



LITEPOINT

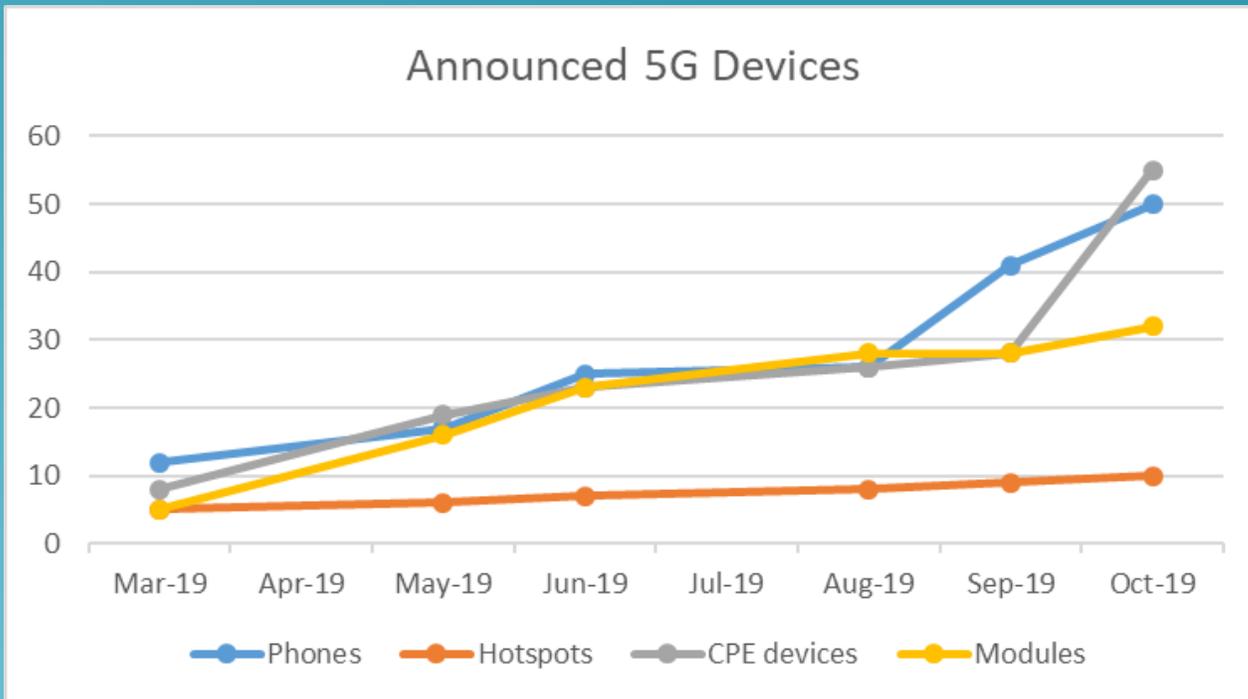
A Teradyne Company

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

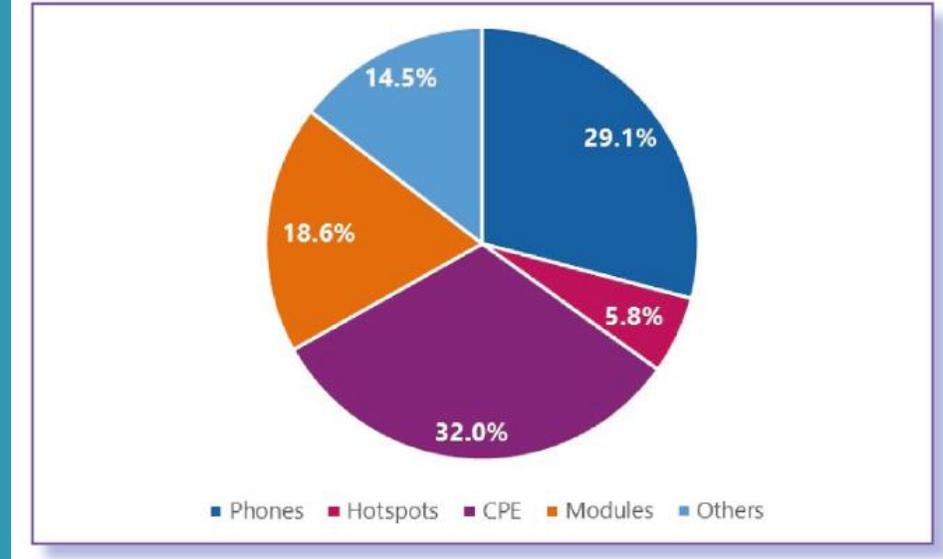
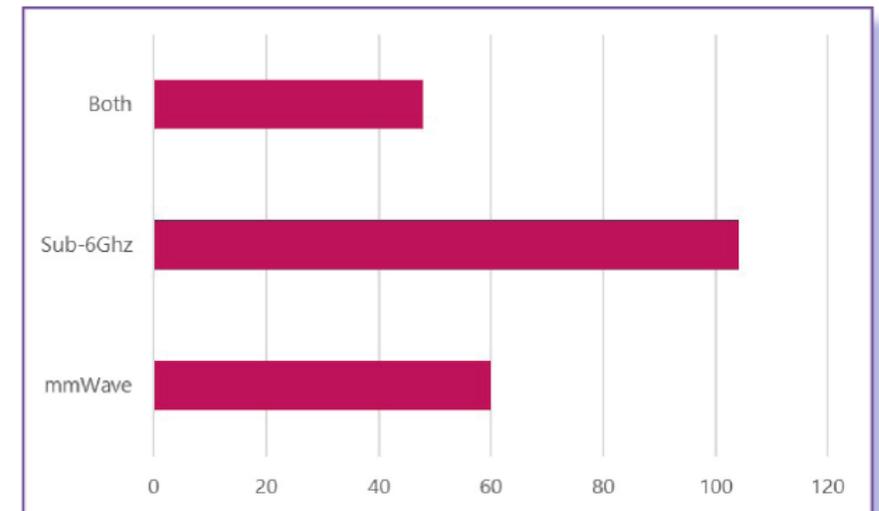


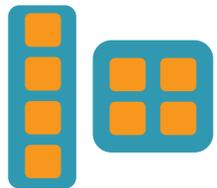
Figure 3: Announced devices with known spectrum support, by broad category (data not available for all devices)



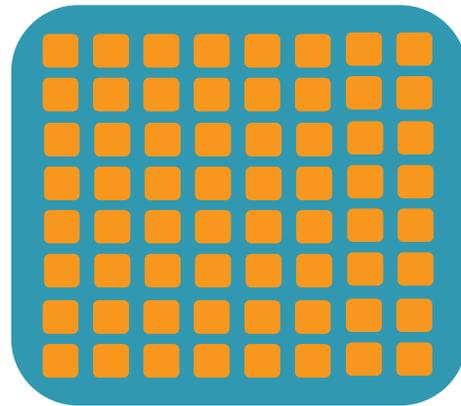
UE Power Class - Antenna and Output Power

- 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

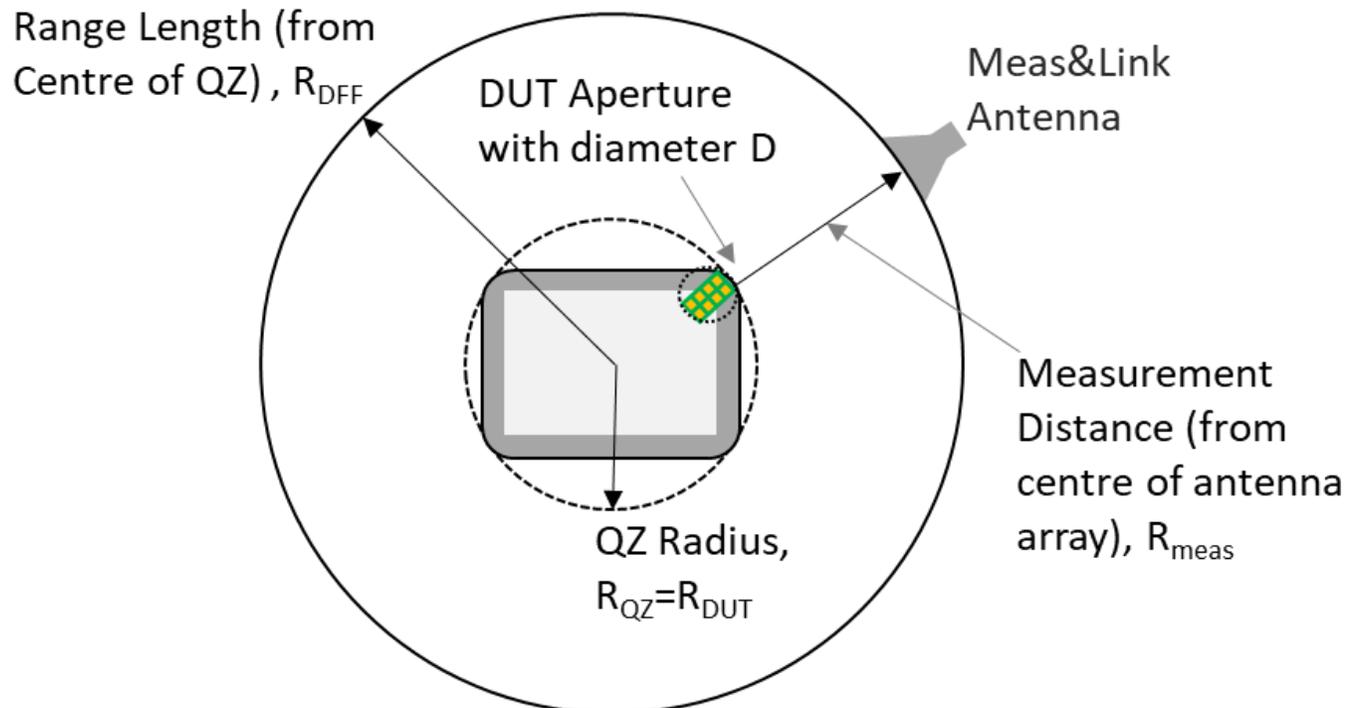
Recap 3GPP TR 38.810

- 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

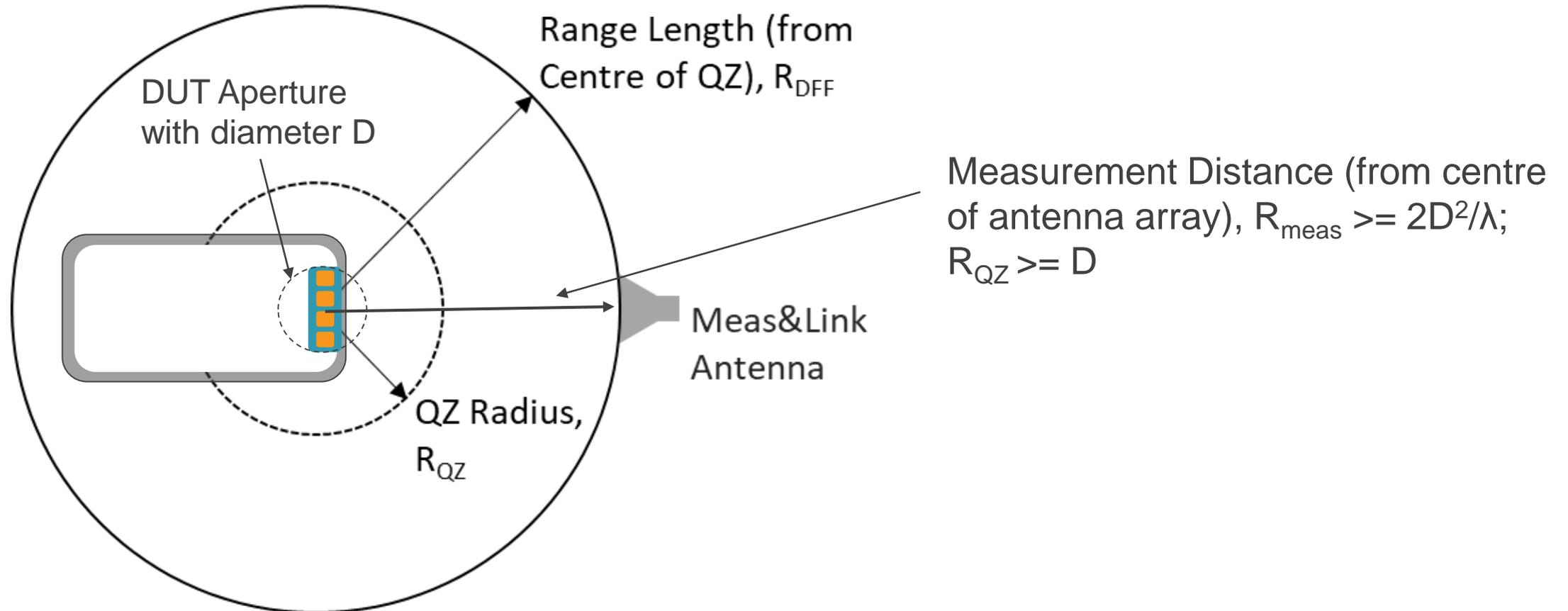
- The centre of DUT is placed in the centre of the test zone
- The minimum range length for NR FR2 DFF systems where the sphere enclosing the DUT matches the QZ and the DUT antenna with radiating aperture diameter D located in the corner of the DUT

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



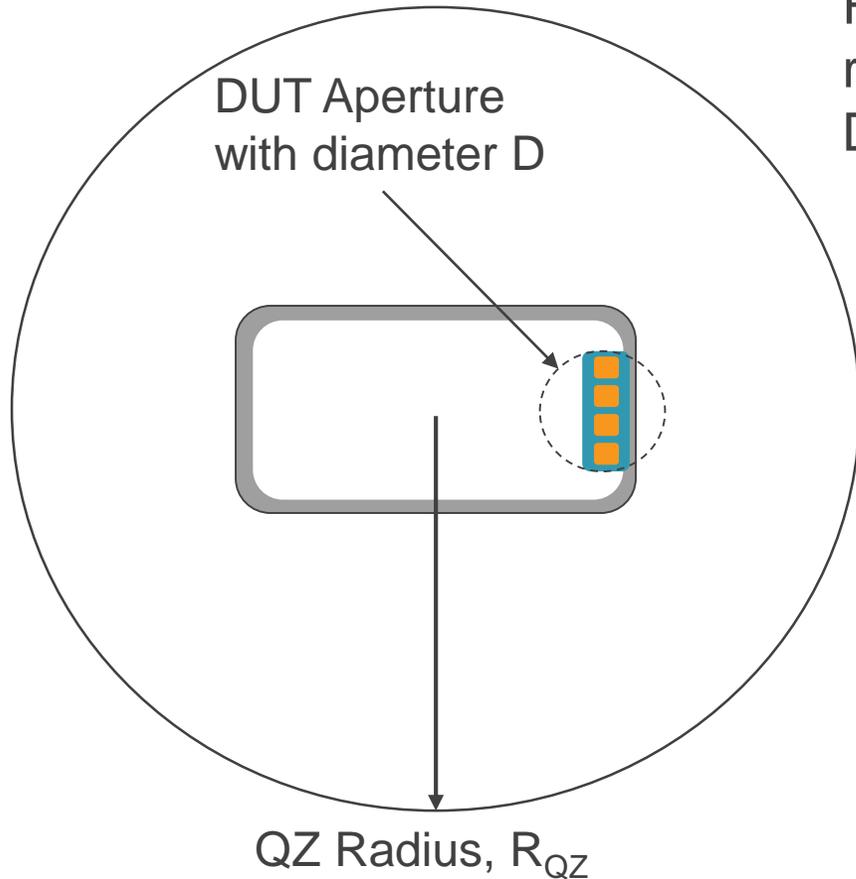
DFF with White-box Testing Approach

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



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)

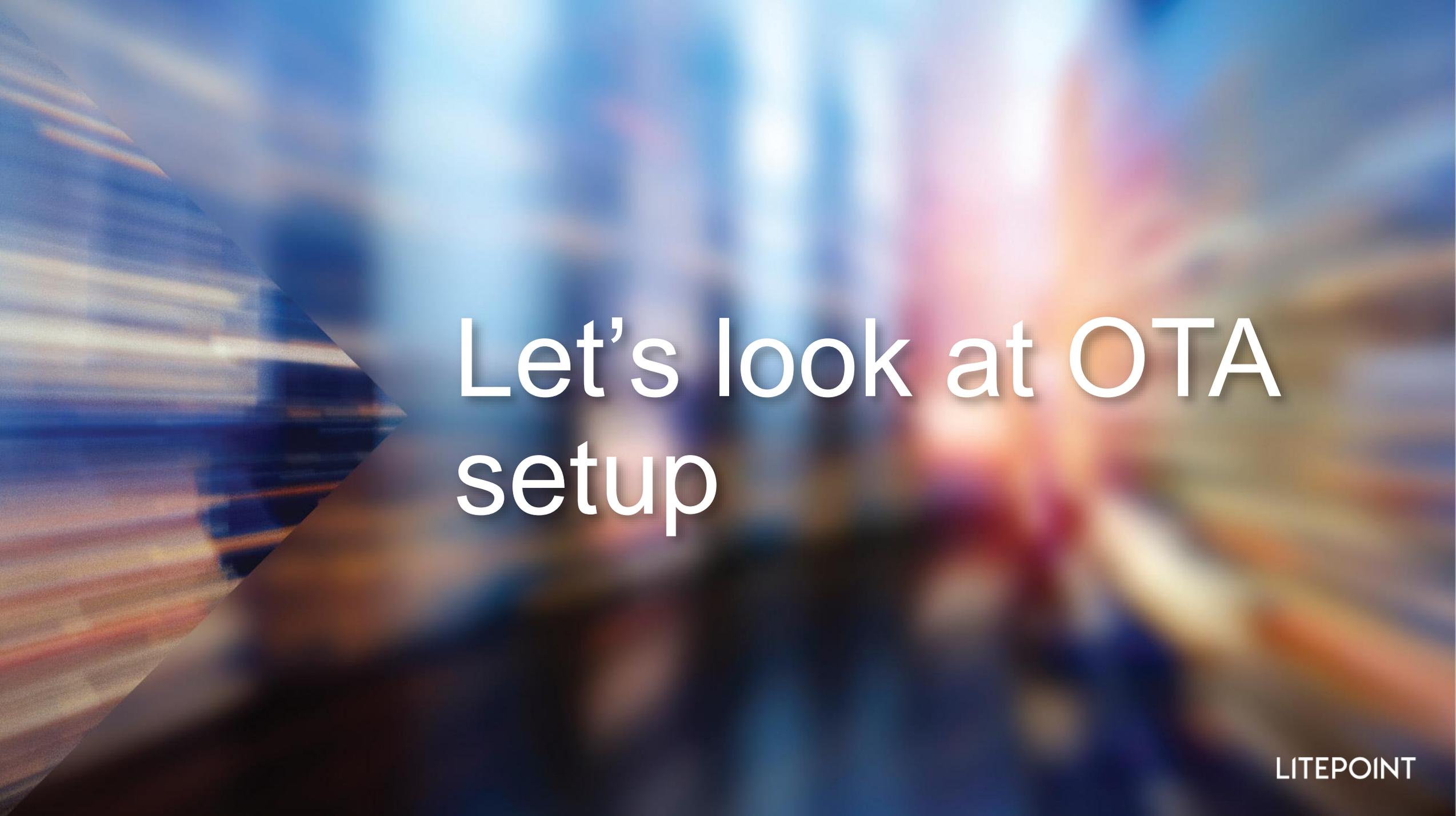
Test Method Applicability

- 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 $D \leq 5$ cm active at any one time
2	More than one antenna panel $D \leq 5$ cm without phase coherence between panels active at any one time
3	Any phase coherent antenna panel of any size (e.g. sparse array)

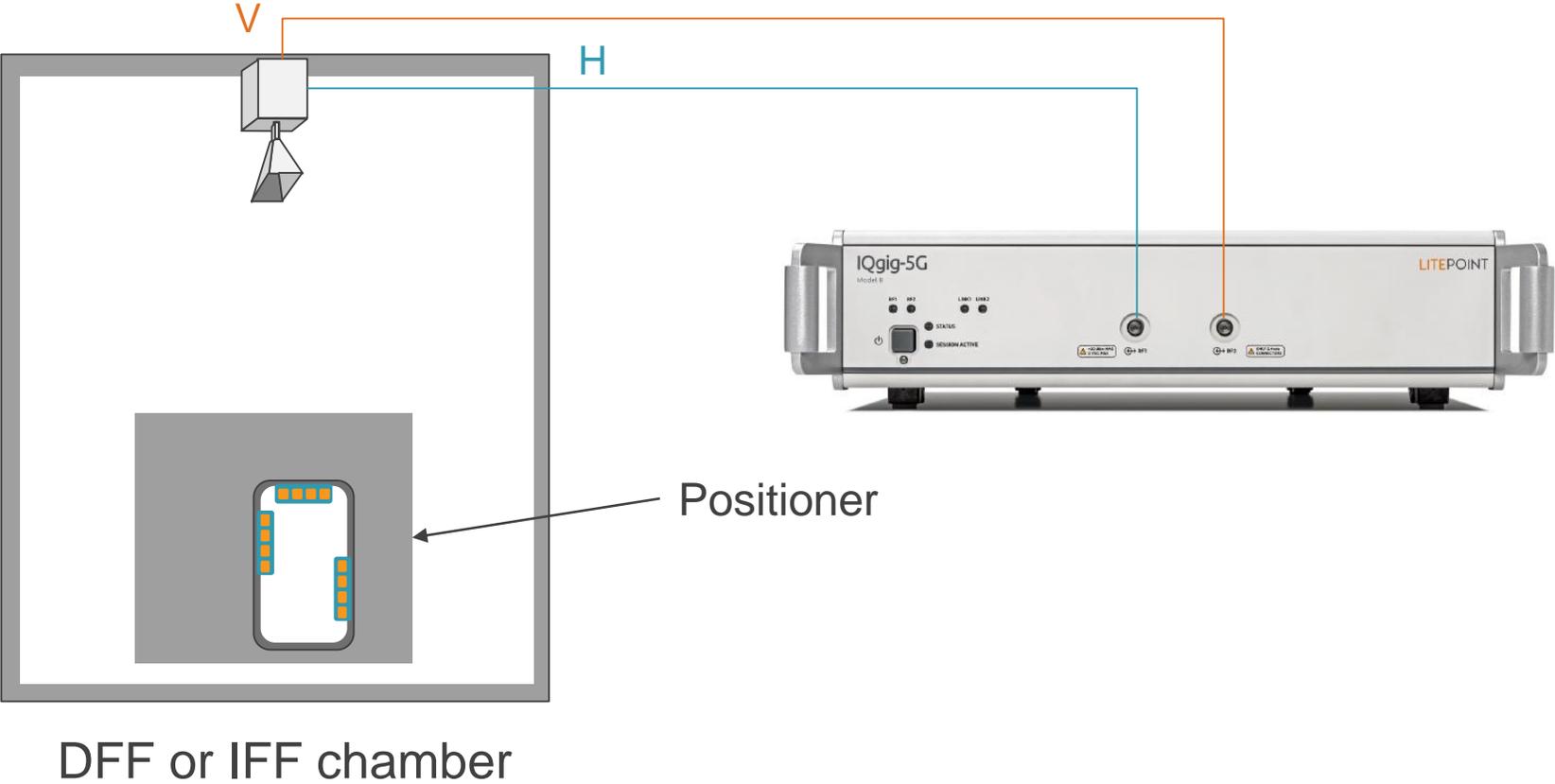
DUT Antenna Configuration	Direct Far Field (DFF)	Indirect Far Field (IFF)	Near Field to far field transform (NFTF)
1	Yes	Yes	Yes
2	Yes	Yes	Yes
3	No	Yes	No

NOTE: A positive indication means that applicability exists for at least one RF test cases for the given DUT Antenna Configuration



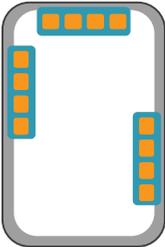
Let's look at OTA setup

Single-DUT DVT Configuration

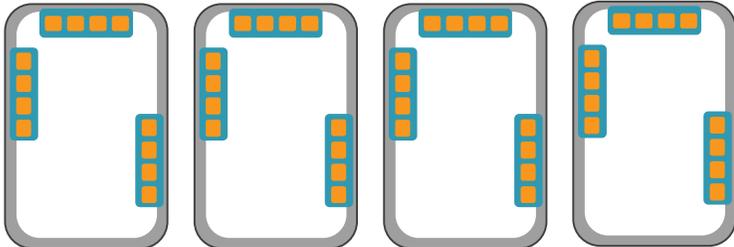


Transitioning from DVT to Manufacturing

Single-DUT



Multi-DUT



Chamber (DFF or IFF) with device positioner



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

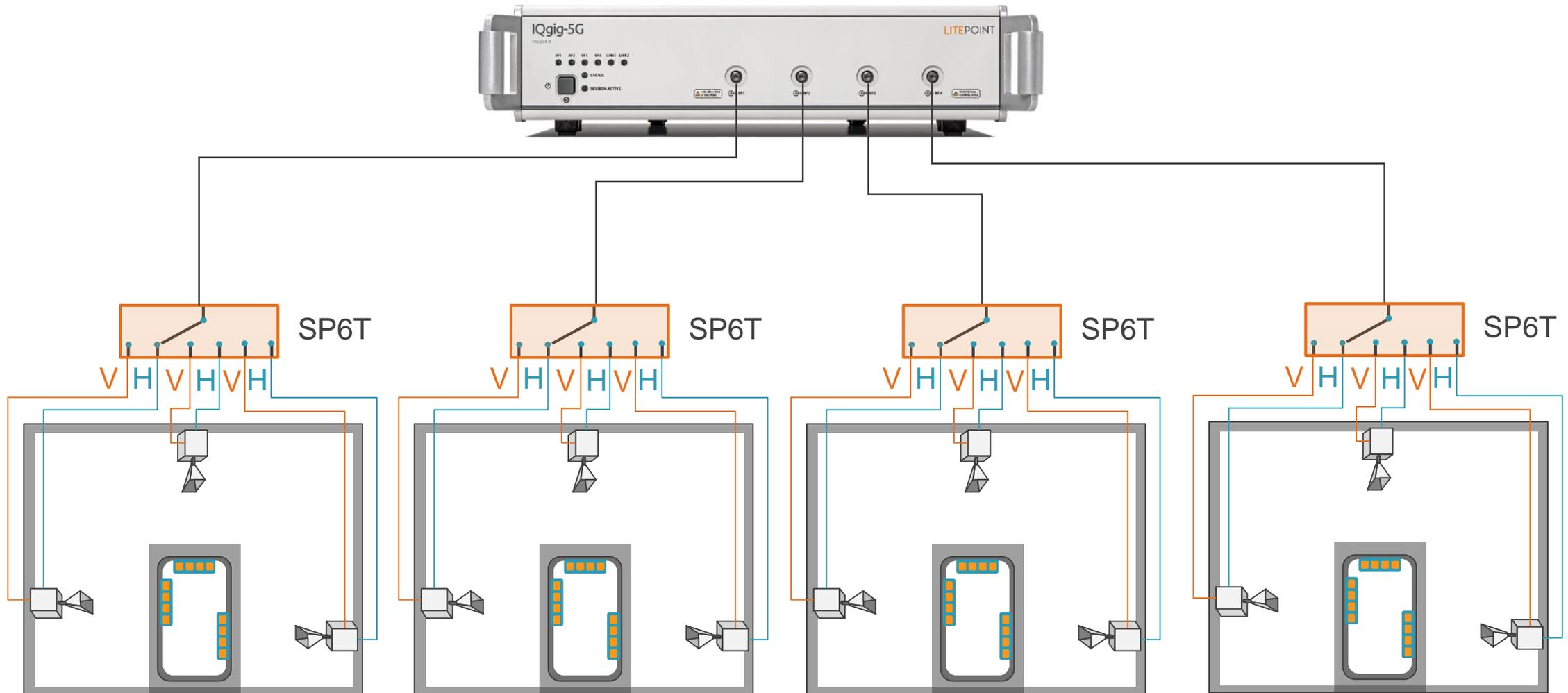
DVT



Manufacturing

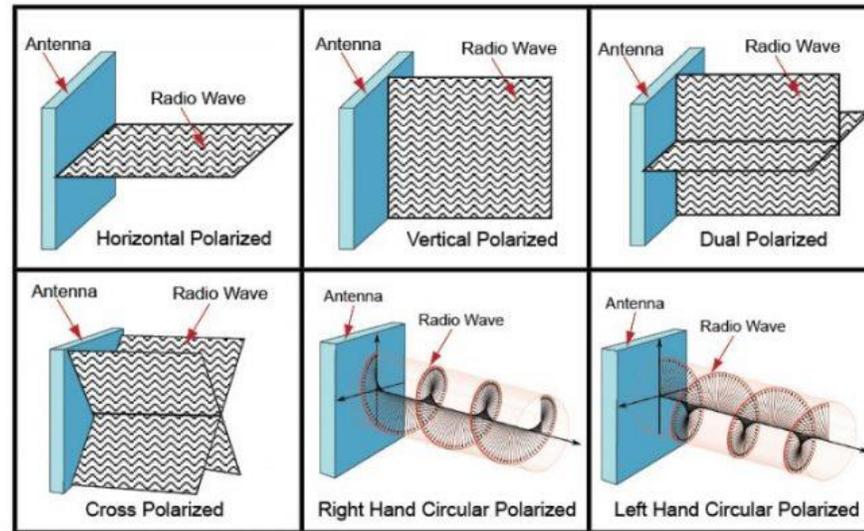
Seamless and robust transition from the lab to the factory floor

Multi-DUT Manufacturing Configuration: Expandability



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	
	45	H	11.5	44	
		E	11.5	32	
High Gain (Aperture 0.745" SQ)	23	H	10.5	46	>20
		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)

The screenshot displays the IQfactStudio software interface, which is used for configuring and executing 5G tests. The interface is divided into several main sections:

- Tree and Log:** A hierarchical tree view on the left shows the test configuration structure, including settings, DUT initialization, and various test scenarios (TX, RX, and Handover) for different beam IDs and channels.
- Input Parameters:** A table in the center lists the input parameters for the test. The parameters include Band, Bandwidth, Beam ID, Channel, DMRS Antenna Port, Modulation Type, Number of RBs, Frequency Adjustment, Section ID, Start RB, TX Power, SW Port, Capture Time, Measurements, MIMO Layer, and VSA Port.
- Return Values:** A table on the right shows the results of the test. The results include SFL Index, ACLR (Adjacent Channel Leakage Ratio) for various margins and offsets, EVM (Error Vector Magnitude), Frequency Error, Carrier Leakage, and Power Average.

Input Parameters				
No filter	Name	Value	Type	Unit
1	BAND	261	Integer	
2	BANDWIDTH	100	Integer	MHz
3	BEAM_ID	13	Integer	
4	CHANNEL	2077099	Integer	
5	DMRS_ANTENNA_PORT	0	Integer	
6	MODULATION_TYPE	0	Integer	
7	NUM_RB	66	Integer	
8	PERFORM_FREQUENCY_ADJUSTMENT	1	Integer	
9	PORT_EXTESION_SECTION_ID	1	Integer	
10	START_RB	0	Integer	
11	TX_POWER	230	Integer	
12	PORT_EXTESION_SWPORT	0	Double	
13	VSA_CAPTURE_TIME	2	Double	ms
14	MEASUREMENTS	Q,P,S,A,O	String	
15	MIMO_LAYER	V	String	
16	VSA_PORT		String	

Return Values						
No filter	Name	Value	Type	Unit	Lower Limit	Upper Limit
1	SFL_INDEX_MAN_1		Integer			
2	SFL_INDEX_MAN_2		Integer			
3	SFL_INDEX_MIN_1		Integer			
4	SFL_INDEX_MIN_2		Integer			
5	ACLR_WORST_MARGIN		Double			
6	ACLR_WORST_OFFSET		Double			
7	ACLR_WORST_RELATIVE_1		Double			
8	ACLR_WORST_RELATIVE_2		Double			
9	ACLR_WORST_TX_POWER_1		Double	dBm		
10	ACLR_WORST_TX_POWER_2		Double	dBm		
11	EVM_ALL_PERCENT		Double	%		
12	FREQ_ERROR_AVG_HZ		Double	Hz		
13	FREQ_ERROR_AVG_PPM		Double	ppm		
14	IBE_CARRIER_LEAKAGE		Double	dBc		
15	IBE_CARRIER_LEAKAGE_MARGIN		Double	dB		
16	IBE_GENERAL_WORST		Double	dB		
17	IBE_GENERAL_WORST_MARGIN		Double	dB		
18	IBE_GENERAL_WORST_MARGIN_RB		Double	Index		
19	IBE_IMAGE_WORST		Double	dB		
20	IBE_IMAGE_WORST_MARGIN		Double	dB		
21	IBE_IMAGE_WORST_MARGIN_RB		Double	Index		
22	IQ_Offset		Double	dBc		
23	OBW		Double	MHz		
24	PORT_EXTESION_SWPORT		Double			
25	POWER_AVERAGE		Double	dBm		



LitePoint 5G mmWave Product

5G Product Family



IQxstream-5G

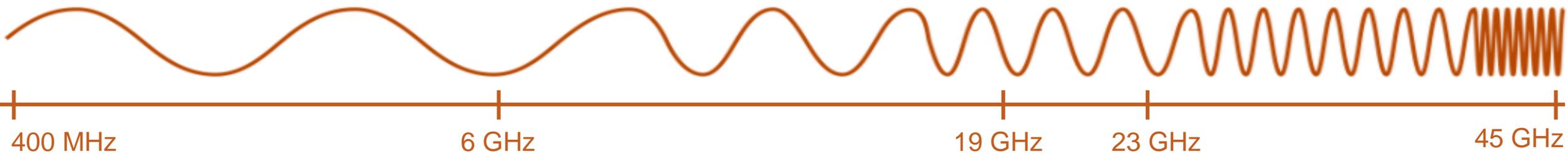
- Frequency Range 400 – 6000 MHz
- 200 MHz Bandwidth
- Sub 6GHz (FR1) 5G & NR-U
- Supports existing 2G/3G/4G
- Supports WiFi 802.11n/ac/ax

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

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

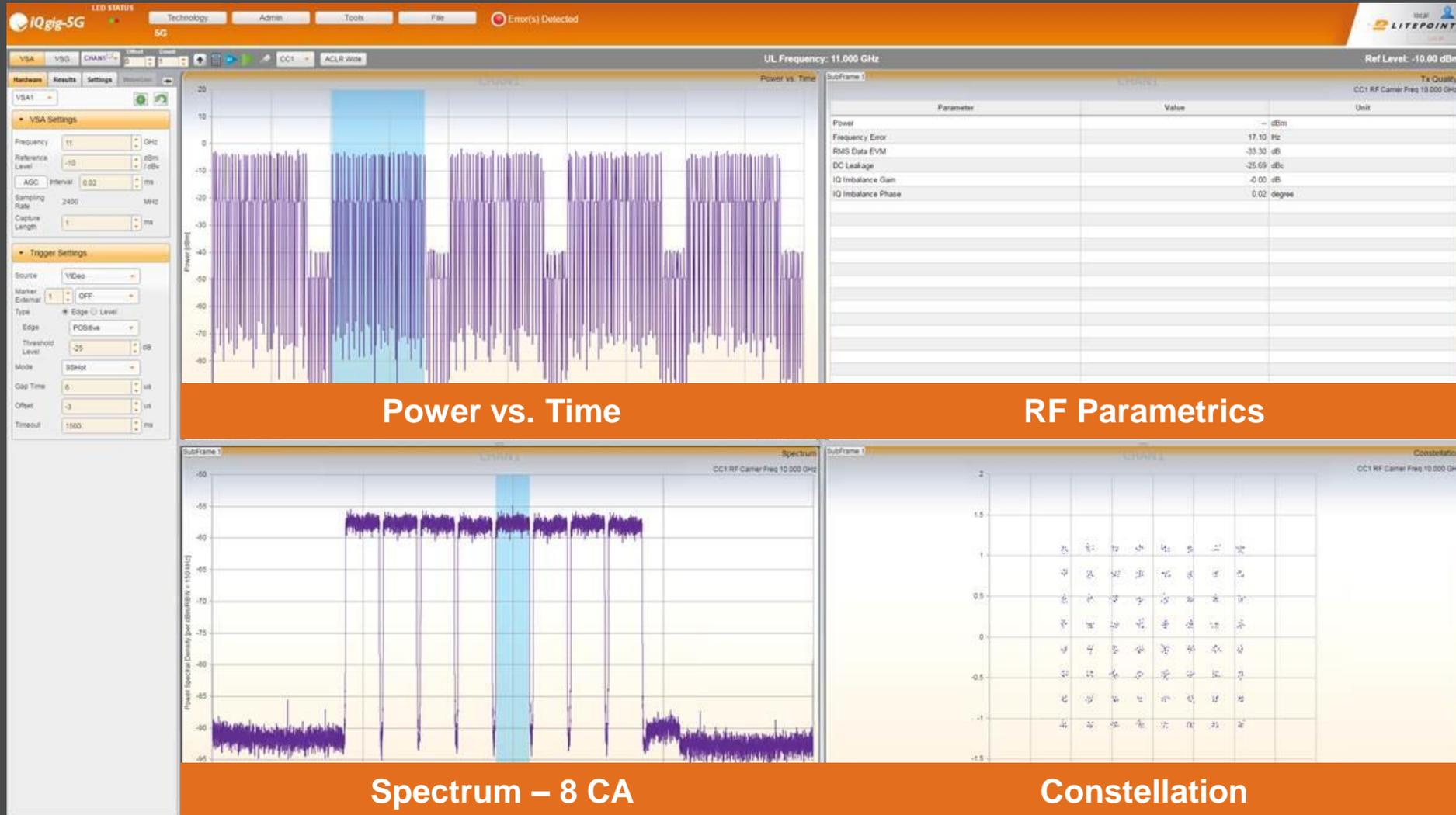
No Compromise 5G performance

- 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



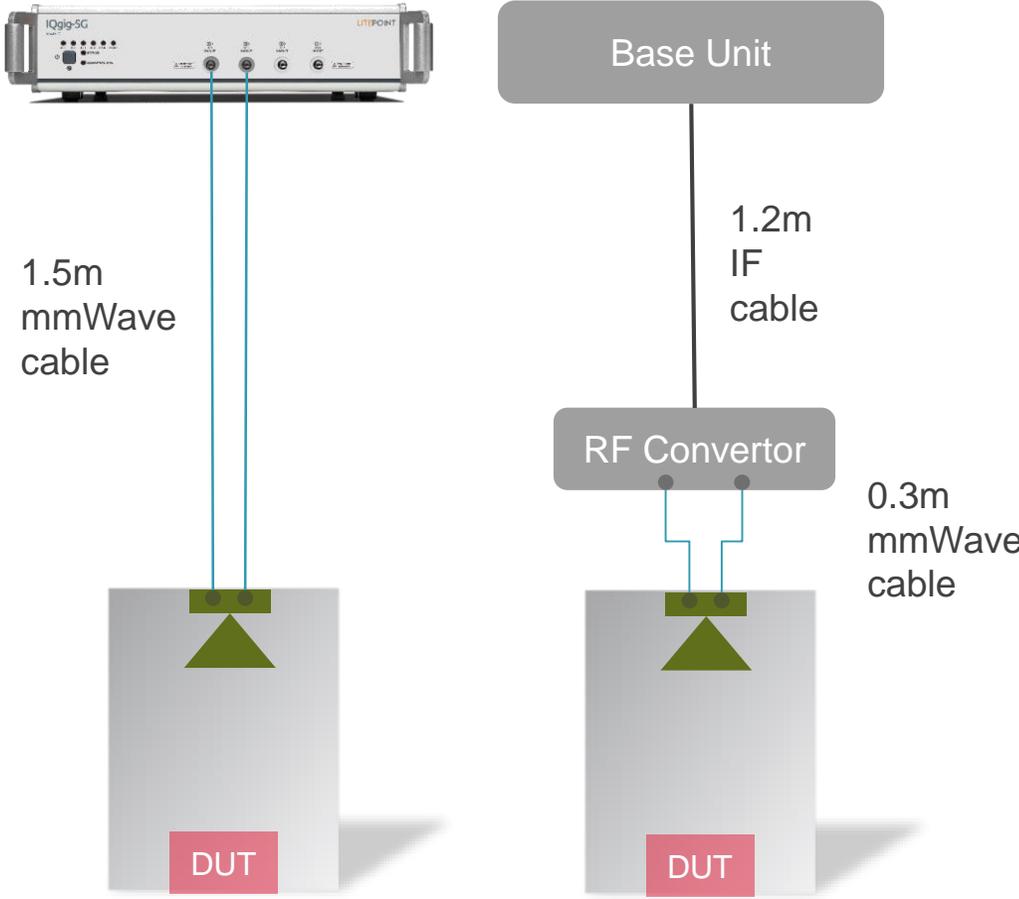
Power vs. Time

RF Parametrics

Spectrum - 8 CA

Constellation

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

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