5GNR Sub6 Production Test Challenge

Blake Chen

Agenda

- 5GNR Sub6 Introduction
- Massive Antenna Port Device Testing
- IQfact5G Automation

Let’s Talk 5G

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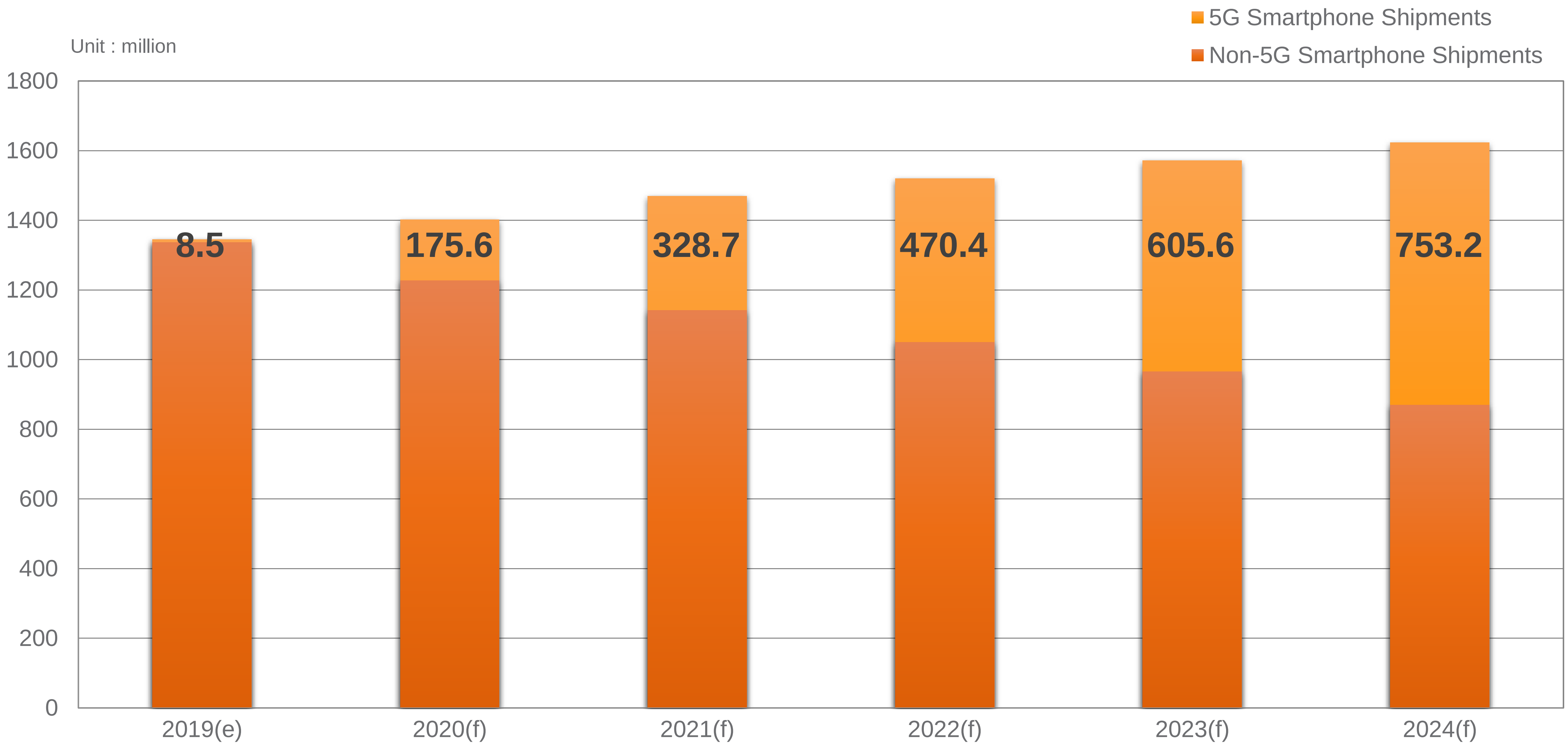
Mobile 5G Subscriptions is forecast to reach 45% in 2024



Source : DIGITIMES Research, 2019/9

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Market Update: 5G Device Ecosystem

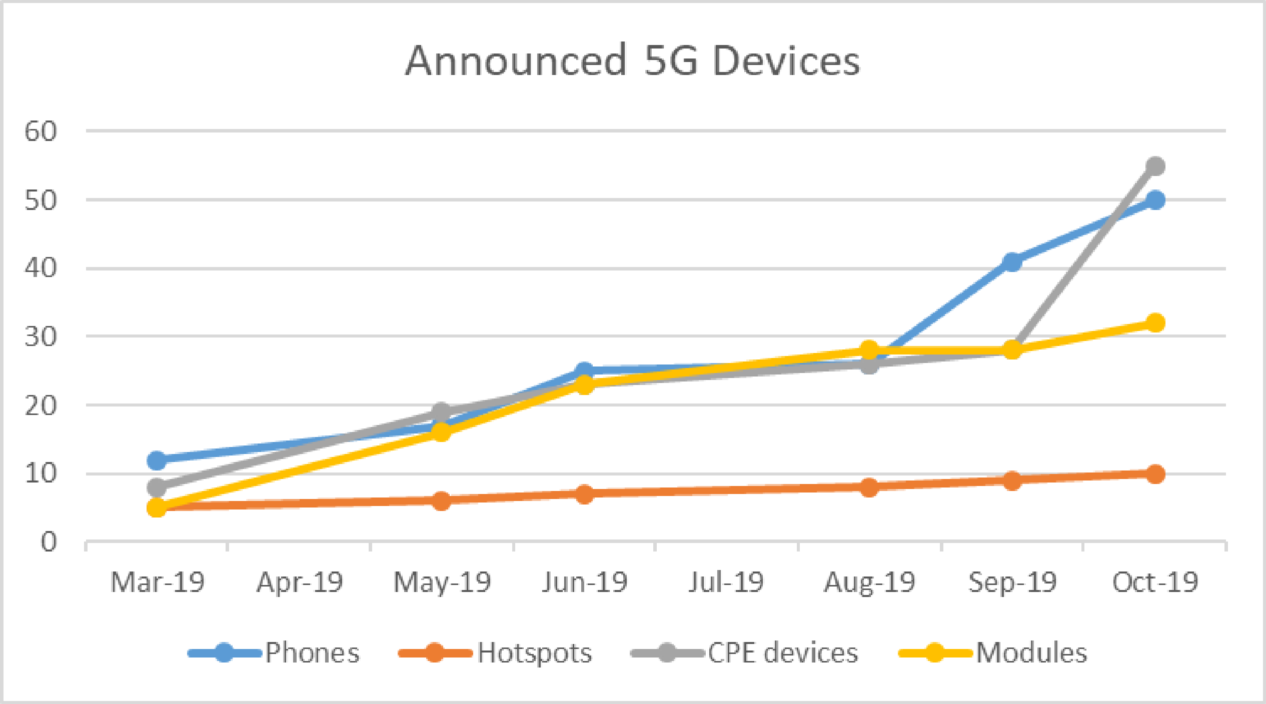


Figure 2: Announced 5G devices, by form factor

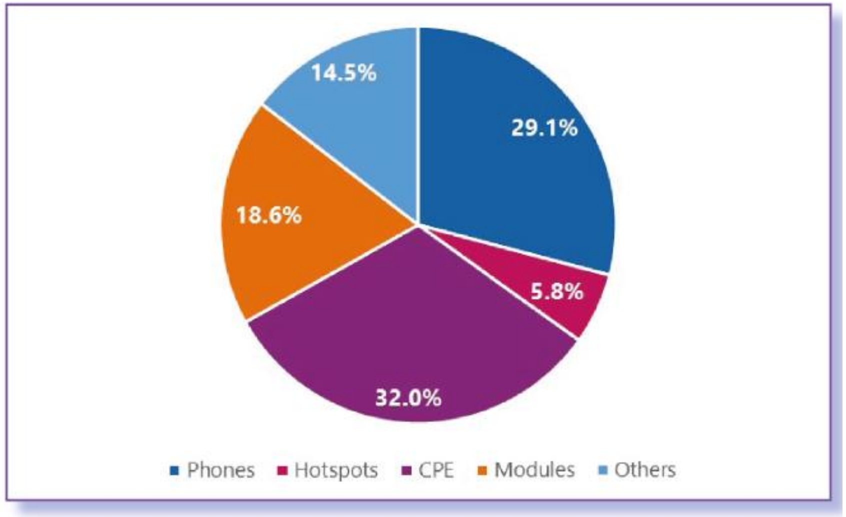
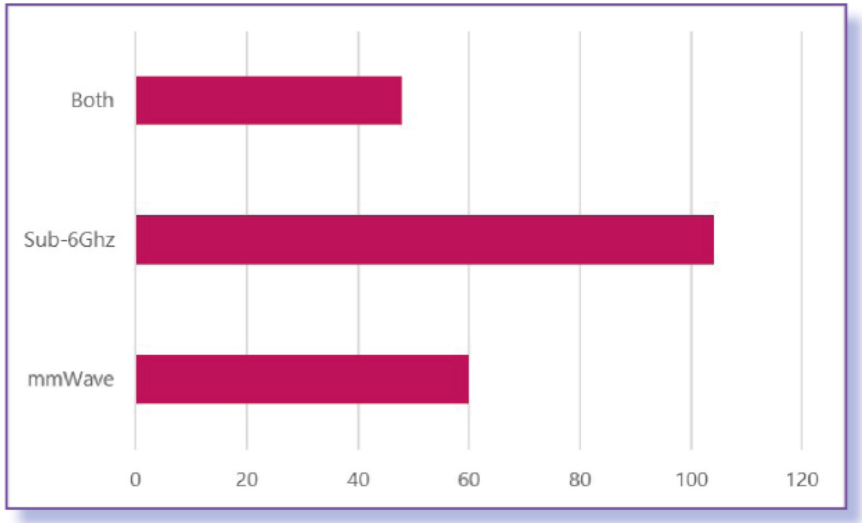


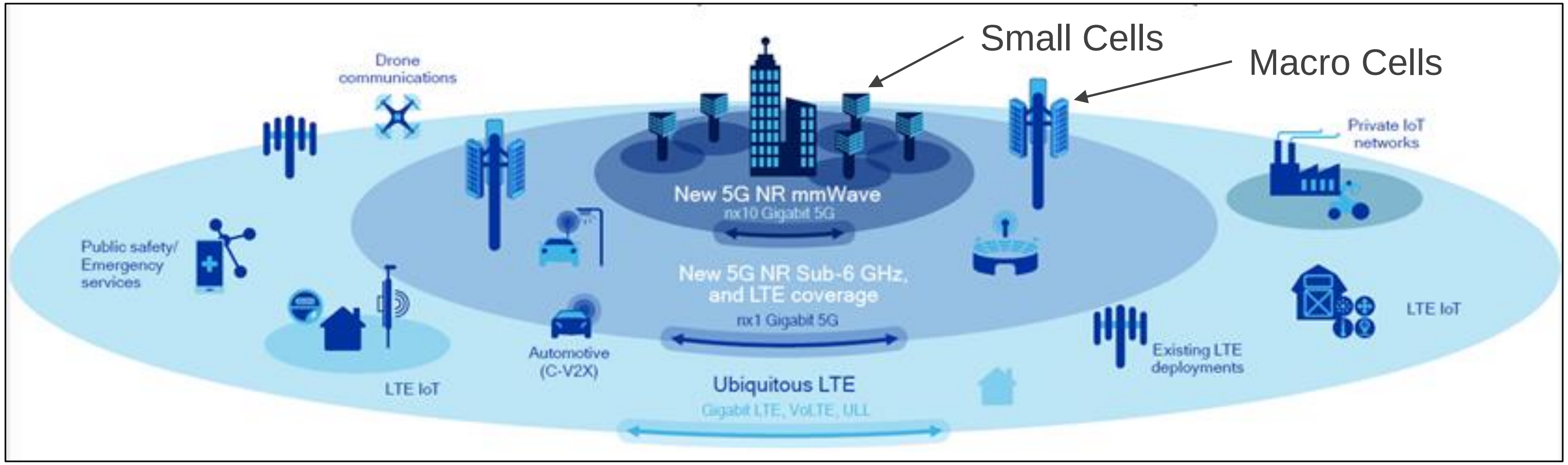
Figure 3: Announced devices with known spectrum support, by broad category (data not available for all devices)



- By 18 October, 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

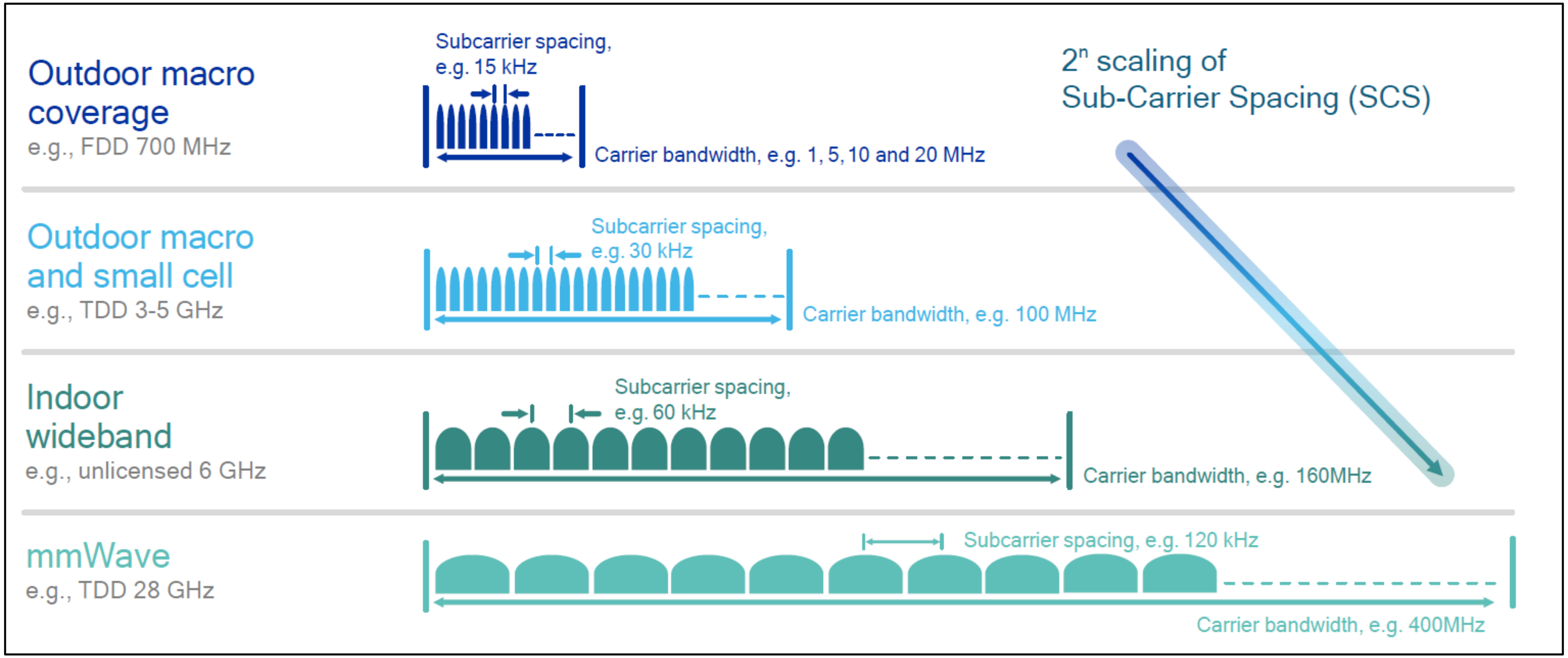
5G NR MIMO: Sub-6GHz vs mmWave



	< 6 GHz	mmWave
Deployment Scenario	Macro cells High user mobility	Small cells Low user mobility
MIMO Order	Up to 8x8	Less MIMO order (typically 2x2)
Number of Simultaneous Users	Tens of users Large coverage area	A few users Small coverage area
Main Benefit	Spatial multiplexing	Beamforming for single user
Channel Characteristics	Rich multipath propagation	A few propagation paths
Spectral Efficiency	High due to the spatial multiplexing	Low spectral efficiency (few users, high path loss)
Transceiver	Digital transceiver	Hybrid

5G NR's Biggest Contribution

- Multiple OFDM numerologies
  - A fancy way to say "scalable Sub-Carrier Spacing (SCS)"
  - SCS is controlled by a parameter called μ
  - Why change SCS? What is the real life application?



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5G-NR Key Parameters

Item	Frequency Range 1 (FR1)	Frequency Range 2 (FR2)
Known As	Sub 6 GHz	mmWave
Frequency Range	450 MHz - 6000 MHz	24250 MHz - 52600 MHz
Duplex Mode	FDD, TDD	TDD
Subcarrier Spacing	15, 30, 60 KHz	60, 120 KHz
Bandwidth	5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 100 MHz	50, 100, 200, 400 MHz
MIMO	DL: 8x8 UL: 4x4	DL: 2x2 UL: 2x2
MIMO Method	Spatial Multiplexing for higher Throughput	Beamforming for better SNR
Radio Frame Duration	10ms	
Subframe Duration	1ms	
Modulation	pi/2-BPSK, BPSK, QPSK, 16QAM, 64QAM, 256QAM	
Access	DL: CP-OFDM UL: CP-OFDM, DFT-s-OFDM	
Carrier Aggregation	16 carriers maximum	
Channel Coding	Polar Codes, LDPC Codes	

Item	Downlink	Uplink
Data Channels	PDSCH, PCH	PUSCH, PRACH
Control Channels	PDCCH	PUCCH (HARQ/CSI/SR)
Synchronization Signals	PSS, SSS, PBCH	-
Reference Signals	DMRS, PTRS, CSIRS	DMRS, PTRS, SRS

Maximum CC (Component Carrier) bandwidth is 100 MHz for FR1 and 400 MHz for FR2: *a 5x to 20x improvement over 4G LTE!*

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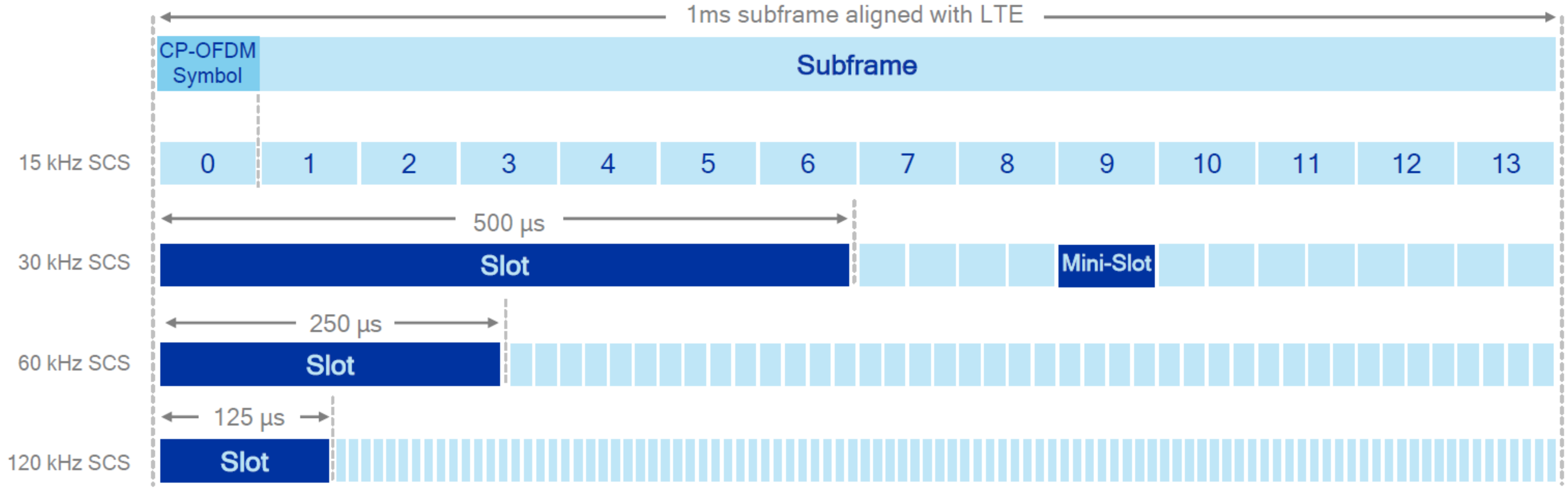
5G NR Frame Structure



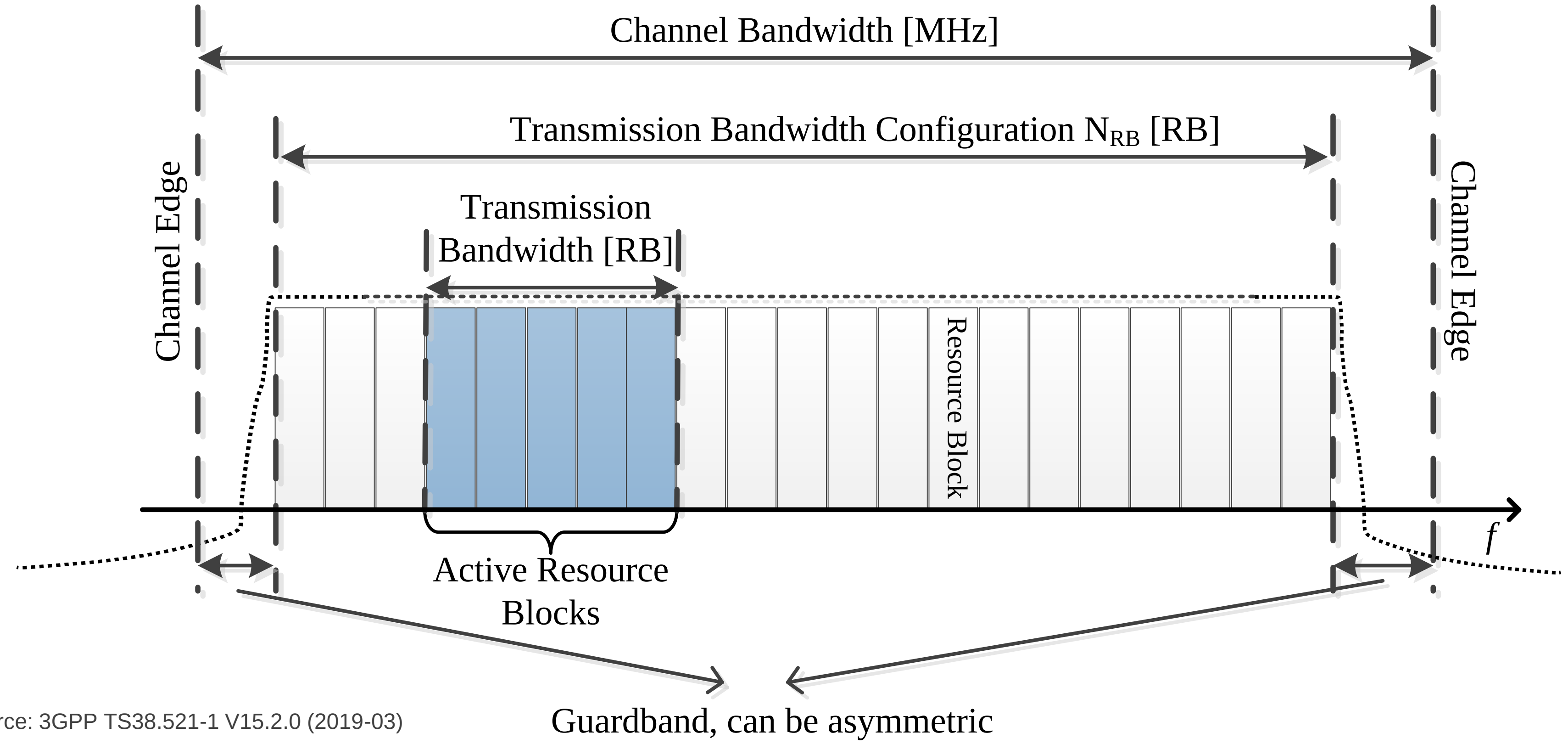
Multiple SCS Options: 15 kHz, 30 kHz, 60 kHz and 120 kHz

Sub-6GHz: Frequency Range 1 (FR1)

Maximum transmission bandwidth configuration N_{RB}

SCS (kHz)	5MHz	10MHz	15MHz	20MHz	25MHz	30 MHz	40MHz	50MHz	60MHz	80MHz	90MHz	100MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}
15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A
30	11	24	38	51	65	78	106	133	162	217	245	273
60	N/A	11	18	24	31	38	51	65	79	107	121	135

Definition of the channel bandwidth and the maximum transmission bandwidth



Source: 3GPP TS38.521-1 V15.2.0 (2019-03)

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FR1 Supported RBO/RBD combinations
From 38.521-1 V16.1.1 (2019-10) Section 6.1

Channel Bandwidth	SCS(kHz)	OFDM	RB allocation							
			Edge_Full_Left	Edge_Full_Right	Edge_1RB_Left	Edge_1RB_Right	Outer_Full	Inner_Full	Inner_1RB_Left	Inner_1RB_Right
5MHz	15	DFT-s	2@0	2@23	1@0	1@24	25@0	12@6	1@1	1@23
		CP	2@0	2@23	1@0	1@24	25@0	13@6	1@1	1@23
	30	DFT-s	2@0	2@9	1@0	1@10	10@0	5@2[1]	1@1	1@9
		CP	2@0	2@9	1@0	1@10	11@0	5@2[1]	1@1	1@9
	60	DFT-s	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		CP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10MHz	15	DFT-s	2@0	2@50	1@0	1@51	50@0	25@12	1@1	1@50
		CP	2@0	2@50	1@0	1@51	52@0	26@13	1@1	1@50
	30	DFT-s	2@0	2@22	1@0	1@23	24@0	12@6	1@1	1@22
		CP	2@0	2@22	1@0	1@23	24@0	12@6	1@1	1@22
	60	DFT-s	2@0	2@9	1@0	1@10	10@0	5@2[1]	1@1	1@9
		CP	2@0	2@9	1@0	1@10	11@0	5@2[1]	1@1	1@9
15MHz	15	DFT-s	2@0	2@77	1@0	1@78	75@0	36@18	1@1	1@77
		CP	2@0	2@77	1@0	1@78	79@0	39@19[1]	1@1	1@77
	30	DFT-s	2@0	2@36	1@0	1@37	36@0	18@9	1@1	1@36
		CP	2@0	2@36	1@0	1@37	38@0	19@9	1@1	1@36
	60	DFT-s	2@0	2@16	1@0	1@17	18@0	9@4	1@1	1@16
		CP	2@0	2@16	1@0	1@17	18@0	9@4	1@1	1@16
20MHz	15	DFT-s	2@0	2@104	1@0	1@105	100@0	50@25	1@1	1@104
		CP	2@0	2@104	1@0	1@105	106@0	53@26	1@1	1@104
	30	DFT-s	2@0	2@49	1@0	1@50	50@0	25@12	1@1	1@49
		CP	2@0	2@49	1@0	1@50	51@0	25@12[1]	1@1	1@49
	60	DFT-s	2@0	2@22	1@0	1@23	24@0	12@6	1@1	1@22
		CP	2@0	2@22	1@0	1@23	24@0	12@6	1@1	1@22
25MHz	15	DFT-s	2@0	2@131	1@0	1@132	128@0	64@32	1@1	1@131
		CP	2@0	2@131	1@0	1@132	133@0	67@33	1@1	1@131
	30	DFT-s	2@0	2@63	1@0	1@64	64@0	32@16	1@1	1@63
		CP	2@0	2@63	1@0	1@64	65@0	33@16	1@1	1@63
	60	DFT-s	2@0	2@29	1@0	1@30	30@0	15@7[1]	1@1	1@29
		CP	2@0	2@29	1@0	1@30	31@0	15@7[1]	1@1	1@29
30MHz	15	DFT-s	2@0	2@158	1@0	1@159	160@0	80@40	1@1	1@158
		CP	2@0	2@158	1@0	1@159	160@0	80@40	1@1	1@158
	30	DFT-s	2@0	2@76	1@0	1@77	75@0	36@18	1@1	1@76
		CP	2@0	2@76	1@0	1@77	78@0	39@19	1@1	1@76
	60	DFT-s	2@0	2@36	1@0	1@37	36@0	18@9	1@1	1@36
		CP	2@0	2@36	1@0	1@37	38@0	19@9	1@1	1@36
40MHz	15	DFT-s	2@0	2@214	1@0	1@215	216@0	108@54	1@1	1@214
		CP	2@0	2@214	1@0	1@215	216@0	108@54	1@1	1@214
	30	DFT-s	2@0	2@104	1@0	1@105	100@0	50@25	1@1	1@104
		CP	2@0	2@104	1@0	1@105	106@0	53@26	1@1	1@104
	60	DFT-s	2@0	2@49	1@0	1@50	50@0	25@12	1@1	1@49
		CP	2@0	2@49	1@0	1@50	51@0	25@12[1]	1@1	1@49
50MHz	15	DFT-s	2@0	2@268	1@0	1@269	270@0	135@67	1@1	1@268
		CP	2@0	2@268	1@0	1@269	270@0	135@67	1@1	1@268
	30	DFT-s	2@0	2@131	1@0	1@132	128@0	64@32	1@1	1@131
		CP	2@0	2@131	1@0	1@132	133@0	67@33	1@1	1@131
	60	DFT-s	2@0	2@63	1@0	1@64	64@0	32@16	1@1	1@63
		CP	2@0	2@63	1@0	1@64	65@0	33@16	1@1	1@63
60MHz	15	DFT-s	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		CP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	30	DFT-s	2@0	2@160	1@0	1@161	162@0	81@40	1@1	1@160
		CP	2@0	2@160	1@0	1@161	162@0	81@40	1@1	1@160
	60	DFT-s	2@0	2@77	1@0	1@78	75@0	36@18	1@1	1@77
		CP	2@0	2@77	1@0	1@78	79@0	39@19[1]	1@1	1@77
80MHz	15	DFT-s	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		CP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	30	DFT-s	2@0	2@215	1@0	1@216	216@0	108@54	1@1	1@215
		CP	2@0	2@215	1@0	1@216	217@0	109@54	1@1	1@215
	60	DFT-s	2@0	2@105	1@0	1@106	100@0	50@25	1@1	1@105
		CP	2@0	2@105	1@0	1@106	107@0	53@26[1]	1@1	1@105
90MHz	15	DFT-s	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		CP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	30	DFT-s	2@0	2@243	1@0	1@244	240@0	120@60	1@1	1@243
		CP	2@0	2@243	1@0	1@244	245@0	123@61	1@1	1@243
	60	DFT-s	2@0	2@119	1@0	1@120	120@0	60@30	1@1	1@119
		CP	2@0	2@119	1@0	1@120	121@0	61@30	1@1	1@119
100MHz	15	DFT-s	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		CP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	30	DFT-s	2@0	2@271	1@0	1@272	270@0	135@67	1@1	1@271
		CP	2@0	2@271	1@0	1@272	273@0	137@68	1@1	1@271
	60	DFT-s	2@0	2@133	1@0	1@134	135@0	64@32	1@1	1@133
		CP	2@0	2@133	1@0	1@134	135@0	67@33[1]	1@1	1@133

Note 1: The allocated RB number L_{CRB} is ceil(N_{RB}/2) -1 in order to meet Inner RB allocation definition ($RB_{Start,Low} \le RB_{Start} \le RB_{Start,High}$) described in subclause 6.2.2 of TS 38.101-1 [2].

Number of Test Cases

- Full Sweep

	SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90 MHz	100 MHz	200 MHz	400 MHz	# of BWs	Test Cases with all possible RB Sweep	# of OFDM Types	# of Modulations	# of Sampling Rates	# of CCs	ALL Test Cases with all possible RB Sweep
		N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}							
FR1	15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A	N/A	N/A	8	92,346	2	6	1	1	1,108,152
	30	11	24	38	51	65	78	106	133	162	217	245	273	N/A	N/A	12	126,633	2	6	1	1	1,519,596
	60	N/A	11	18	24	31	38	51	65	79	107	121	135	N/A	N/A	11	30,744	2	6	1	1	368,928
FR2	60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	66	N/A	N/A	N/A	132	264	N/A	3	45,969	2	6	2	1	1,103,256
	120	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32	N/A	N/A	N/A	66	132	264	4	46,497	2	6	2	1	1,115,928
															Total		342,189					5,215,860

- 3GPP

	SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90 MHz	100 MHz	200 MHz	400 MHz	# of BWs	3GPP Suggested RBs for all supported BWs	# of OFDM Types	# of Modulations	# of Sampling Rates	# of CCs	ALL Test Cases with all possible RB Sweep
		N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}							
FR1	15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A	N/A	N/A	8	8	2	6	1	1	768
	30	11	24	38	51	65	78	106	133	162	217	245	273	N/A	N/A	12	8	2	6	1	1	1,152
	60	N/A	11	18	24	31	38	51	65	79	107	121	135	N/A	N/A	11	8	2	6	1	1	1,056
FR2	60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	66	N/A	N/A	N/A	132	264	N/A	3	6	2	6	2	1	432
	120	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32	N/A	N/A	N/A	66	132	264	4	6	2	6	2	1	576
															Total		36					3,984

The Test cases can increase significantly with multiple TX antennas, more CCs, different CC combinations with different parameters, different slot combinations in burst mode etc.

FR1: Frequency Range 1 Operating Bands

NR operating band	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}	Duplex Mode
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD[1]
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL
n86	1710 MHz – 1780MHz	N/A	SUL
NOTE 1: UE that complies with the NR Band n50 minimum requirements in this specification. Shall also comply with the NR Band n51 minimum requirements.			
NOTE 2: UE that complies with the NR Band n75 minimum requirements in this specification. Shall also comply with the NR Band n76 minimum requirements.			

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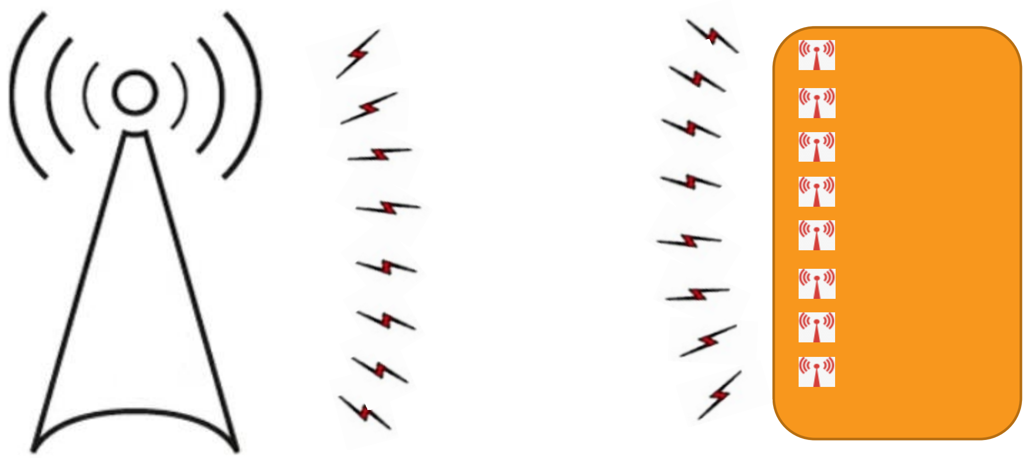
Source: 3GPP TS38.521-1 V15.2.0 (2019-03)

NR5G Sub6 Test Solution

- The *IQxstream-5G* is LitePoint's test solution for **5G user equipment (UE) applications** at sub-6GHz:
  - A future-proof test solution with **200 MHz** of continuous bandwidth for 5G
  - Supports the new 5G sub-6GHz and legacy FDD/TDD 3G/4G LTE cellular standards
  - Available in a 2U chassis in an 8-port configuration that can be expanded to 16 ports with LitePoint's slim IQ3101 switch.
  - Superior EVM performance of -46 dB at 100 MHz CC
  - Supports the popular mobile Wi-Fi connectivity standards

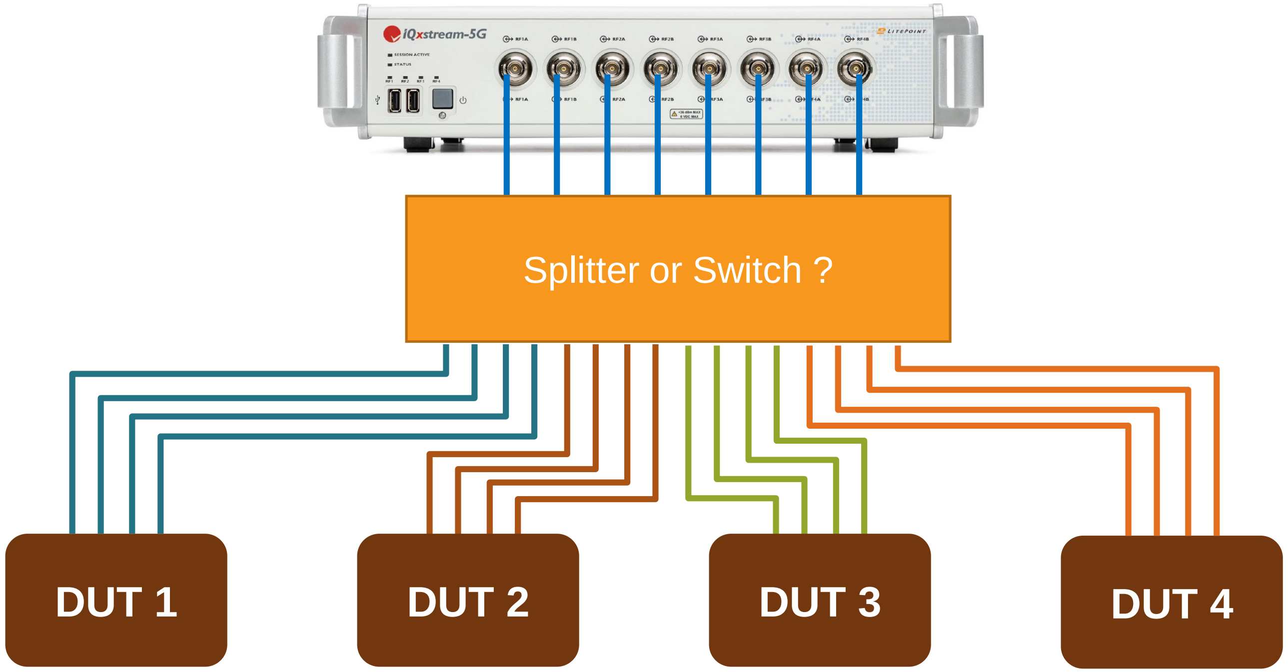
5G FR1 Device Has massive antennas

- More antenna ports than before
  - Up to 8x8 MIMO order
  - Existed LTE bands + new NR su6 bands
- What could be the challenges to production testing?
  - Production station setup complicated
  - Production station calibration complicated
  - Tester ports requirement
  - Test time longer than before



Massive antennas connection challenge

- The tester needs to connect to 8+ antenna connectors…
- …but we also need to deliver great test economics (multi-DUT)
- Adding a splitter or switch to the test fixture can deliver great economics without reducing the quality of test
- Let’s explore if this should be a splitter or a switch…



Power Splitter or Switch?

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Power Splitter

- Key tech. spec on splitter
  - Insertion loss : spec insertion loss + 6dB for 4-ways splitter
  - Isolation : Usually less than switch.
  - Amplitude Unbalance : This matters when testing with RX broadcast mode

Model Number	No. of Ways	F Low (MHz)	F High (MHz)	Isolation (dB), Typ.	Insertion Loss (dB) Above Theoretical, Typ.	Phase Unbalance (deg), Typ.	Amplitude Unbalance (dB), Typ.	Power Input (W) as Splitter, Max.	Technology	Case Style
ZC8PD-5R263-S+	8	500	26500	35	4.1	3.1	0.2	20	Stripline	UU2415-1
ZC8PD-01263-S+	8	1000	26500	26	3.2	2.9	0.14	20	Stripline	UU2415-2
ZC8PD-02263-S+	8	2000	26500	31	2.1	2.3	0.11	20	Stripline	UU2415-3
ZC8PD-06263-S+	8	6000	26500	28	1.2	2.6	0.11	20	Stripline	UU2415-4
ZC8PD-K5R44W+	8	500	40000	35	4.1	1.9	0.18	20	Stripline	UU2415-1
ZC8PD-K0644+	8	6000	40000	28	2.0	2.2	0.12	20	Stripline	UU2415-4
ZC16PD-06263-S+	16	6000	26500	24	2.2	3.3	0.2	20	Stripline	UU640-1
ZC16PD-K0644+	16	6000	40000	26	2.2	6	0.28	20	Stripline	UU640-1
ZFRSC-4-842+	4	DC	8400	6.4	0.3	4	0.3	0.16	Resistive	G15
ZFRSC-123+	2	DC	12000	19.5	3.5	3	0.25	0.16	Resistive	JJJ245
ZFRSC-183+	2	DC	18000	6.5	0.7	7	0.5	0.16	Resistive	JJJ245

Source: minicircuits.com

Power Splitter

- ZC8PD-5R263-S+
  - 8 Way-0° 50Ω 500 to 26500 MHz
  - https://www.minicircuits.com/pdfs/ZC8PD-5R263-S+.pdf

Splitter Division Reduction Loss Table

Number of Output Ports	Theoretical Division Reduction (dB)
2	3
4	6
6	7.8
8	9
10	10

Electrical Specifications at 25°C

Parameter	Frequency (MHz)	Min.	Typ.	Max.	Unit
Frequency Range		500		26500	MHz
Insertion Loss Above 9.0 dB	500-8000		1.9	3.4	dB
	8000-18000		4.1	5.8	
	18000-26500		6.3	8.0	
Isolation	500-8000	14	30		dB
	8000-18000	18	35		
	18000-26500	18	36		
Phase Unbalance	500-8000		1.3	4	Degree
	8000-18000		3.1	5	
	18000-26500		5	7	
Amplitude Unbalance	500-8000		0.16	0.5	dB
	8000-18000		0.20	0.5	
	18000-26500		0.26	0.5	
VSWR (Port S)	500-8000		1.16	1.6	:1
	8000-18000		1.16	1.6	
	18000-26500		1.16	1.6	
VSWR (Port 1-8)	500-8000		1.1	1.6	:1
	8000-18000		1.1	1.5	
	18000-26500		1.18	1.6	

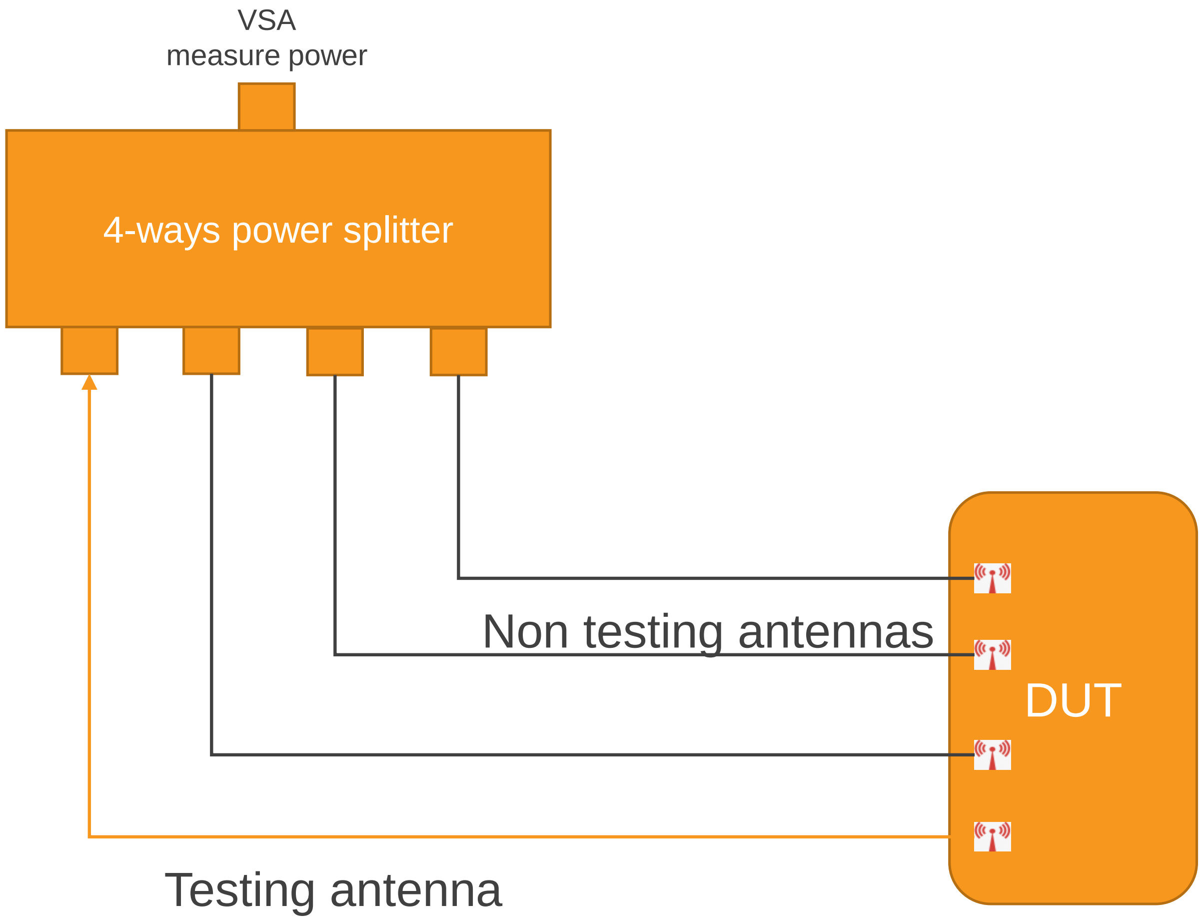
Typical Performance Data

Freq. (MHz)	Total Loss[1] (dB)						Amp. Unbal. (dB)	Isolation (dB)				Phase Unbal. (deg.)	VSWR S	VSWR 1	VSWR 8
	S-1	S-2	S-3	S-4	S-6	S-8		1-2	2-4	5-7	7-8				
500	9.55	9.55	9.54	9.55	9.55	9.55	0.01	17.14	21.19	21.71	16.99	0.32	1.20	1.07	1.09
1000	9.86	9.86	9.87	9.87	9.87	9.88	0.02	29.50	27.07	27.33	30.20	0.37	1.33	1.10	1.11
2000	10.18	10.19	10.20	10.20	10.22	10.22	0.04	58.92	41.22	40.75	44.07	0.52	1.18	1.24	1.23
4000	10.80	10.79	10.82	10.84	10.85	10.87	0.08	27.88	34.39	36.25	30.31	0.68	1.09	1.07	1.07
6000	11.36	11.34	11.40	11.43	11.44	11.44	0.10	30.99	36.29	36.68	32.70	0.91	1.06	1.10	1.11
8000	11.90	11.87	11.95	12.00	12.00	12.00	0.14	28.76	46.30	45.88	28.34	1.20	1.18	1.08	1.08
10000	12.40	12.36	12.46	12.53	12.50	12.51	0.17	29.11	40.85	41.52	29.19	1.37	1.16	1.04	1.04
12000	12.85	12.81	12.93	13.00	12.98	12.99	0.19	43.25	47.97	44.96	47.08	1.58	1.05	1.15	1.14
14000	13.43	13.38	13.54	13.62	13.58	13.57	0.24	33.94	43.16	43.11	35.65	1.77	1.19	1.27	1.25
16000	13.82	13.76	13.94	14.01	13.98	13.98	0.25	35.46	60.23	50.43	37.16	2.00	1.05	1.11	1.09
18000	14.33	14.27	14.47	14.56	14.51	14.52	0.28	45.45	36.83	37.56	48.61	2.09	1.35	1.08	1.09
20000	14.84	14.79	15.03	15.09	15.05	15.07	0.30	36.90	42.20	39.77	36.78	2.18	1.36	1.22	1.25
22000	15.23	15.18	15.48	15.51	15.48	15.47	0.34	38.30	47.97	54.47	36.66	2.24	1.20	1.22	1.23
24000	15.73	15.70	15.98	16.04	15.99	15.99	0.34	31.40	48.18	45.25	31.11	2.30	1.19	1.17	1.19
26500	16.25	16.22	16.53	16.54	16.48	16.49	0.32	48.47	44.45	44.94	40.25	2.79	1.16	1.09	1.10

1. Total Loss = Insertion Loss + 9dB splitter loss.

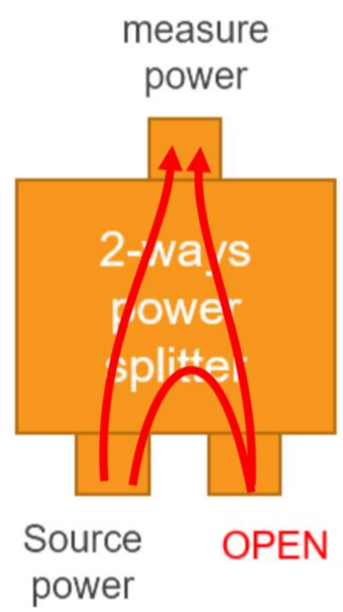
Power Splitter

- How will the non-testing antenna ports impact the test result of the testing antenna?
  - What's the state of the non-testing antenna ports?
  - Are they OPEN/SHORT/LOAD?
  - We can't guarantee the non-testing antenna ports input impedance



Power Splitter Experiment

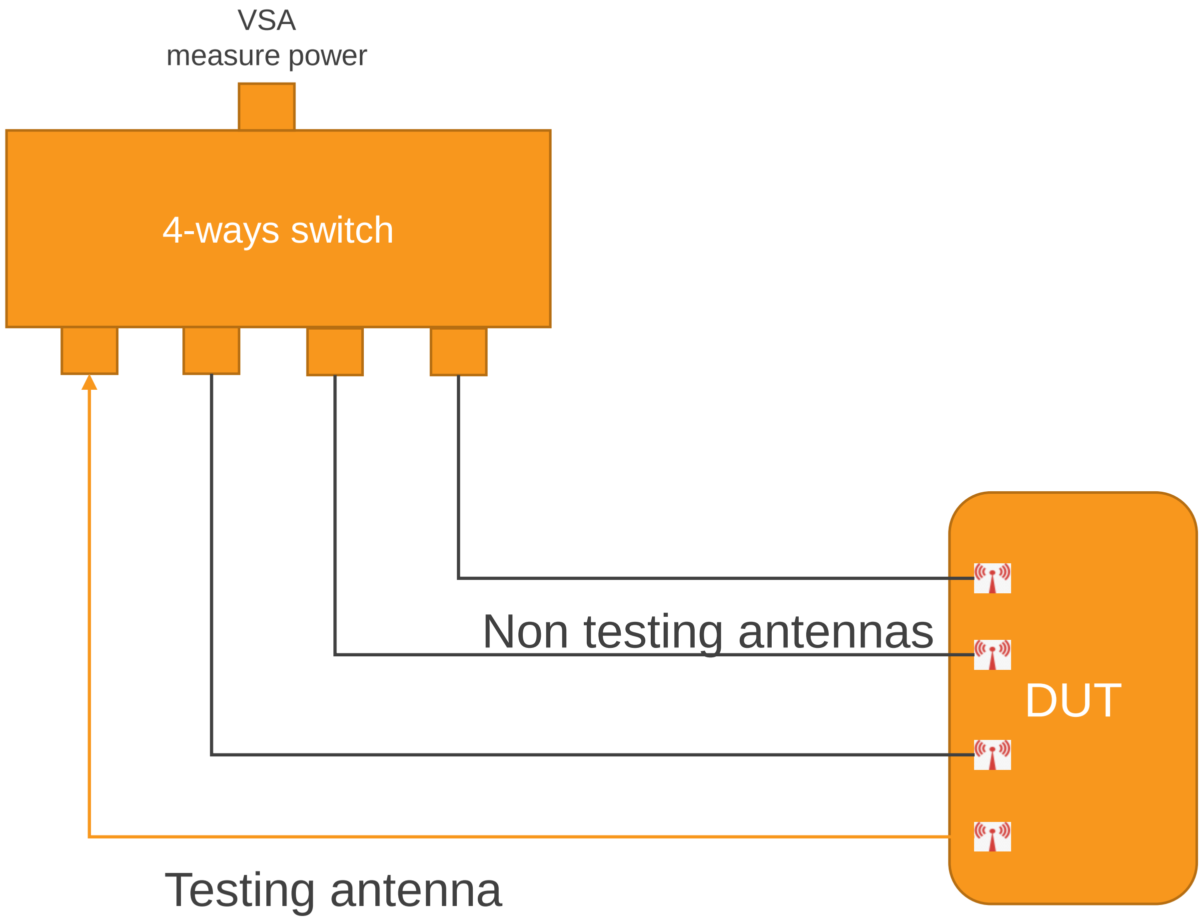
- We use a 2-ways splitter to understand how the non-testing port impact the measurement result of the testing port
  - The non-testing port impedance and phase contribute power variation to the testing port
  - The better the isolation of the splitter the less impact from the non-testing ports



	Splitter A	Splitter B
Input Power	24 dBm	24 dBm
Isolation	19 dB	15 dB
Measurement Uncertainty	0.05 dB	0.14 dB

Switch

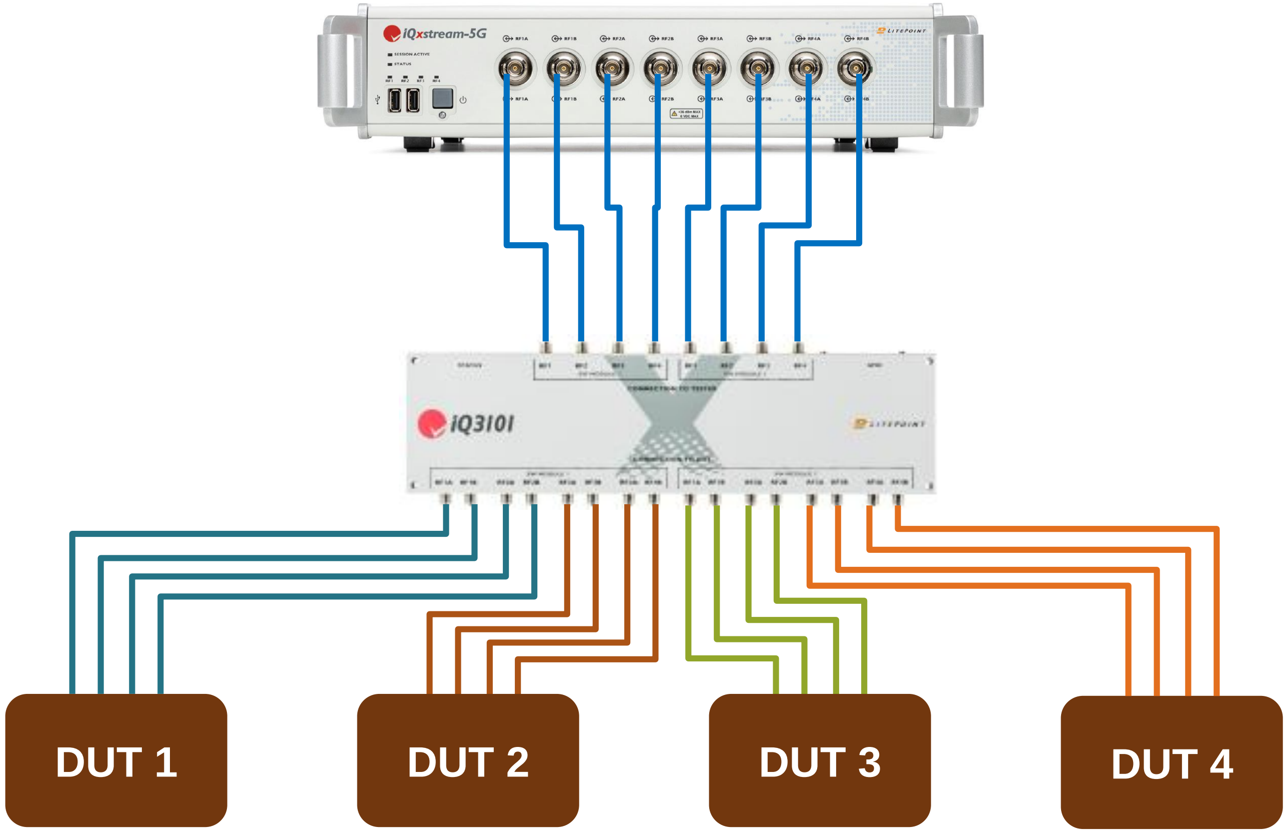
- The most different of RF switch to the power splitter is the non-testing ports can well controlled impedance and phase
  - RF switch the non-testing ports impedance and phase from the RF switch tech. spec
  - Power splitter the non-testing ports impedance and phase from the DUT ant. ports



Power Splitter vs. Switch

	Switch	Power Splitter
Insertion Loss	Low	High
Port-to-Port Isolation	High	Low
RF Input Power	High	Low
External Control	USB / Ethernet / GPIO	None
Multiple Outputs Simultaneously	Only one active path	Multiple path simultaneously

Multi-DUT Port Expandability with IQ3101



IQfact5G

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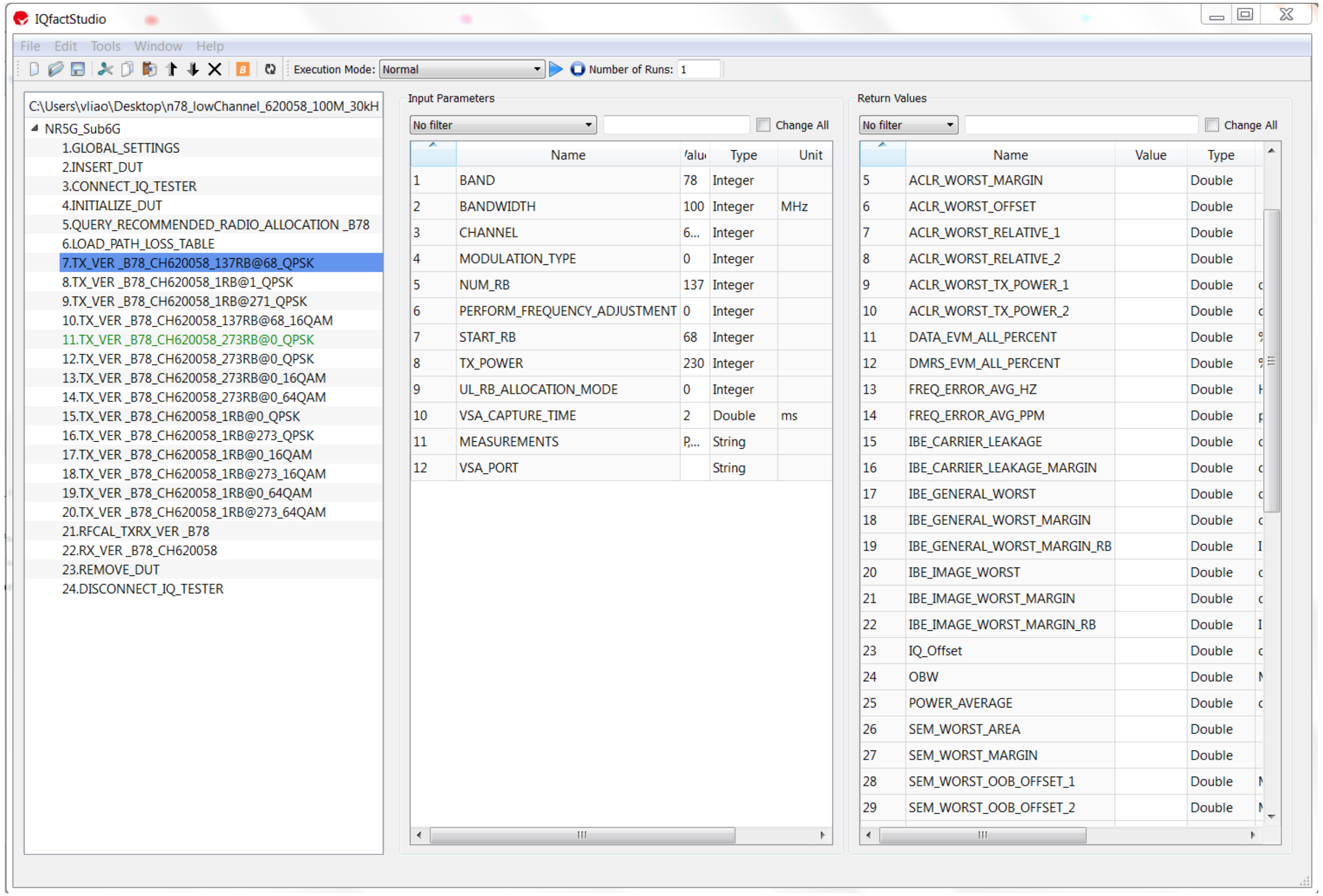
IQfact5G solution

- Built-in chipset production solution
- 5G sub6 and mmWave test supported
- Chamber control integrated
- Switch port extension supported
- Native multiDUT test support with good PTE



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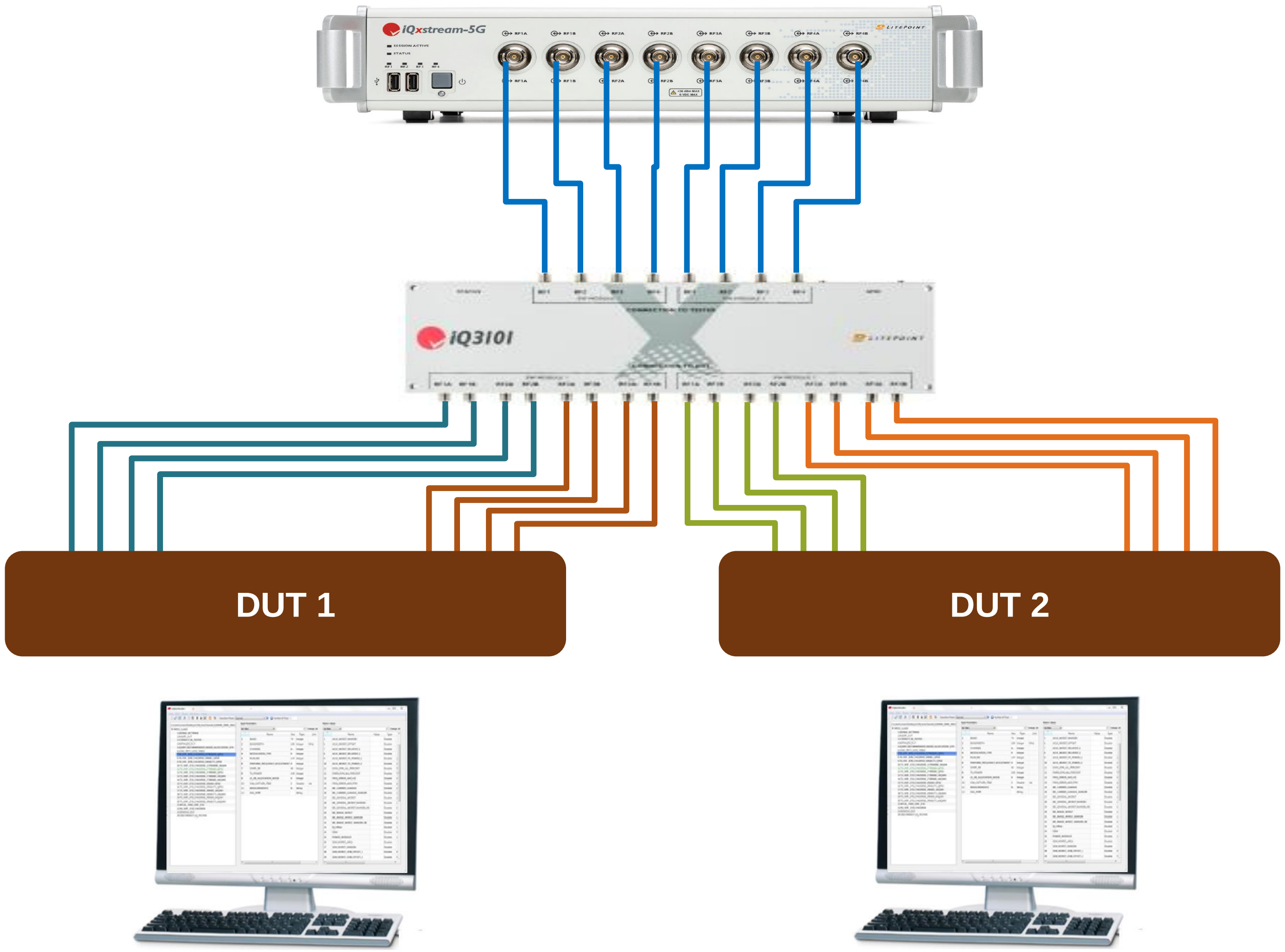
IQfact5G MultiDUT test configuration



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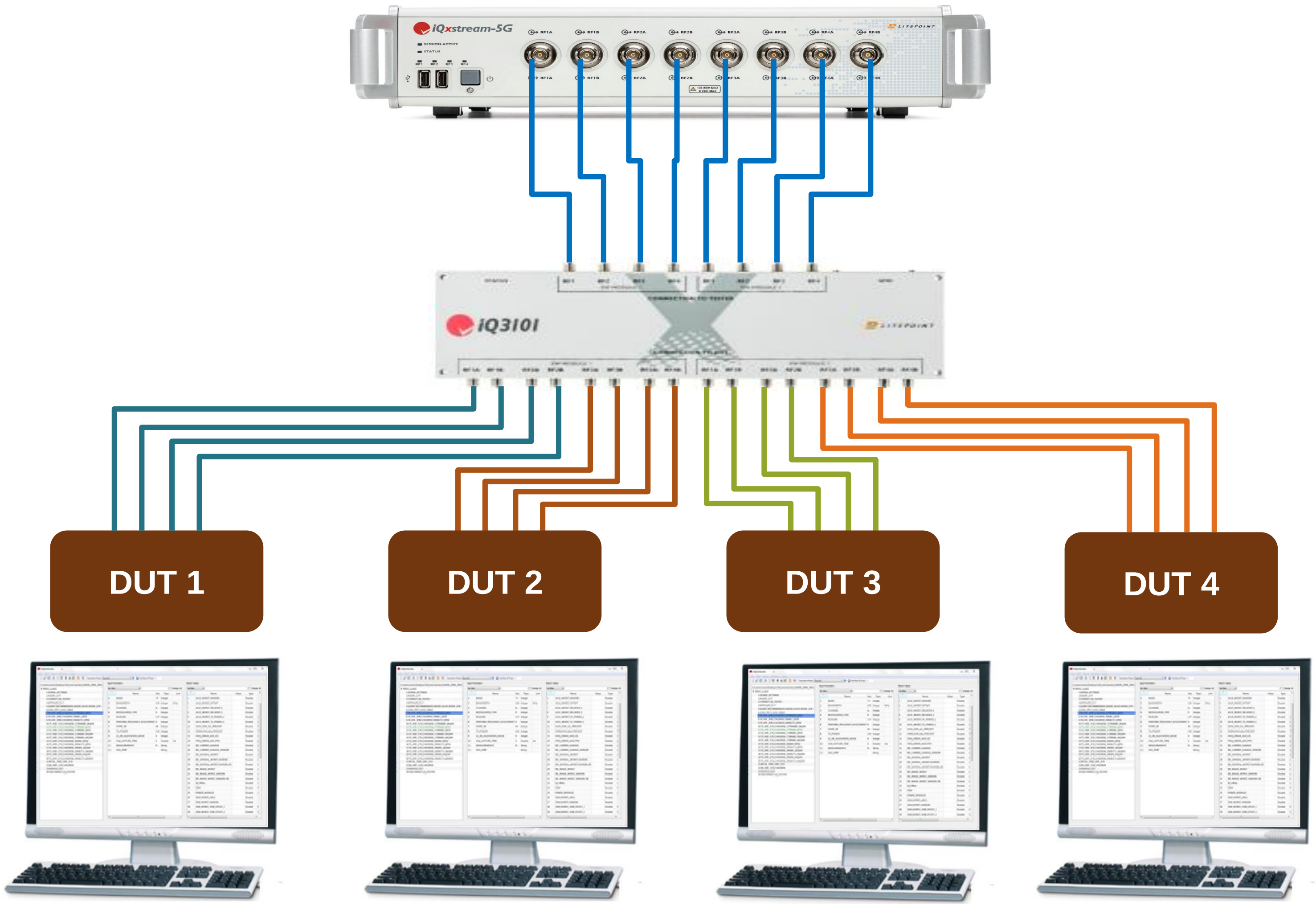
IQfact5G MultiDUT test configuration



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Summary

Summary

- 5G is ramping up rapidly, and we are ready!
- Massive antenna ports in 5G sub6 phone is a big challenge to production line on test time efficiency and also production line maintenance
- IQfact5G provide an efficient and easy to use production tool
- IQ3101 switch provide a painless tester port extension option

Thank you

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