

Test. Measure. Innovate.

5G FWA: Ensuring the ultimate CPE experience

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ROHDE & SCHWARZ

Make ideas real



THE STATE OF THE 5G GLOBAL ECOSYSTEM

Q4CY2022 SNAPSHOT



94

Chipsets
out of which



1696

Devices
out of which



502

Operators
out of which



990M

Connections

Commercial **88**

mmW **45**
SA **11**

Announced **6**

mmW **4** (FWA)
SA **3**

Commercial **1431**

mmW **128**
FWA CPE **203** mmW 26
Indoor 122
Outdoor 81
SA **1222**

Announced **265**

mmW **38**
FWA CPE **71** (mmW 19)
SA **22**

Commercial **228**

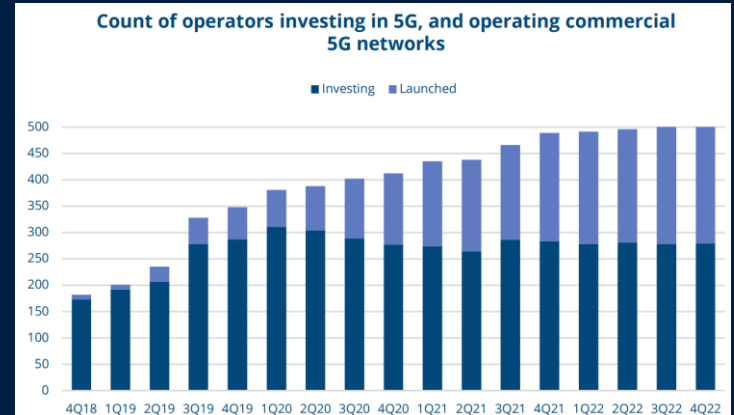
5G SA **32**
mmW **59**
5G FWA **99**

Investing **281**

Deploying SA **21**
5G FWA investing **52**

5G private **193**

Deploying/trialing/investing



THE STATE OF

5G users vs. 4G users

- use 40 GB of data every month
- stream 2x more video
- spend 1.5x more time on social media
- play mobile games 3x more often
- eMBB is the most common use case

FUTURE SERVICES

FWA

fixed wireless brings broadband connectivity at home, so users can enjoy the same ultra-fast and reliable 5G experience in the place they spend much of their time across an ecosystem of devices.

(I)IoT

pushes 5G to other use cases and device types. For example connectivity in 5G smart factories is enabled with 5G routers and other peripheral sensor-based devices based on NR-Light/RedCap.

NTN

brings connectivity to areas where there is no service at all today, especially for mission critical messaging

XR

extended reality services are in the making by the biggest companies of the world. The possibility of these devices are endless fueled by 5G and low latency.

5G IS MAKING FWA COMPETITIVE**

FBB technologies

Download speeds

**ADSL/
ADSL2**
24 Mbps

**GEO
satellites**
12 – 50 Mbps

**LTE
FWA**
up to 100 Mbps

**LEO
satellites**
50 – 500 Mbps

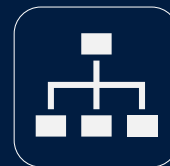
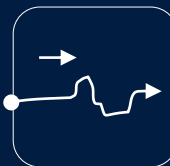
**FTTC/
VDSL2**
200 Mbps

G.Fast
100 Mbps
– 1 Gbps

HFC
10 Gbps

5G FWA
1 – 10 Gbps*

FTTH/B
2.4 – 40 Gbps



<100 Mbps

<1 Gbps

<40 Gbps

21%

of FBB connections are VDSL
and between 2024 and 2025 this technology will not suffice
and can not offer more than 100 Mbps, in contrast FWA can
offer more for less



THE FWA VALUE PROPOSITION

FWA Positioning



FWA TCO

10 years TCO FWA
vs. FTTH

When new ducts/poles
are needed

In rural
up to 65% costs saving

In suburban
up to 45% cost saving

In urban
up to 25% cost savings

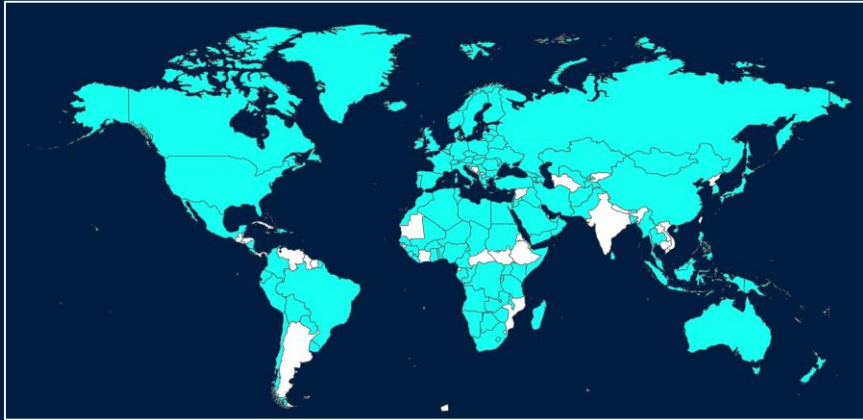
FBB and FWA Strategy

1. Fiber where viable
2. FWA where viable
3. Leo as last resort

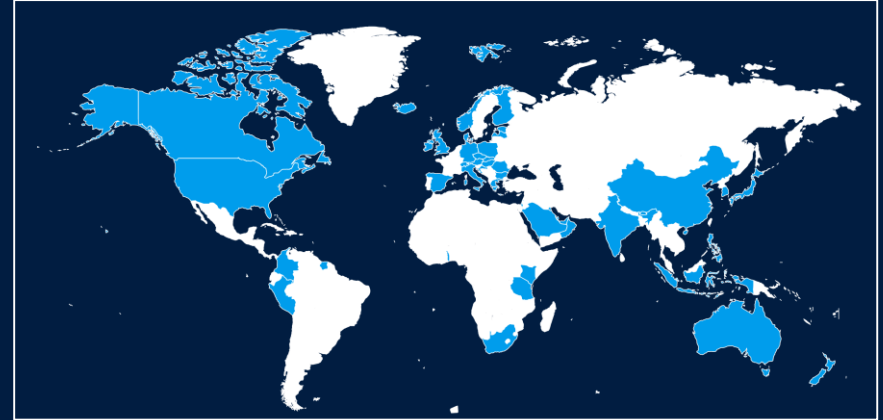


FWA GROWTH

431 4G FWA Operators (Launched Services)



99 5G FWA Operators (Launched Services)



FWA opportunities
and drivers

DSL replacement

Work/schooling from home

Government Broadband plans

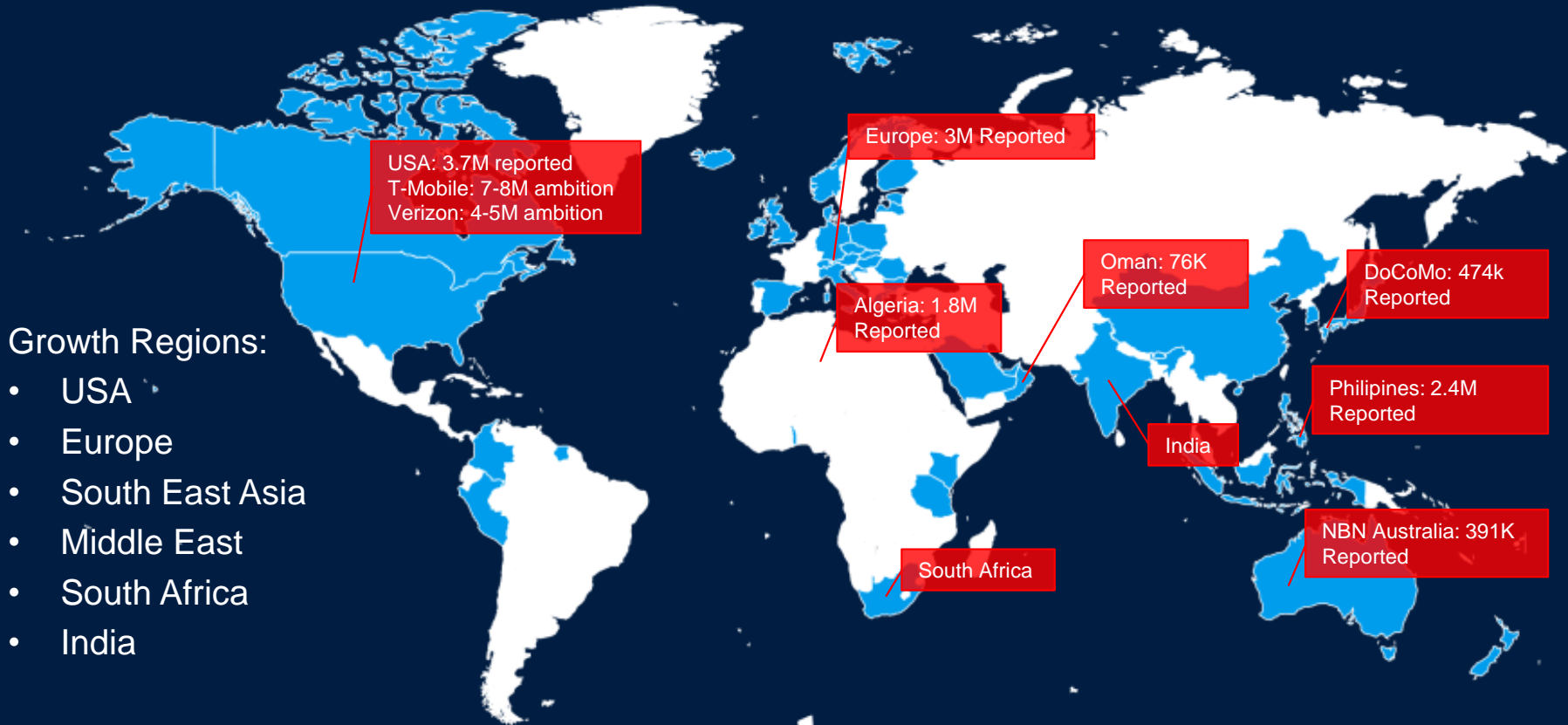
Connect the unconnected

Holiday homes

5G Launch



FWA GROWTH



Growth Regions:

- USA
- Europe
- South East Asia
- Middle East
- South Africa
- India

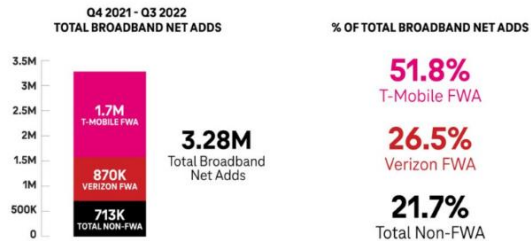
FWA GROWTH

Growth Regions:

- USA
- Europe
- South East Asia
- Middle East
- South Africa
- India

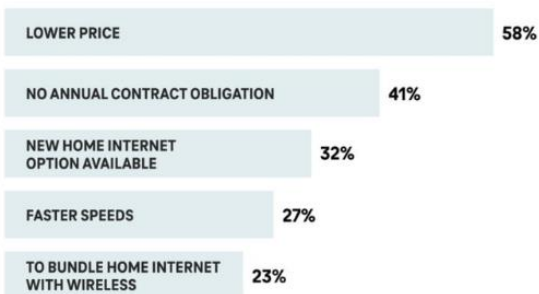
USA: 3.7M reported
T-Mobile: 7-8M ambition
Verizon: 4-5M ambition

SUBSCRIBER GROWTH



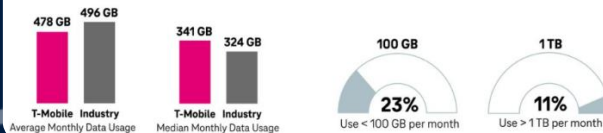
Sources: T-Mobile, OpenVault, Leichtman Research

WHY CUSTOMERS SWITCH



Sources: T-Mobile, Institute for Local Self-Reliance

USAGE TRENDS



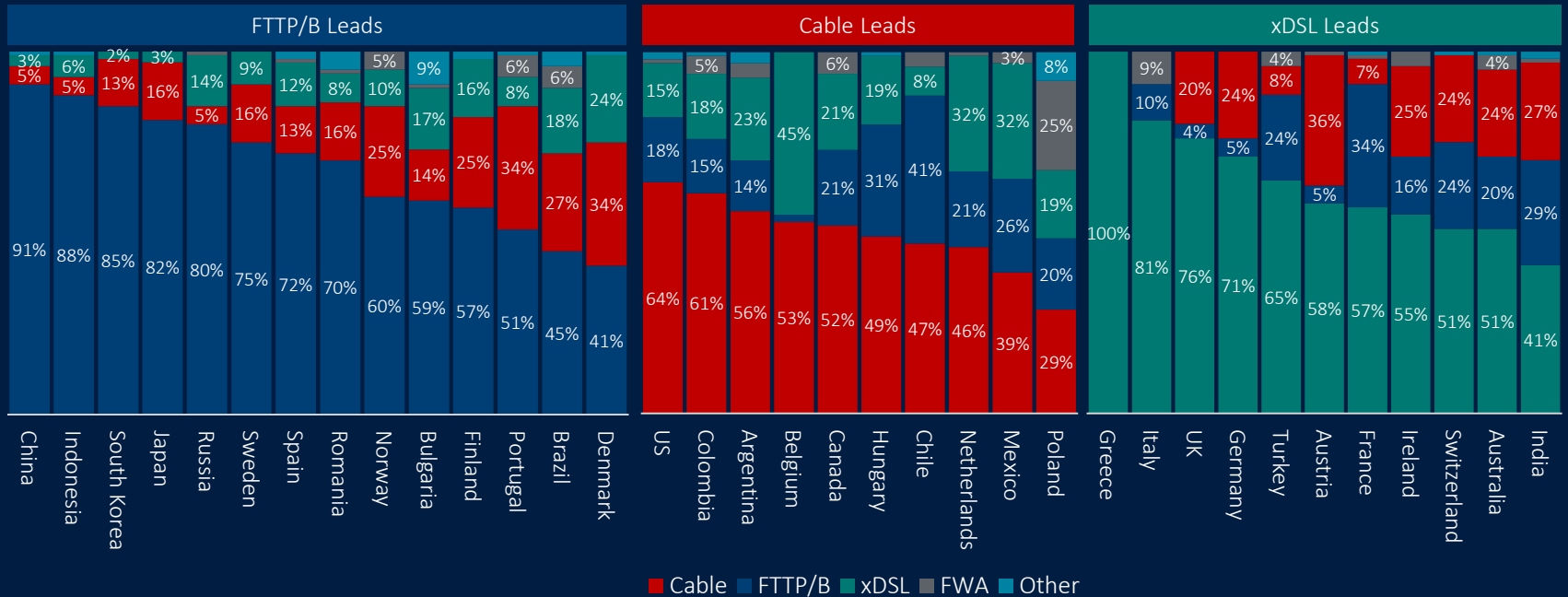
DoCoMo: 474k Reported

Philippines: 2.4M Reported

N Australia: 391K Reported

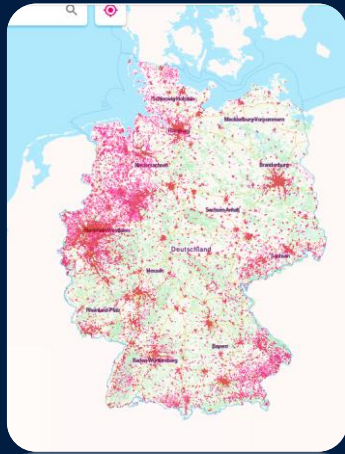
FBB WORLDWIDE TECHNO MIX

Fixed broadband connections by technology as a percentage of total fixed broadband connections – end of 2020



FWA OPPORTUNITY – EXAMPLE: GERMANY

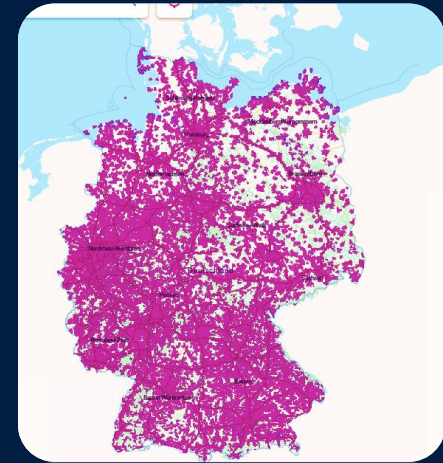
DSL Coverage



FTTH Coverage

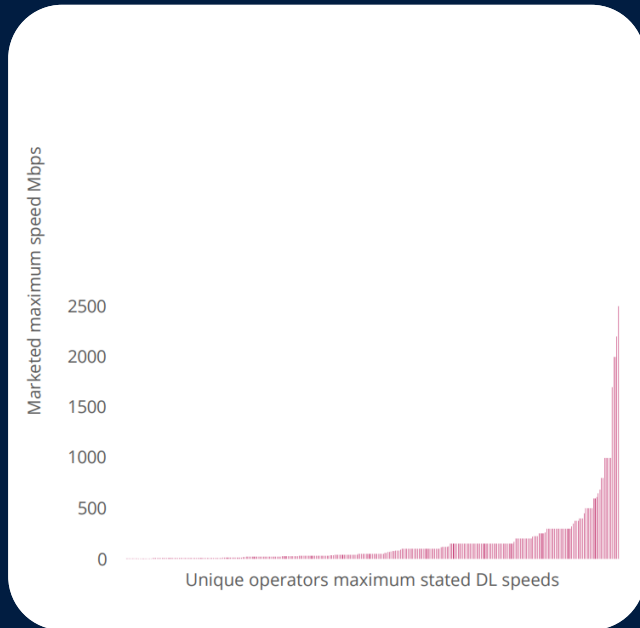


5G Coverage

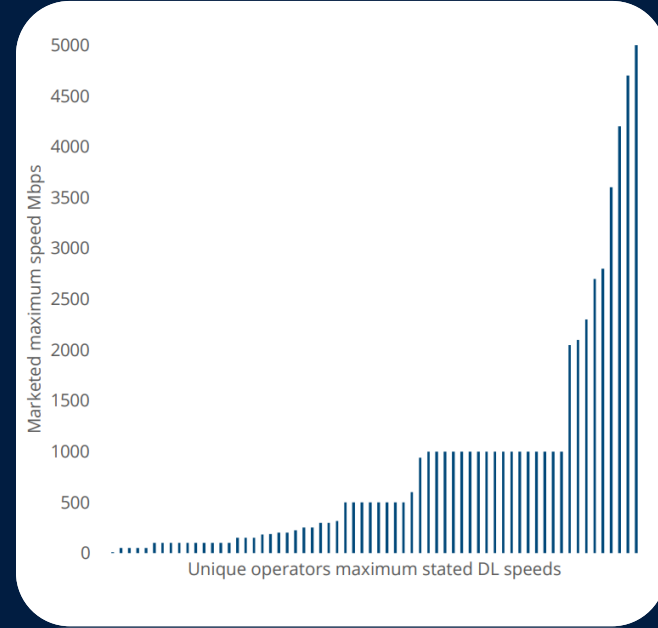


5G OFFERS SIGNIFICANTLY FASTER DL SPEEDS

LTE FWA max. DL speeds



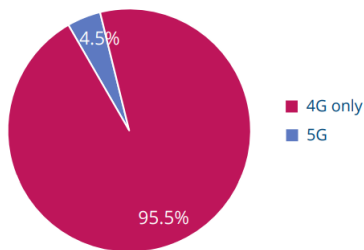
5G FWA max. DL speeds



FWA 5G CPE SHIPMENTS ON THE RISE

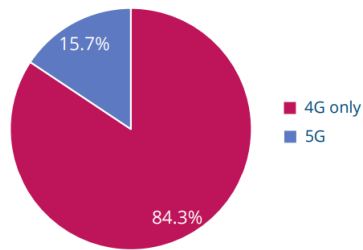
Breakdown of 2020 shipments by technology

Sample: 2021 FWA survey, 25 respondents



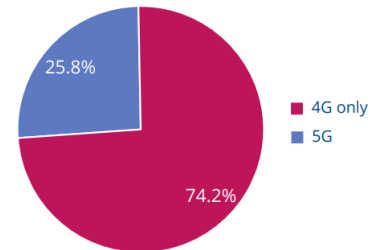
Breakdown of 2021 shipments by technology

Sample: 2022 FWA survey, 26 respondents



Breakdown of 2022 shipments (forecast) by technology

Sample: 2022 FWA survey, 26 respondents



| | Shipments (M) | | | YoY growth (%) | |
|------------------------|---------------|------|-----------------|----------------|-----------------|
| | 2020 | 2021 | 2022 (forecast) | 2021 | 2022 (forecast) |
| Total device shipments | 30.2 | 22.7 | 29.5 | -25.0% | 30.4% |
| 4G-only shipments | 28.8 | 19.1 | 21.8 | -34% | 14% |
| 5G shipments* | 1.4 | 3.6 | 7.6 | 162% | 114% |

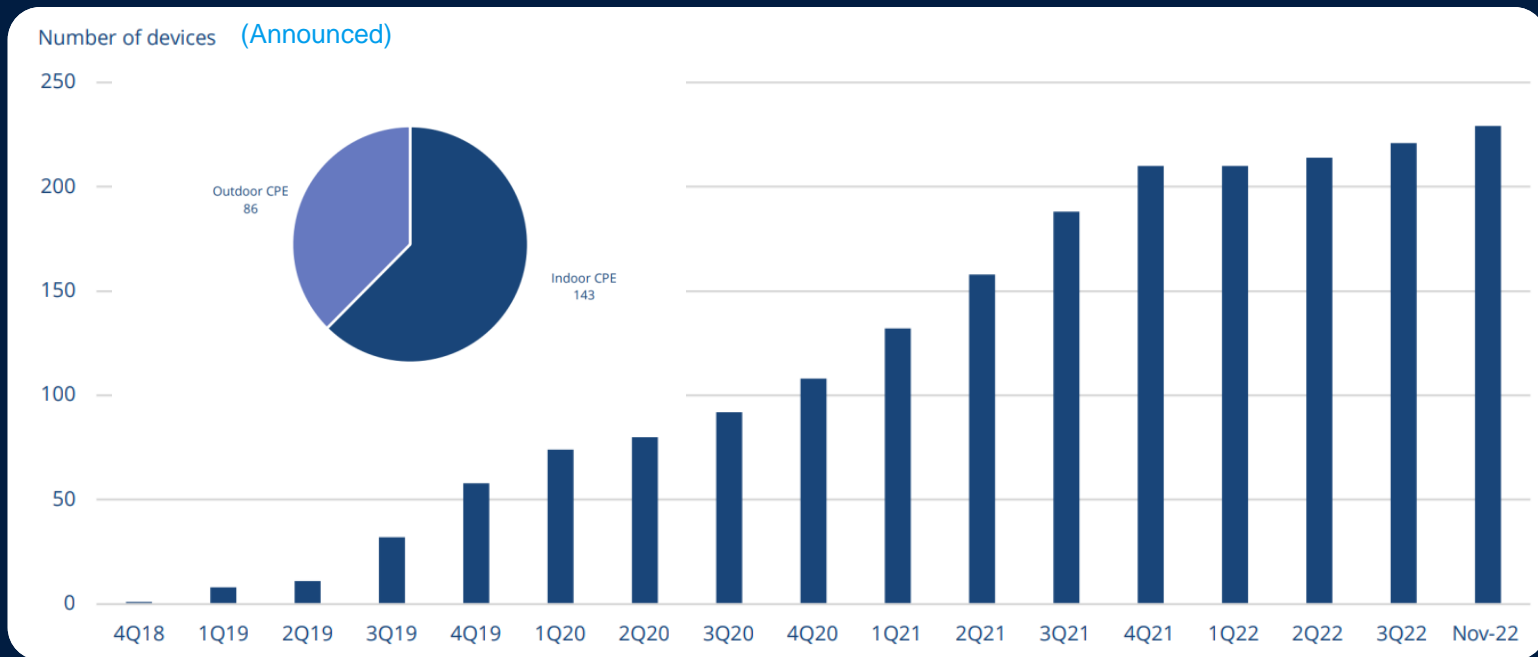


FWA 5G CPE SHIPMENTS ON THE RISE

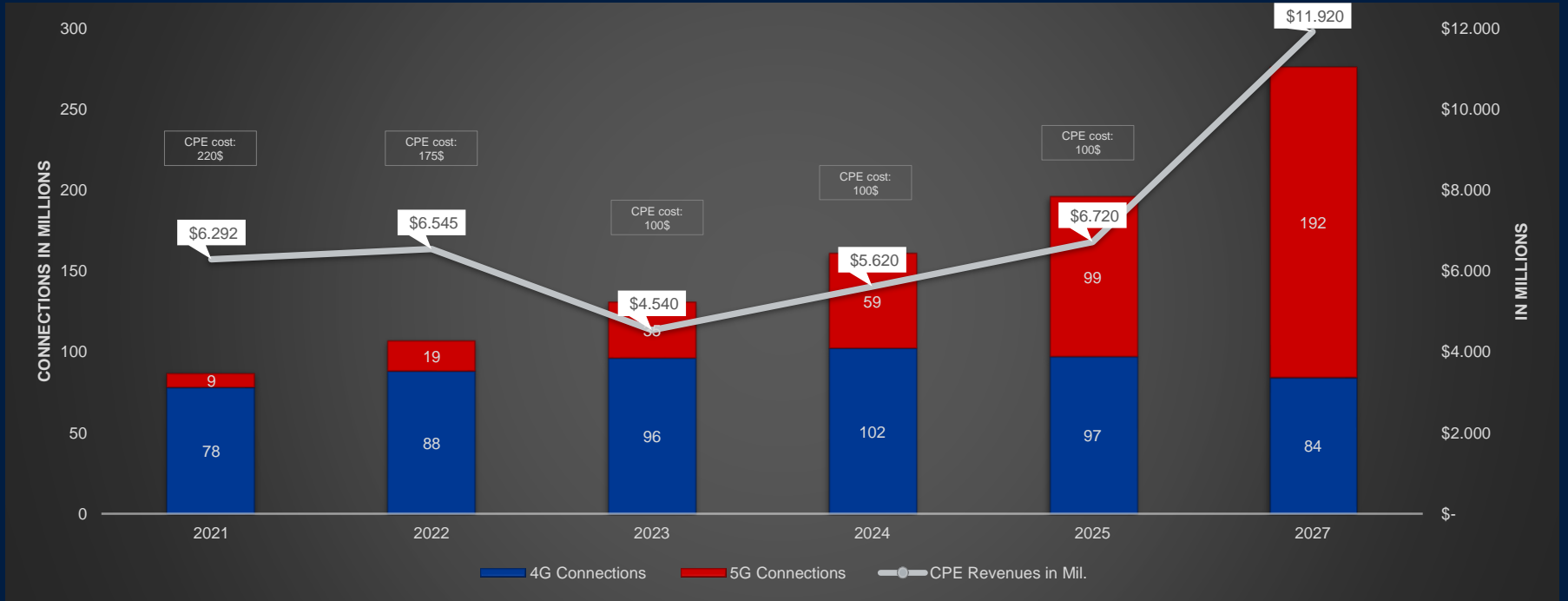
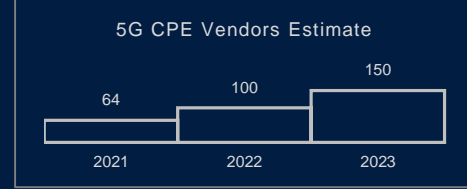
| | Combined Units | | Growth |
|------------------------------|----------------|-----------------|---------------|
| | 2021 | 2022 (forecast) | 2022 forecast |
| Battery-operated hot spot | 6.3 | 7.7 | 22.9% |
| Indoor CPE | 14.6 | 19.6 | 34.2% |
| Outdoor CPE | 1.8 | 2.2 | 25.9% |
| Total shipments | 22.7 | 29.5 | 30.4% |
| FWA CPE (indoor and outdoor) | 16.4 | 21.9 | 33.3% |



FWA 5G CPE SHIPMENTS ON THE RISE



FWA ESTIMATE ON CPE REVENUES*



*Source: ABI Research, Dell'oro, and Ericsson Mobility report 2022



FWA DEVICES FAMILY EXAMPLE

MEIG 美格

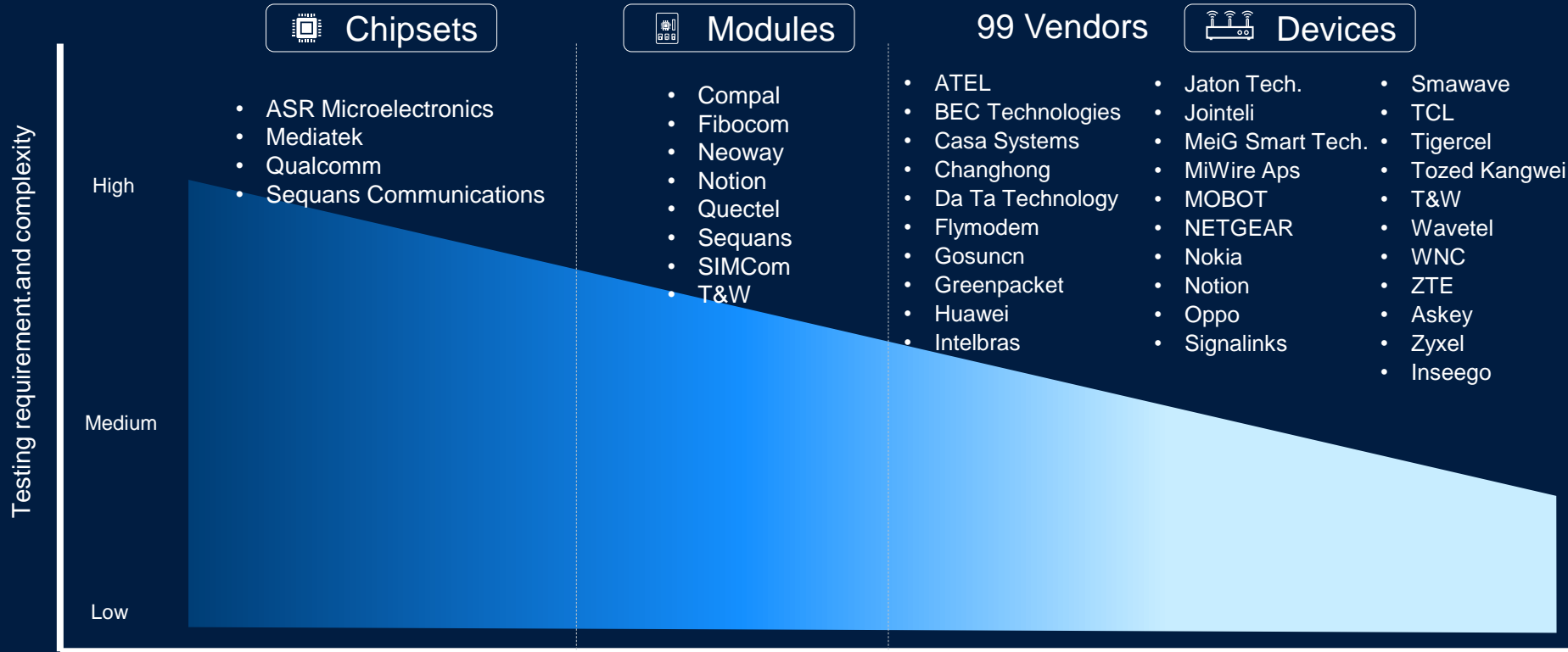
 **casa systems**

| | | |
|--|--|--|
| <p>Indoor Sub 6 GHz CPE (FR1)</p>  <p>4G Cat16 SLT868Q</p>  <p>5G SRT856S</p>  <p>4G Cat6 SLT818</p>  <p>4G Cat4 SLT711</p> | <p>Outdoor Sub 6 GHz CPE (FR1)</p>  <p>4G Cat16 SLT869-A51</p>  <p>4G Cat16 SLT867-A31</p>  <p>4G SLT869-A53</p> | <p>Battery Operated Hotspot</p>  <p>5G Sub6 SRT873</p>  <p>4G Cat6 SLT879</p> |
| <p>Indoor mmWave CPE (FR2)</p>  <p>5G Sub5 SRT856s</p> | <p>Outdoor mmWave CPE (FR2)</p>  <p>5G SRT853</p> | <p>4G Cat4 SLT778</p>  <p>4G Cat4 SLT778</p> |

| | | | |
|--|--|--|--|
| <p>Indoor Sub 6 GHz CPE (FR1)</p>  <p>4G Enhanced Hybrid Gateway</p> | <p>Outdoor Sub 6 GHz CPE (FR1)</p>  <p>5G AurusPRO Urban Wide Band</p>  <p>4G AurusPRO High-Gain</p>  <p>5G AurusPRO Remote Rural Low Band</p> | | |
| <p>Outdoor mmWave CPE (FR2)</p>  <p>5G AurusAI</p> |  <p>5G AurusPRO Rural High Band</p>  <p>4G AurusPRO CBRS High-Gain</p>  <p>5G AurusPRO Rural CBRS (CAT B) C-Band</p>  <p>5G AurusPRO Rural Wide Band</p> | | |

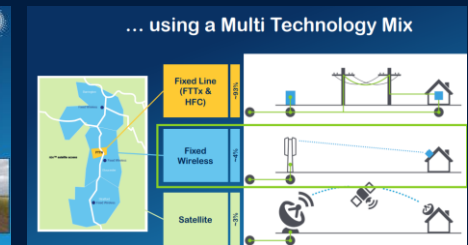
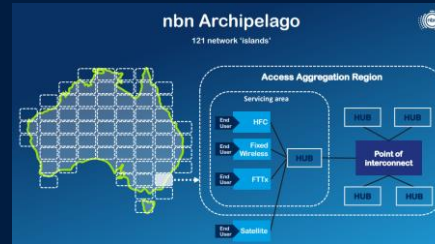


5G FWA ECOSYSTEM*



NBN AUSTRALIA

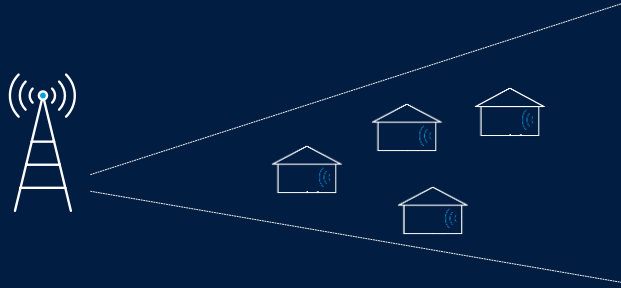
- 400K customers on FWA, scale to 750K
- Use 300 GB per month, per customer
- mmW used to offload mid band in no foilage flat areas
- Current CPE is Cat.20 device
- Lifetime of FWA devices is a challenge to swap.
- Lifespan of 5 to 8 years



CPE Deployments

1. Outdoor CPE improves spectrum efficiency and allows 2 to 3 times more households to be served in comparison to indoor CPEs. Alternatively 2 to 3 times more spectrum is needed for indoor CPEs.
2. mmW extended range could serve customers in range of several kilometers.
3. Multi-user MIMO allows multiple users to be served at the same time.
4. 1024QAM could be used to increase capacity, especially in stable environments.

1. Indoor CPE

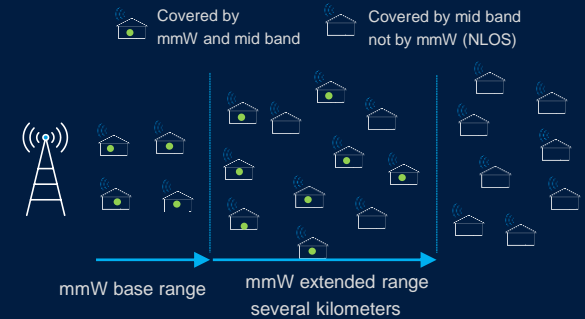


2. Outdoor CPE



ToolSet

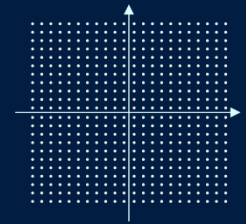
3. mmW Extended Range



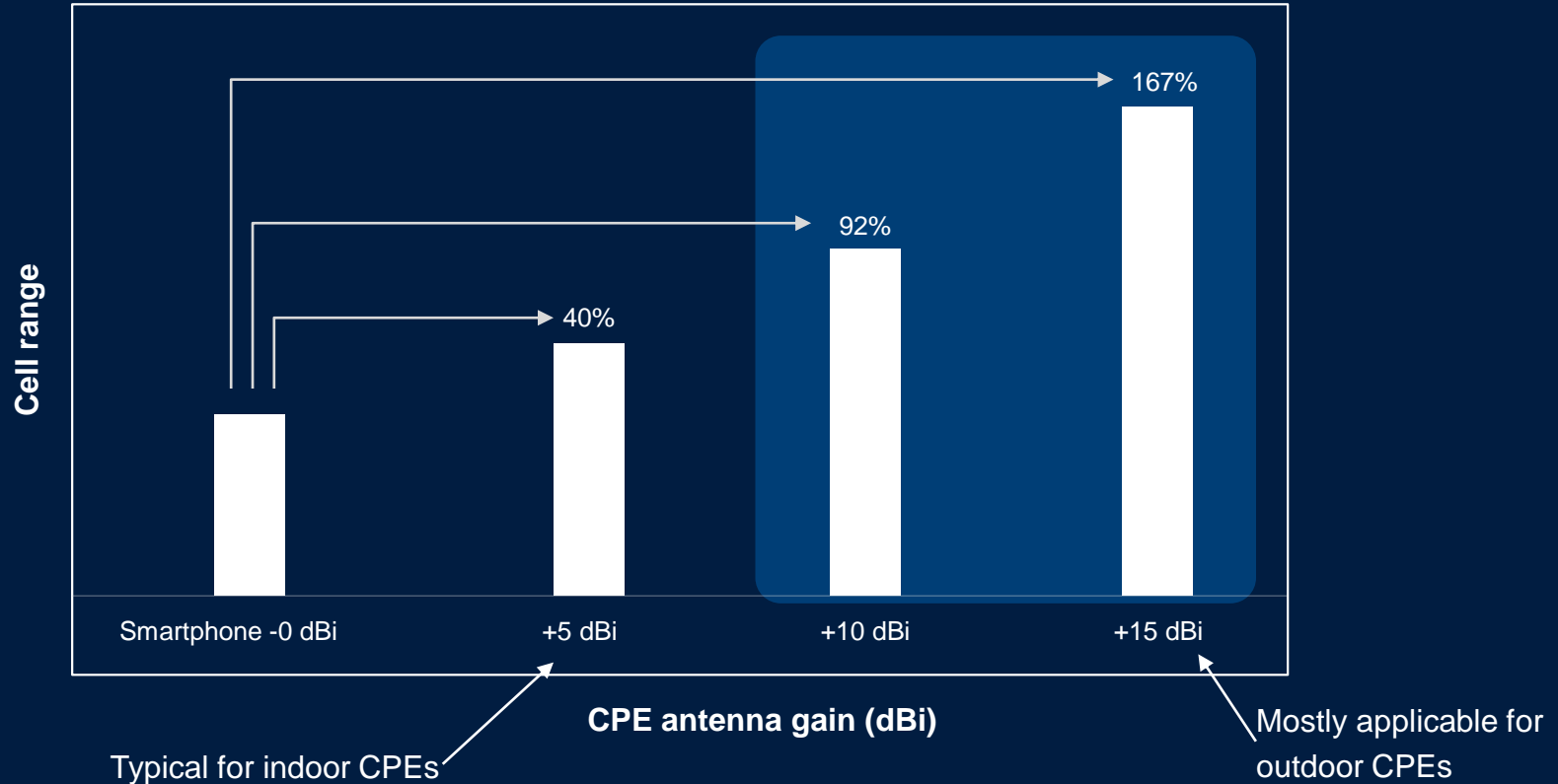
4. MU-MIMO



5. 1024QAM



IMPACT ON CELL RADIUS W.R.T CPE ANTENNA GAIN



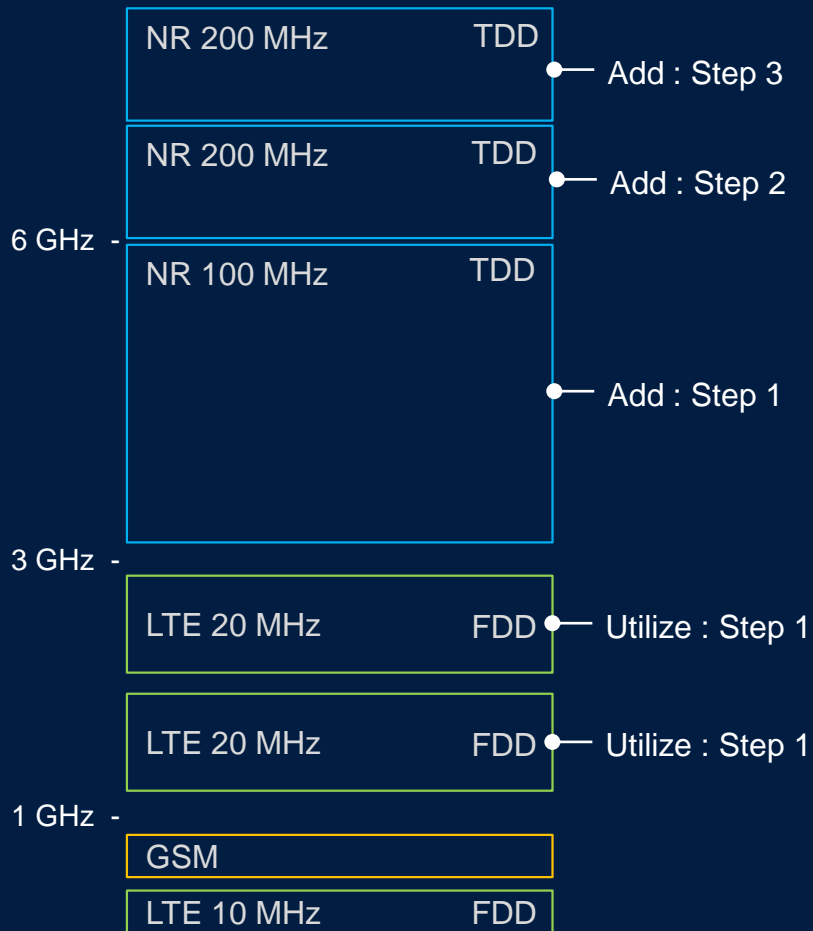
CPE POWER CLASSES FOR 5G NR

FR1 UE Power Classes

| Classes | Max RF Output Power | Applicable Bands |
|-----------------|---------------------|---------------------|
| Power Class 1 | 3 dBm | N14 |
| Power Class 1.5 | 29 dBm | N41 |
| Power Class 2 | 26 dBm | N41, n77, n78, n79 |
| Power Class 3 | 23 dBm | All other FR1 bands |

FR2 UE Power Classes

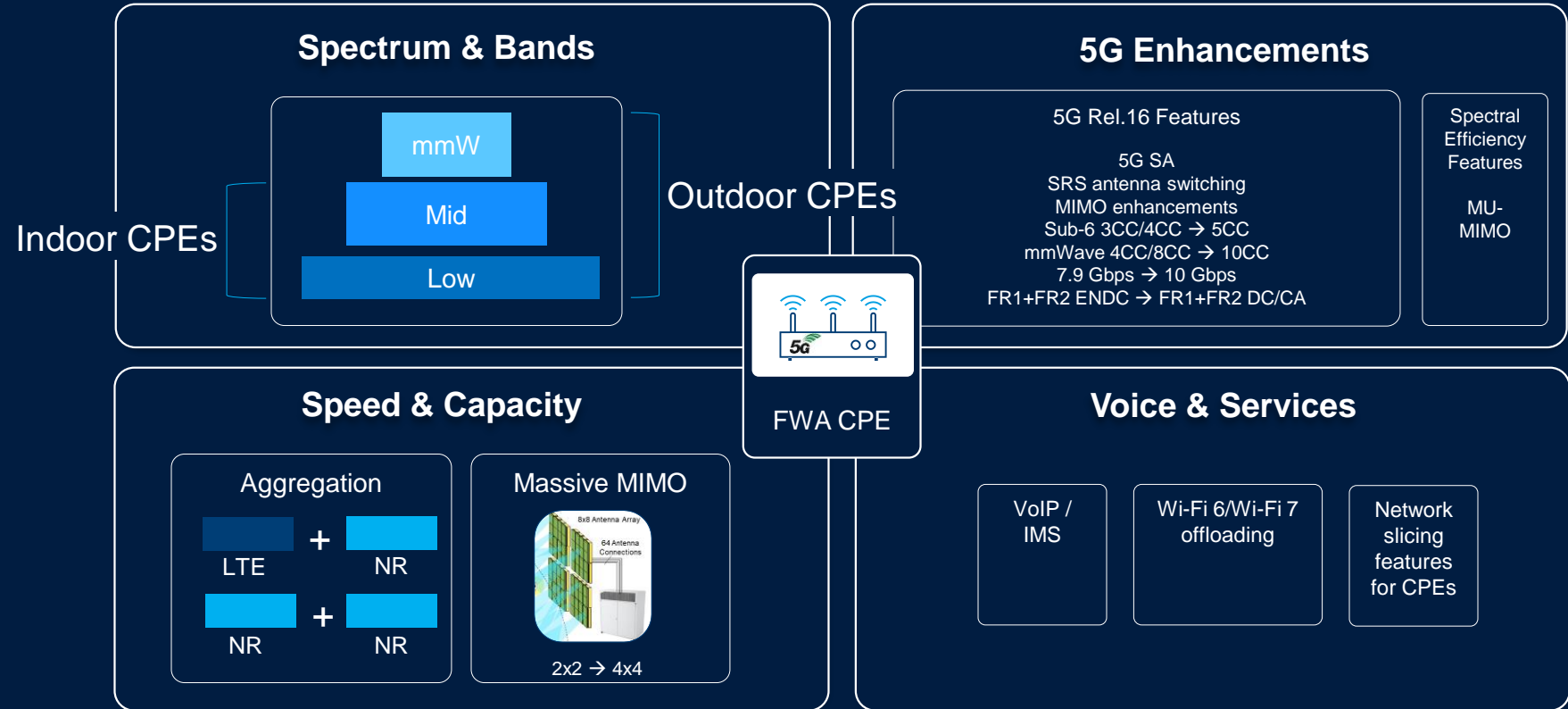
| Classes | Max TRP | Min/Max EIRP | Notes |
|---------------|---------|-----------------|--------------------------------------|
| Power Class 1 | 35 dBm | 40 dBm/55 dBm | FWA UEs n260 min is 38 dBm |
| Power Class 2 | 23 dBm | 29 dBm/43 dBm | Automotive applications (radar, etc) |
| Power Class 3 | 23 dBm | 22.4 dBm/43 dBm | Handheld UEs n260 min is 20.6 dBm |
| Power Class 4 | 23 dBm | 34 dBm/43 dBm | Non-handheld UEs n260 min is 31 dBm |



OVERALL OPERATOR SOLUTION EXAMPLE

- **Utilize** existing macro sites, baseband and transport
- **Utilize** available spare capacity on deployed sub-3 GHz bands for LTE
- **Add** NR in TDD mid band
- **Add** NR in TDD mmWave band with mmW extended range support
- **Add** baseband and transport capacity.
Use all LTE carriers above 1 GHz for MBB and FWA
-Add QOS/slice separation
- Outdoor CPE focus to maximize performance
-Indoor CPE as complement

5G CPE REQUIREMENTS – OPERATOR PERSPECTIVE Rel.16

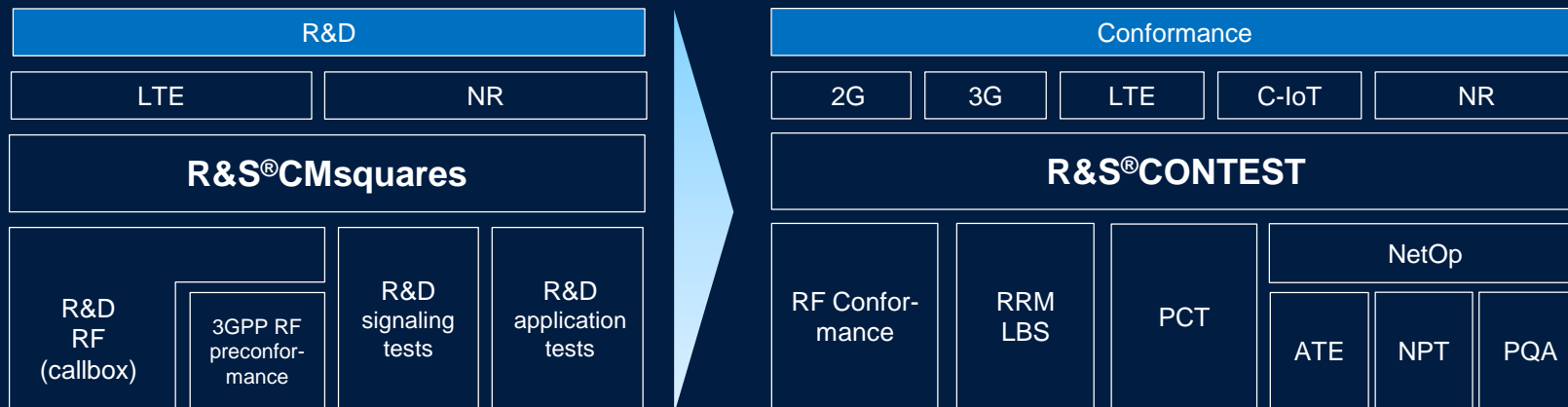


5G FWA UE TEST REQUIREMENTS AND SOLUTIONS

| Test Types | Indicators | Goal |
|---------------------|---|--|
| RF parametric | NR: 3GPP RF TRx test specification Output power, EVM, OBW, receiver sensitivity level BLER, band permutations and CAs etc. | Checks RF TRX performance in accordance with common test specifications Mostly required by operators |
| Functional | E2E max. throughput DL/UL per band CA/ENDC/DC combos 24/7 long duration tests NSA/SA attach; Different modulations <1024QAM Operational stability during long connection and throughput Latency SMS USIM/eSIM authentication FW versioning | Tests to improve customer satisfaction Tests device behavior to check: Battery life, thermal status Firmware regression Benchmark for selecting wireless module CPE under heavy load Generally, end-device vendor-specific parameters (as well as RF parametric, operator acceptance, OTA tests) |
| Operator acceptance | Operator-specific test criteria | Verifies whether device meets with operator's test criteria |
| Conformance | RF/RRM/PCT | GCF/PCTRB certification |
| OTA | CTIA OTA test specification | Verifies antenna performance, required by operators |
| Coexistence | WLAN coexistence testing with Wi-Fi signaling | Ensuring there is no impact between different radios |
| Security | TCP/IP application message flows | SW vulnerability testing |
| Regulatory | RF output power, emission mask, spurious emissions etc. | CE/FCC certification |



CMX500 TOOLCHAIN: CMSQUARES & CONTEST



R&S®CMSquares

R&S®CMX500

R&S®ATS CATR

R&S®NGM200

R&S®TS8980



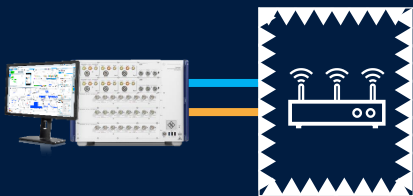
Rohde & Schwarz

TIER 1 CUSTOMER EXAMPLE SCENARIO

Test Plan

E2E high throughput testing
FR1 5CC+NR (DL), FR2 LTE+8CC (DL),
FR2 LTE + 2CC UL, 8CC (DL,UL)
1Gbps UL, 1Gbps DL , IPv4, IPv6

Test Environment



Band Combinations

| | |
|--------------|----------------|
| 0CA_1A | 42DC_41A_n78A |
| 1CA_2A | 43DC_5A_n66A |
| 2CA_3A | 44DC_5A_n78A |
| 3CA_4A | 45DC_66A_n2A |
| 4CA_5A | 46DC_66A_n25A |
| 5CA_7A | 47DC_66A_n66A |
| 6CA_8A | 48DC_66A_n71A |
| 7CA_12A | 49DC_66A_n78A |
| 8CA_13A | 50DC_7A_n5A |
| 9CA_25A | 51DC_12A_n2A |
| 10CA_38A | 52DC_12A_n66A |
| 11CA_39A | 53DC_12A_n78A |
| 12CA_40A | 54DC_13A_n66A |
| 13CA_41A | 55CA_n1A |
| 14CA_48A | 56CA_n2A |
| 15CA_66A | 57CA_n3A |
| 16CA_71A | 58CA_n5A |
| 17CA_12A-66A | 59CA_n7A |
| 18CA_13A-48A | 60CA_n12A |
| 19CA_13A-66A | 61CA_n25A |
| 20CA_2A-12A | 62CA_n30A |
| 21CA_2A-13A | 63CA_n40A |
| 22CA_2A-5A | 64CA_n48A |
| 23CA_2A-66A | 65CA_n66A |
| 24CA_2A-71A | 66CA_n71A |
| 25CA_41A-41A | 67CA_n77A |
| 26CA_48A-48A | 68CA_n78A |
| 27CA_48B | 69CA_n79A |
| 28CA_48A-66A | 70CA_n2(2A) |
| 29CA_48C-66A | 71CA_n2A-n5A |
| 30CA_4A-12A | 72CA_n2A-n12A |
| 31CA_4A-13A | 73CA_n2A-n66A |
| 32CA_4A-71A | 74CA_n5A-n66A |
| 33CA_5A-13A | 75CA_n12A-n66A |
| 34CA_5A-66A | 76CA_n25A-n66A |
| 35CA_5B | 77CA_n25A-n71A |
| 36CA_66A-71A | 78CA_n25(2A) |
| 37DC_1A_n78A | 79CA_n48(2A) |
| 38DC_2A_n2A | 80CA_n66A-n71A |
| 39DC_2A_n12A | 81CA_n71A-n77A |
| 40DC_2A_n66A | 82CA_n77(2A) |
| 41DC_2A_n71A | |

Results

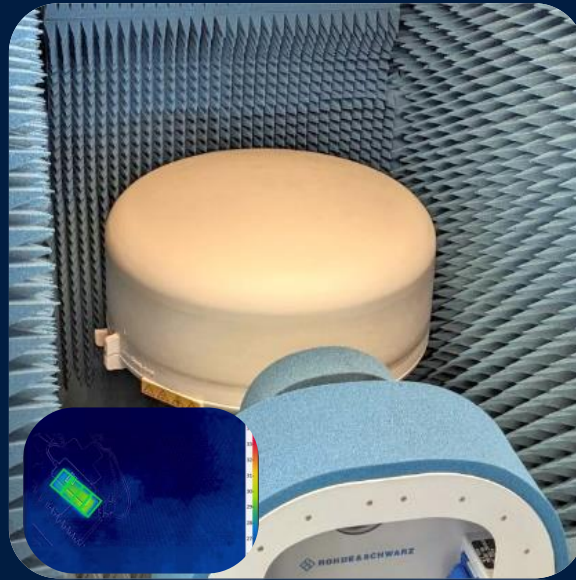
BandCombo 49: DC_66A_n78A
Direction: DL
Test duration: 2.0 s
Verdict: **PASS**
5G IPv6 TPUT: 1.7 Gbps
Config: ['arfcn:620058 bw:100.0 rsrp:-
70.0 tdd_dl: 8 ul: 1 MCS Tables
dl:QAM_256:25 ul:QAM_256:5']
BLER: 0.00%

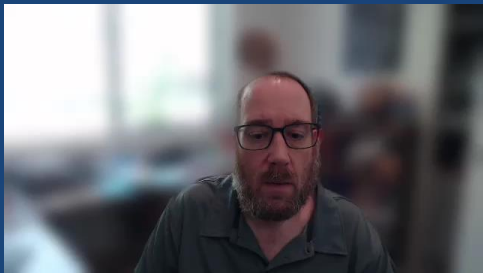
5G FWA UE OTA TEST FOR FR2 AND THERMAL MEASUREMENTS

3D positioner for TRP/TIS



Thermal bubble/camera





Casa Systems

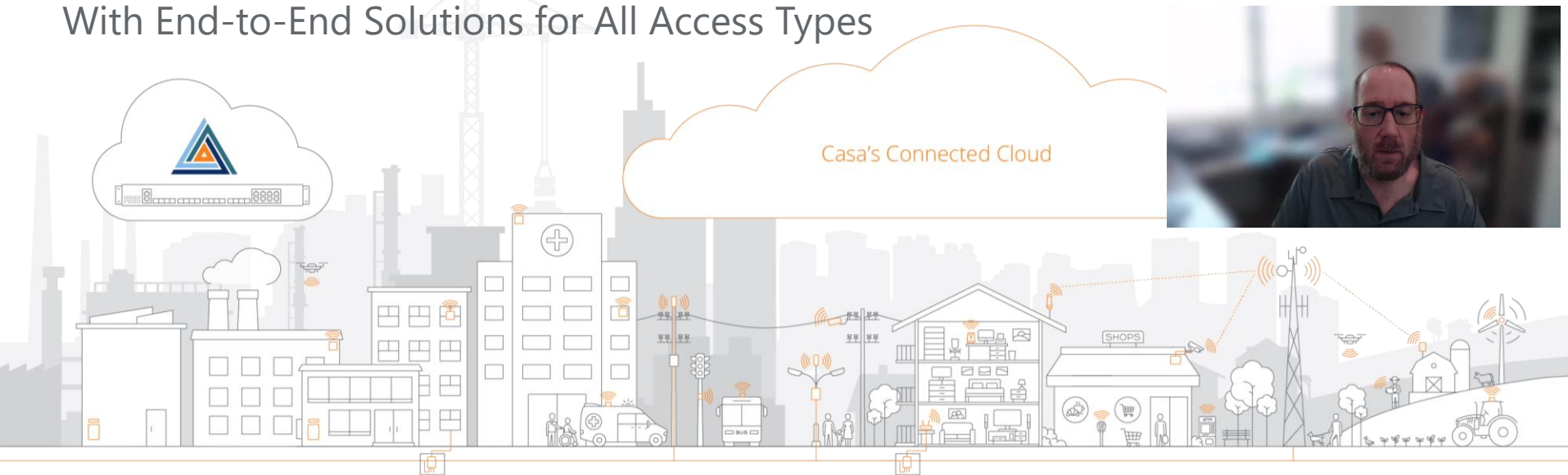
Rethink 5G Testing Webinar

January 2023



Transforming Networks from the Core to the Customer

With End-to-End Solutions for All Access Types



Axyom Network Core

- DOCSIS Cores (vRMD-M, vCAAP)
- 5G Core
- vBNG
- Disaggregated Multiservice Router
- Element Network Manager

Residential / Commercial

- Distributed Access Architecture
- DOCSIS 4.0
- Apex Indoor / Outdoor 5G Evo Radio
- Apex Enterprise Small Cell
- AurusPRO Global 5G Outdoor CPE
- 5G High Power mmWave Outdoor CPE
- IIoT Solutions

Home

- Apex Pebble / Triangle Lifestyle Small Cells
- CloudMesh Satellite / Gateway
- 5G Sub-6 Indoor Outdoor CPE
- 5G mmWave Indoor Outdoor CPE

Broadband Access & Rural

- Fiber Extension DPU / NTD
- 5G Cat B CBRS
- Global 5G Outdoor CPE
- AurusPRO
- AurusAI

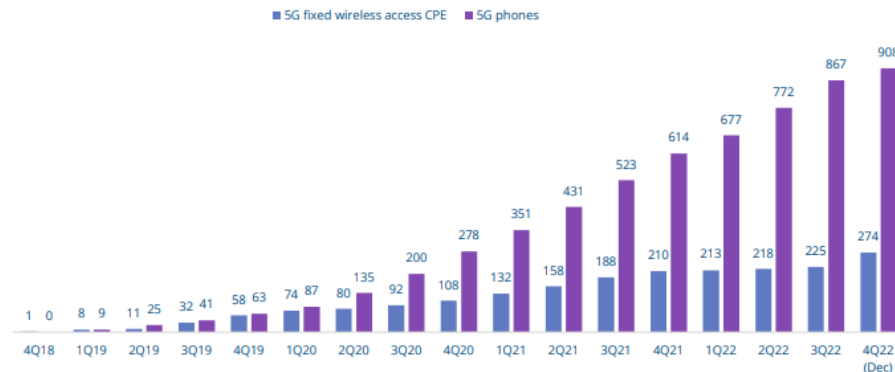


5G Global Growth

5G Ecosystem



- 515 operators investing in 5G worldwide
- 243 global commercial launches
- Over 1400 5G devices commercially
- More than \$130B spent on 5G auctions



Source: Announced 5G Fixed Wireless Devices - 2023 Global mobile Suppliers Association

Use Cases

5G is fueling new use cases



Fixed Wireless is continuing to gain more and more market share as global service providers turn to 5G Fixed Wireless to address an ever-growing number of use cases.



Home Internet



Rural Broadband



SMB Connectivity



Industrial IoT



Private Networks

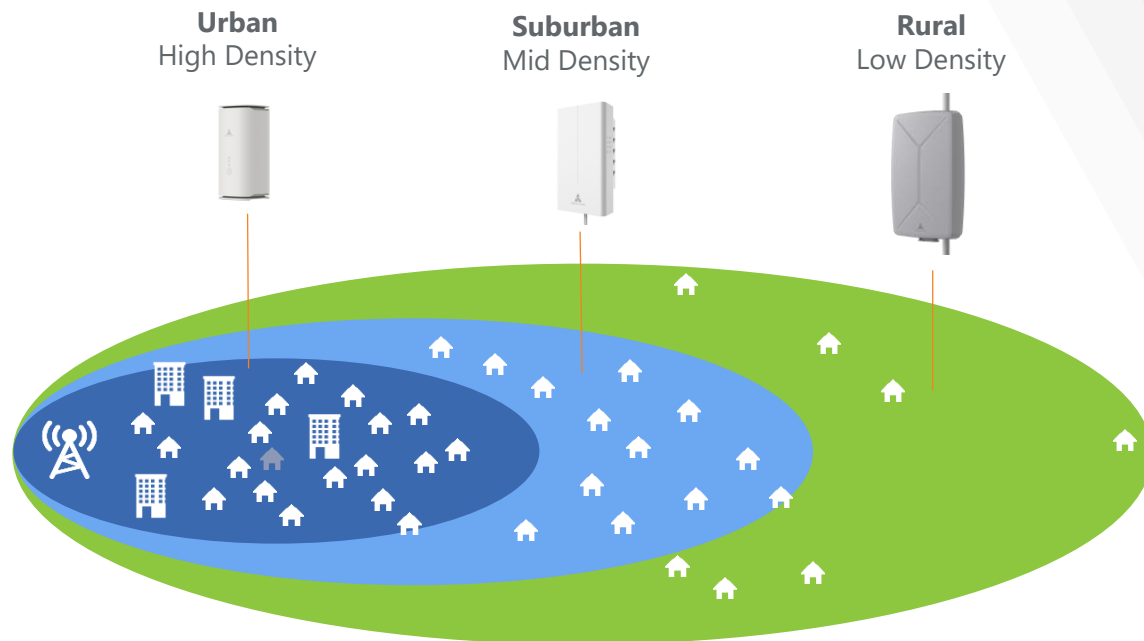


Deployments Scenarios

Driving individual design & test cases



- 5G FR1 v 5G FR2 deployments
- Distance from the gNB
- Link budget requirements
- Climate / geography
- Local regulatory requirements
- Installation (pro v self-installation)



CMX

Use Cases



Thermal Performance

Fixed Wireless Access



In mmWave, high transmit power is necessary to ensure good performance in poor RF conditions but can cause high temperatures on the product.

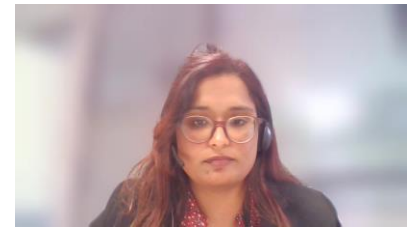
Throughput is crucial to identify when thermal mitigation kicks in

Unlike other base station emulators, CMX is easy to set up and establish a stable connection and therefore is a good option for thermal testing.



Regulatory RF compliance

Fixed Wireless Access

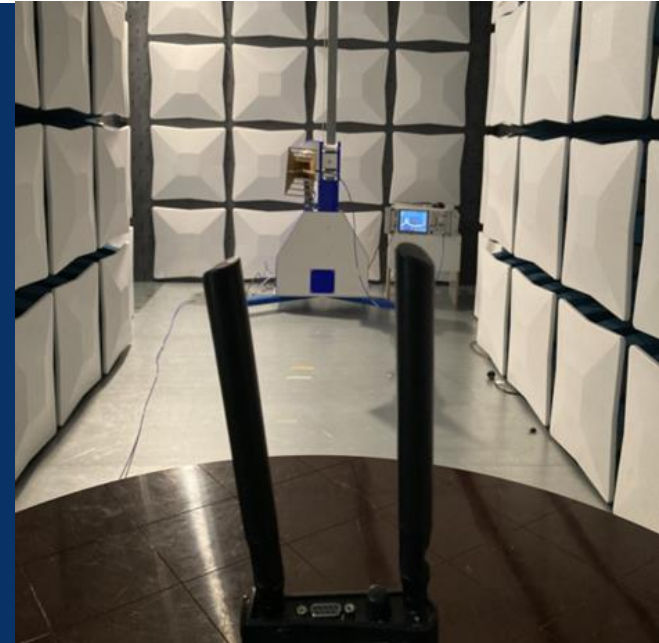


Spurious Emissions are unwanted emissions at frequencies outside of the intended transmission frequencies and need to adhere to regulatory limits.

Evaluation of spectral masks to reduce adjacent channel interference.

Measure maximum power levels and sensitivity of the receiver.

The CMX has proven useful in these scenarios & has allowed a quick verification & resolution of problems, rather than sending it overseas to a lab for verification.



Functional Test

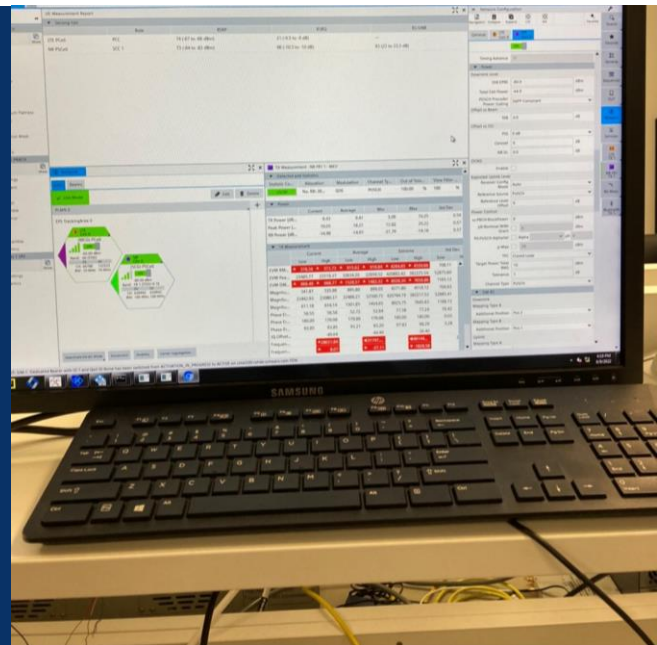
Fixed Wireless Access



Display of ASN.1 decoded messages enables a quick debug

Functional tests for antenna performance, maximum power levels, receiver sensitivity.

The CMX reduces complexity and allows configuration issues to be identified in a matter of seconds. It allows an easy setup for throughput and end to end testing.



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THANK YOU

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