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A Teradyne Company

Making 5G A Reality

5G To Transform Lives

5G, the biggest innovation platform ever.

How 5G could speed up global growth

One G to Rule Them All

5G and its Potential

New!

5G Changes Everything

5G is Now

5G. A Future Beyond Imagination.

The trillion dollar race: what 5G means to the global economy

5G is foundational to what's next.

Nearly 1 in 4 consumers want 5G

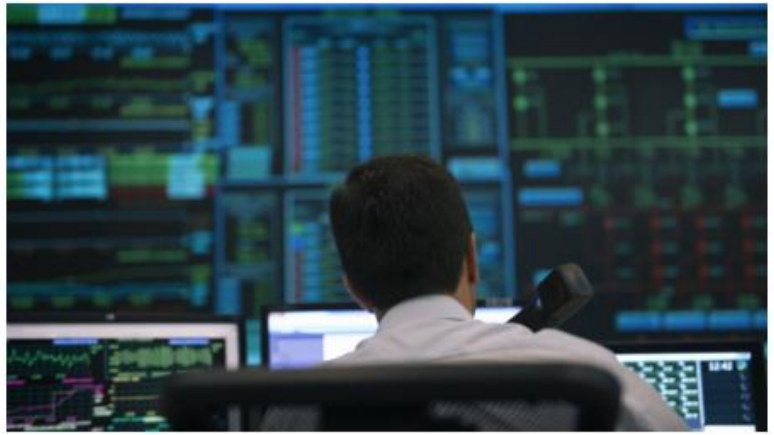
AR is big — 5G will make it huge

5G has been designed considering future connectivity needs

Top 5G Use Cases

Broadband and media everywhere

Smart vehicles and transport



Critical services and infrastructure control

Critical control of remote devices

Human machine interaction

Sensors networks

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Source: Ericsson

Source: Huawei

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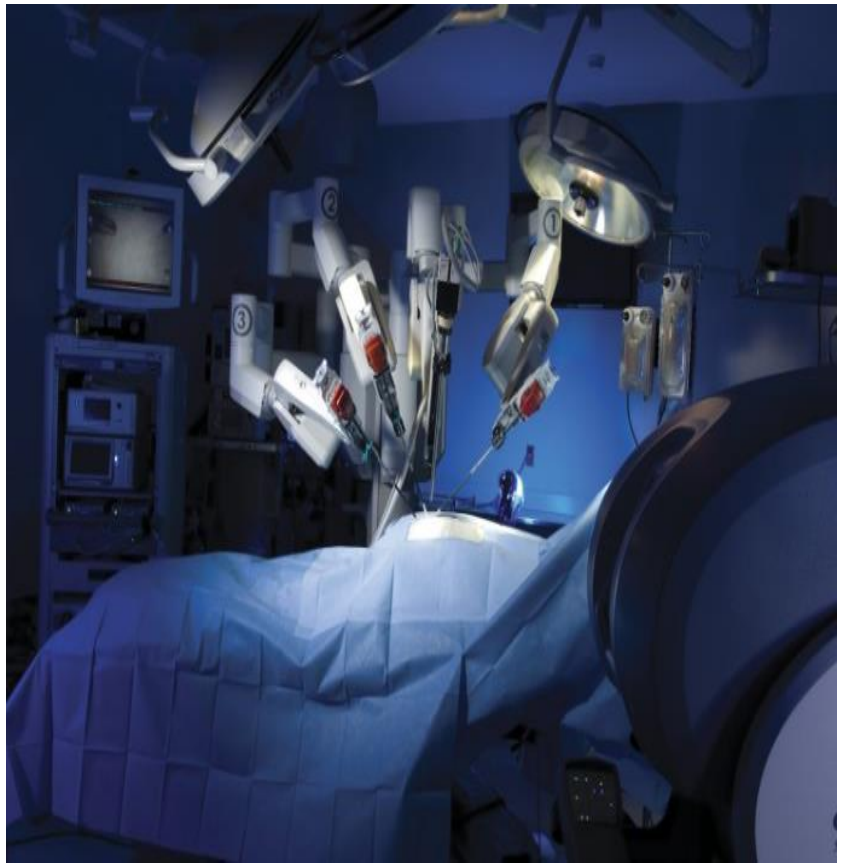
A Step Towards Reality…

5G mobile network goes live at all BMW Brilliance Automotive production sites in China

Source: bimmerfest.com

5G impact on healthcare: massive impact on connected devices



Source: medicalfuturist.com

Verizon brings 5G to 13 NFL stadiums
Partners to Add 5G Football Game Features

Source: mediapost.com

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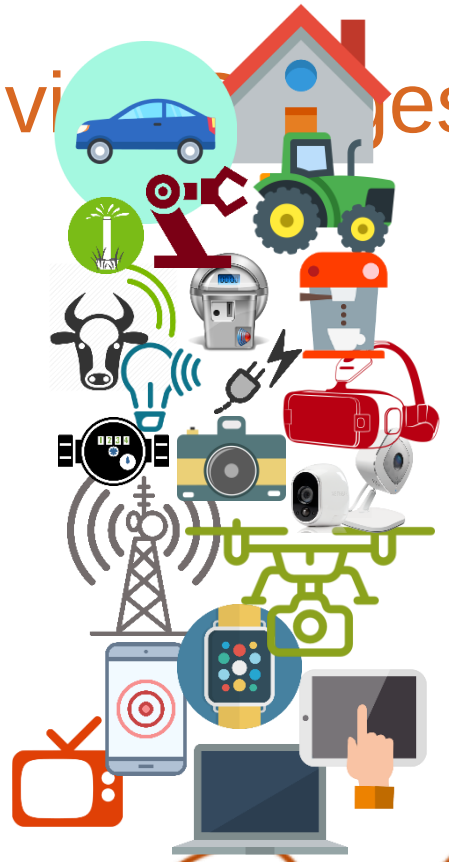
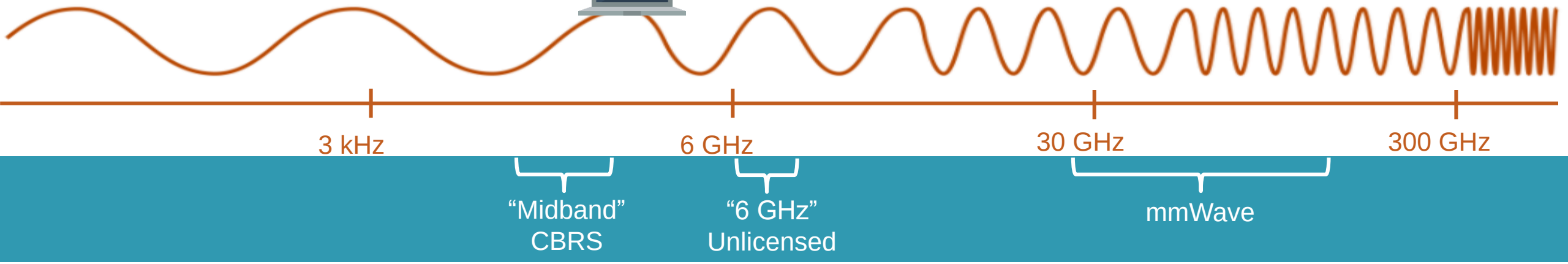
5G Requires Solvi gested Spectrum



New Spectrum has opened to enable 5G deployments



Electromagnetic Spectrum

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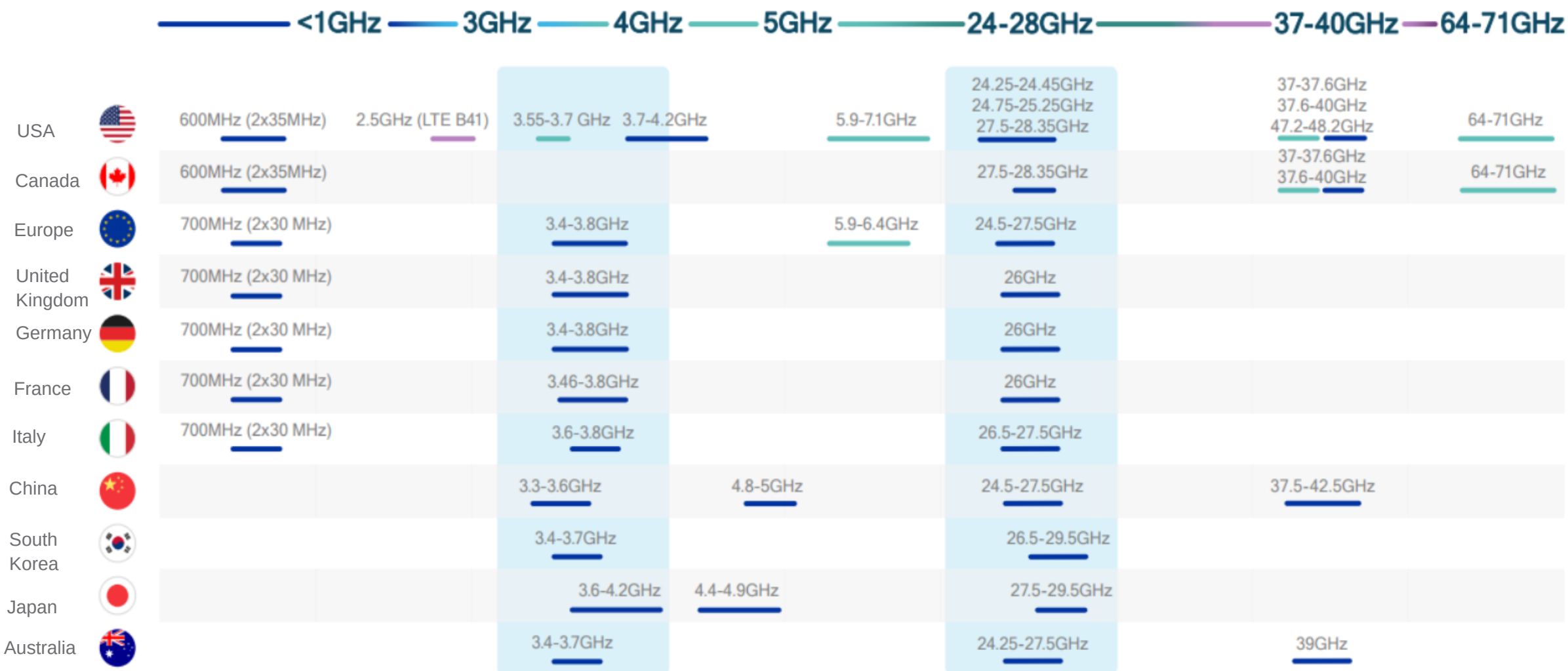
Global Snapshot of 5G Spectrum



Source – anandtech.com

License — Unlicensed/shared — Existing band

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5G availability in USA

Concrete 5G network availability in North America - 2020
By 2023, 32% mobile connections will be on 5G

Carrier	Verizon	AT&T	Sprint	T-Mobile
Current Status	5G Fixed Wireless internet (5G Home) – starting Oct 2018 5G Mobile service (Ultra Wideband) - Beginning April 2019	Currently marketing LTE Advanced as 5G Evolution Expecting to have a nationwide 5G in 2020 across many cities	Total 5G footprint - 2,100 square miles covering 11 million people in the U.S.	Plans to cover nearly 2/3 of the US population with 5G by 2021, with speeds exceeding 100 Mbps
Locations	5G Home in four cities: Houston TX, Sacramento CA, Indianapolis IN, and Los Angeles CA 5G Mobile service - in Chicago, Denver, Atlanta, Washington DC	In 21 cities including, Los Angeles, San Diego, San Francisco, San Jose, Atlanta, Austin, NYC, etc	Beginning May 2019, Offers 5G in six cities: Chicago, Atlanta, Los Angeles, New York city, Washington, Phoenix	Beginning June 2019, Offers 5G in six locations - Atlanta, Cleveland, Dallas, Las Vegas, Los Angeles, and New York
Spectrum Availability	**28** & 39 GHz spectrum	700MHz & **39** GHz spectrum	2.5GHz spectrum	600MHz, 28GHz, 39 GHz spectrum

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5G availability in other parts of the world

- Three major carriers SK Telecom, LG Uplus, and KT.
- 5G SKT and 5G Korea Telecom showcase 5G service at the 2018 Olympic Winter Games in Pyeong Chang
- SK telecom acquired 3.5 GHz and 28 GHz bands
- 5% mobile users by 2020, 90% by 2026

- GSMA estimates 460 million 5G connections in China by 2025
- 100 5G base stations launched across China, with aim for 45000 by end of 2020
- China Mobile to use 515 MHz to 2.675 GHz
- China Telecom to use 3.4 GHz to 3.5 GHz
- mmWave - candidate bands– 24.75–27.5 GHz and 37– 42.5 GHz, although allocation plans haven't been crystalized.

- NTT DoCoMo planning to launch 5G service at 2020 Tokyo Olympics
- Bands of operation - 3.7 GHz, 4.5 GHz and 28 GHz bands
- DoCoMo, KDDI, SoftBank, Rakuten looking for mid 2020 launch

- EE rolled out 5G service in 6 cities
- O2 launching 5G in 20 cities in October 2019
- EE home broadband supported using HTC 5G Hub
- C-band frequencies 3.4-3.8GHz, main band for launch
- Promoting 37-43.5 and 66-71 GHz bands, although no operators are using it

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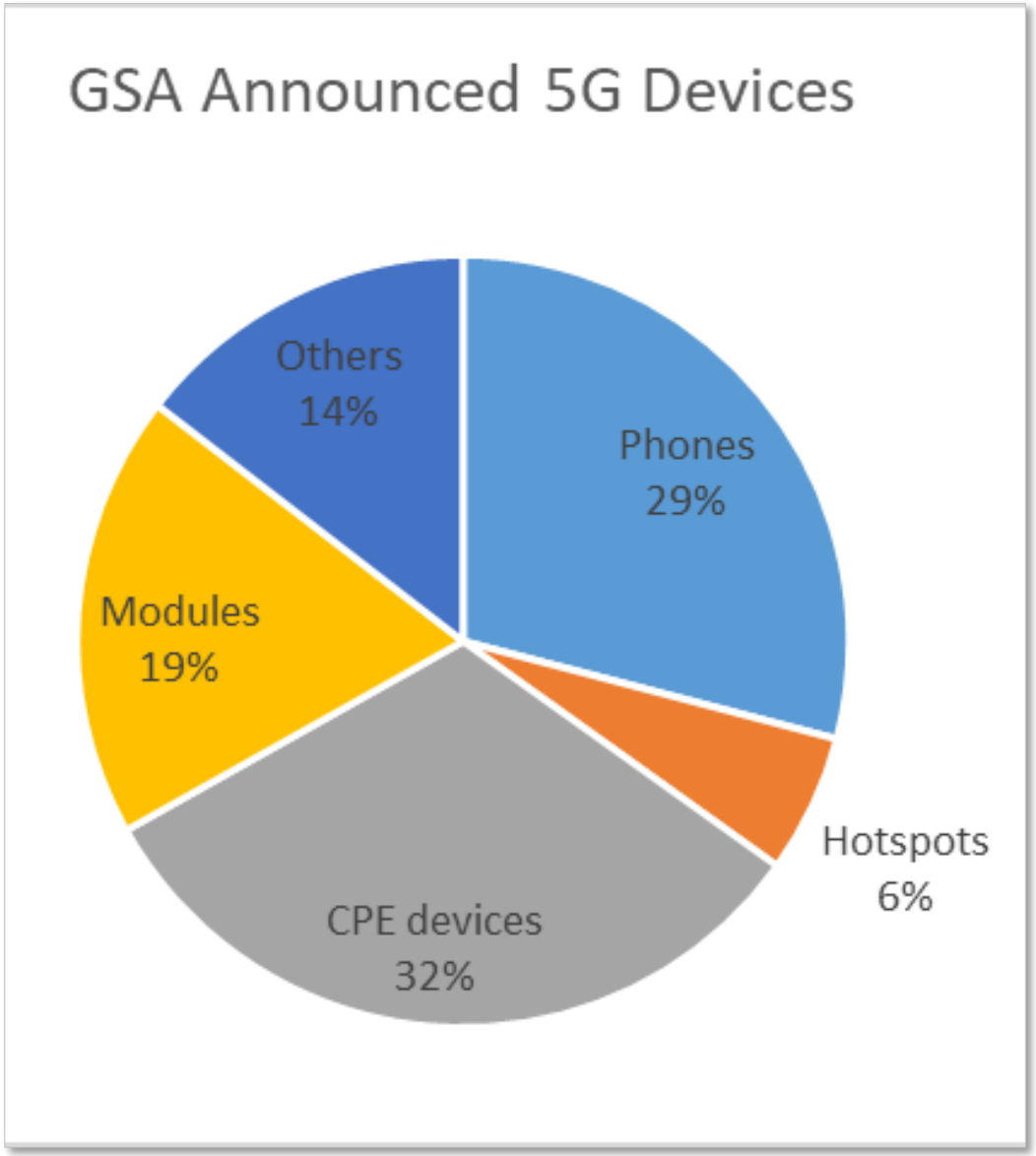
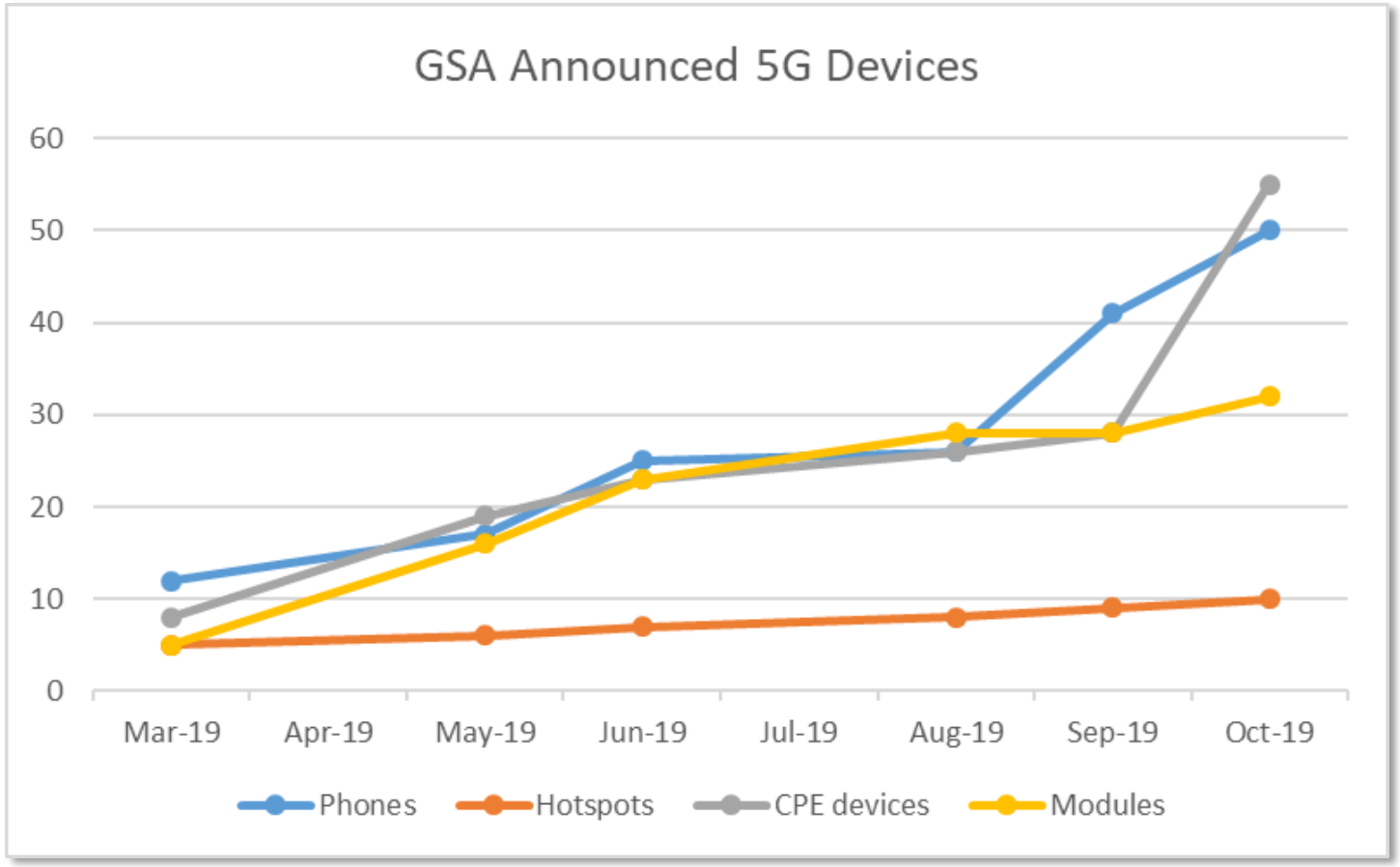
An Explosion of 5G Devices in 2019





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Moto Z3 w/ 5G mod

Moto Mod Z4

LG V50 ThinQ 5G

ZTE Axon 10 Pro 5G

OPPO Reno 5G

Netgear Nighthawk
(mobile hotspot)

Samsung Galaxy S10 5G

Huawei Mate X

Xiaomi Mi Mix3 5G

Huawei 5G CPE Pro
(CPE)

Inseego
(mobile hotspot)

Samsung Galaxy Fold

Huawei Mate 20 X 5G

OnePlus 7 Pro
5G

Alcatel 7 5G

Lenovo Project Limitless
(Laptop)

Samsung Galaxy
Note10+ 5G

hTC 5G Hub
(mobile hotspot)

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5G Ramping Faster than Expected, Driven by Sub 6GHz (FR1)

September 2019 Forecast

3G, 4G, and 5G Smartphone Shipments, '15 - '22E

	2015	2016	2017	2018	2019E	2020E	2021E	2022E
3G	470	323	241	95	60	25	5	0
4G	967	1150	1220	1310	1250	1150	800	525
5G	0	0	0	0	11	180	585	875
Total	**1437**	**1473**	**1461**	**1405**	**1321**	**1355**	**1390**	**1400**

Source: Arete Research, **September 2019**

April 2019 Forecast

SmartPhone forecast (EE Times)	2019	2020	2021	2022	2023	2024	2025
FR2 Units (M)	1	5	15	45	250	350	500
FR1 Units (M)	12	59	166	407	450	650	1000
4G / legacy Units (M)	1737	1736	1669	1448	1240	970	500
Total 5G Units (M)	13	64	181	452	700	1000	1500
Total Units (M)	1750	1800	1850	1900	1940	1970	2000

Source: EE Times, **April 2019**

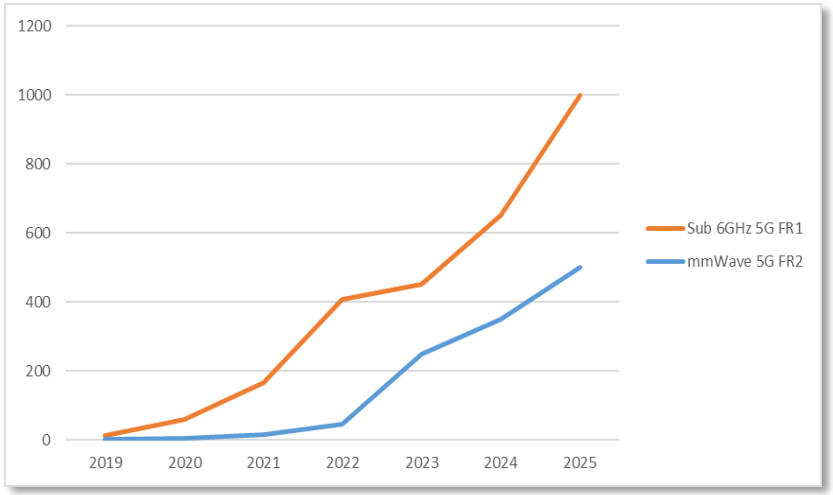
Volume forecast pulled in by 1 year

Key 5G Handset Players

Table 2: 5G Handset Outlook by OEM, 2020-22E

OEM Breakdown	CY20	CY21	CY22
Huawei	45	150	195
Samsung	37	131	185
Apple	35	120	175
Oppo/Vivo	33	104	165
Other	30	80	155
Total	**180**	**585**	**875**

Source: Arete Research estimates.



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MOBILES

Qualcomm expects 200 million 5G phones next year

by NICK FARRELL on 07 NOVEMBER 2019 Tweet Like Sign Up to see what your friends like. FONT SIZE PRINT EMAIL

Qualcomm said it expects 200 million 5G smartphones to be sold in 2020 and that will make it the world's largest supplier of mobile phone chips.

Qualcomm Chief Financial Officer Akash Palkhiwala said on an investor call there would be "two inflexion points" for 5G chips next year.

One would be in the spring when firms like Samsung and several Chinese handset makers tend to introduce new phones. "The second point will be in the Autumn when another set of flagship devices will adopt 5G."

Fall is when Apple and Alphabet launch new models.
Qualcomm's 5G market estimate, disclosed during a fourth quarter earnings report, is the first from the company.

MediaTek, Samsung and Huawei Technologies will produce 5G chips, but Qualcomm stands to reap patent licensing revenue from essentially every 5G device and sell chips for many of the most expensive handsets. Qualcomm's 5G devices estimate is nearly 60 percent higher than research firm IDC's 123.5 million forecasts and Goldman Sachs' 120 million.

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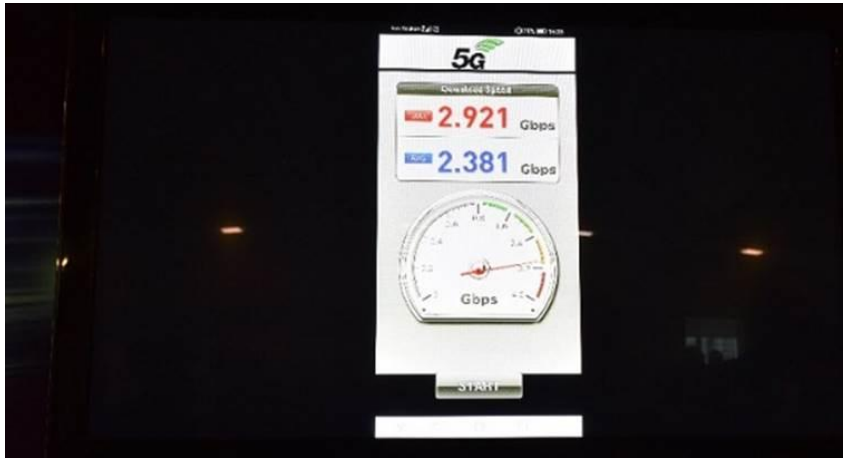
Source: Fudzilla, November 2019

Some Real World 5G Cases…

Huawei achieves new 'world record' 5G speed

By Steve McCaskill a day ago Mobile Phones

Huawei and Turk Telecom break record



Huawei has delivered a reminder of its technical expertise by breaking the world record 5G speed for a single user smartphone.

The Chinese network equipment manufacturer built a 3GPP compliant test network at a Turk Telecom facility in Istanbul to achieve speeds in excess of 2.92Gbps.

Although it's unlikely that commercial users will be able to access speeds any time soon, it does demonstrate the theoretical potential of 5G using commercial equipment. A Huawei Mate X
smartphone was used, alongside a Turk Telecom 5G SIM card.

The test was based on C-band (mid-band) 200MHz IBW and 2CC Carrier Aggregation technologies.

Source: TechRadar.com, November 2019

RCRWireless News
INTELLIGENCE ON ALL THINGS WIRELESS

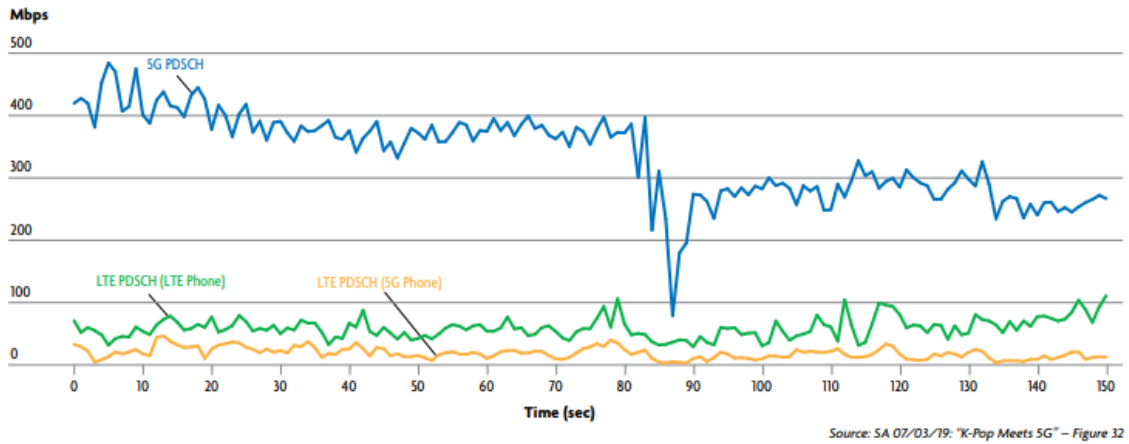
By Prakash Sangam on OCTOBER 24, 2019

5G, Analyst Angle, Test and Measurement

Wondering whether all of those 5G performance claims are true– Now we have conclusive proof!

Download Speed

Figure 4. SK Telecom 5G Walk Test Real-Time Data Speeds

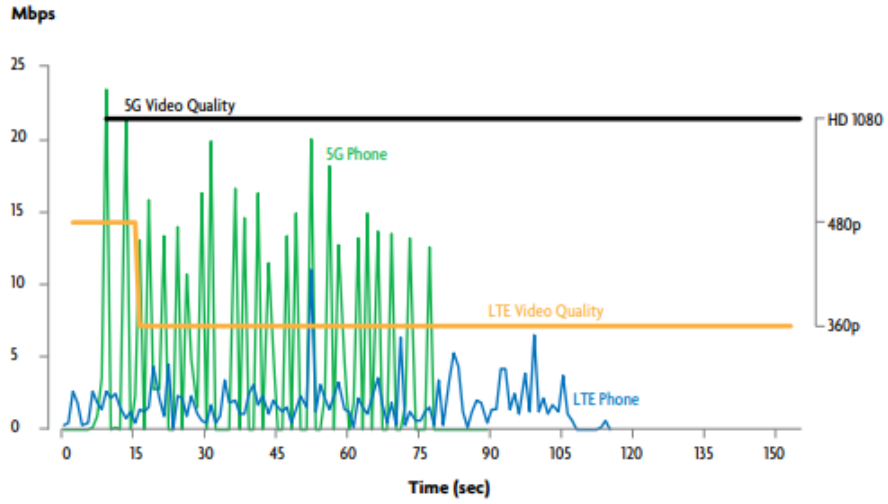


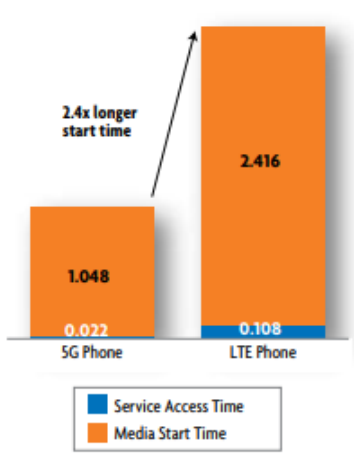
Source: SA 07/03/19: "K-Pop Meets 5G" – Figure 32

5G speeds and capacity were **2x to 10x better than LTE**. The wide bandwidths of 5G are the major reason for this improvement, especially the millimeter-wave bands. Here is a chart for a test in Seoul, comparing **Sub-6GHz 5G vs LTE speeds**.

User Experience with Video

Figure 29. Physical Layer Throughput and Video Quality with YouTube Streaming – 5G vs. LTE





In Figure 29, we show the physical layer throughput associated with streaming an HD 1080p video. The video on the **5G smartphone retained the 1080p resolution** throughout the playback. The LTE smartphone video quality **started at 480p ("Large")** before quickly **dropping to 360p ("Medium")**. The application resorted to the lower video quality due to network loading.

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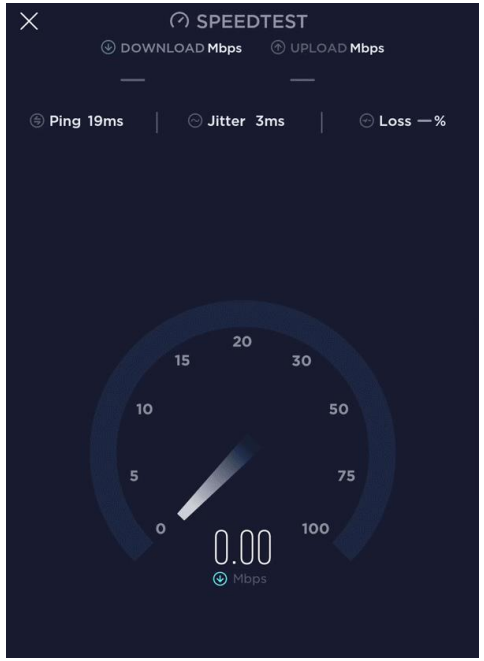
THE WALL STREET JOURNAL.

We Tested 5G Across America. It's Crazy Fast—and a Hot Mess



Finding 1: Soooo fast.
"Holy spit!" I said the first time I saw a speed test hit 1,800 megabits per second on Verizon's network in downtown Denver. (OK, I didn't actually say "spit.")

Finding 2: Got a 5G signal? Don't move.
It's super-duper fast but can't travel long distances.

Finding 3: Got a 5G signal? Don't go inside.
When I stepped inside, the 5G signal vanished.

NETWORK	LOCATION	'STRANGER THINGS' SEASON 3 DOWNLOAD TIME (2.1GB)	SPEED
Verizon 5G	Denver	33.6s	1,270 Mbps
AT&T 5G	Atlanta	37.9s	1,100
T-Mobile 5G	New York	2m 57s	381
Sprint 5G	Chicago	3m 20s	301
4G average	Nationwide	Roughly an hour	34.1

Finding 4: AT&T's 5GE isn't 5G.
No matter what carrier you are on, you'll need a new phone for real 5G.

Finding 5: Ice packs not included.
In Atlanta, where it was 90 degrees the day I visited, I could run only one or two 5G download tests before the phone would overheat and switch to 4G.

Finding 6: Sprint finally has an edge.
Currently deployed by Sprint in Chicago, Dallas and other cities, mid-band networks have slower speeds but coverage areas that span much wider distances. I tested Sprint versions of the LG and Samsung

Finding 7: 5G doesn't do much right now.
When the stars aligned and things worked, the only real benefit I found was speedily downloading TV shows before a flight. Emailing, web browsing, Instagramming, streaming video—none of that felt any different.

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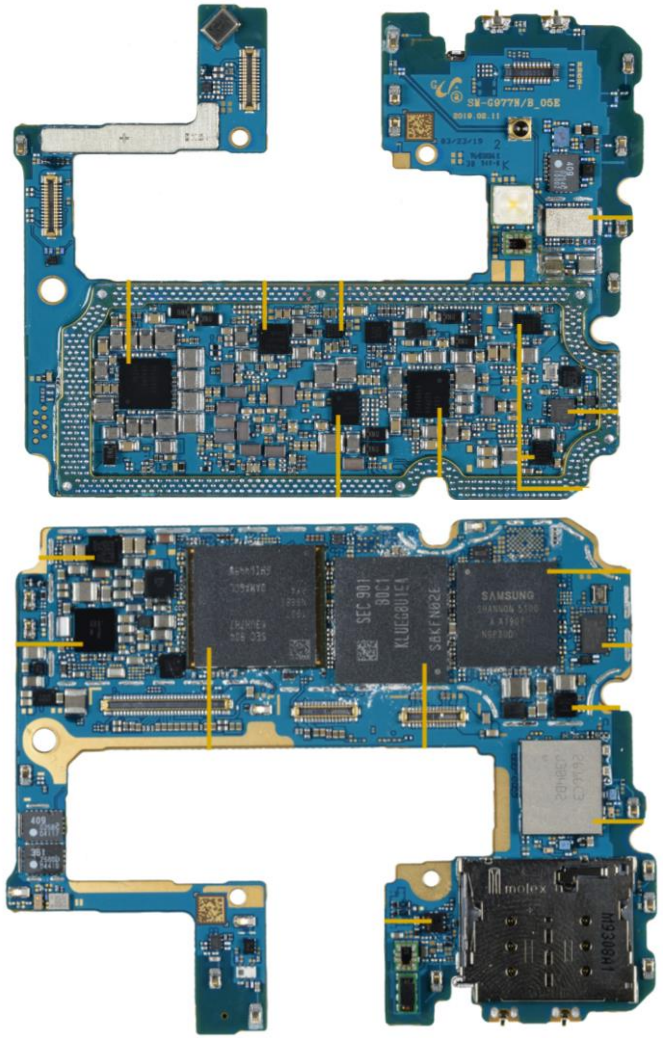
Making 5G A Reality…

5G Scorecard:
How are we doing so far?

Making 5G A Reality:
From Trials to Production

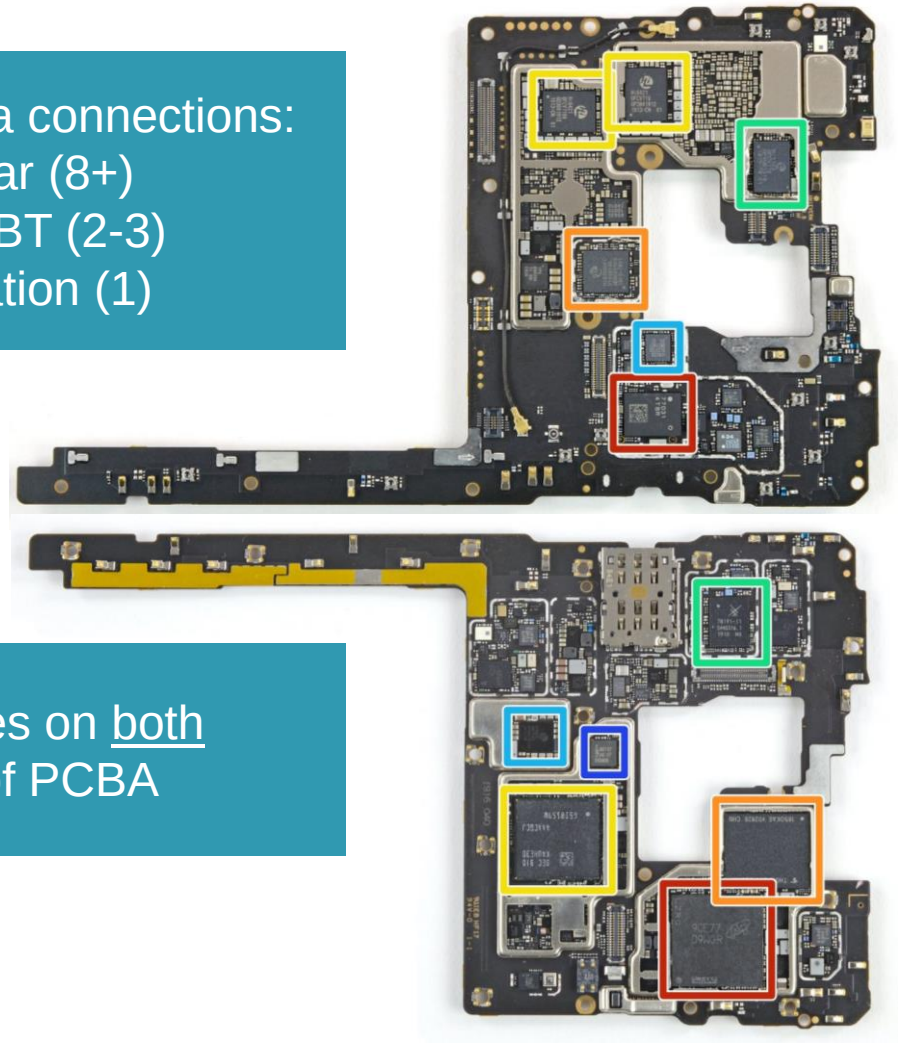
Making 5G A Reality: FR1 Sub 6GHz Production Challenges



Techinsights.com

Many antenna connections:
Cellular (8+)
Wi-Fi / BT (2-3)
Navigation (1)

RF Probes on both sides of PCBA



ifixit.com

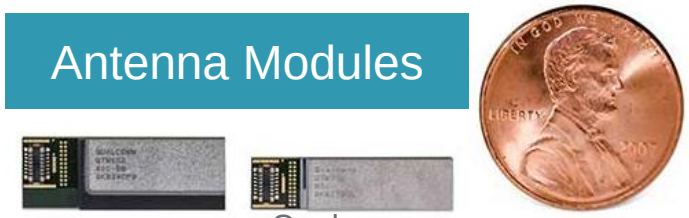
Making 5G A Reality: FR2 mmWave Production Challenges

Test moves from PCBA to final product

ihs.com

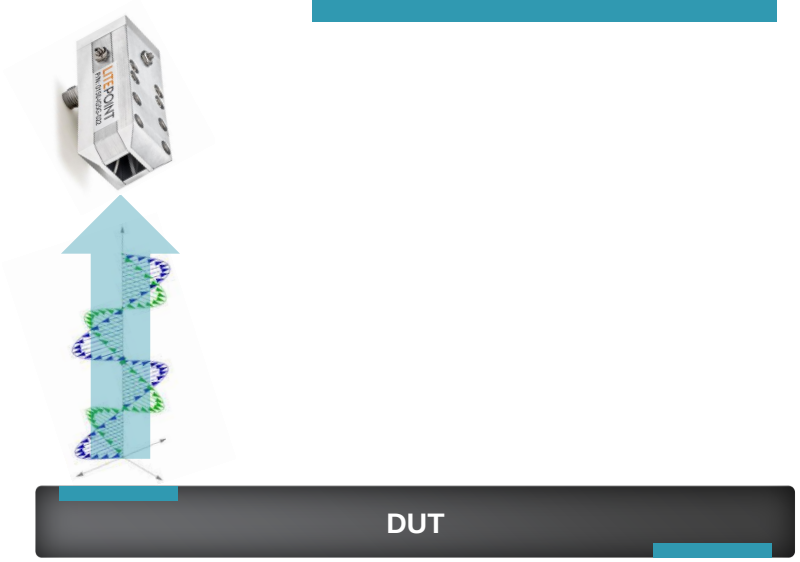
Multiple antenna modules per product

Antenna Modules



Qualcomm

Custom IF Interface



Two polarizations per antenna array

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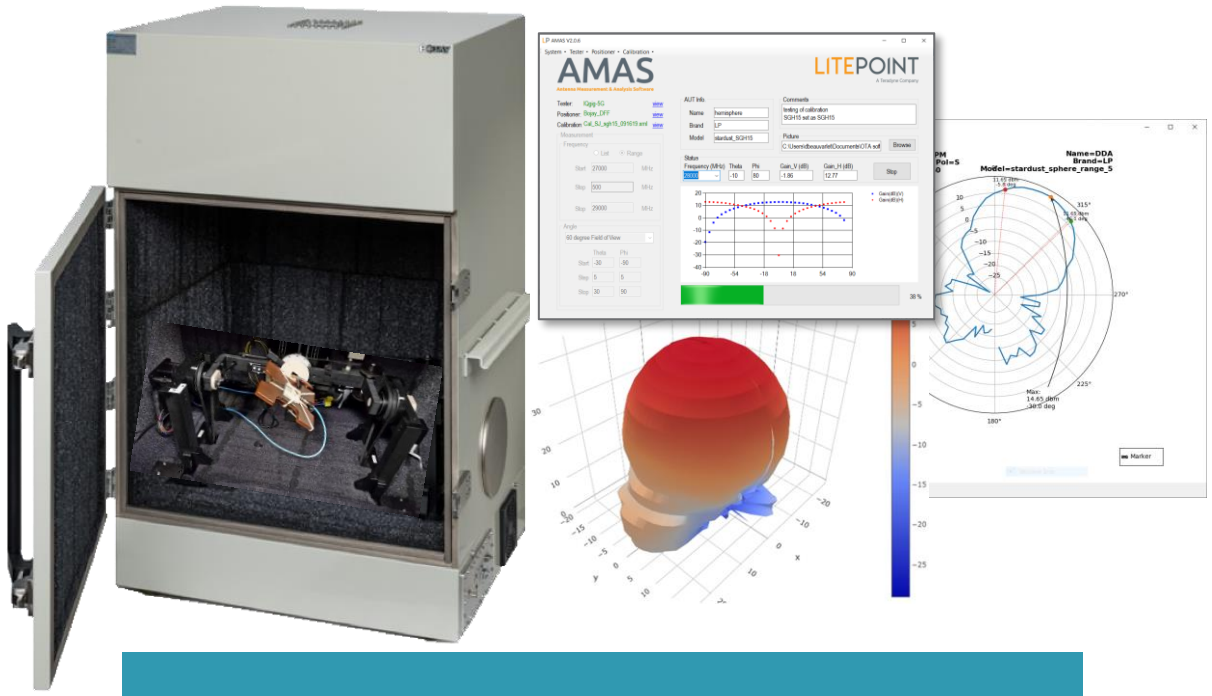
Making 5G A Reality: 2019 Advances in Test

DVT & Characterization



- Lab-friendly DFF chambers
- Antenna measurement and visualization
- Software automation

Production

- Small manufacturing-oriented chambers
- Horn antennas with short far-fields
- Simple, fully-integrated test equipment

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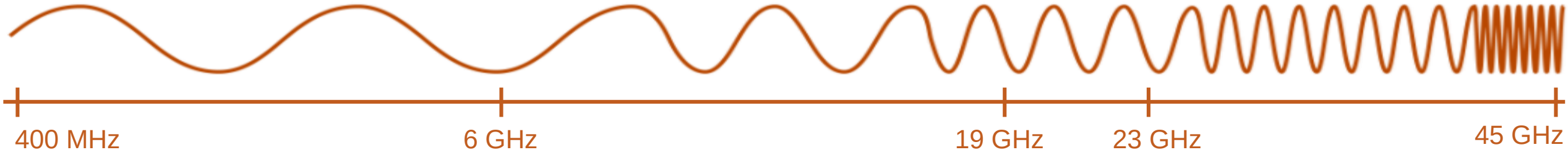
Making 5G Testing A Reality: 5G Product Family

IQxstream-5G

IQgig-IF

IQgig-5G



Comprehensive 5G Test Coverage for FR1 and FR2 Devices

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Making 5G A Reality… Are We There Yet?

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