From 5G mmWave to 6G THz: What's Next in RF Test Challenges

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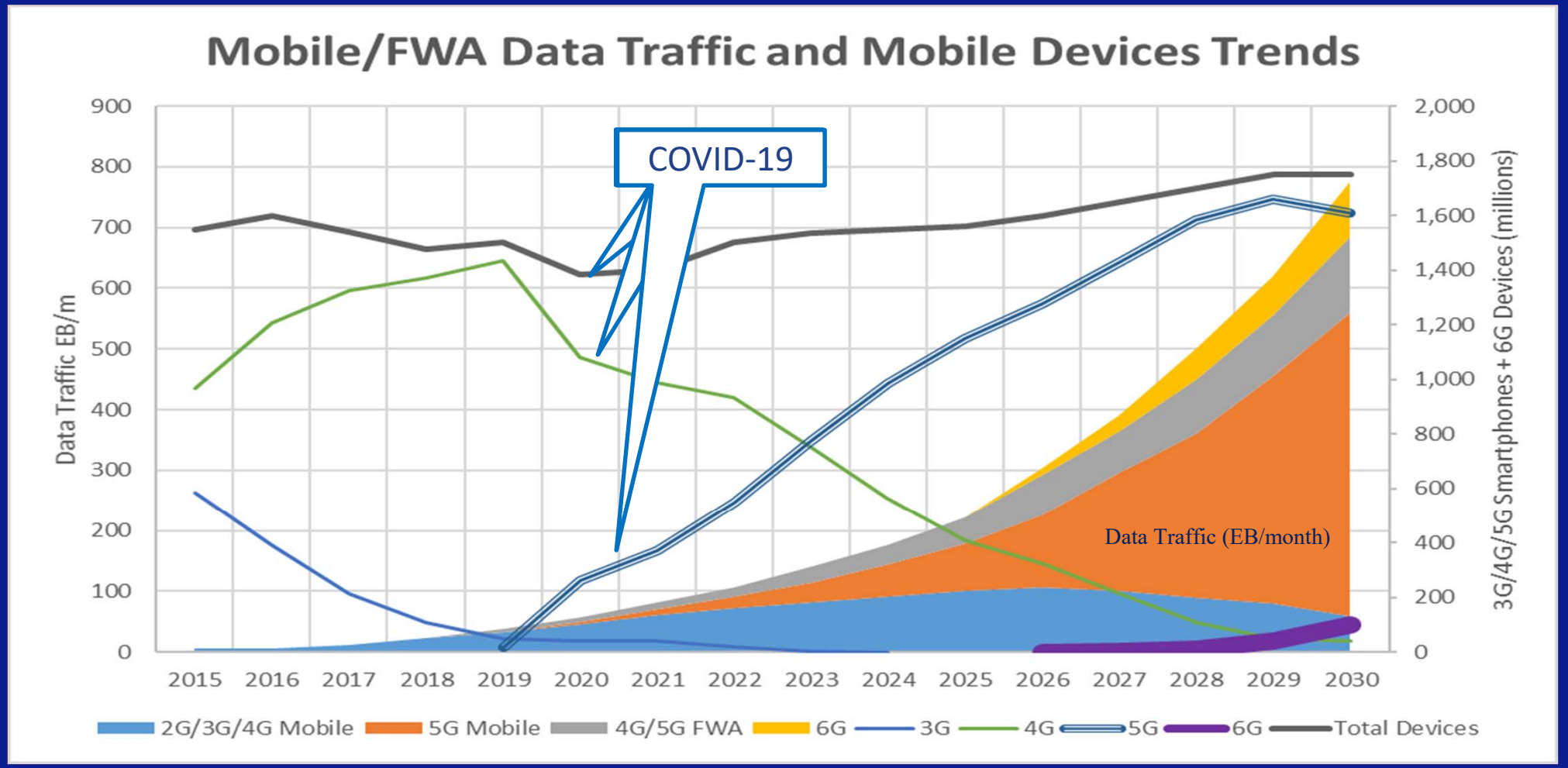
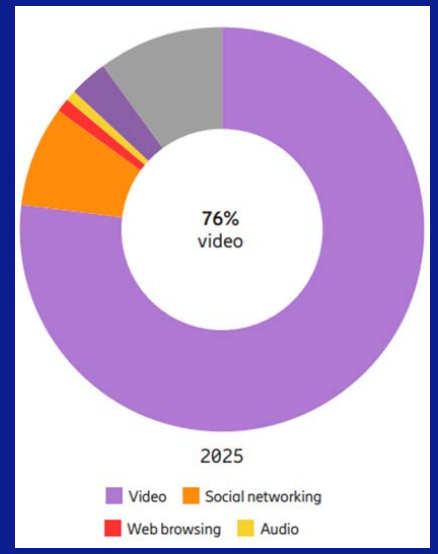
Teradyne

TERADYNE

Virtual Event ● May 3 - 7, 2021

Mobile/FWA Data Traffic and Mobile Devices Trends





2026+: Human Sensory

Main drivers for video traffic growth

- Video is part of most online content (news, ads, social media, etc.)
- Video sharing services
- Video streaming services
- Changing user behavior – video being consumed anywhere, any time
- Increased segment penetration, not just early adopters
- Evolving devices with larger screens and higher resolutions
- Increased network performance through evolved 4G deployments
- Emerging immersive media formats and applications (HD/UHD, 360-degree video, AR, VR)

Source: Ericsson's Mobility Report (Nov. 2020), internet sources and Teradyne's projections

A New "G" Technology Every 8-10 Years

			2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
2001	3G (100 kbps)	MHz	3G started 8 years after 2G															
2009	4G (1 Gbps)	cmWave	4G started 8 years after 3G															
2018	5G (10 Gbps)	mmWave				5G started 10 years after 4G												
2026	6G (1 Tbps)	THz												6G will start 8 years after 5G				

We are here

4-5 years to 6G

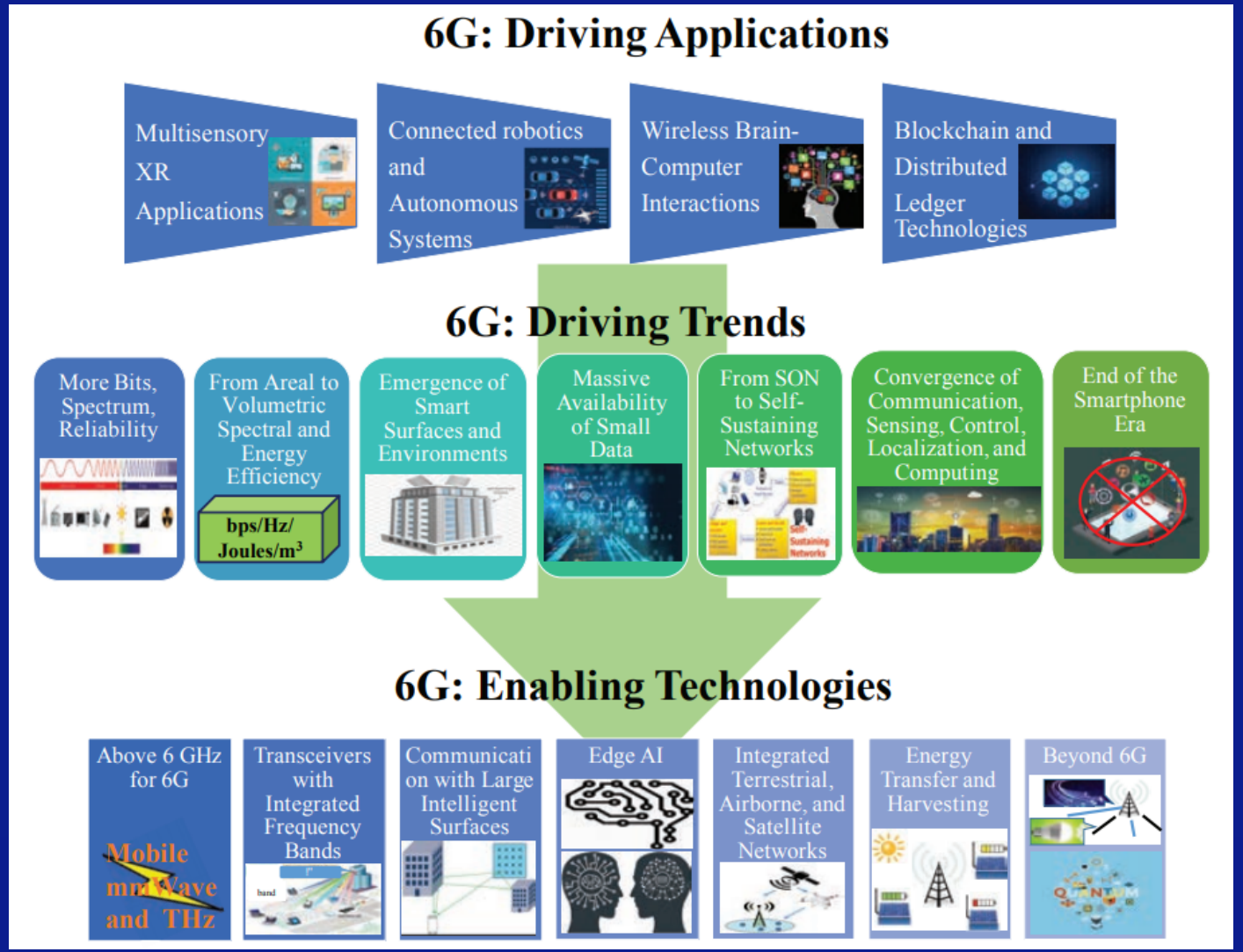
$$\lambda = \frac{c}{f}$$

c =	3.00E+08	m/s	6 GHz	**4G**	5G wavelength 10**x** smaller than 4G
f =	6.00E+09	Hz			
λ =	50	mm			
c =	3.00E+08	m/s	53 GHz	**5G**	
f =	5.30E+10	Hz			
λ =	5.7	mm			
c =	3.00E+08	m/s	3 THz	**6G**	6G wavelength 60**x** smaller than 5G
f =	3.00E+12	Hz			
λ =	0.1	mm			

6G will bring “human-grade” wireless sensory technologies

Attribute	5G	6G
Application Types	eMBB URLLC mMTC	MBRLLC mURLLC HCS MPS
Device Types	Smartphones Sensors Drones	Sensors and DLT CRAS XR and BCI Smart implants
Rate requirements	1 Gbp/s	1 Tbp/s
Latency Requirements	5 ms	< 1 ms
Reliability requirements	99.999%	99.99999%

HCS: Human-centric services
DLT: Distributed Ledger Technologies
CRAS: Connected Robotics and Autonomous Systems
BCI: Wireless Brain-Computer Interactions



Source: IEEE Network • May/June 2020

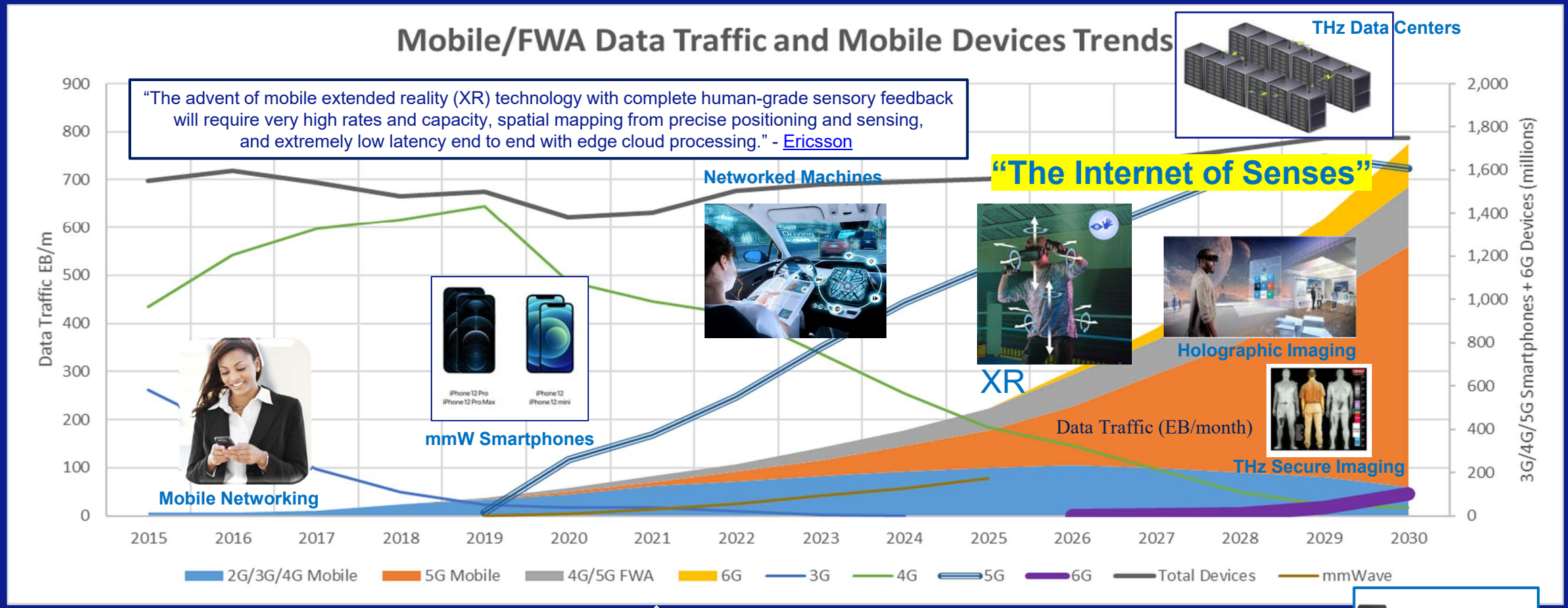
mmWave & THz Applications – the potential for 6G

mmWave & THz Applications—the potential for 6G [1]	
Wireless Cognition	Robotic Control [27, 28] Drone Fleet Control [27]
Sensing	Air quality detection [5] Personal health monitoring system [6] Gesture detection and touchless smartphones [7] Explosive detection and gas sensing [8]
Imaging	See in the dark (mmWave Camera) [9] High-definition video resolution radar [10] Terahertz security body scan [11]
Communication	Wireless fiber for backhaul [12] Intra-device radio communication [13] Connectivity in data centers [14] Information shower (100 Gbps) [15]
Positioning	Centimeter-level Positioning [9,16]

[1] T. S. Rappaport, Y. Xing, O. Kanhere, S. Ju, A. Alkhateeb, G. C. Trichopoulos, A. Madanayake, S. Mandal, "Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond (Invited)," IEEE ACCESS, submitted Feb. 2019.

Source: https://docs.fcc.gov/public/attachments/DOC-356643A1.pdf

Mobile Data Traffic and Device Unit Volume Trends

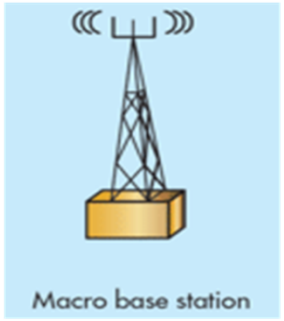


We are here

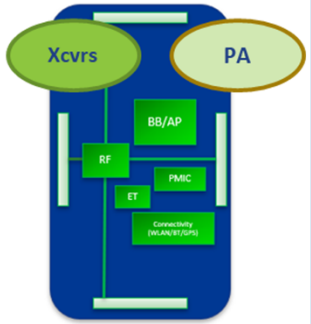
Source: Ericsson's Mobility Report (Nov. 2020), internet sources and Teradyne's projections

The 5G Era Brings 2X-3X RF Test TAM Multiplier

4G



4G LTE bands mostly < 3 GHz and < 20 MHz BW



4x4 MIMO
Up to 1,000 Mbps
< 6GHz Frequencies
Up to 100MHz CC bandwidth
6DL/2UL
5-7 Major ICs (*depending on AP/BB integration*)

The 5G Era

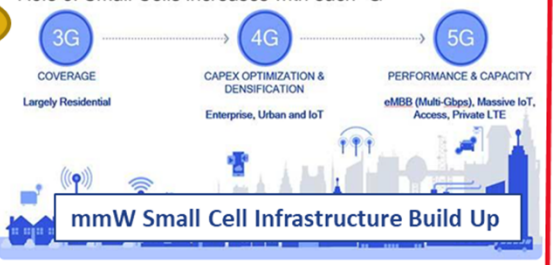
This view does not include Wi-Fi, UWB, WiGig, Radar

10X Frequency and 10X Bandwidth Multiplier

mmW Fixed Wireless Access Infrastructure Build Up

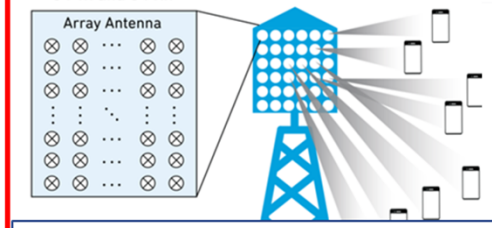
mmWave

Role of Small Cells increases with each "G"



mmW Small Cell Infrastructure Build Up

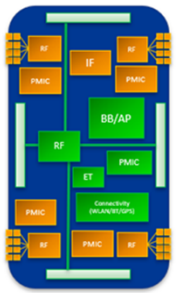
Massive MIMO
64 Tx and 64 Rx



Sub 6 GHz mMIMO BTS Transceiver Multiplier

3-6 GHz and mmWave Spectrum

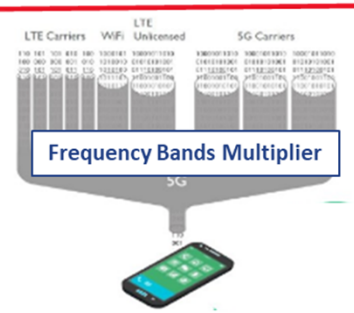
3-6GHz	24-100GHz
5G (New Spectrum)	5G (mmWave)
100MHz	400MHz
6.5Gbps	18Gbps
1-2km	<250m



Sub-6 GHz Xcvrs

PA

mmWave

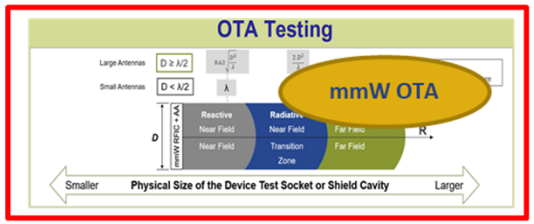


Frequency Bands Multiplier

5G-Wi-Fi Mobile Routers Devices: "Cut the Cord"

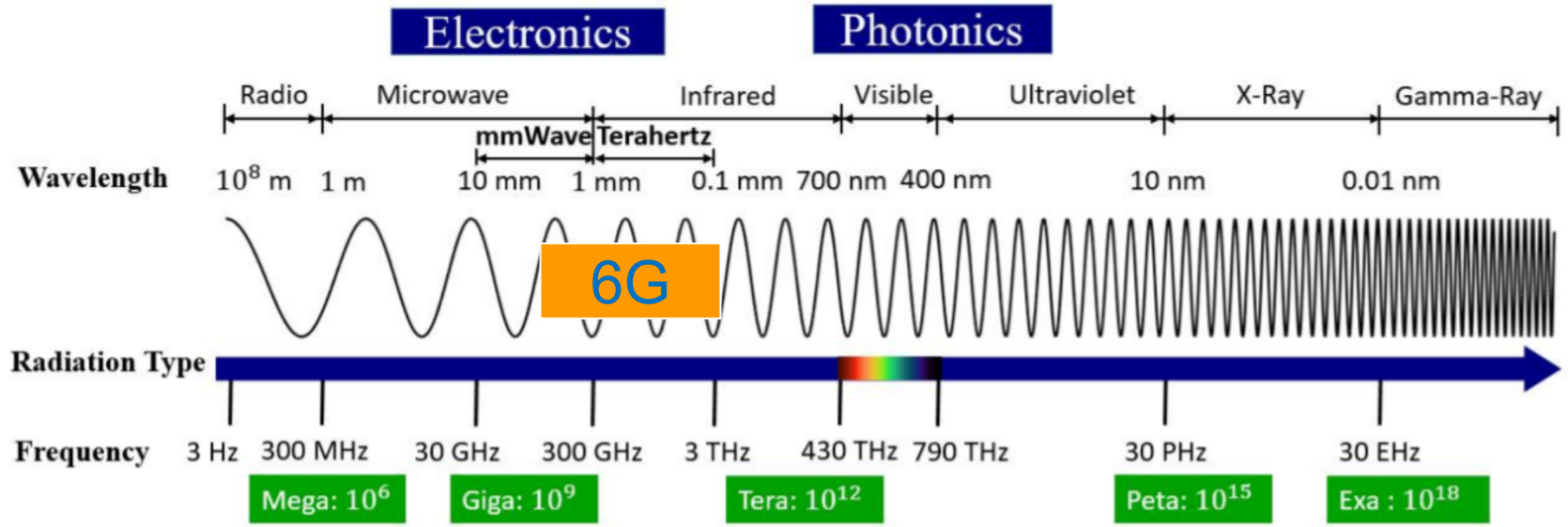
Smartphone IC Complexity and Test Intensity Increase

< 6GHz + mmWave Frequencies
Up to 100MHz CC bandwidth
9DLP (Component Carriers)
9-15 Major ICs (*depending on AP/BB integration & mmWave RF devices*)



Source: various internet sources and Teradyne's projections

Electromagnetic Spectrum and Applications



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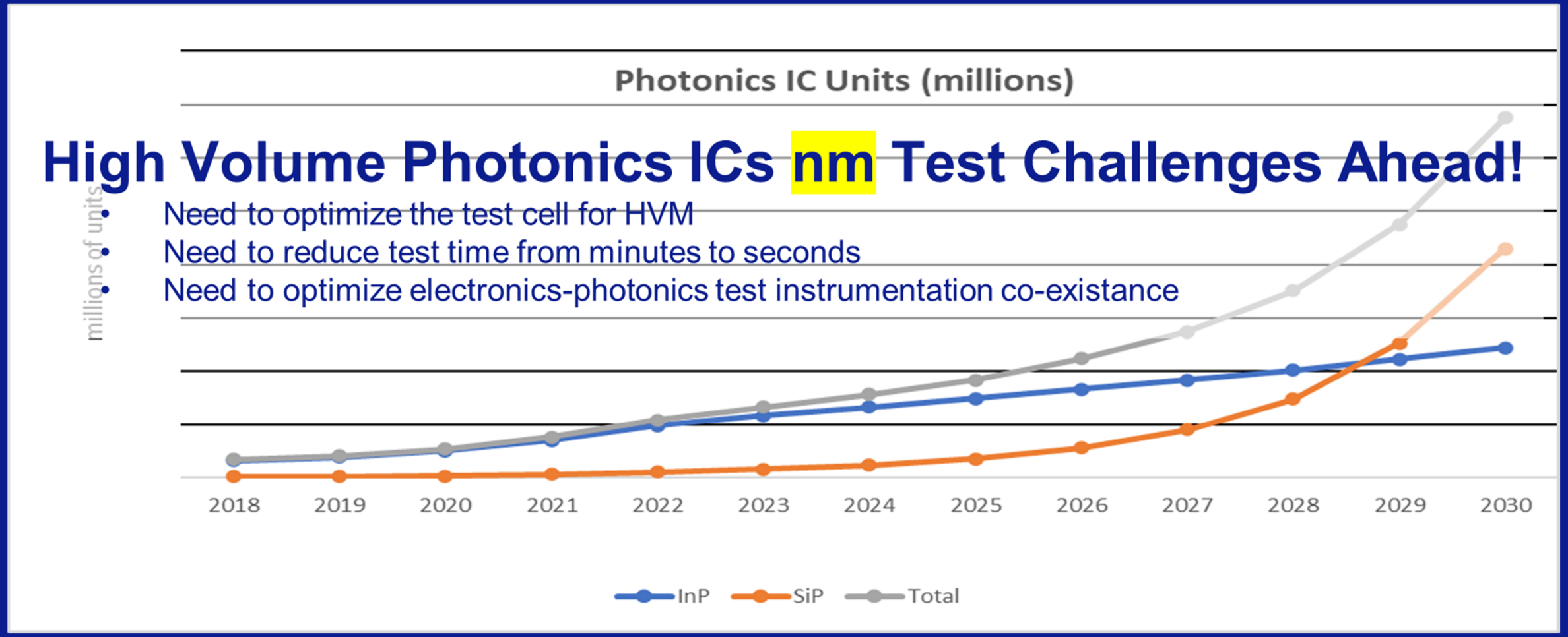
Source: https://docs.fcc.gov/public/attachments/DOC-356643A1.pdf

Wireless 5G Fronthaul is Clogging the Digital Backhaul and Data Center Networks!



Source: various internet sources and Teradyne's projections

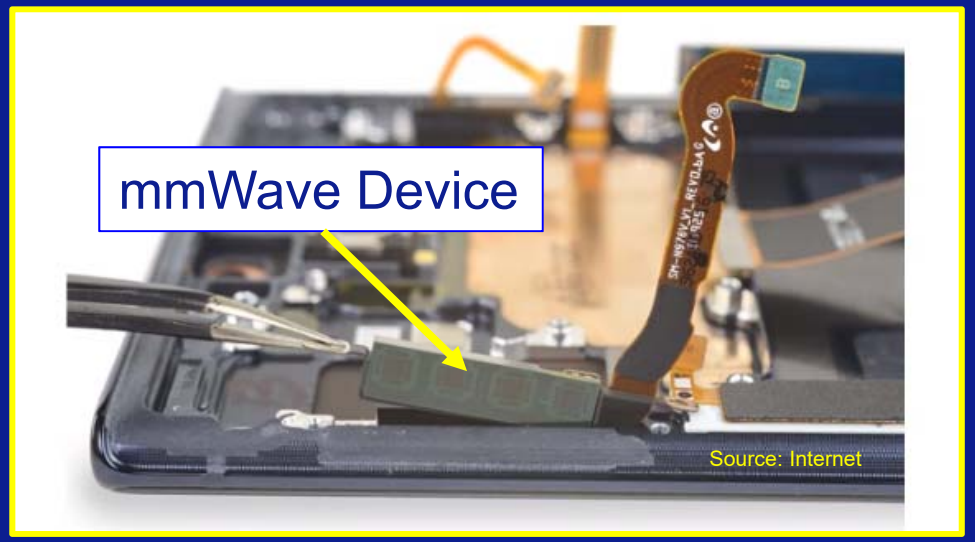
Global snapshot of allocated/targeted 5G Spectrum

Source: https://www.qualcomm.com/media/documents/files/spectrum-for-4g-and-5g.pdf

Why Test?

If 5G fails, your brand fails.

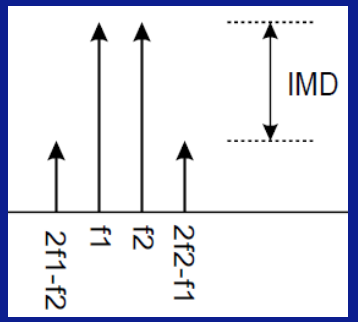
- 5G mmWave devices in early product life cycle stage, performance risks need sound test strategies
- 5G mmWave premium phones will demand 0 DPPM quality levels
- Need to establish a reliable 5G brand

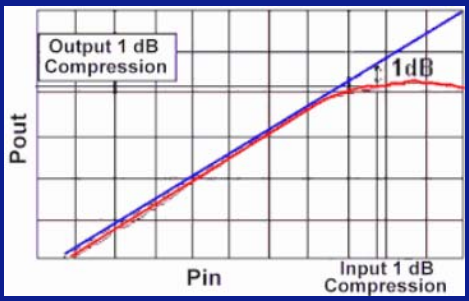


- High quality brand strategy requires more functional tests at probe and module insertions
- Poor upstream module, sub-assembly & final product OTA yields drive more functional test
- Characterization tests uncover failure mechanisms
- 5G use cases that drive volume and performance turn drive more device functional testing
- Any “emergency” massive field failures require functional-test-ready ATE on site

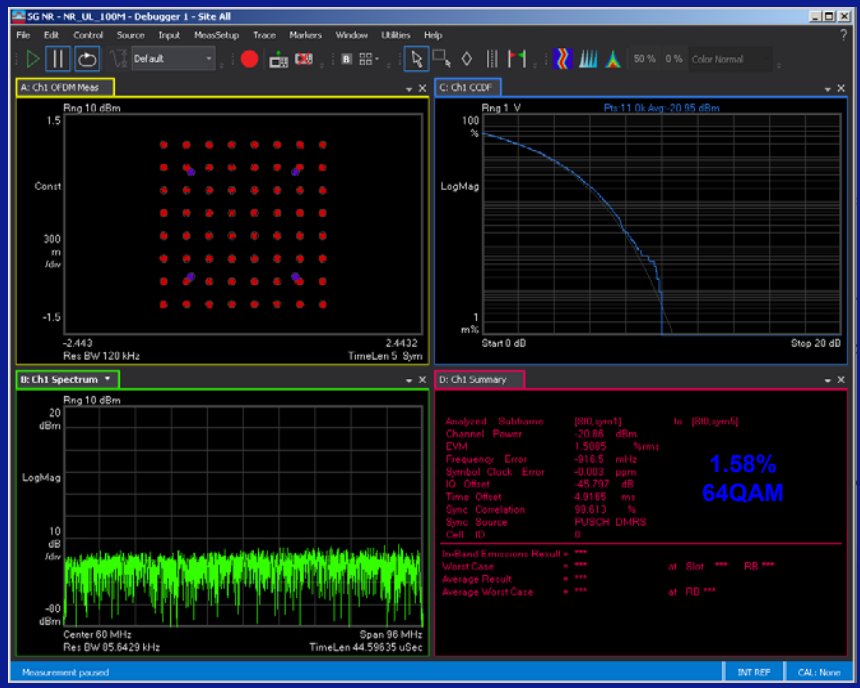
What to Test?

- mmWave RFIC
  - Gain
  - P1dB and IP3
  - Band pass filter(channel select) gain/flatness/out-band attenuation
  - PLL lock
  - ACLR
  - EVM
  - Phase trimming
  - OTA beamforming?
  - Others (DC, leakage, pattern-scan and BIST)

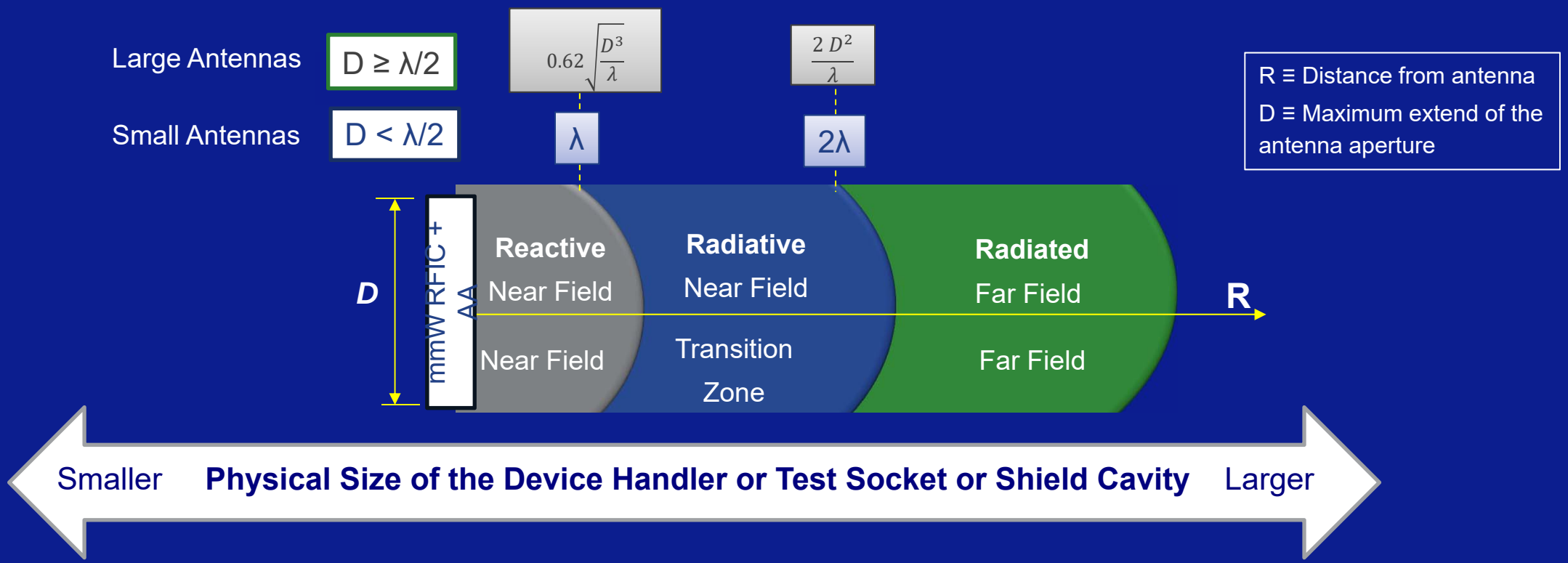




- mmWave RFBB (IFIC)
  - Gain
  - IP3
  - Low pass filter(channel select) gain/flatness/out-band attenuation
  - PLL lock
  - ACLR
  - EVM
  - IQ mismatch / IQ cal(phase and gain cal for Image rejection and carrier suppression)
  - Others (DC, leakage, pattern-scan and BIST)



What Type of "OTA" Test?



Reactive near-field region: It is the region where stored energy dominates. These reactive fields are generally created by strong **EM coupling** within the antenna or between antennas and very nearby electrical components. No radiative energy exists.

Radiative near-field region (NF): This is the region where the near fields still exist but is not dominant. Radiative near-fields start to dominate. However, the shape of **the radiation pattern may still vary appreciably with distance.**

Far-field region (FF): the shape of the radiation pattern does not change with distance. The spherical fields propagating outward can be considered as plane waves.

mmWave Test Strategies in Mass Production

UltraFLEX mmWave ATE

IQgig-5G

LITEPOINT
A Teradyne Company

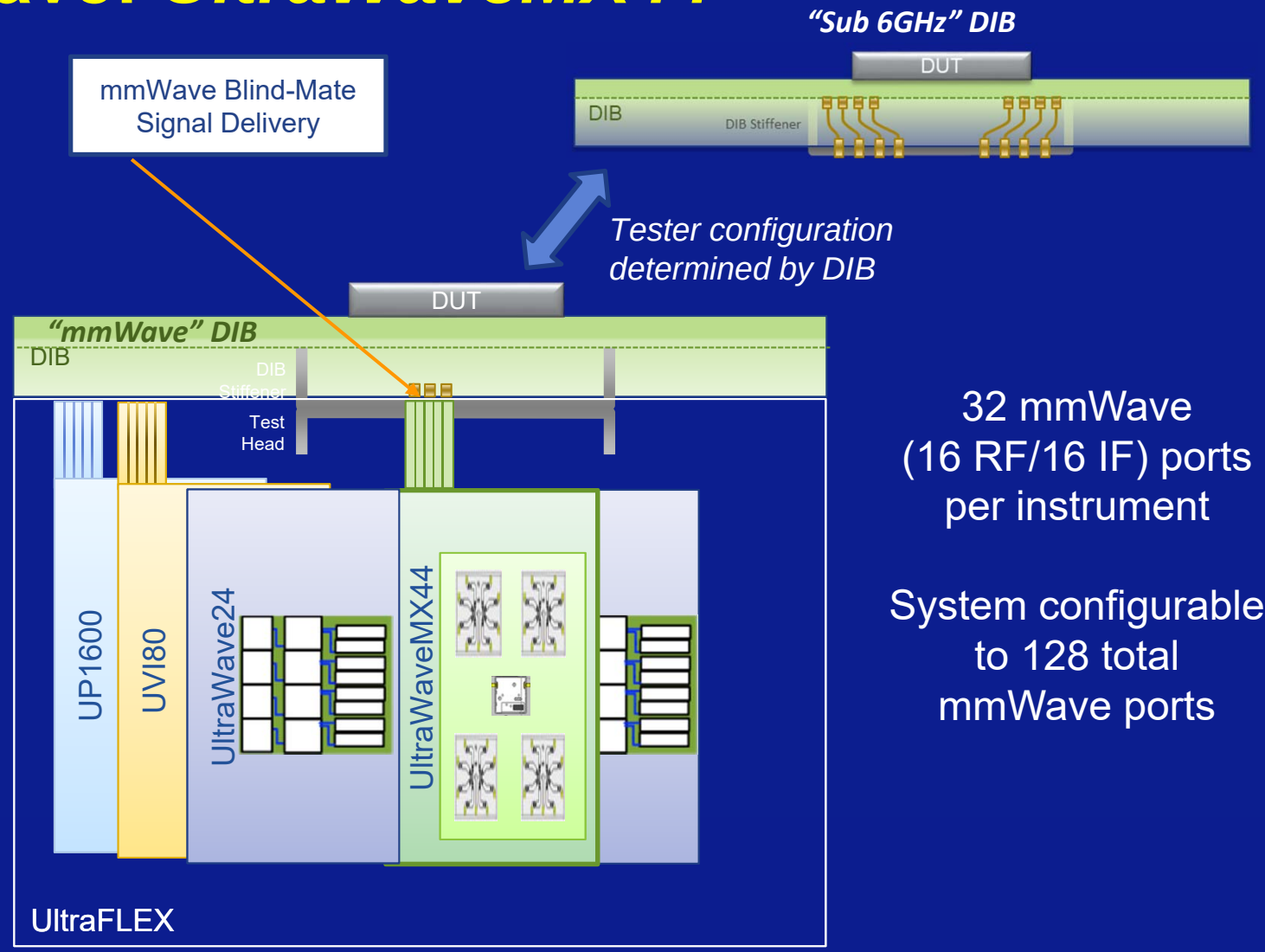
Silicon Wafer Test	Module Assembly (AiP or AoB)	Module "OTA Continuity" Test	Module Functional OTA Test	Sub-Assembly PCBA OTA Test	Final Product OTA Test
Verify performance in order to maximize upstream test yields	**Need 0 DPPM for mmWave Antenna Assembly**	**Need 0 DPPM for mmWave Antenna Radiation**	**Need 0 DPPM for mmWave module performance**	**Need mmWave performance test of sub-assembly antenna interaction**	**Need 0 RMA. Need mmWave performance test and calibration of final assembly antenna interaction.**
• **ATE Probe** • CW mmWave functional test • DC/Digital • BIST • Tri-Temp for 5G RAN	• **X-Ray Inspection** for mmWave antennas • AiP vs AoB assembly yields? • Multiple SKUs for different frequency bands	• **ATE Handler** • OTA Socket • "Continuity" test for dipole and patch antennas • Limited functional tests • Multiple SKUs	• **Functional Test** • OTA Socket or shield box • OTA NF or FF • Full functional test • Beamforming corner tests (FF) • Multiple SKUs • Tri-Temp for 5G RAN	• **System Level Test** • OTA Far Field • Full Functional Test • Beamforming corner tests • Multiple SKUs • Can add value if calibration factors can be added	• **System Level Test** • OTA Far Field • Full Functional Test • Full CC BW EVM Test • Full CA Test Possible • Beamforming calibration • Multiple SKUs • Tri-Temp for 5G RAN

= Must = Likely = Optional

Expecting similar test strategy options at THz

Need ATE with a Simple Upgrade from Sub-6 GHz to mmWave: *UltraWaveMX44*

- Zero change to existing DIB load board standard
- No system reconfiguration required to switch between sub-6GHz and mmWave applications
- Performance specified at blind-mate with fully integrated calibrations
- No change to docking or Z-height



32 mmWave (16 RF/16 IF) ports per instrument

System configurable to 128 total mmWave ports

Source: https://www.teradyne.com/products/test-solutions/semiconductor-test/ultraflex-mmwave-instruments

Summary

- The 5G Era is here and ramping faster than 4G
  - 2X-3X RF Test TAM Multiplier
- 6G only 4-5 years away
  - Integrated multi-band transceivers will require microwave/mmWave/THz test
  - Need to continue innovation on test techniques for mmW/THz contacted signal delivery and OTA
- Fronthaul 5G clogging the Backhaul and Data Center Networks
  - Need innovation on high-volume photonics ICs nm test
- 5G is changing the strategy for device testing
  - Teradyne millimeter wave test solutions are at the forefront of the 5G Era

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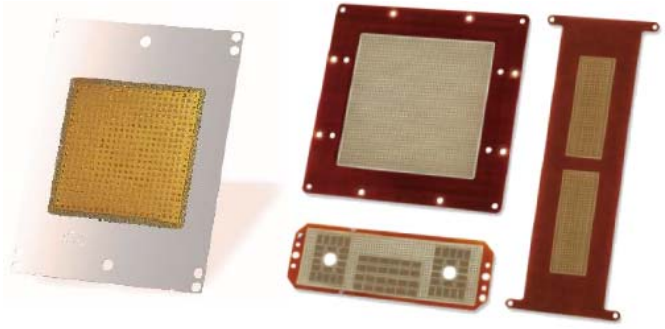
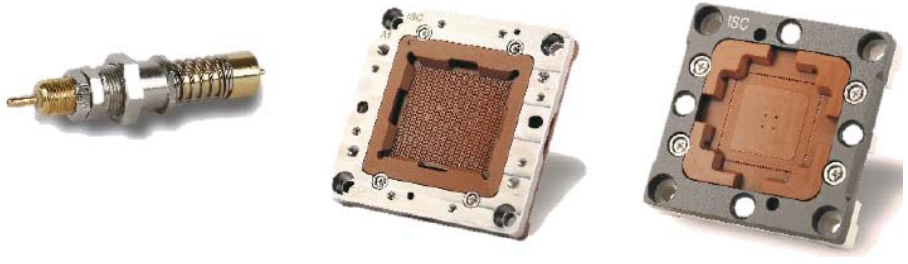
- High speed & RF device capability
- Various customized design to meet challenge requirement



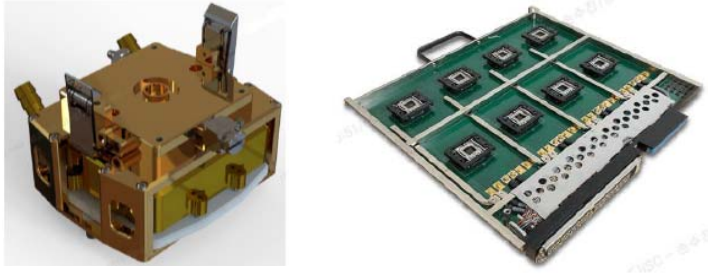
POGO SOCKET SOLUTIONS

- Excellent gap control & long lifespan
- High bandwidth & low contact resistance



THERMAL CONTROL UNIT

- Extreme active temperature control
- Safety auto shut-down temperature monitoring of the device & thermal control unit
- Full FEA analysis & Price competitiveness



BURN-IN SOLUTIONS

- Direct inserting on the board without soldering
- Higher performance BIB solution

CONTACT
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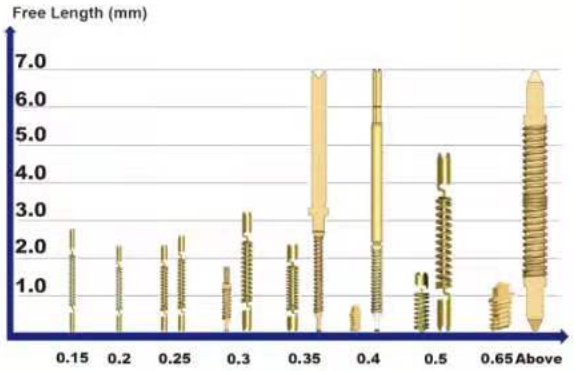
IWIN Co., Ltd. The test probe for high signal integrity at extremely high speed test

Spring probe by stamping



250 kinds of spring probe pin

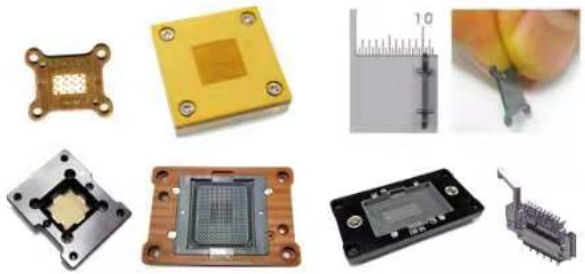
300 kinds of test socket (44,000 Pin count socket possible)

One piece spring probe

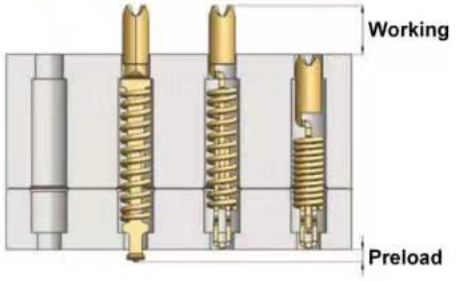
Three piece spring probe

High speed product → 0.63mm free length spring probe pin available

Finest Pitch → 0.15mm Pitch



Spring probe by stamping

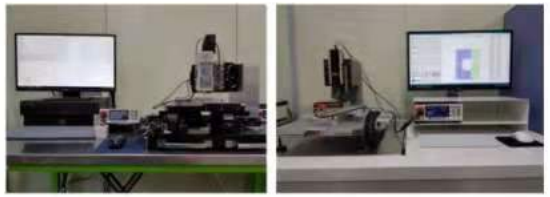


Patented

Pitch(mm)	Free Length(mm)	Current Carrying(Amps)
0.15/0.2/0.25	2.17~	0.5~
0.3	1.5~	1.5~
0.35	2.08~	1.8~
0.4	0.8~	2.5~
0.5	1.5~	3.0~
0.65	1.13~	9.0~
0.8	3.14~	3.0~

Automation

Pin assembly and Quality control



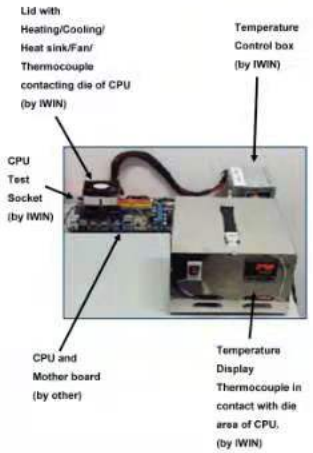
Top Figure: Socket CRES, Force, Stroke test

Bottom Figure: Data displayed

Top Figure: Socket CRES test

Bottom Figure: Data display 5,903 pins socket

Socket and Lid



Pin assembly

(Fully automated machines)

- Stamped piece parts attached to a reel fed into the assembly machine

- Assembled pins can be attached to a reel, or, supply in separate for socket assembly.

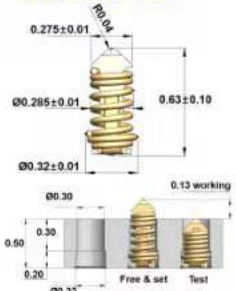
Spring probe pins for High speed

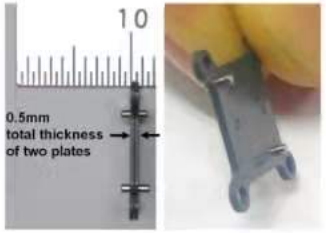
Extremely short spring probes by stamping

One piece spring probe

Three piece spring probe

Design approach





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High Performance Probe solution

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