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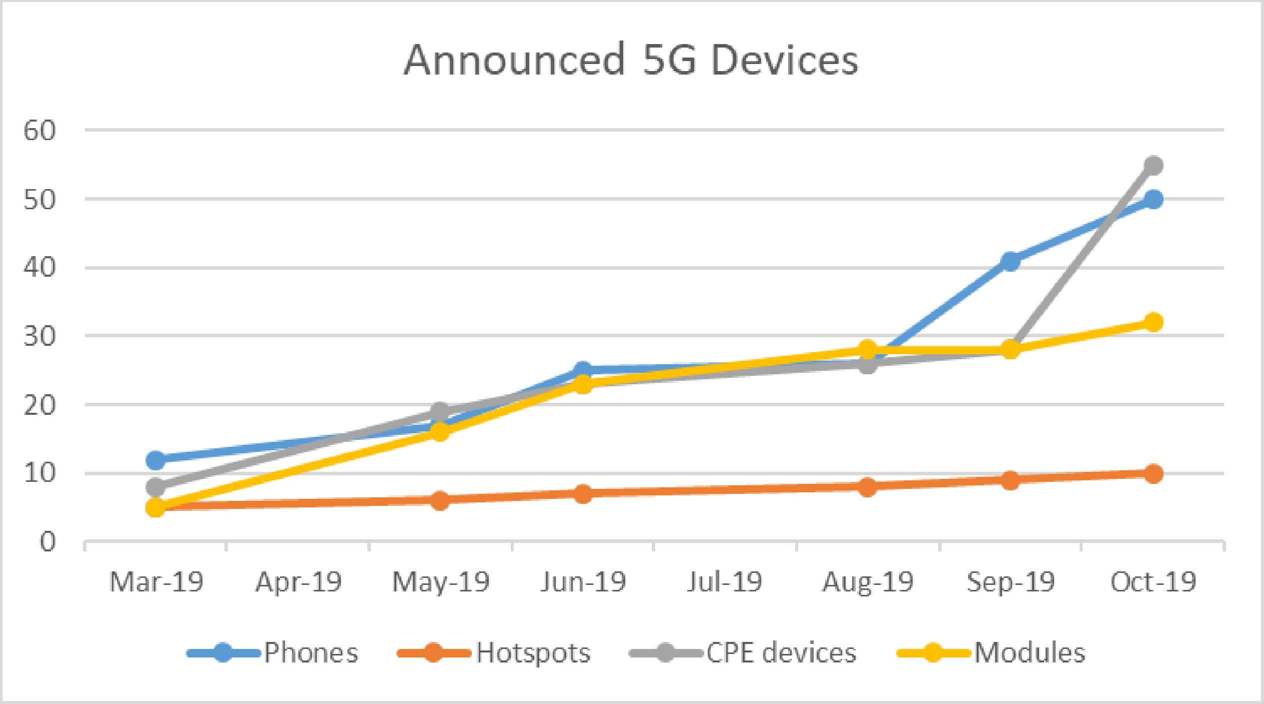
A Teradyne Company

Transitioning from DVT to manufacturing for 5G FR2 mmWave devices

Market Update: 5G Device Ecosystem

By Oct. 2019, GSA had identified 15 announced form factors
71 vendors announced 172 devices (50 phones, 10 hotspots, 55 CPE devices, 32 modules, etc.)



Source: GSA 5G Devices Report

Figure 2: Announced 5G devices, by form factor

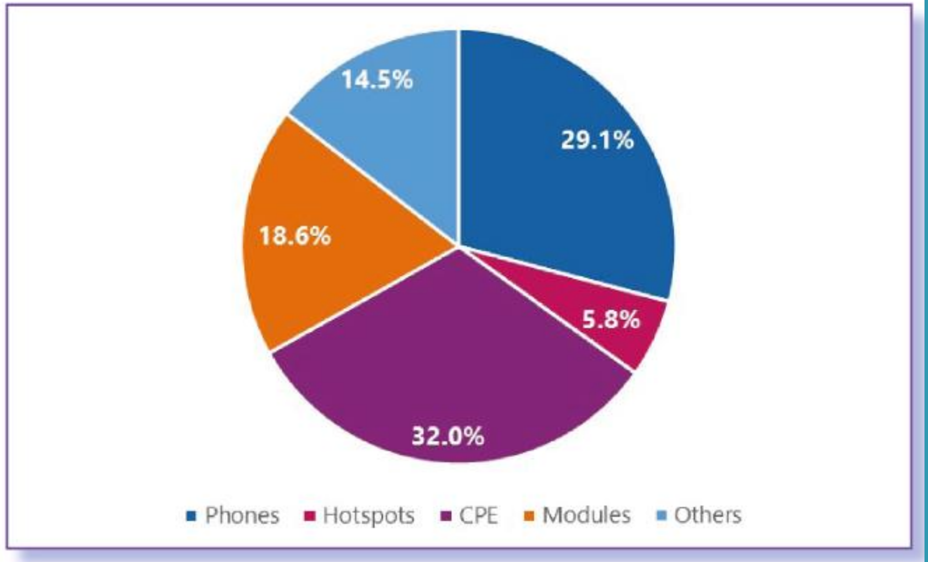
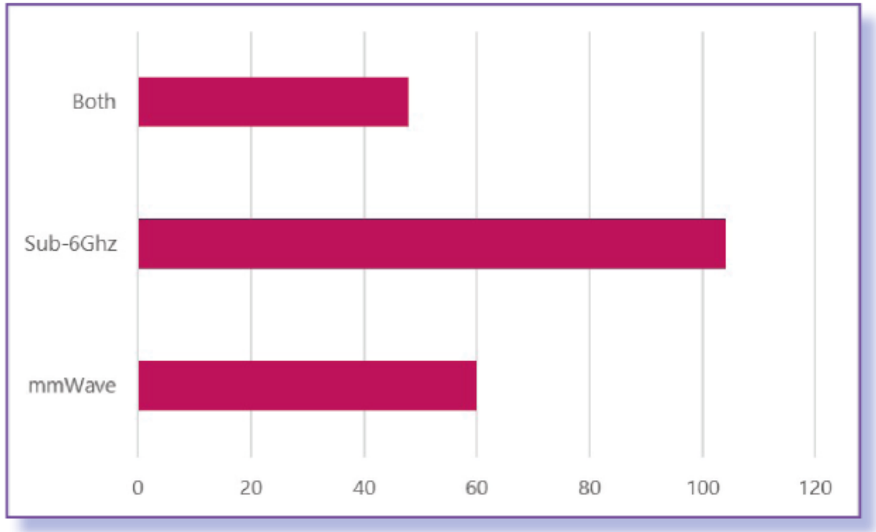


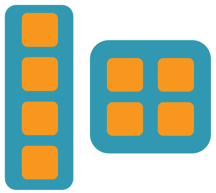
Figure 3: Announced devices with known spectrum support, by broad category (data not available for all devices)



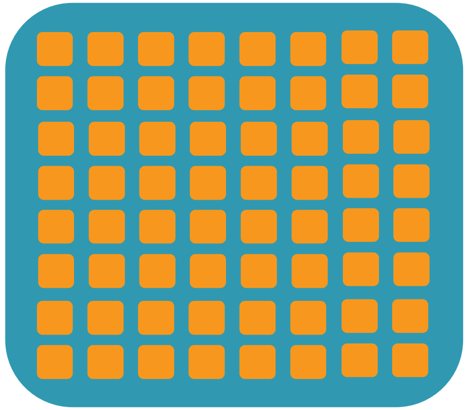
UE Power Class - Antenna and Output Power

- Different UE power classes are characterized by different UE antenna design assumptions and have different UE maximum output power and reference sensitivity requirements.

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



Power class 1

	Operating band	Min Peak EIRP (dBm)	Max TRP (dBm)	Max EIRP (dBm)
Power class 1	n257	40	35	55
	n258	40	35	55
	n260	38	35	55
	n261	40	35	55
Power class 2	n257	29	23	43
	n258	29	23	43
	n261	29	23	43
Power class 3	n257	22.4	23	43
	n258	22.4	23	43
	n260	20.6	23	43
	n261	22.4	23	43
Power class 4	n257	34	23	43
	n258	34	23	43
	n260	31	23	43
	n261	34	23	43

3GPP TS38.101-2

UE Power Class - Reference Sensitivity

3GPP TS38.101-2

Power class 1

Operating band	REFSENS (dBm) / Channel bandwidth			
	50 MHz	100 MHz	200 MHz	400 MHz
n257	-97.5	-94.5	-91.5	-88.5
n258	-97.5	-94.5	-91.5	-88.5
n260	-94.5	-91.5	-88.5	-85.5
n261	-97.5	-94.5	-91.5	-88.5
NOTE 1: The transmitter shall be set to P_{UMAX} as defined in subclause 6.2.4				

Power class 2

Operating band	REFSENS (dBm) / Channel bandwidth			
	50 MHz	100 MHz	200 MHz	400 MHz
n257	-92.0	-89.0	-86.0	-83.0
n258	-92.0	-89.0	-86.0	-83.0
n261	-92.0	-89.0	-86.0	-83.0
NOTE 1: The transmitter shall be set to P_{UMAX} as defined in subclause 6.2.4				

Power class 3

Operating band	REFSENS (dBm) / Channel bandwidth			
	50 MHz	100 MHz	200 MHz	400 MHz
n257	-88.3	-85.3	-82.3	-79.3
n258	-88.3	-85.3	-82.3	-79.3
n260	-85.7	-82.7	-79.7	-76.7
n261	-88.3	-85.3	-82.3	-79.3
NOTE 1: The transmitter shall be set to P_{UMAX} as defined in subclause 6.2.4				

Power class 4

Operating band	REFSENS (dBm) / Channel bandwidth			
	50 MHz	100 MHz	200 MHz	400 MHz
n257	-97.0	-94.0	-91.0	-88.0
n258	-97.0	-94.0	-91.0	-88.0
n260	-95.0	-92.0	-89.0	-86.0
n261	-97.0	-94.0	-91.0	-88.0
NOTE 1: The transmitter shall be set to P_{UMAX} as defined in subclause 6.2.4				

When we talk about 5G FR2 mmWave, we must discuss OTA

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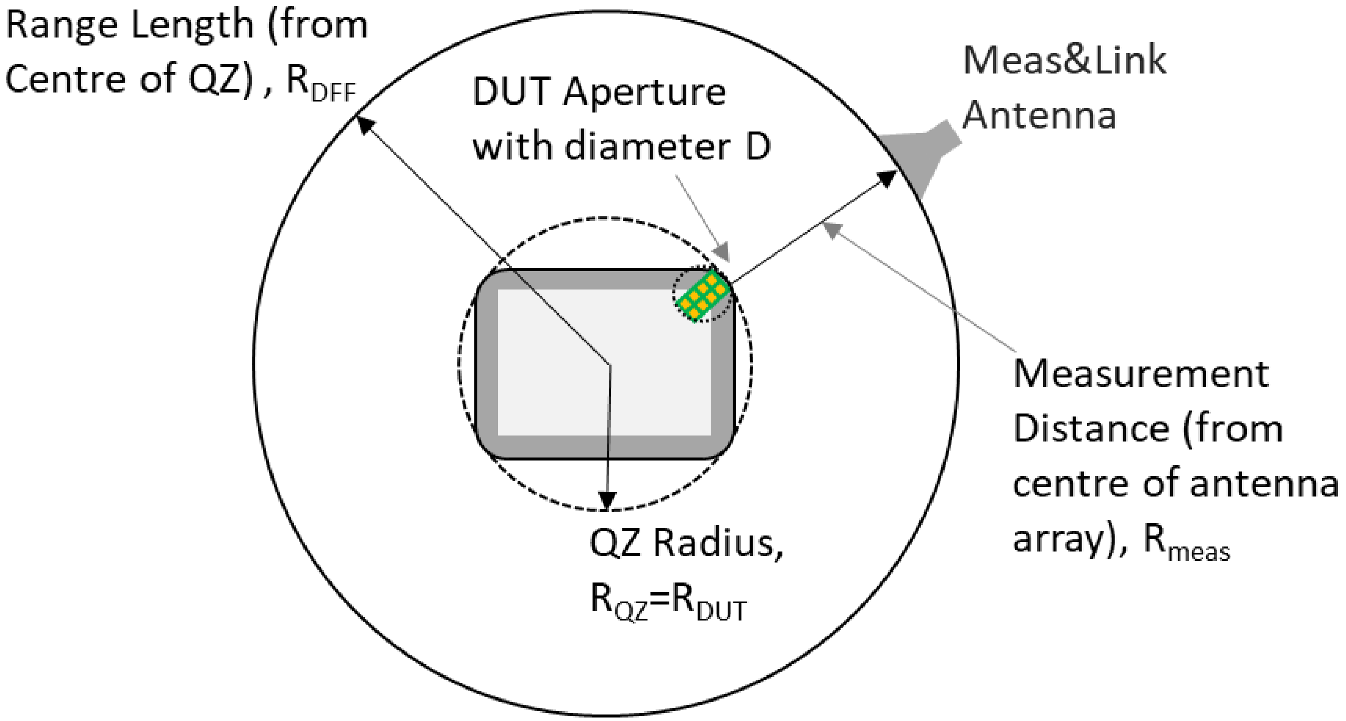
Recap 3GPP TR 38.810

- To define the over the air (OTA) testing methodology for UE RF, UE RRM, and UE demodulation requirements for New Radio, the associated measurement uncertainty budget(s), and the related test tolerances.
- The test methods defined are introduced for handheld UEs and applicable to FR2 UE Power Class 3
- Permitted test methods for UE RF testing
  - Direct far field (DFF)
  - Indirect far field (IFF), aka Compact Antenna Test Range (CATR)
  - Near field to far field transform (NFTF)

DFF with Black-box Testing Approach

- The centre of DUT is placed in the centre of the test zone
- The minimum range length for NR FR2 DFF systems where the sphere enclosing the DUT matches the QZ and the DUT antenna with radiating aperture diameter D located in the corner of the DUT

$$\text{Minimum } R_{DFF} = R_{QZ} - D/2 + R_{meas} = R_{QZ} - D/2 + 2D^2/\lambda$$



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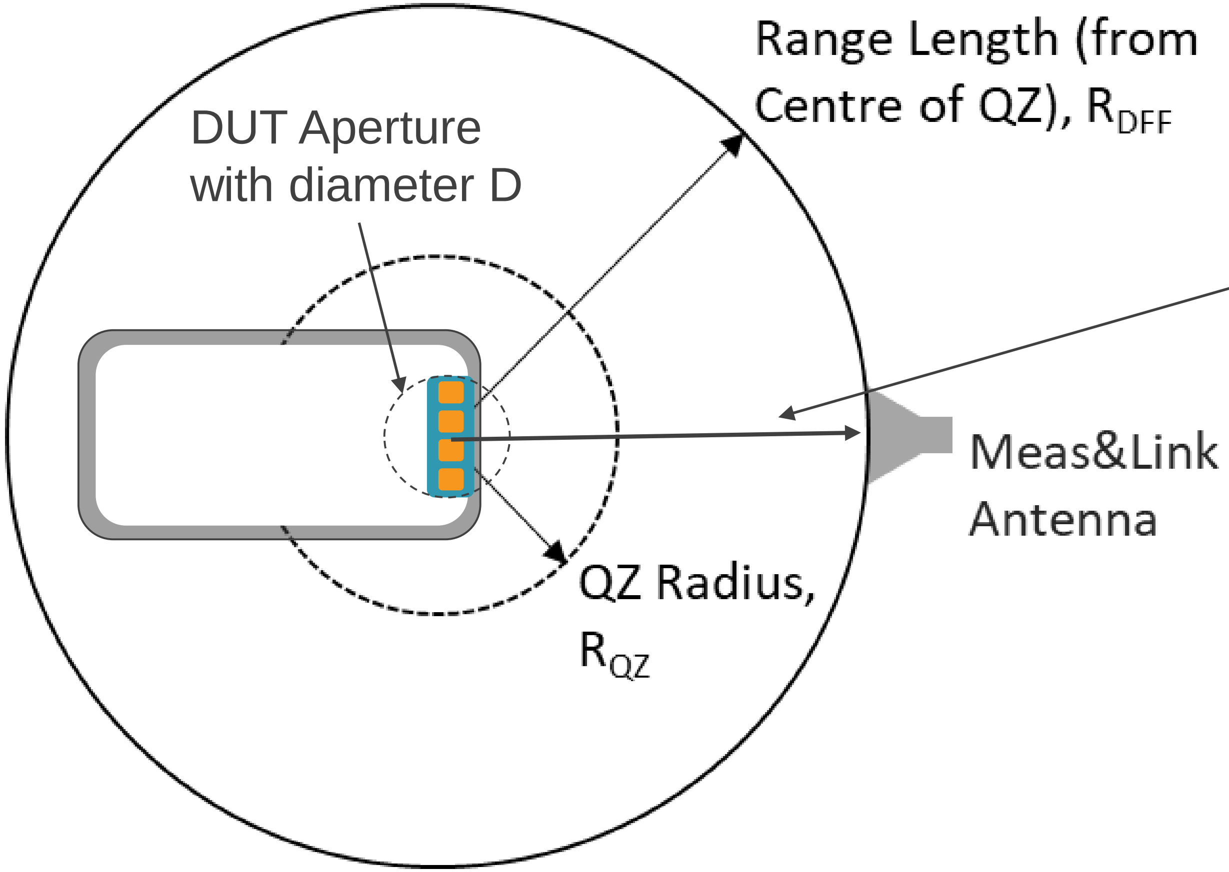
DFF with White-box Testing Approach

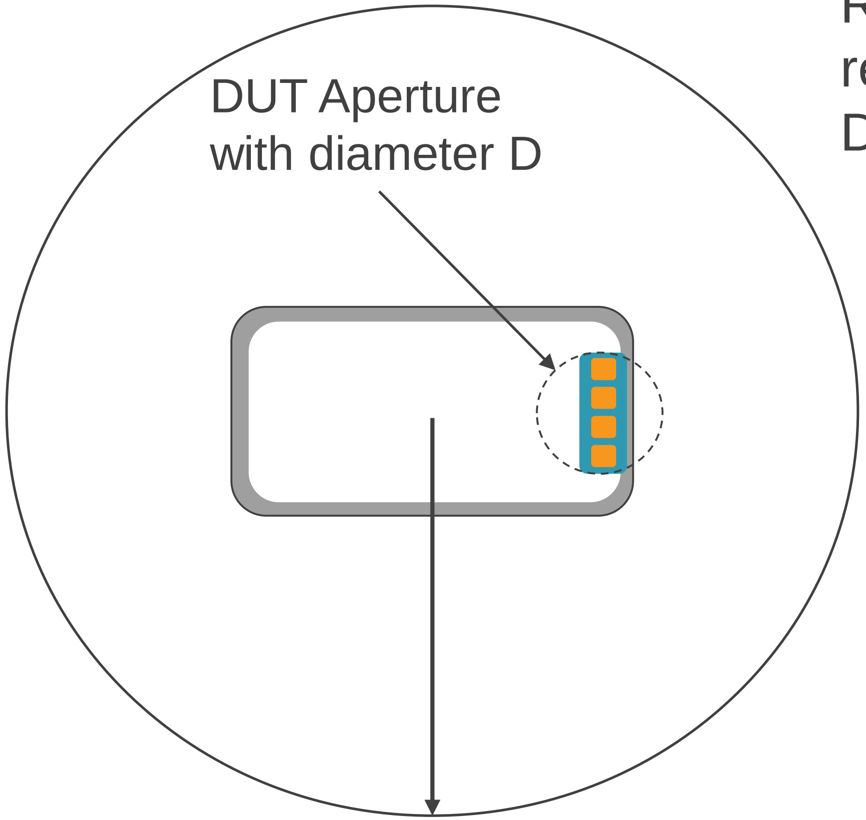
- The centre of DUT aperture is placed in the centre of the test zone



Measurement Distance (from centre of antenna array), R_{meas} >= $2D^2/\lambda$;
R_{QZ} >= D

IFF with Black-box Testing Approach

- The centre of DUT is placed in the centre of the test zone



R_{IFF} = focal length (distance between the feed and reflector for a CATR) = 3.5 x size of reflector = 3.5 x (2 x D)

Test Method Applicability

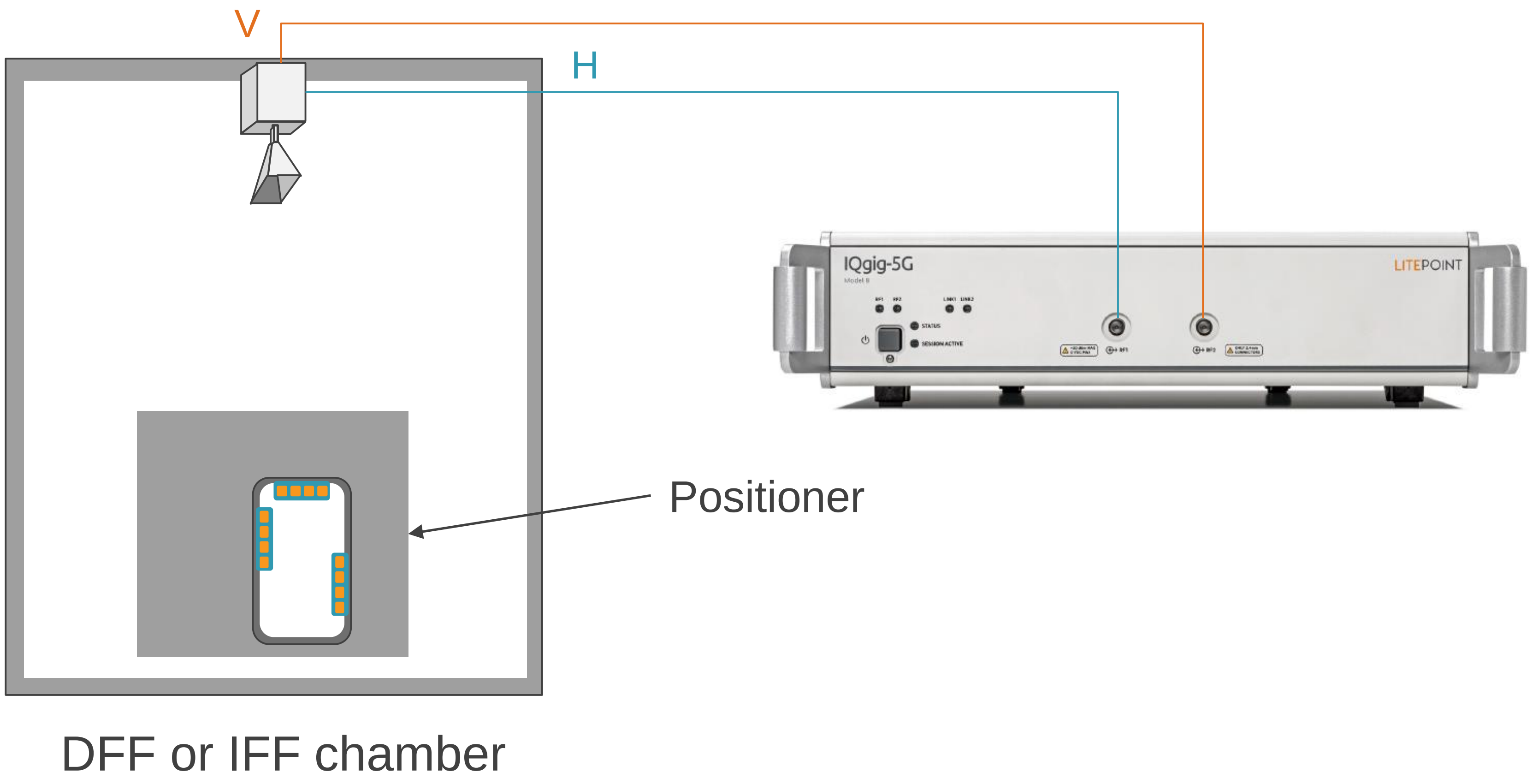
- Test method depends on DUT aperture and preferred testing approach
- Different scenarios for different power class UE and different test applications
  - Power class 1 UE may adopt near field test method, stay tuned for LitePoint solution

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

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

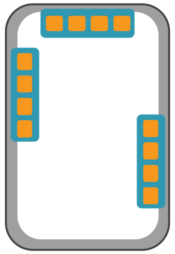
Let’s look at OTA setup

Single-DUT DVT Configuration

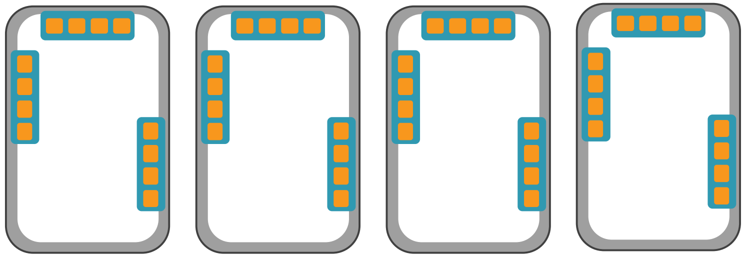


Transitioning from DVT to Manufacturing

Single-DUT



Multi-DUT



Chamber (DFF or IFF) with device positioner

Chamber (DFF) without device positioner (or simple device positioner)

DVT

Manufacturing

Seamless and robust transition from the lab to the factory floor

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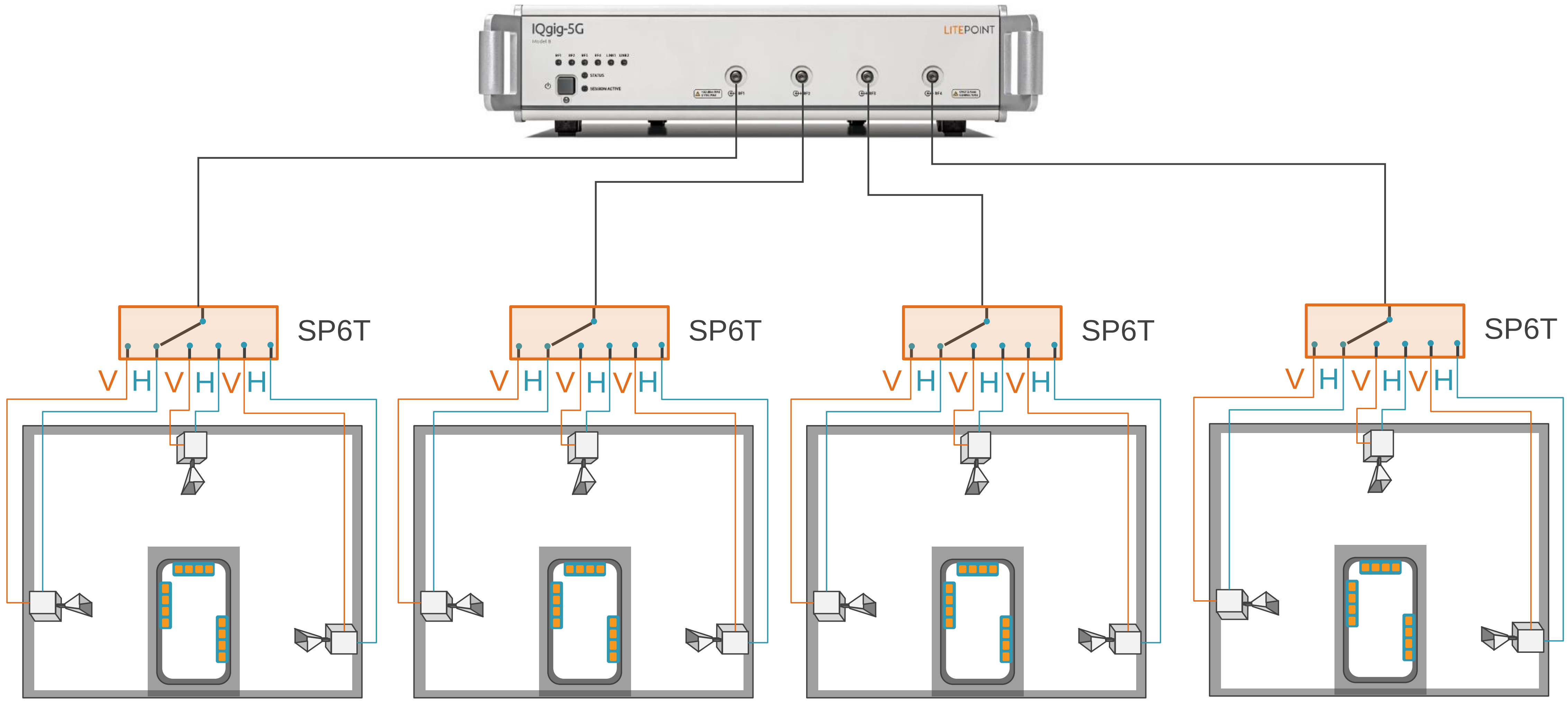
Multi-DUT Manufacturing Configuration: Expandability



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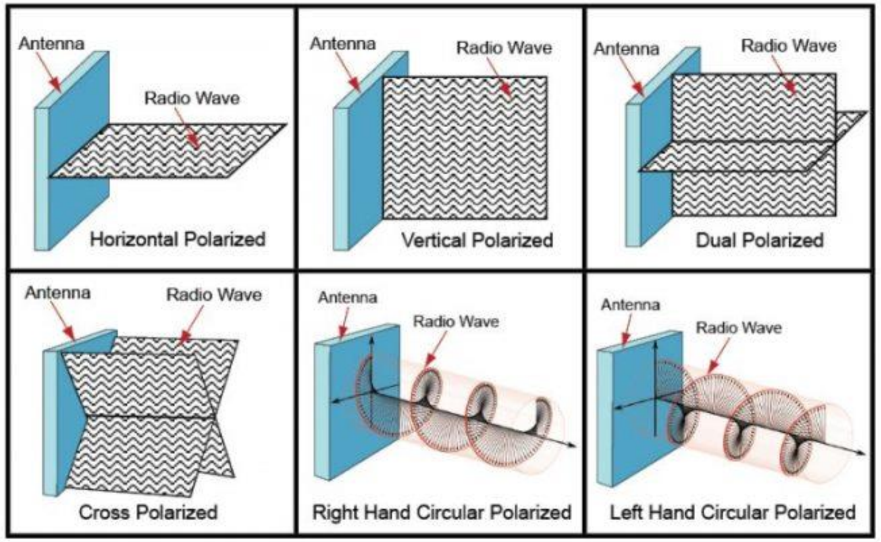
Options of Measurement Antenna

- Dual polarization horn antenna
- 2* Single polarization horn antennas
- Single polarization horn antenna at 45 degrees
- Circular polarization antenna



LitePoint 23-45 GHz Dual-Pol Antenna

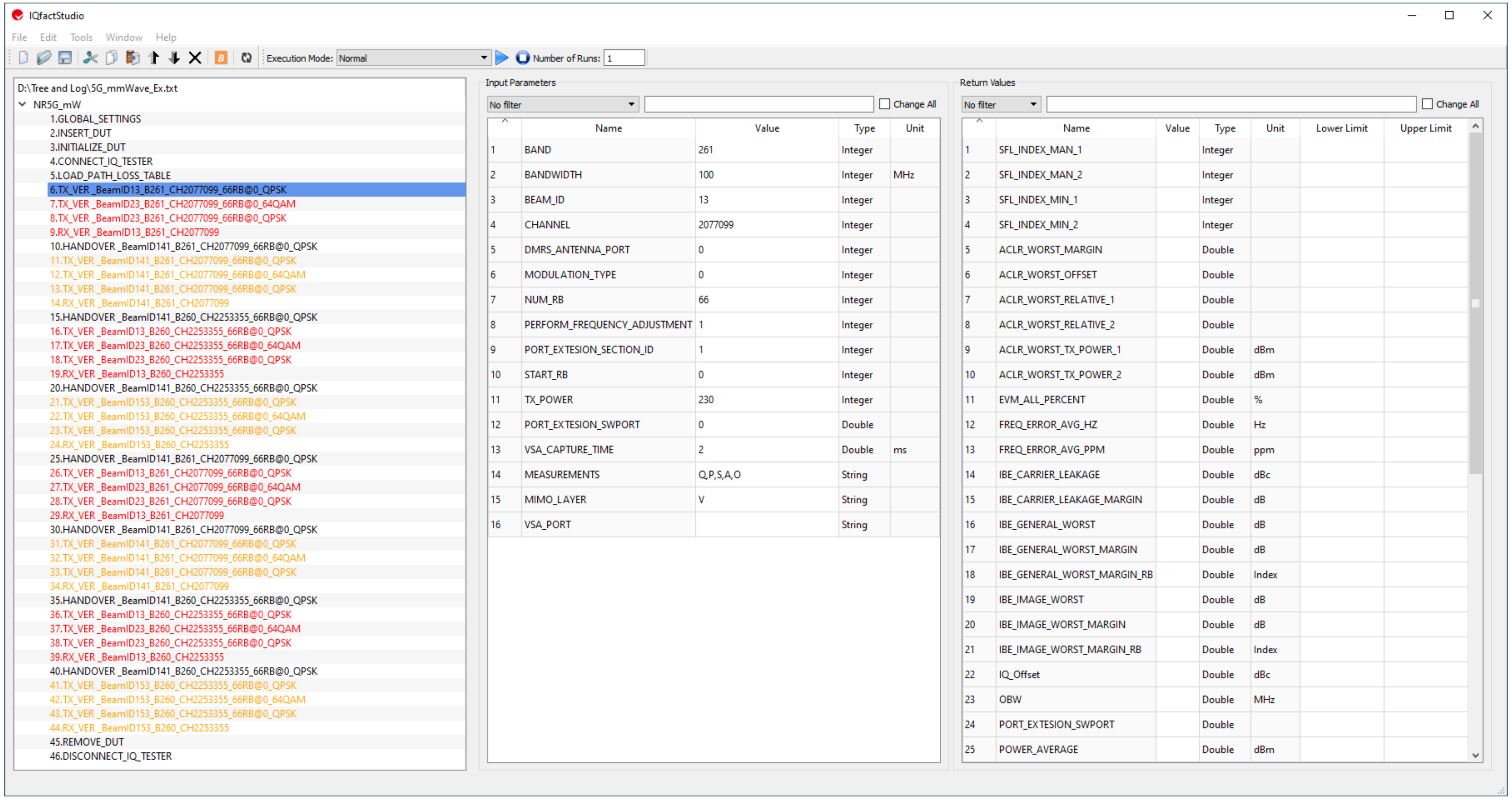
- Quad-Ridged Flared Horn (QRFH) design to achieve broadband and dual-pol capabilities.
- 2.4 mm coax interface (< 50 GHz)
- Two models (low & high gain) in fab – Scalable design for different beamwidth/ gain/ FF requirements.

- Performance:

	Band (GHz)	Plane	Gain (dBi)	BeamW (°)	Cross-Pol Iso.
Low Gain (Aperture 0.3" SQ)	23	H	6.5	62	>20
		E	6.5	62	>20
	45	H	11.5	44	
		E	11.5	32	
High Gain (Aperture 0.745" SQ)	23	H	10.5	46	
		E	10.5	32	
	45	H	14.5	24	
		E	14.5	22	

IQfact5G Automation Software for Manufacturing

- LitePoint IQfact5G enables superior Multi-DUT test efficiency (over 98% when doing 2-DUT)



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LitePoint 5G mmWave Product

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5G Product Family

IQxstream-5G

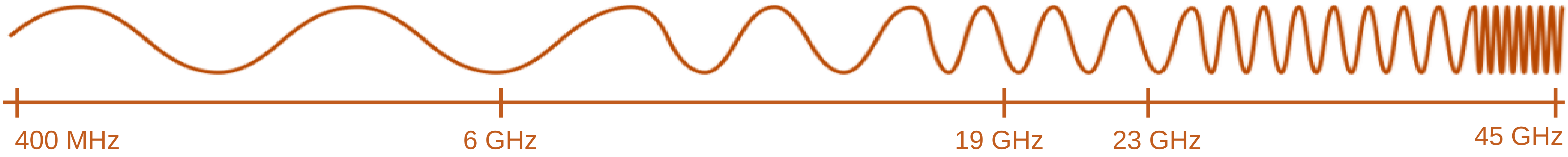
- Frequency Range 400 – 6000 MHz
- 200 MHz Bandwidth
- Sub 6GHz (FR1) 5G & NR-U
- Supports existing 2G/3G/4G
- Supports WiFi 802.11n/ac/ax

IQgig-IF

- Frequency Range 5 – 19 GHz
- 1.7 GHz Bandwidth
- Module IF interface testing
- Supports 3GPP NR specifications
- Supports WiGig 802.11ad/ay

IQgig-5G

- Frequency Range 23 – 45 GHz
- 1.7 GHz Bandwidth
- Fully-integrated 3GPP NR 5G
- Supports 100MHz, 400 MHz & 8x100 MHz CA test cases



Comprehensive 5G Test Coverage for FR1 and FR2 Devices

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IQgig-5G for 5G mmWave

First fully-integrated 5G mmWave test system

- Simplest 5G testing with single unit covering all 3GPP mmWave bands: 23 – 45 GHz
- All signal generation, analysis, and RF front-end routing H/W are self-contained
- Single intuitive S/W interface

5G measurements in minutes

- Simple connections – just power up and go
- Four bi-directional 2.4 mm connectors enable dual polar testing in multi-DUT
- Source and Measure capabilities fully calibrated to the instrument front panel

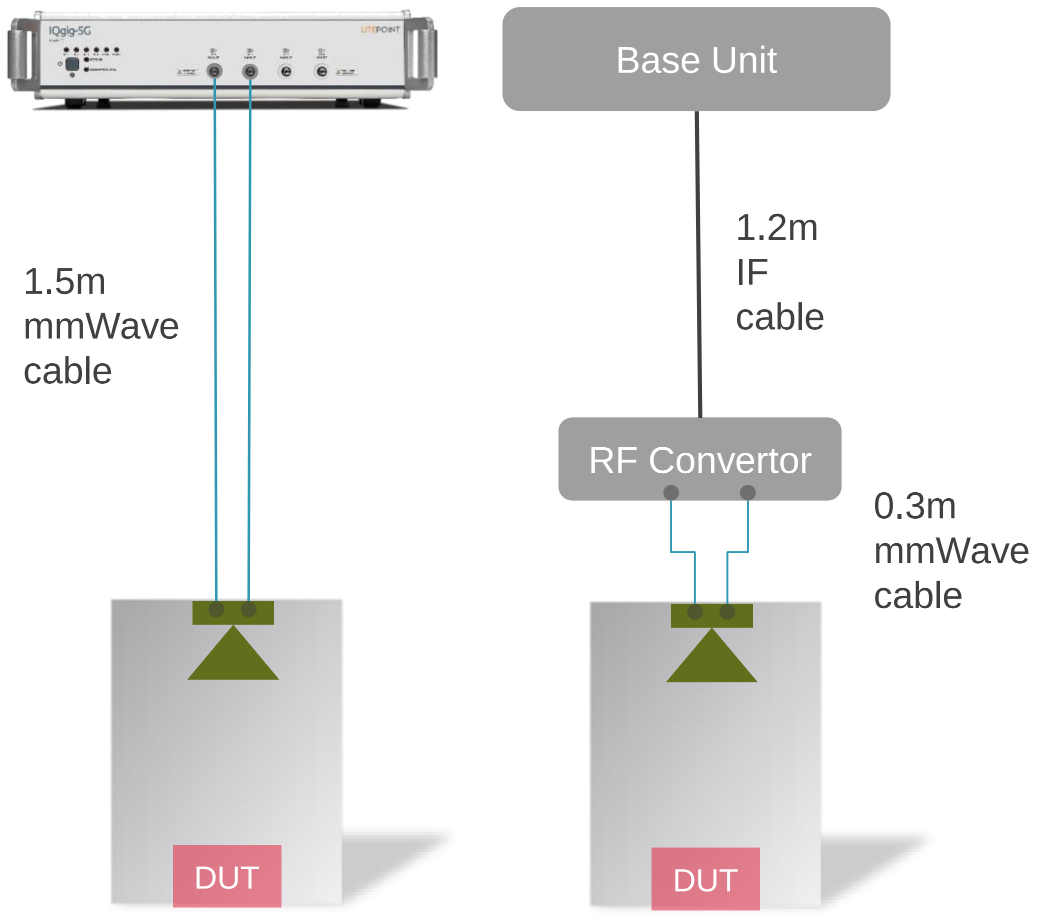
No Compromise 5G performance

- Supports the 3GPP NR standards evolution
- 1.7 GHz of single-shot bandwidth.
- EVM performance better than -42 dB (0.8%)

Intuitive Graphical User Interface

5G Waveform Generation and Analysis

Architecture Comparison



Horn antenna gain 15 dBi,
far field distance 30 cm

It's true RF converter architecture has less loss due to shorter mmWave cable.
However does it matter that much? NO!

Frequency	40	GHz	
Lambda	7.5000	mm	
Cable insertion loss	-2.6	dB/m	40 GHz
Cable insertion loss	-2.1	dB/m	28 GHz
Cable insertion loss	-1.65	dB/m	18 GHz

Link budget	LitePoint	Base Unit + RF Converter	
Cable length	1.5	0.3	m
Cable loss	-3.9	-0.78	dB
Horn antenna gain	15	15	dBi
OTA distance	30	30	cm
OTA loss	-54.03	-54.03	dB
Composite loss	-42.93	-39.81	dB

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Architecture Comparison

- OTA loss contributes over 90% of composite loss, cable loss is minor
- With RF converter architecture, when number of DUTs increase, number of RF converters increase, number of module in base unit increase → Cost increase and poor expandability
- Fully integrated architecture is simple, provide good multi-DUT expandability and competitive cost of test

Summary

- UE power class
- Recap OTA test methods
- OTA setup for DVT and manufacturing
- Expertise from DVT to Manufacturing
  - Total solution provider
    - Test equipment + mmWave chamber (partnership with mmWave chamber vendor)
  - Multi-DUT expandability
  - IQfact5G automation software (APT built-in)
- IQgig-5G fully-integrated architecture vs Base Unit+RF Converter architecture