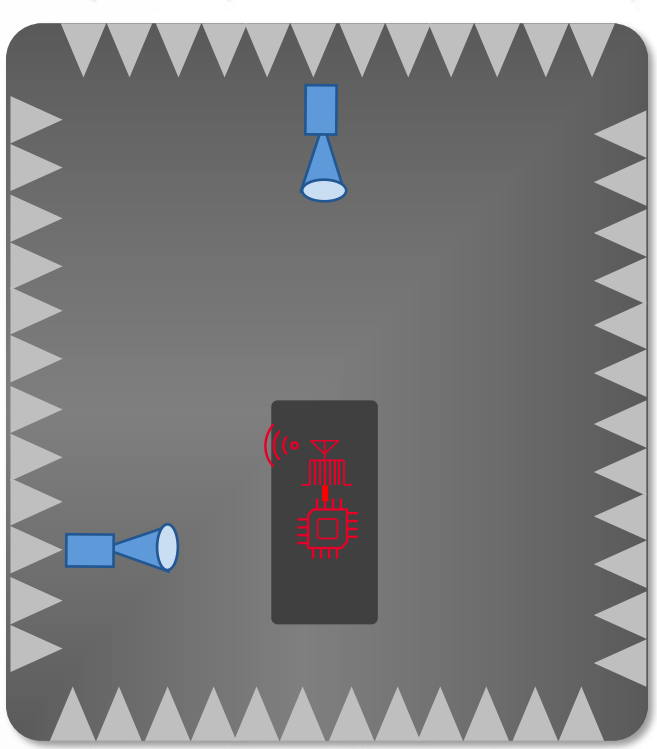
- Chipset verification
- KPI: Signaling, Throughput

Over-the-air

Cable Connected

Device Development Work Flow

TEST AND MEASUREMENT PERSPECTIVE



Over-the-air

How good is my device?

- Device Performance
- KPI: SISO and MIMO Throughput

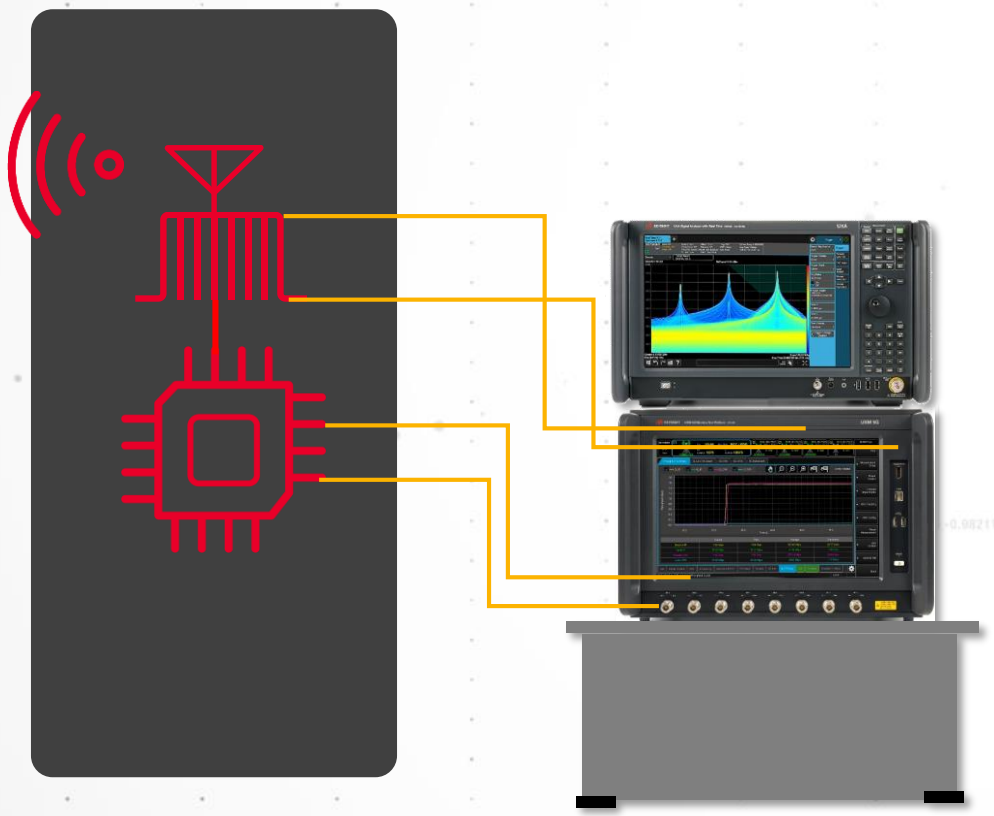
5G NR – A New Perspective for Test

FR1 (Sub-6 GHz)

<1 GHz	2.5 GHz	3.4 – 3.7 GHz	4.4 – 4.9 GHz	ISM

FR2 (mmWave)

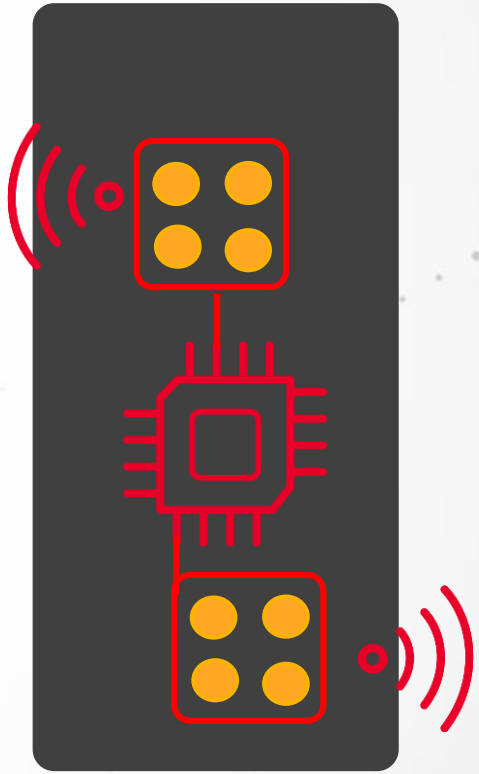
28 GHz	39 GHz



Connector less test for

- Protocol Functionality testing
- Signaling, Full stack, Data throughput testing
- RF parameters
- Antenna
- Full Device testing

The scope and nature of test has changed



5G mmW Means …..

KEEP CALM

BECAUSE

WE ARE GOING OVER THE AIR

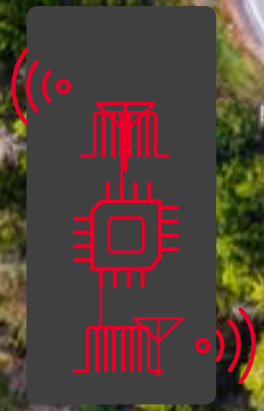
WHETHER WE LIKE IT OR NOT!

What is OTA?

Let’s Build a Device Together

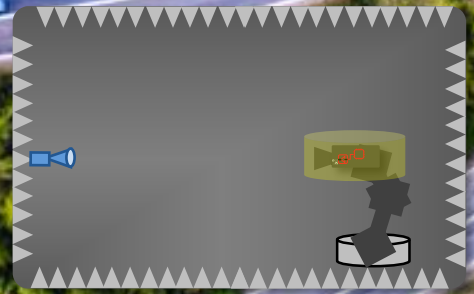
COMPASS FOR THE UNKNOWN

Workflow



How do we test a device today, and what changes

Basics



Establish Definitions
Outline Challenges

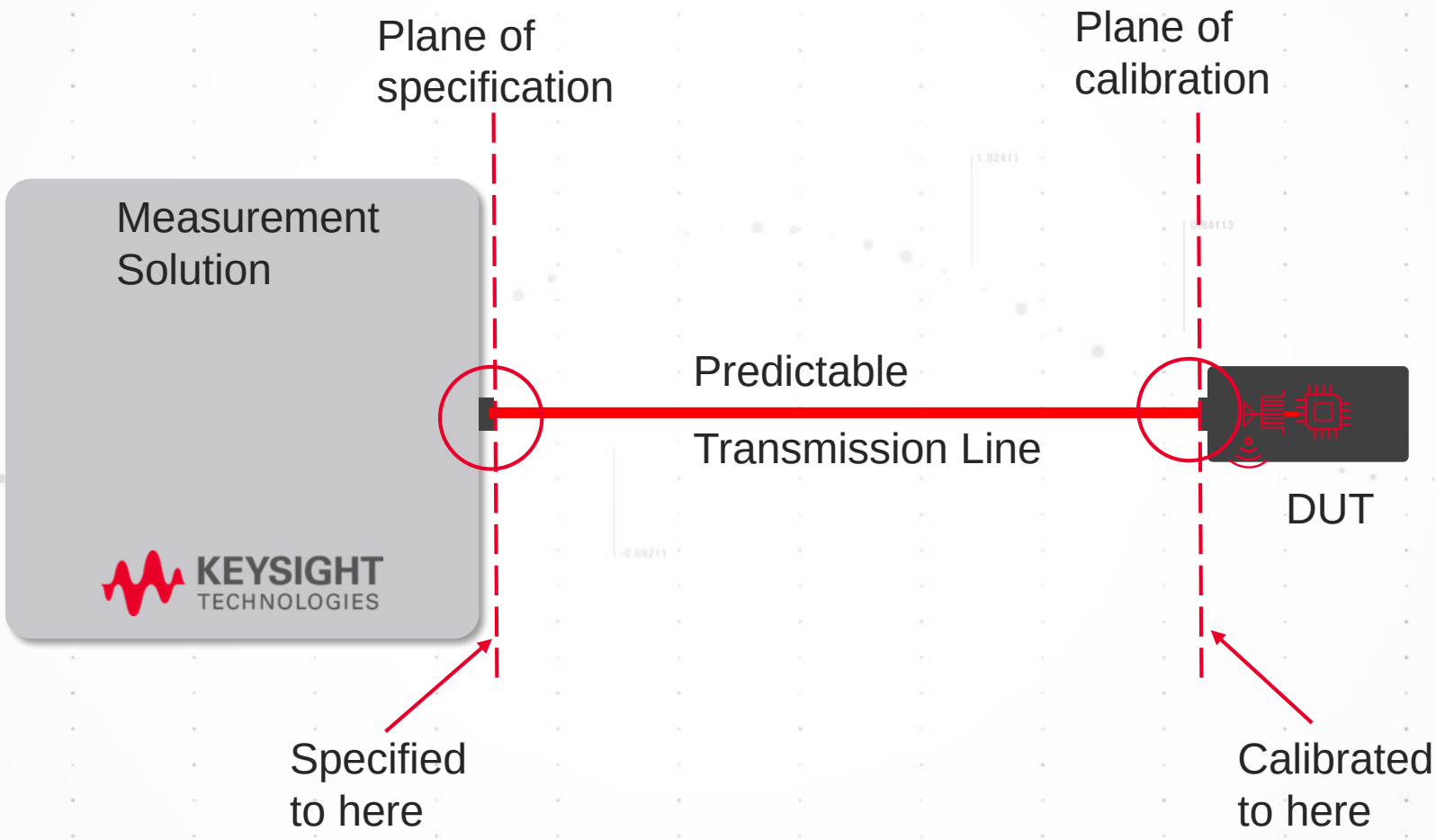
Solutions

EXIT

Device Development & Acceptance

What is ”Over-the-Air”?

LEAVING THE SAFETY OF A TRANSMISSION LINE

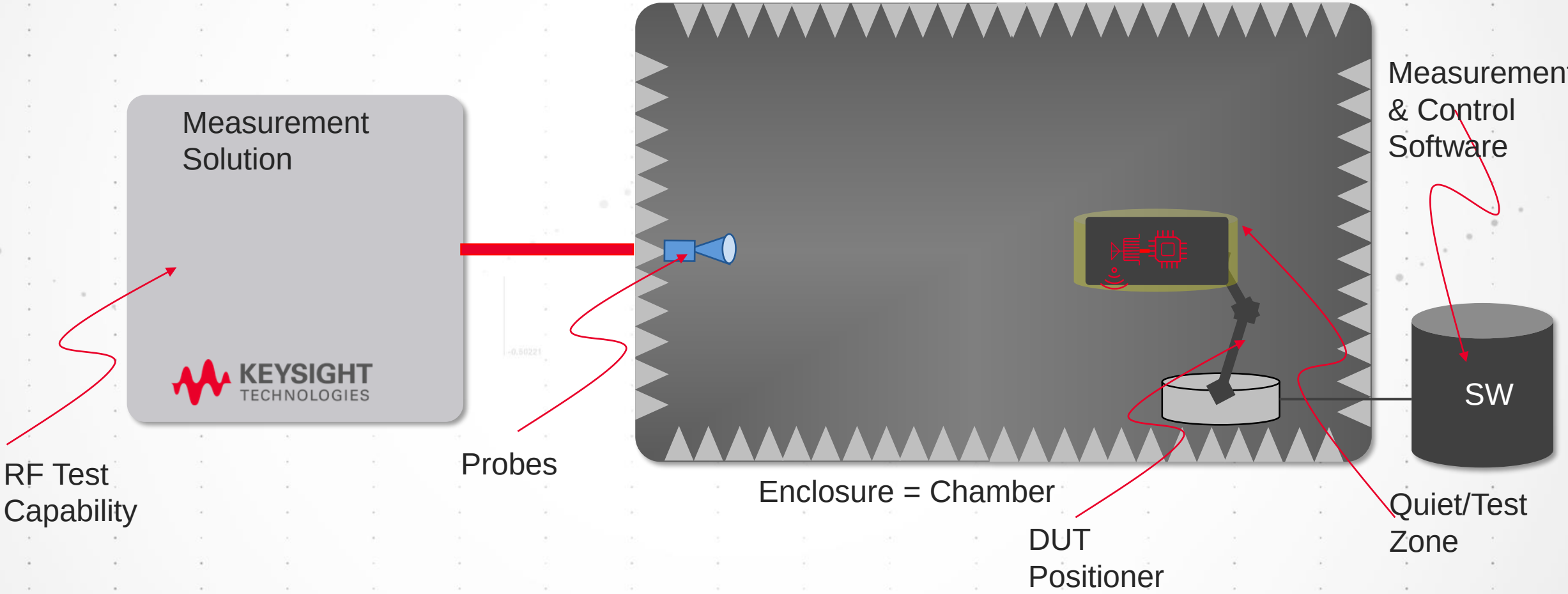


What is ”Over-the-Air”?

LEAVING THE SAFETY OF A TRANSMISSION LINE

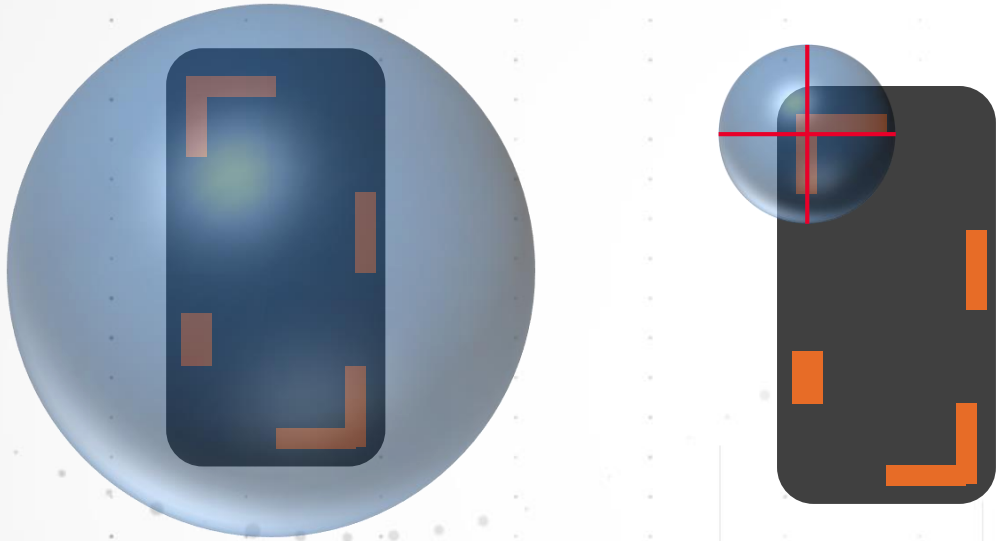
OTA Fundamentals

PRIMARY COMPONENTS OF A OTA SYSTEM



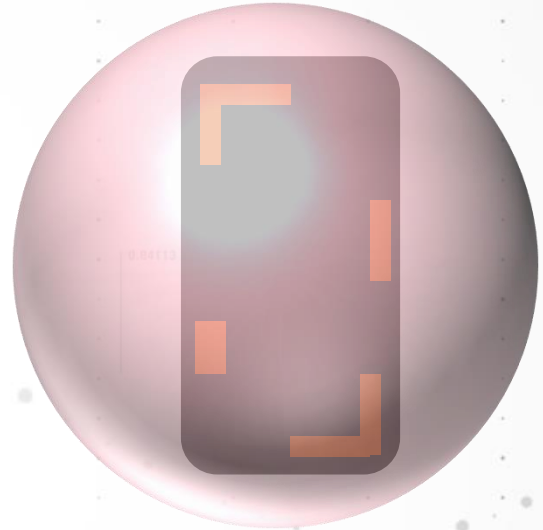
OTA Fundamentals

KEY CONCEPT: QUIET ZONE VS. TEST ZONE



Quiet Zone

- Function of chamber design, where RF Propagation is predictable and well behaved
- Applicable when test accuracy is dependent on path loss and phase characteristics
- Critical for RF Parametric measurements



Test Zone

- Applied when OTA test is a functional KPI or protocol test (cable replacement type)
- There are alternate algorithms available to compensate for any induced variation OR the test thresholds are set so that the MUs are built into the tests

OTA Fundamentals

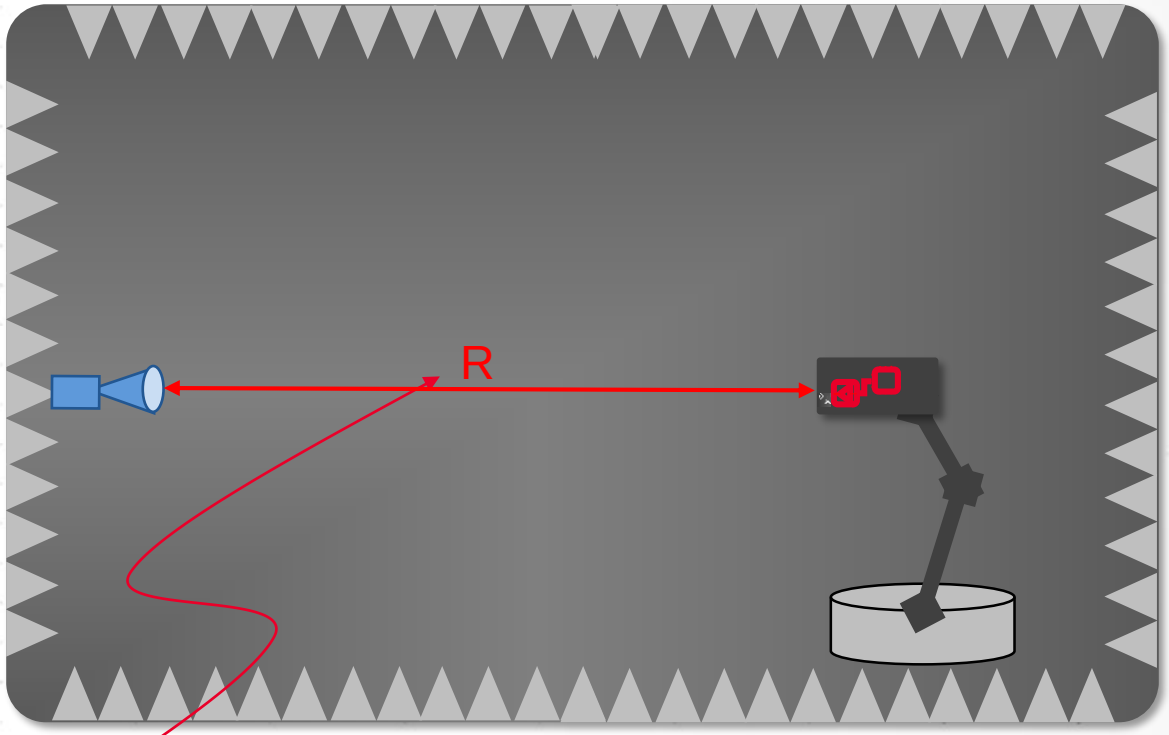
KEY CONCEPT: RANGE LENGTH

Range Length

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

Size of the DUT antenna

Decreases when f_c increases



Enclosure = Chamber

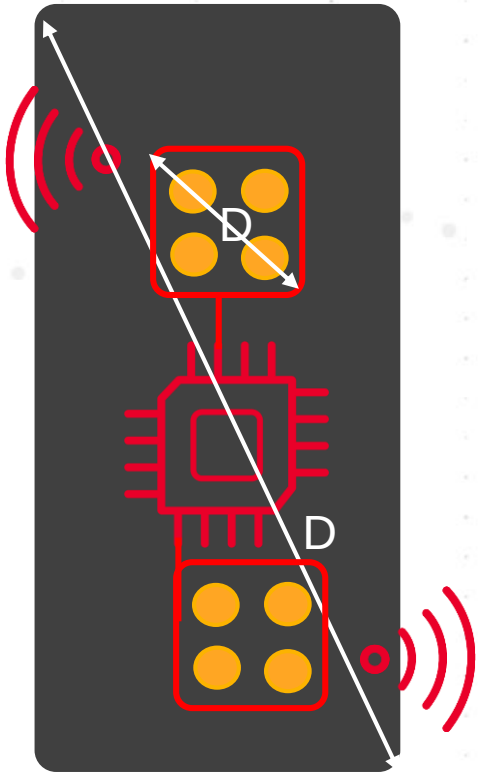
Range Length = What should be the distance between the probe and DUT

OTA Fundamentals

KEY CONCEPT: DEVICE SIZE ”D”

What is D?

- D can be small as the radiating element or as large as the entire device
- In handsets, must include coupling to other radiating elements
- 3GPP has defined 3 device categories
- 3GPP has mandated that the location of the antennas are not known (black box testing)
- In short – D – can be very large potentially 15 – 30 cms



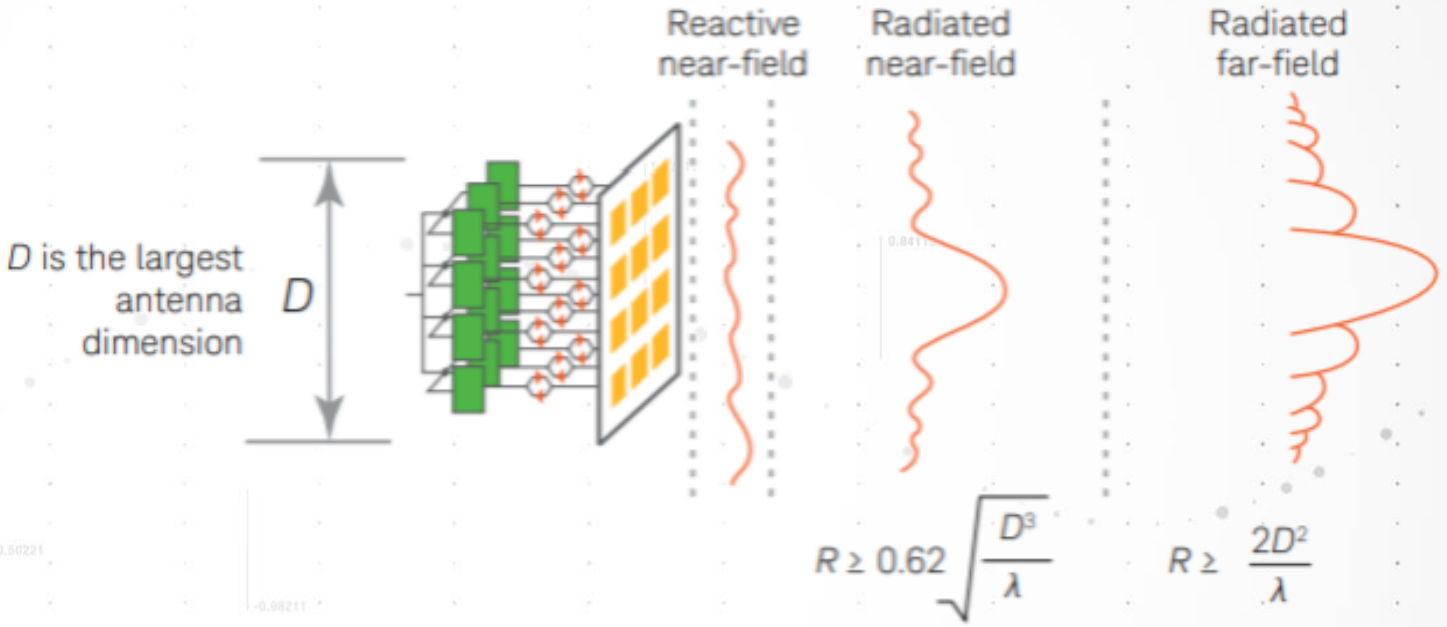
TR 38.810 Table 5.3-1: DUT Categories

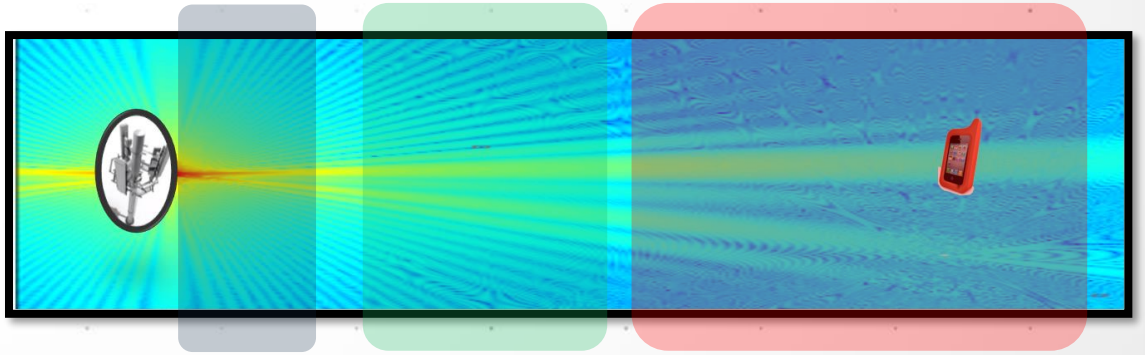
DUT category	Description
Category 1	Maximum one antenna panel with D ≤ 5 cm illuminated by test signal at any one time
Category 2	More than one antenna panel D ≤ 5 cm without phase coherency between panels illuminated at any one time
Category 3	Any phase coherent antenna panel of any size (e.g. sparse array)

OTA Fundamentals

KEY CONCEPT: REACTIVE NF, NF, AND FF

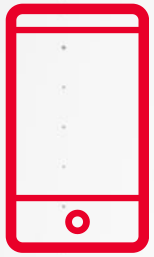
- Reactive Near-Field:
  - Non-propagating, evanescent fields predominate.
  - Not typically used for measurement
- Radiated Near-Field
  - Radiated fields predominate
  - But angular distribution is evolving
  - Radial field components exist
- Radiated Far-Field
  - Angular field distribution stops evolving
  - Receiving antenna sees plane-waves
  - Only transverse fields
  - Obvious location for measurement





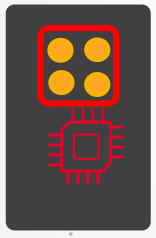
What Does All This Mean?

VERY LARGE CHAMBERS, WEAK SIGNALS



Device

D = 15 cm
28 GHz
R = 420 cm

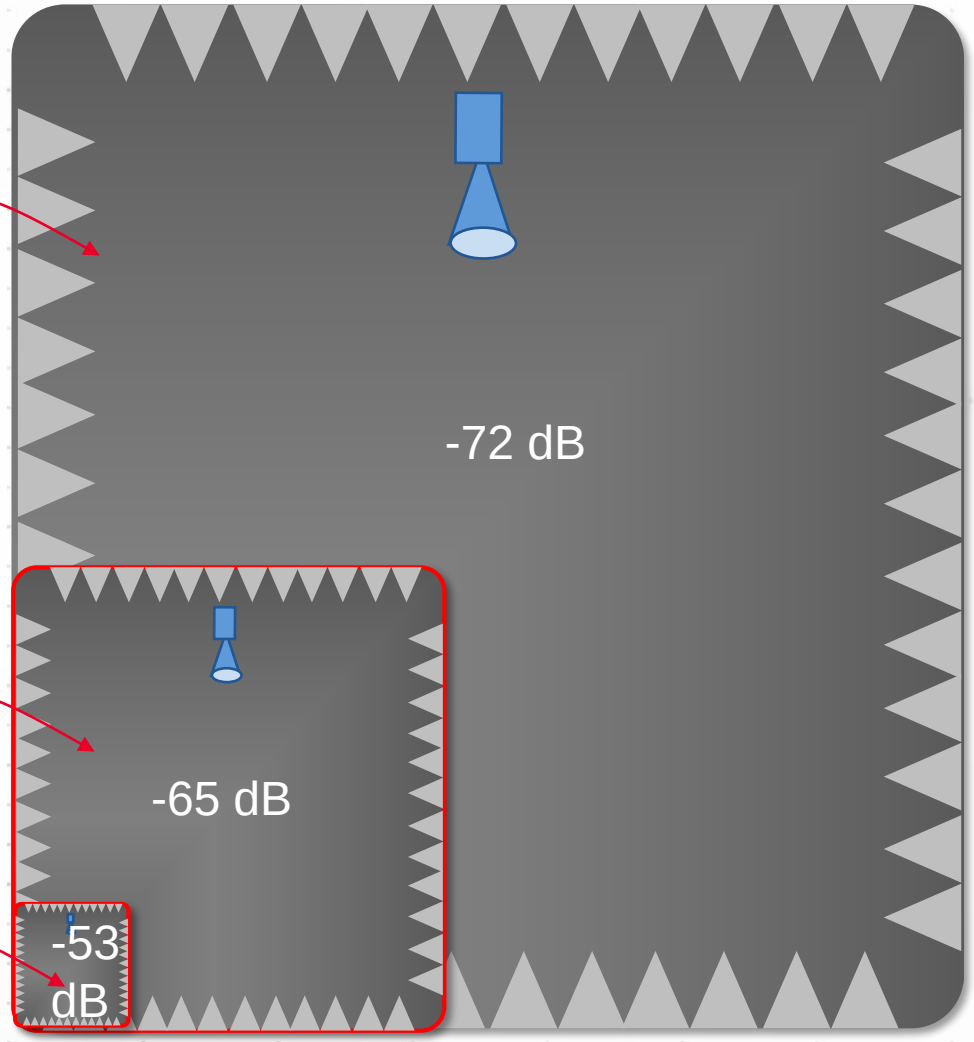


Module

D = 10 cm
28 GHz
R = 190 cm

Antenna

D = 5 cm
28 GHz
R = 50 cm



D(mm)	28 GHz	39 GHz
50	0.47	0.65
100	1.87	2.60
150	4.20	5.85
200	7.47	10.40
300	16.80	23.40

Far-field distance at different frequencies (in m)

Path loss: -53 dB to -72 dB

Far-Field Matter of Scale

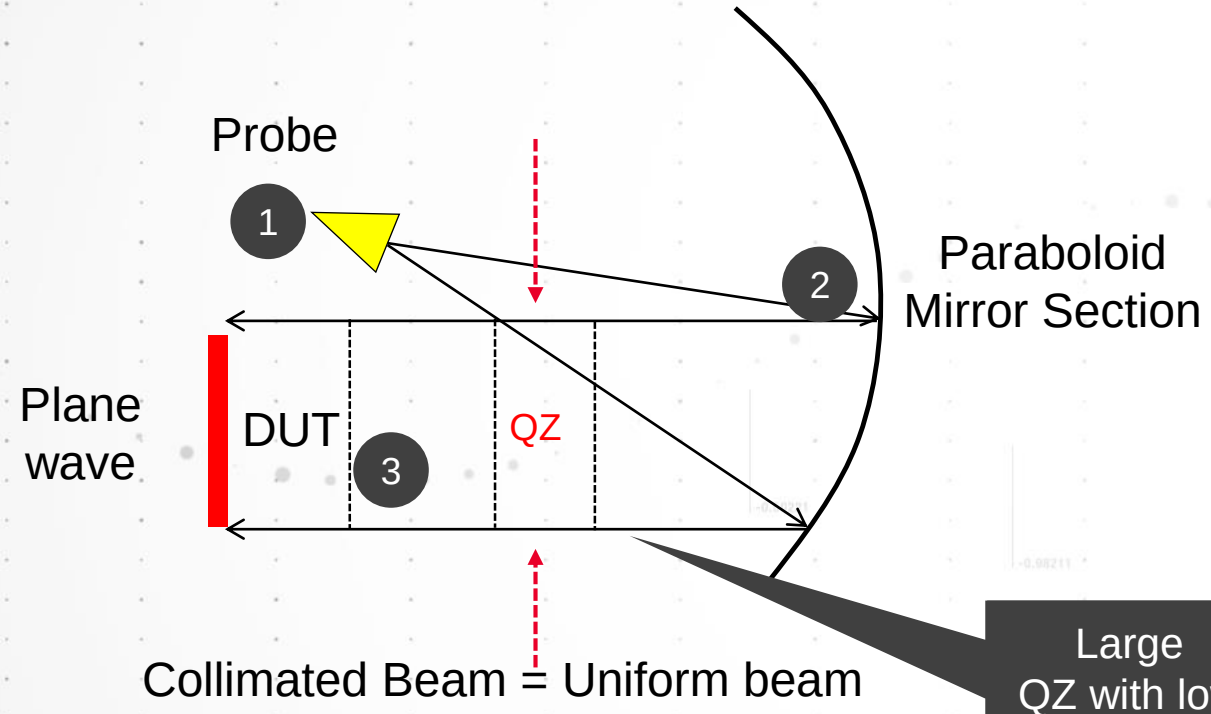
Big

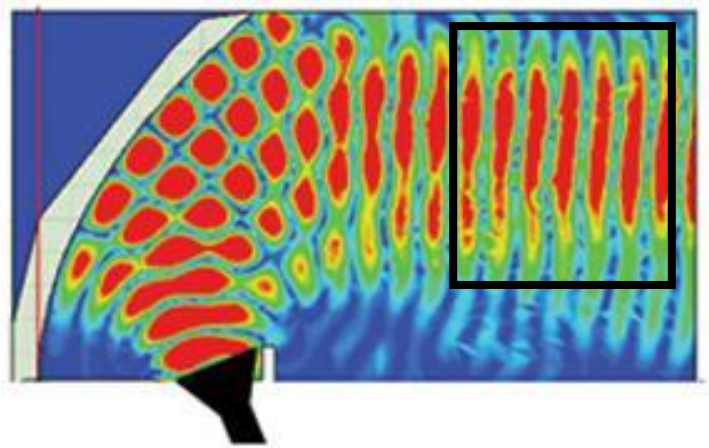
Bigger

Much Bigger

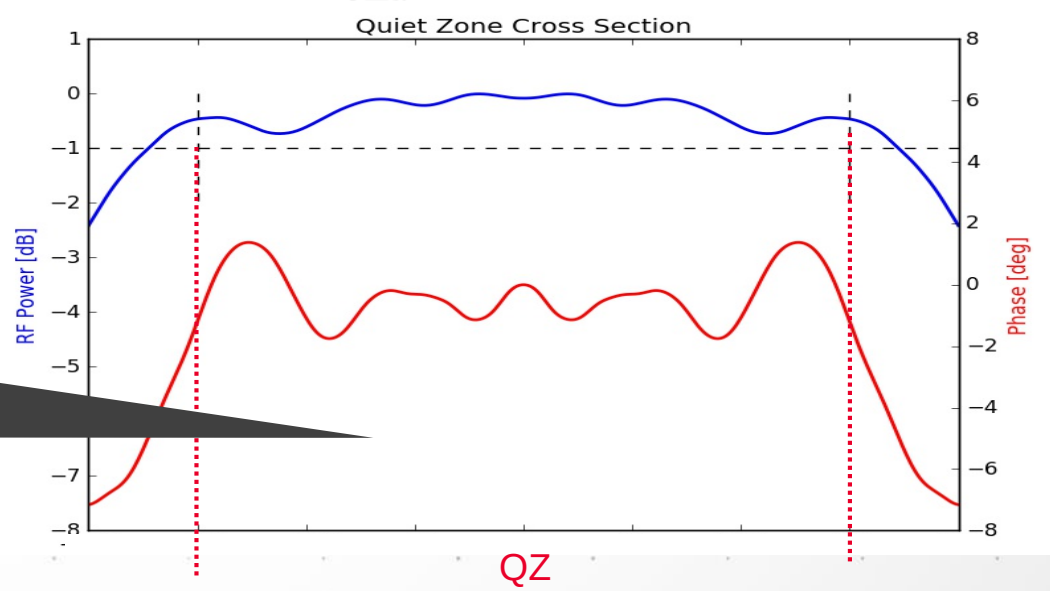
Alternate Approach: Indirect Far-Field

COMPACT ANTENNA TEST RANGE (CATR)



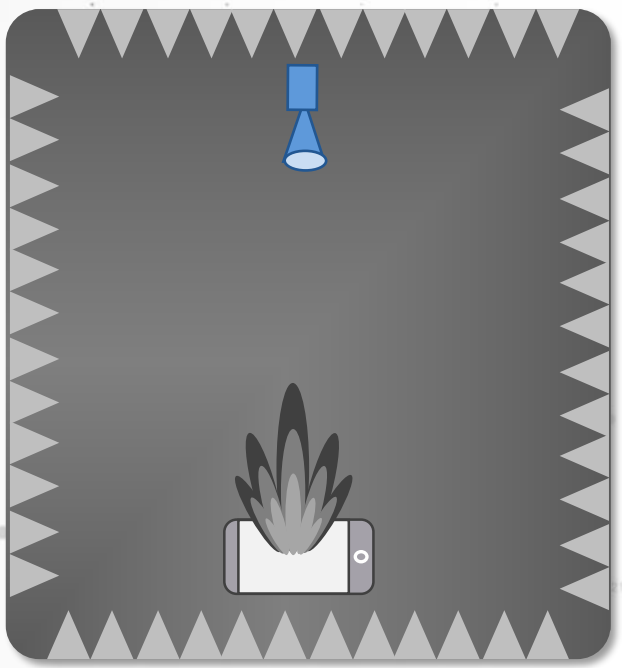


Large
QZ with low
Amp/Phase
Ripple



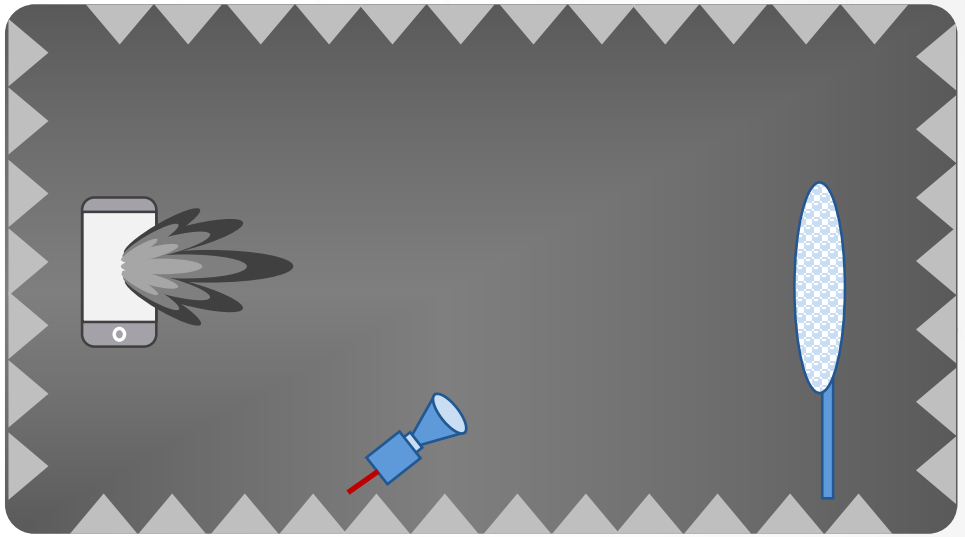
Contrast: DFF vs IFF

Direct Far-Field



- Simplest design for OTA test
- Devices normally operate in far-field

Indirect Far-Field



- Allows testing of larger mmWave devices with more compact footprint
- Broadest applicability to 3GPP DUT categories
- Supports testing w/o antenna position declaration

Example: Indirect Far Field OTA for UE Test

BASED ON CATR / IFF

- The IFF test method based on compact antenna test range (CATR) uses a parabolic reflector to collimate the signals transmitted by the probe antenna.
- Creates a far-field test environment in a much shorter distance and with less path loss than the DFF method.

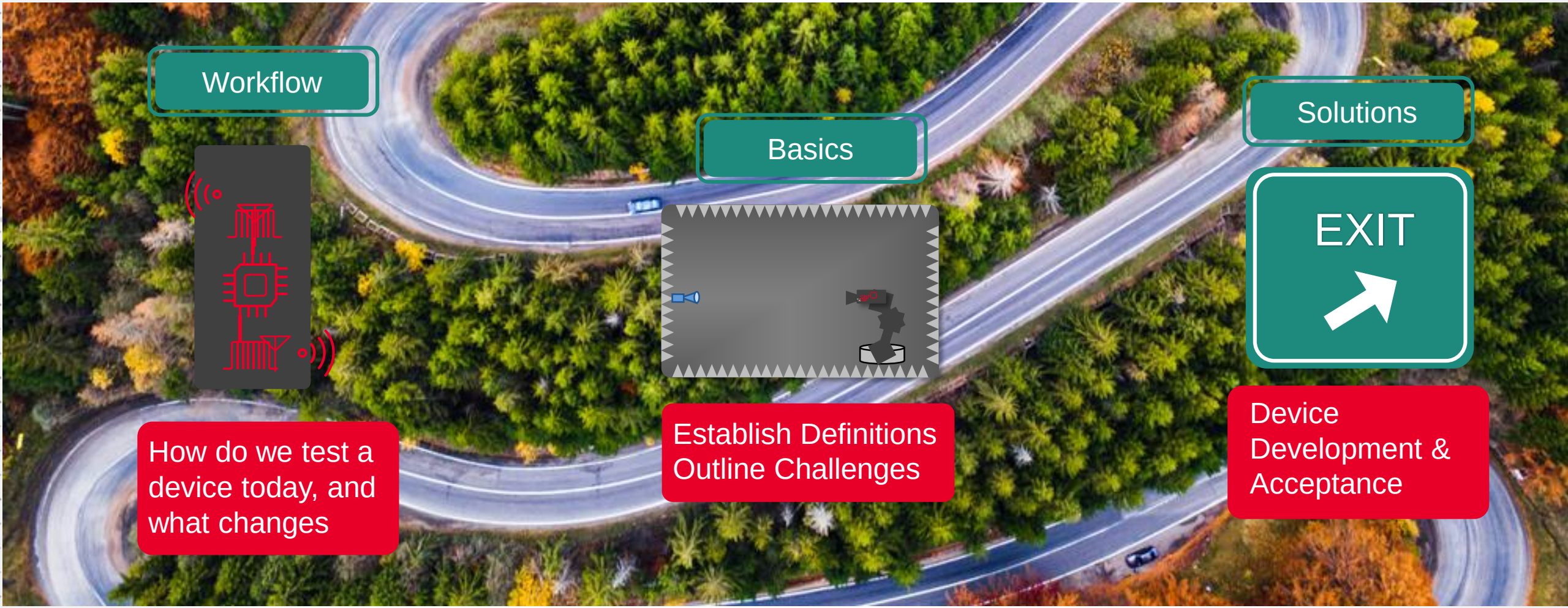
- Verizon over-the-air (OTA) testing solution using Compact Antenna Test Range Chamber (CATR)

  https://www.youtube.com/watch?v=IJOVIHHB9bw

Beyond OTA to Solutions

Let’s Build a Device Together

COMPASS FOR THE UNKNOWN



5G Device End-To-End Solutions

ACCELERATING INNOVATION FOR NEW 5G DEVICES

5G Interactive R&D Solutions

- Protocol R&D
- RF Automation
- Functional KPI

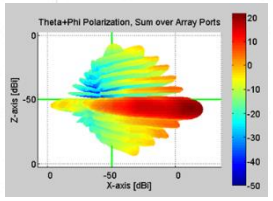
5G Device Acceptance Solutions

- Protocol Conformance
- RF/ RRM Conformance
- Carrier Acceptance

5G MFG Solutions

- Manufacturing

Network Emulator



Channel Emulator

mmWave OTA Solutions

Non-Signaling Test Set

Scale From Benchtop R&D to Full Rack Acceptance Test

END-TO-END TEST COVERAGE

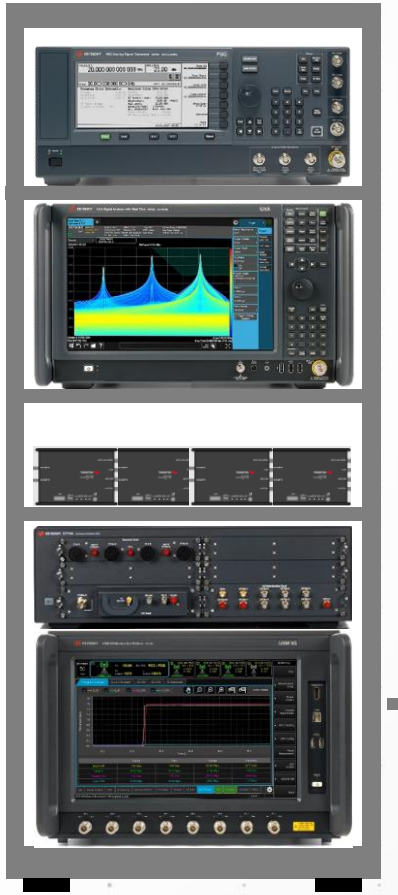
FR1 (sub-6GHz)

Protocol, RF, RRM and Functional

Industry leading GCF and PTCRB test case support for 5G NR SA and NSA

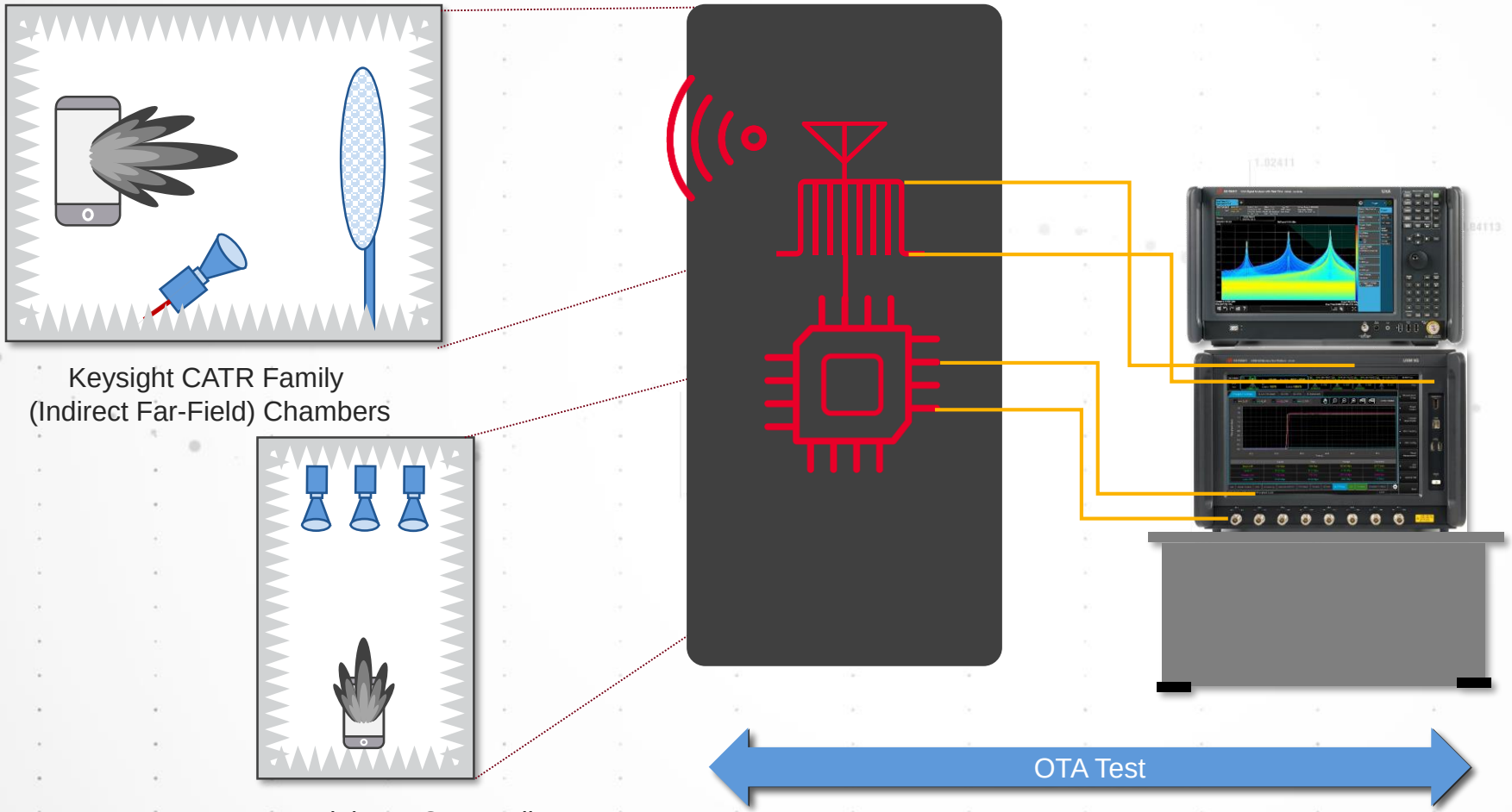
Add FR2 (mmWave) and OTA

Add spurious and interference for RF conformance



Device Development Work Flow

TEST AND MEASUREMENT PERSPECTIVE



Keysight CATR Family
(Indirect Far-Field) Chambers

Keysight RACK Family
(Cable Replacement/Direct Far-Field)
Chambers

How good is my antenna?

- Antenna performance
- KPI: Antenna Gain, Correlation

Do I have a working device?

- Functional Verification
- KPI: Throughput, Battery Drain

Is my RF working?

- RF Verification and Test
- KPI: Output power, Spurious emission, EVM

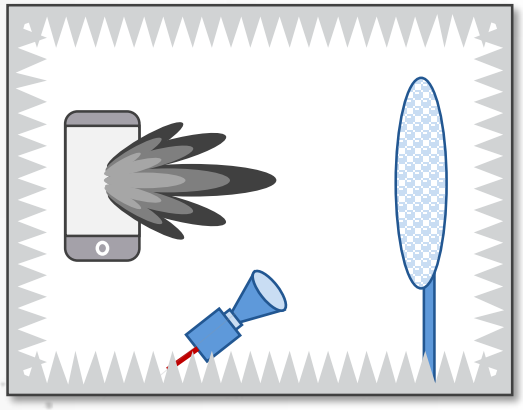
Is my chipset working?

- Chipset verification
- KPI: Signaling, Throughput

Industry's Most Complete mmWave OTA Portfolio

VALIDATE MMWAVE 5G DEVICES ACROSS WORKFLOW

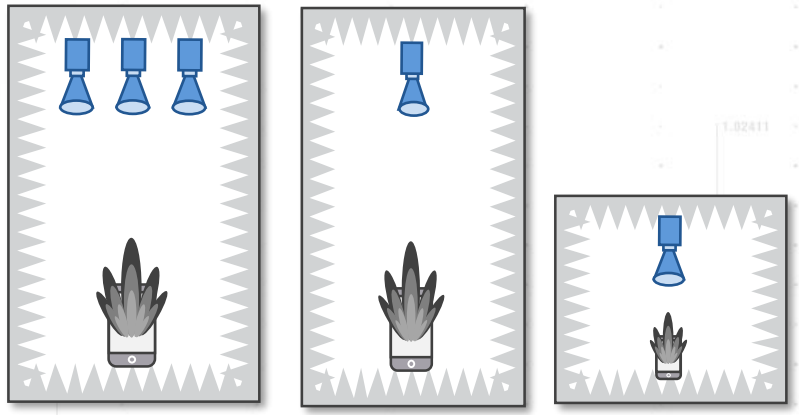
RF/Antenna/RCT



CATR

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

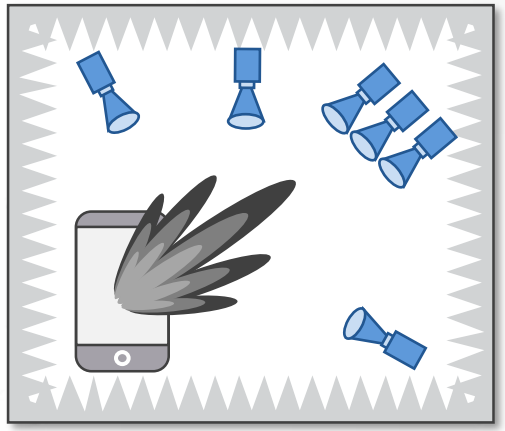
Protocol/Functional/PCT



2DMPAC *RMTC* *mini-RMTC*

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

Mobility and Performance

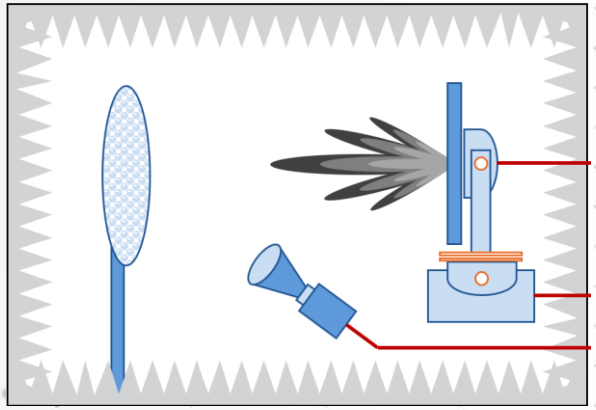


3D MPAC

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

gNB Over-the-Air (OTA) Portfolio

RF/Antenna

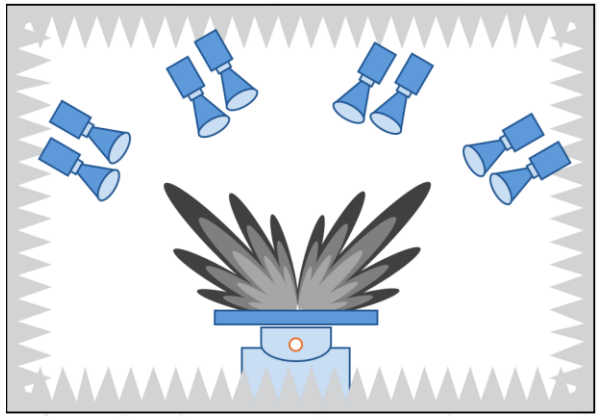


CATR

TX Tests
- *Output power*
- *Output power dynamics*
- *Frequency error*
- *EVM*
- *Occupied BW*
- *ACLR*

RX Tests
- *Reference sensitivity*
- *Dynamic Range*
- *In Band Selectivity & Blocking*
- *Receiver IM*

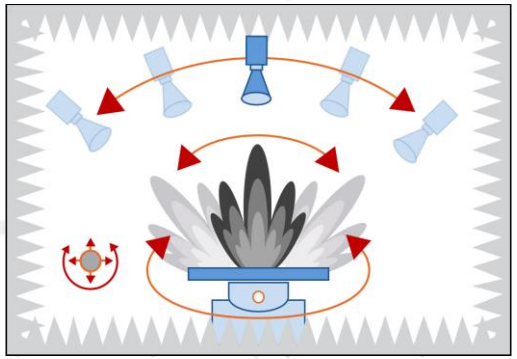
Protocol/Functionality Performance/ IOT



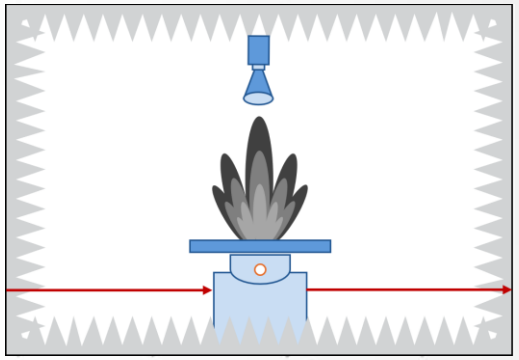
gNB MPAC

Functional and Performance Testing With Bi-Directional Fading
- *Protocol Functionality testing*
- *Integration and Verification of baseband functionality (CA, Massive MIMO, beam forming)*
- *NV-IOT functionality*
- *HETNET functionality*
- *gNB performance testing*

Manufacturing



Compact MPAC



Ultra-Compact Near Field

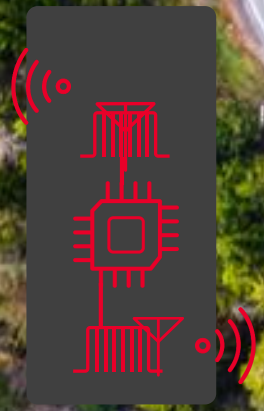
R&D and Early Manufacturing
Volume Manufacturing
- *Near field Beam Pattern measurement*
- *Near field TX Beam parameteric measurement*
- *Near field Beam RX EIS measurement*
- *Near field TX Array Calibration*
- *Near field RX Array Calibration*
- *OTA RF Parametric Measurements*
- *Fast measurements for Pass/Fail of DUT*

Summary and Conclusions

Let’s Build a Device Together

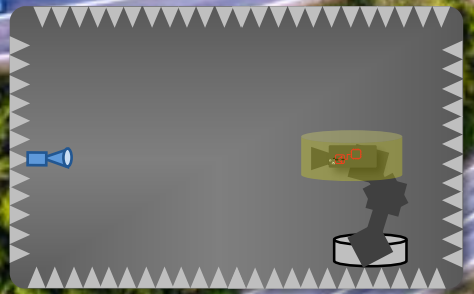
COMPASS FOR THE UNKNOWN

Workflow



- 4 stages of test: Chipset, RF, Antenna and Functional test.
- Conducted for FR1
- OTA in FR2 due to lack of connectors

Basics

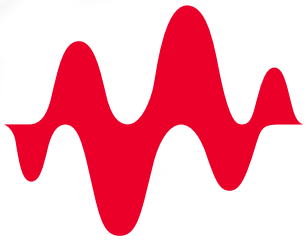


- How a chamber enables OTA
- Larger device sizes and smaller wavelengths lead to bigger chambers
- Alterative is to create far-field indirectly using physics - CATR

Solutions

EXIT

- Device development and device acceptance
- One size fits all approach will not work
- Keysight’s workflow based solutions pair right OTA enviroments with right tools



KEYSIGHT
TECHNOLOGIES