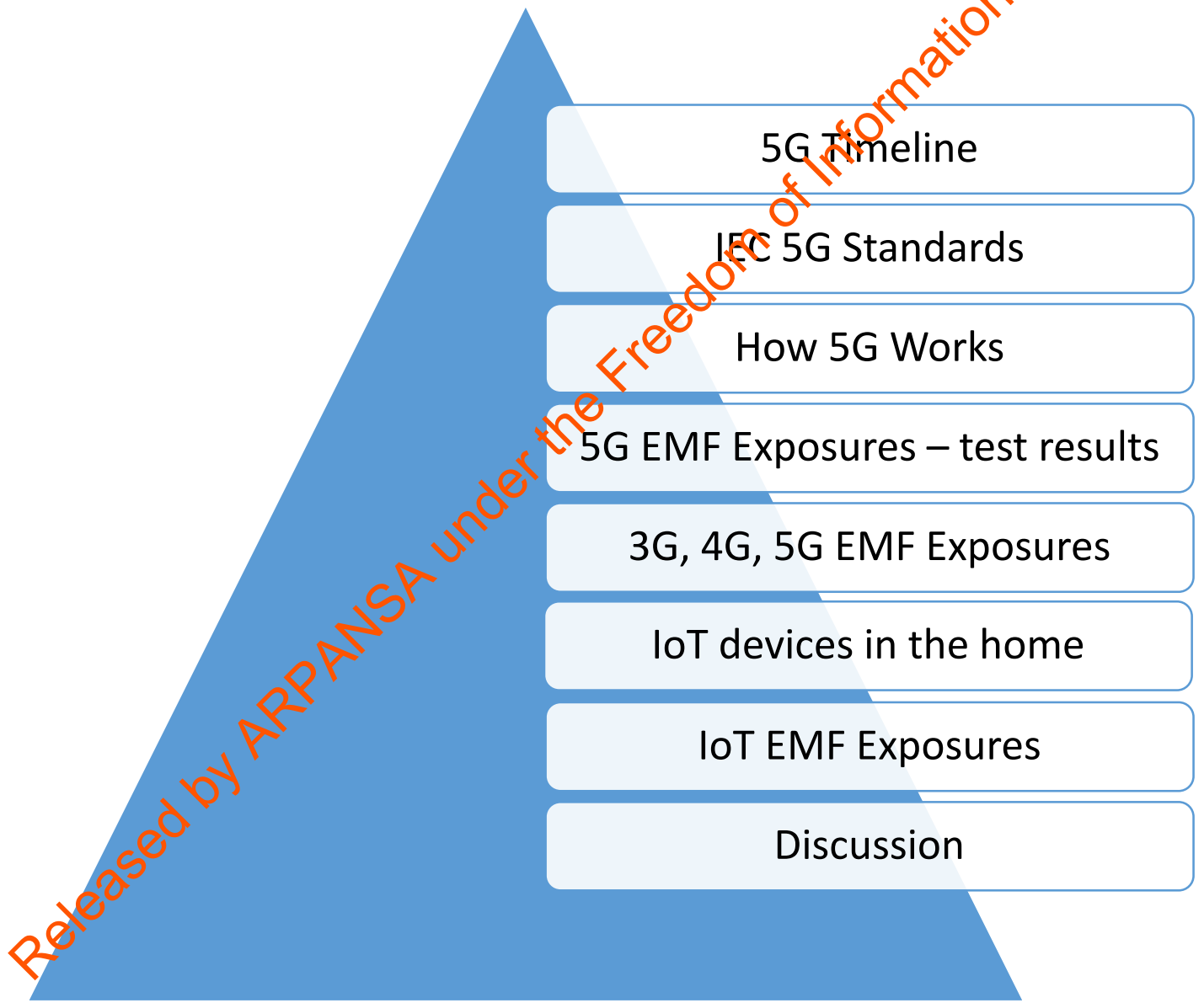
5G and the Internet of Things

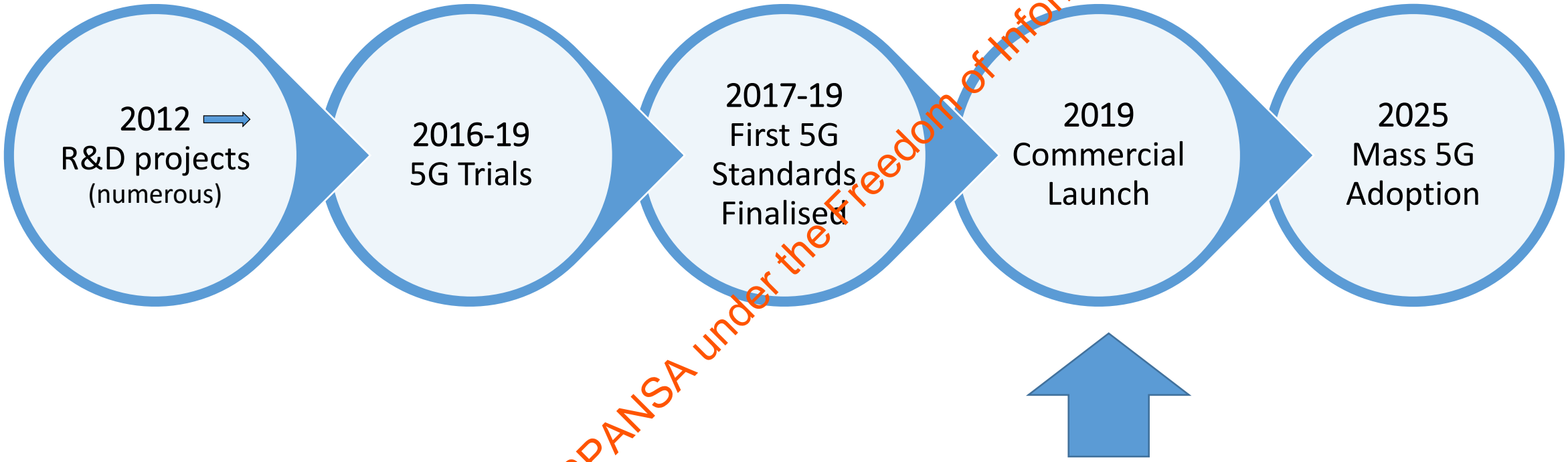
Exposure Scenarios

Mike Wood - Chairman
International Electrotechnical Commission
Technical Committee 106

Presentation Overview



5G Timeline



Fixed wireless access for homes and **enhanced mobile broadband** first applications using new 5G.

5G & IoT applications will be widespread by 2025.

IEC Overview

International Electrotechnical Commission: (est1906)

International Standards and Conformity Assessment for all electrical, electronic and related technologies

Vision

"IEC everywhere for a safer, more efficient world."

IEC Masterplan

A global network of some 170 countries that covers 99% of world population and electricity generation

Offers an Affiliate Country Programme to encourage developing countries to use and participate in IEC work free of charge

Develops International Standards that represent a global concensus of state-of-the-art know-how and expertise. Administers Conformity Assessment Systems

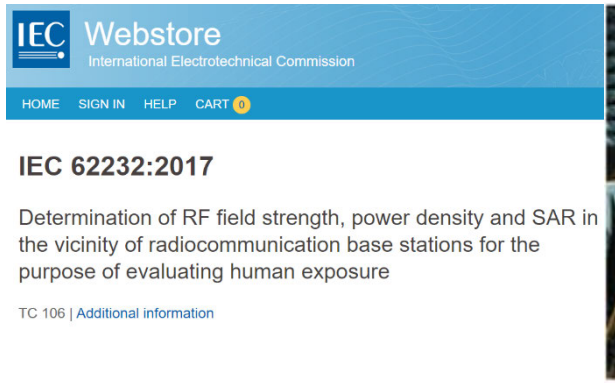
Over 20 000 experts

100 years expertise.

IEC - Preparing for 5G

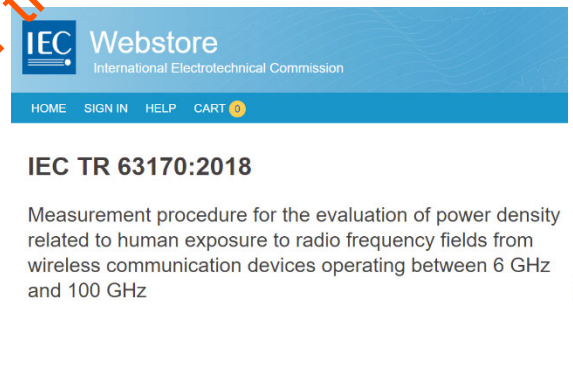
- IEC Strategic Business Plan – 5G focus
- Ensure Standards and Technical Reports are developed
  - Trials & early deployments in 2018 – 2019, Commercial Launch 2019 - 2020

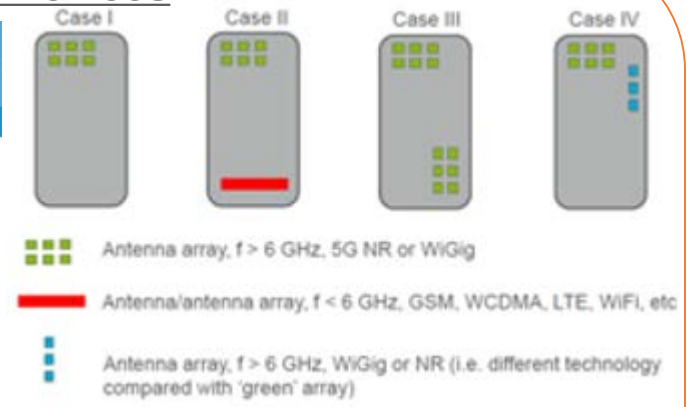
5G Base Stations



Standards	
IEC 62232-2 Int Std	110MHz -100GHz – Aug 2017
IEC 62669-2 Tech Report	6GHz -100GHz – April 2019
IEC 62232-3 Int Std	110MHz-300GHz –June 2020

5G Devices





Standards	
IEC TR36170 Technical Report	6-100GHz – July 2018
IEC / IEEE 62704-5 Int Std (Calc)	6-100GHz – Dec 2020
IEC / IEEE 63195-1 Int Std (Meas)	6-100GHz – Dec 2020

IEC Standards - 5G Base Station Testing

Example: 5G site with massive MIMO

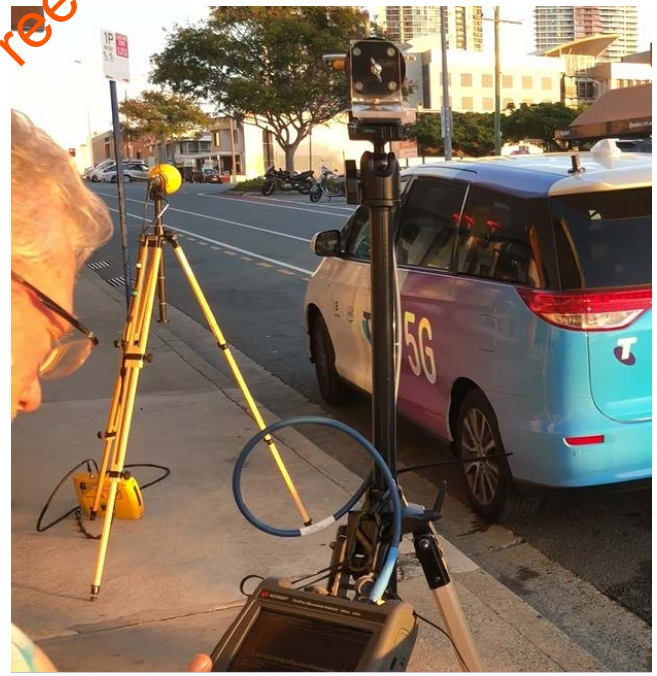
3.5 GHz and 28 GHz, actual maximum power

5G urban roof-top installation

Exclusion zone
10 W/m²
ICNIRP general public limit

Actual maximum power = 25% of theoretical maximum
RF EMF exposure below ICNIRP limits in public areas
Case study to be included in IEC TR 62669 (2018) and ITU-T Supplement on 5G EMF compliance

Modelling actual power due to beam steering



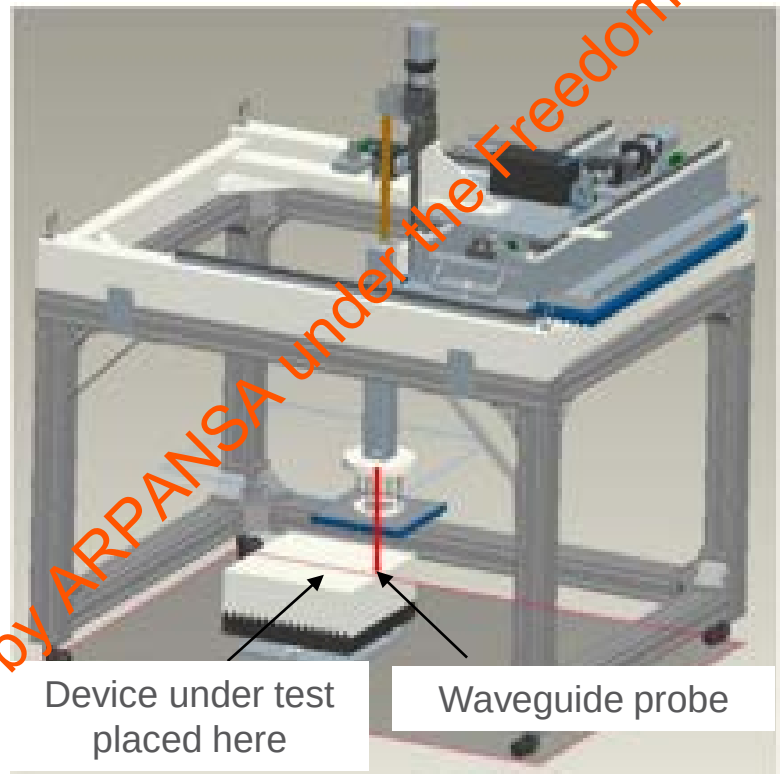
Measurements of 5G in Australia using IEC 62232
Locating beam and observing level variation

IEC Standards - 5G Device Testing

5G at 3.5GHz – existing SAR test systems are used

5G at mmWave - test laboratories initiated development of new 5G mmWave device test systems

IT'IS EUmmW Poynting vector probe



Art-Fi mmWave guide probe development

APREL mmWave probe development

What is 5G?

5G is the 5th generation of mobile networks

Extreme speeds - Gbps
High Capacity – 10x
Low Latency – 1ms

1G 1980s — Analogue

2G 1990s — Digital SMS

3G 2000s — Multimedia, Video Calling, Mobile internet

4G 2010s — Mobile Broadband, Enhanced Video

5G 2019 / 2020 — Mobile Connected World, Enhanced Mobile Broadband, Low latency applications, Internet of Things, AR & VR

Why 5G?

1. Communities are using significantly more data and applications in everyday life

2. Todays 4G LTE networks are reaching maximum capacity

3. A solution is needed to enable additional capacity and innovation for future societies

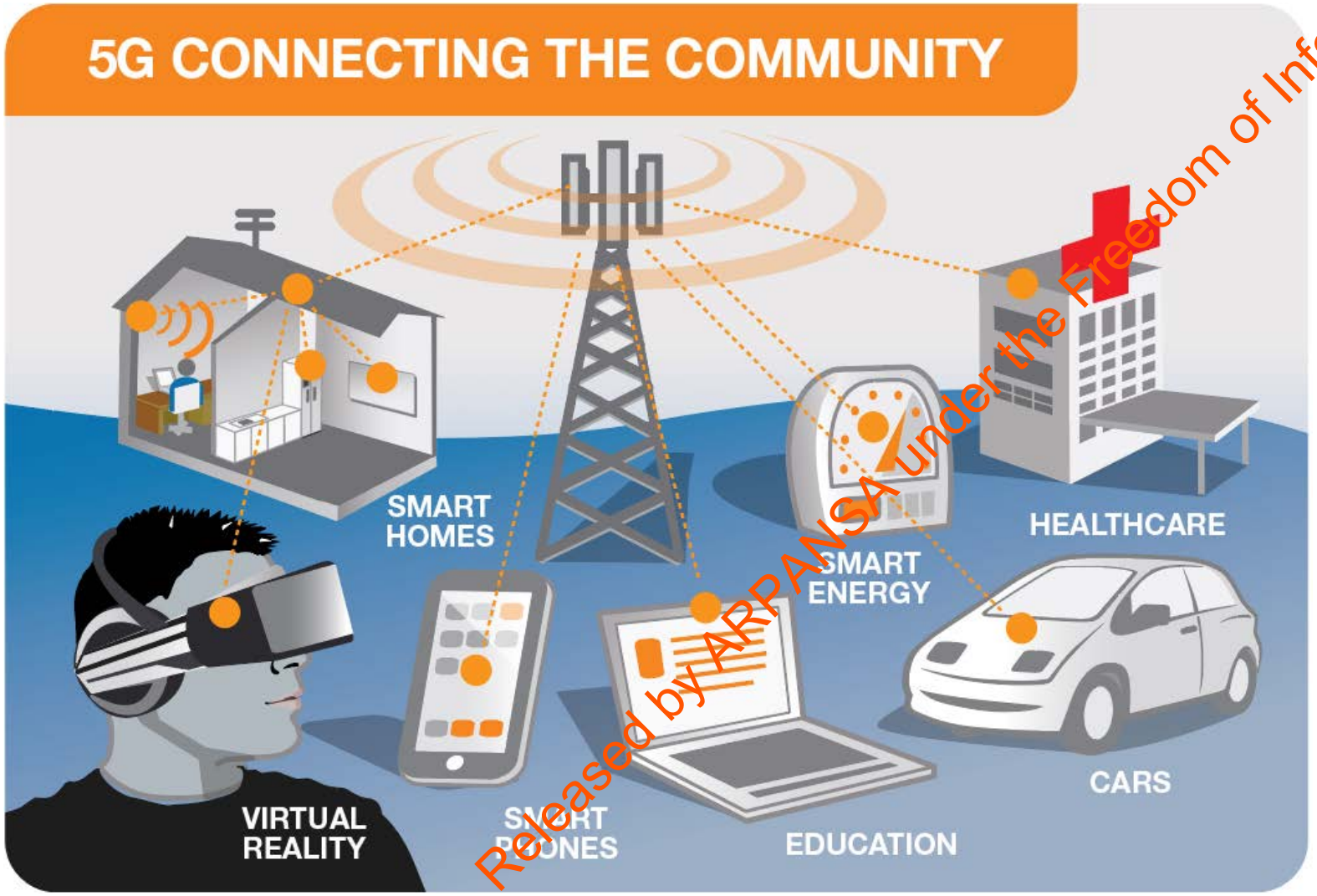
4. Enables digitalization of various industry sectors

5G – Connecting the Community

5G uses radio waves or radio frequency (RF) energy to transmit and receive voice and data connecting our community.

5G will enable the connectivity of today's modern society, the Internet of Things and tomorrow's innovations.

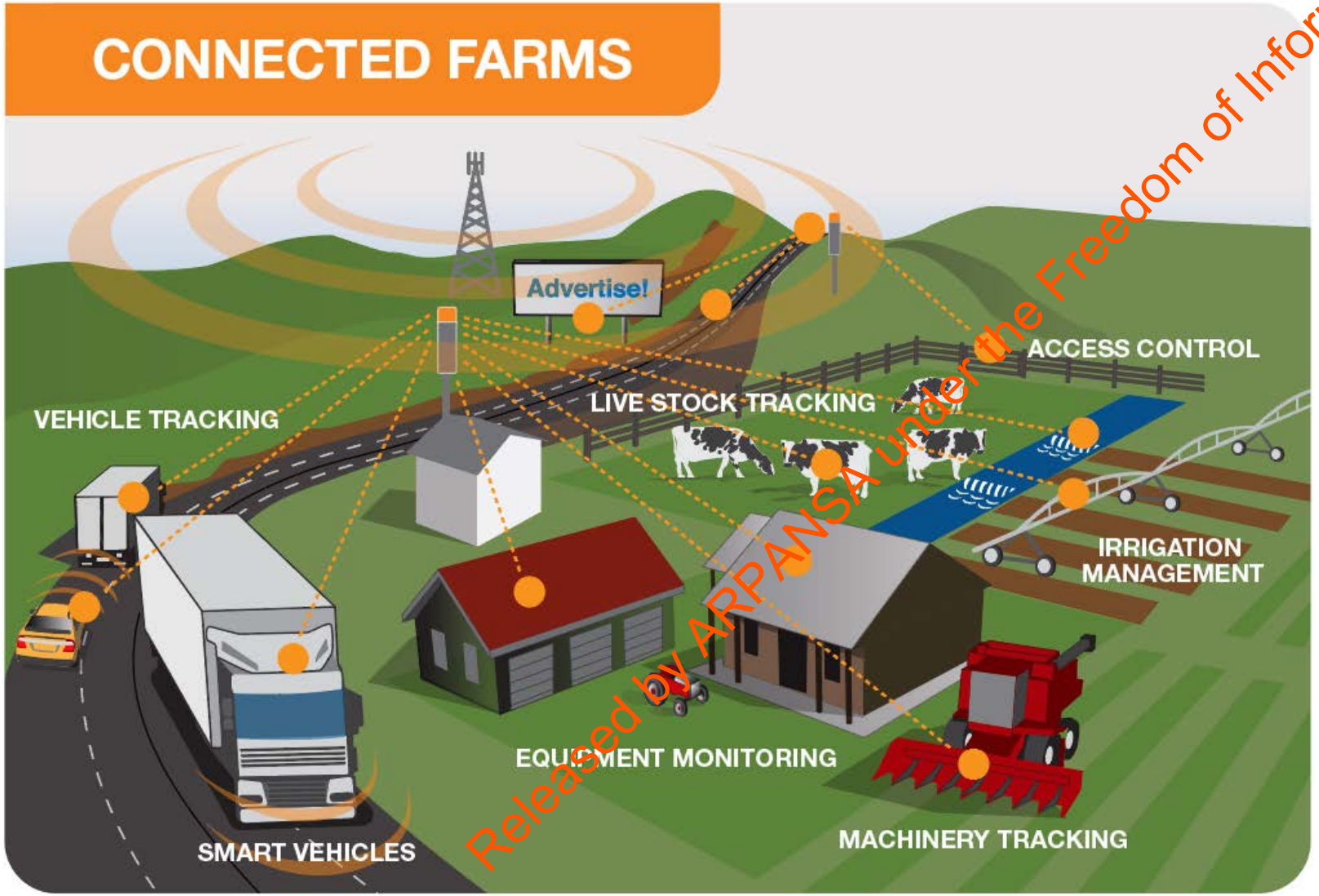
Benefits to society



5G opens up a new world of connectivity and benefits.

- Smart cities, schools, homes
- Safer roads & transportation
- Remote health care
- Connected ambulance
- Smart manufacturing industries and farms

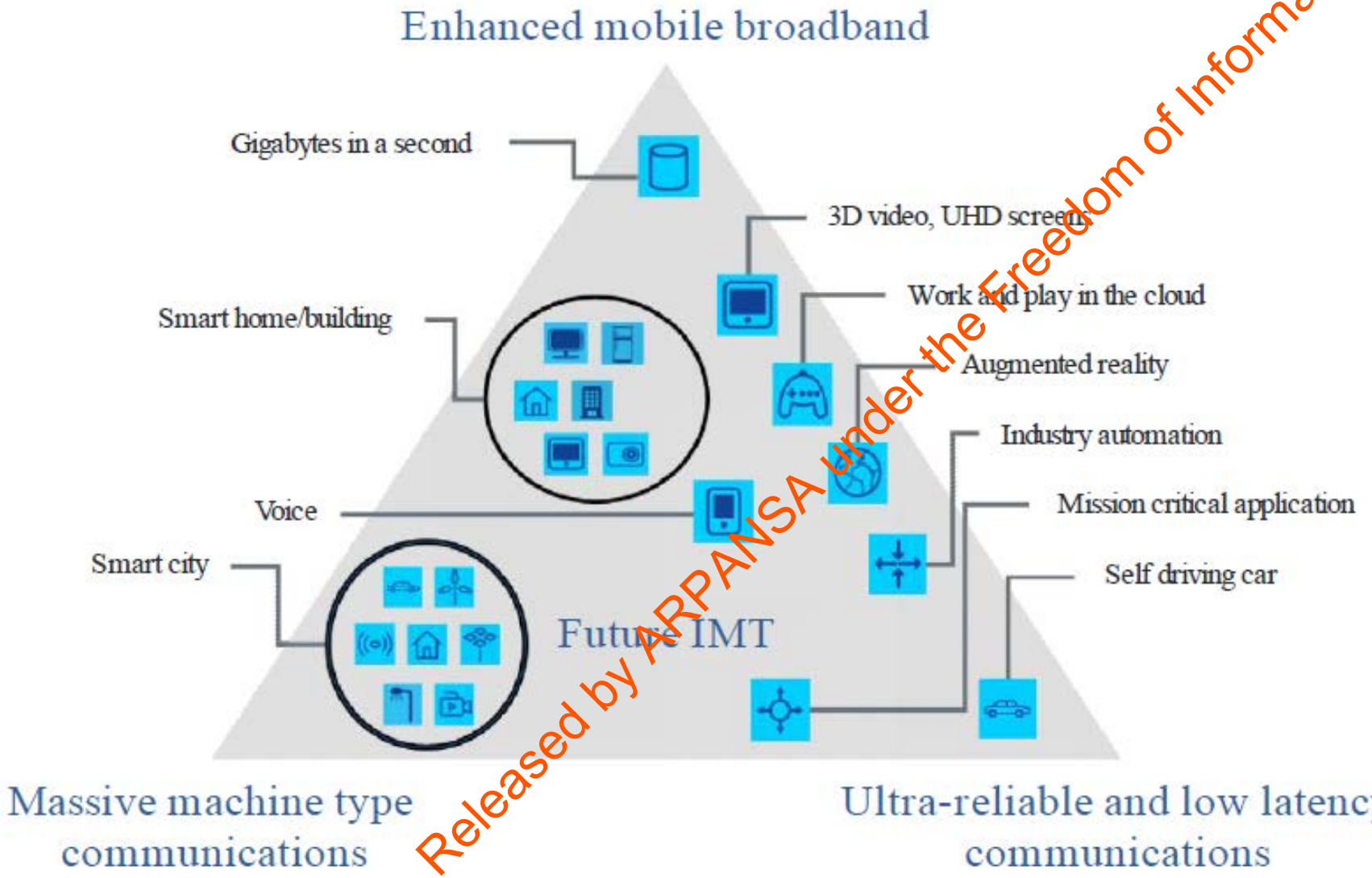
Benefits to society – connected farms



5G enabling smart agriculture and connected farms through

- new IoT applications
- connecting everything
- low power long range sensors
- smart data management

5G Use Cases – 3 main categories



Source Recommendation ITU-R M.2083-0

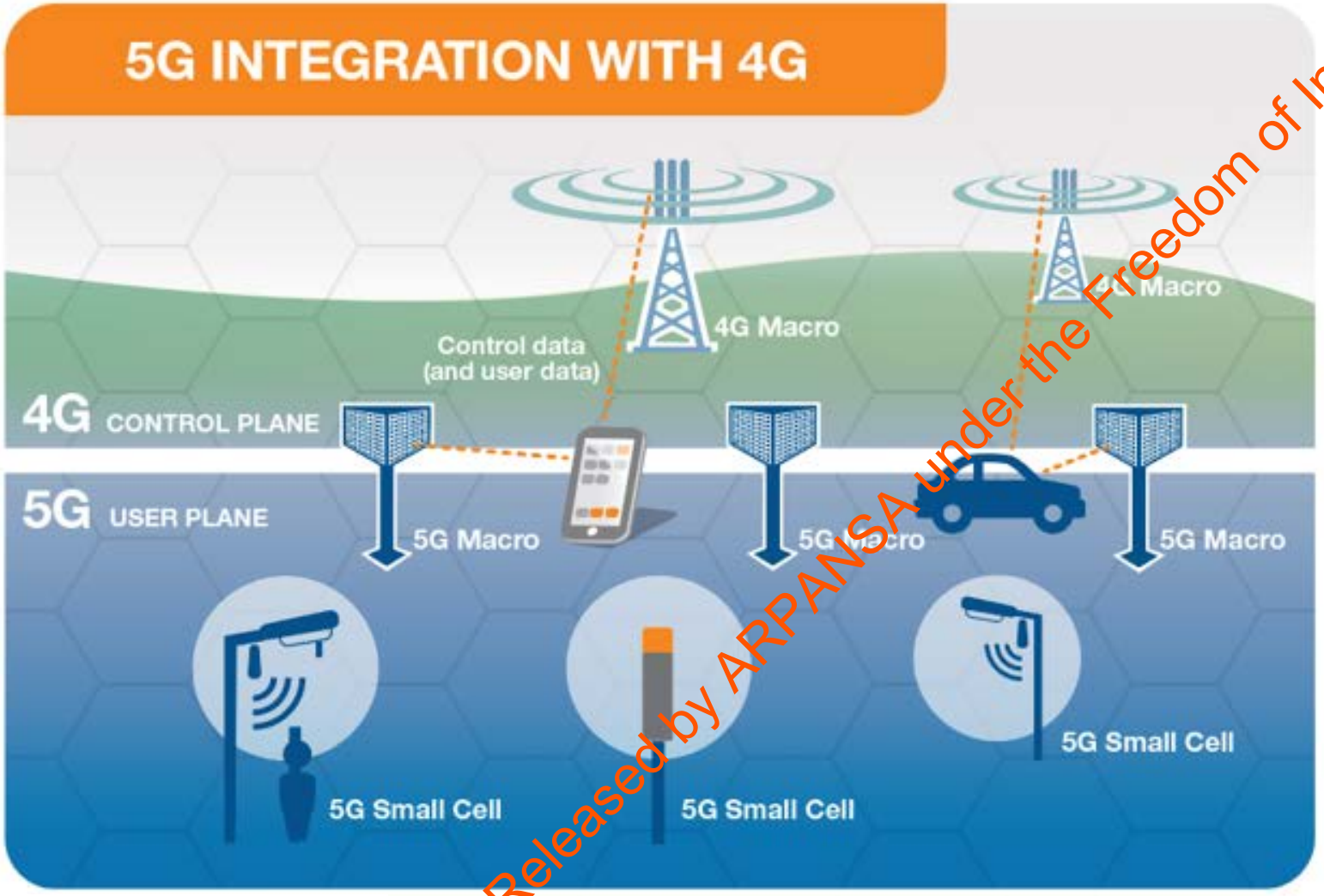
5G Technical Requirements

Peak Data Rate	1 - 20 Gbps
User Experienced Data Rate	10 - 100 Mbps
Spectral Efficiency	×1 - ×3
Mobility	350 - 500 km/h
Latency	1 - 10 ms
Connection Density	10k – 1M devices / km^2
Network Energy Efficiency	×1 - ×100
Area Traffic Capacity	0.1 - 10 Mbps / m^2
Availability	99.999% (of time)
Battery life	10 years*
Reliability	99.999% (of packets)
Position accuracy	10m - <1m
Security	Strong subscriber authentication, user privacy and network security

*For low-power IoT devices

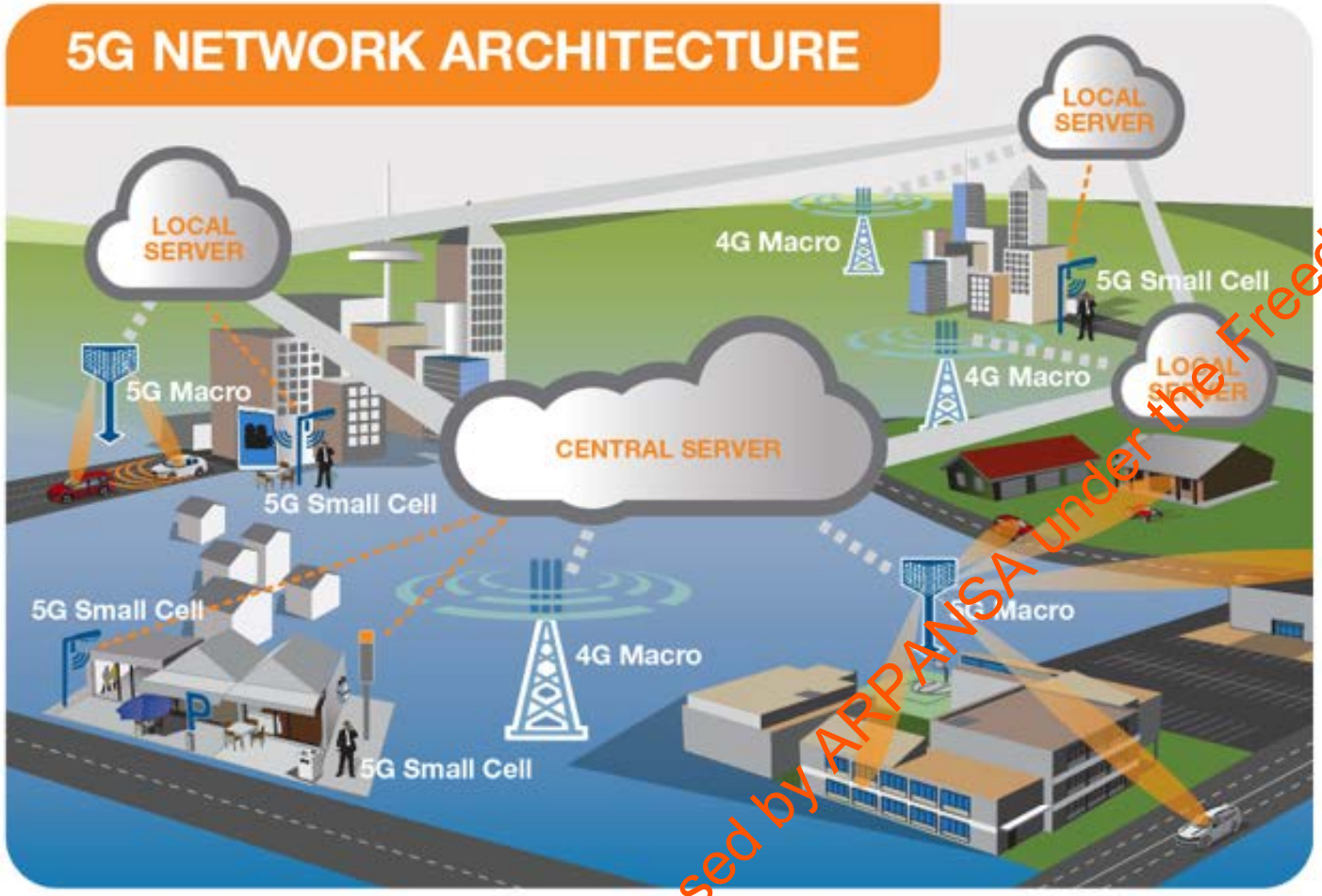
Source: ITU-R, NGMN, 3GPP

How does 5G work?



- 5G works together with 4G (initially non standalone NSA)
- 4G acts as control plane
- 5G acts as data/user plane
- 5G will operate stand alone in later releases

How does 5G work – network architecture



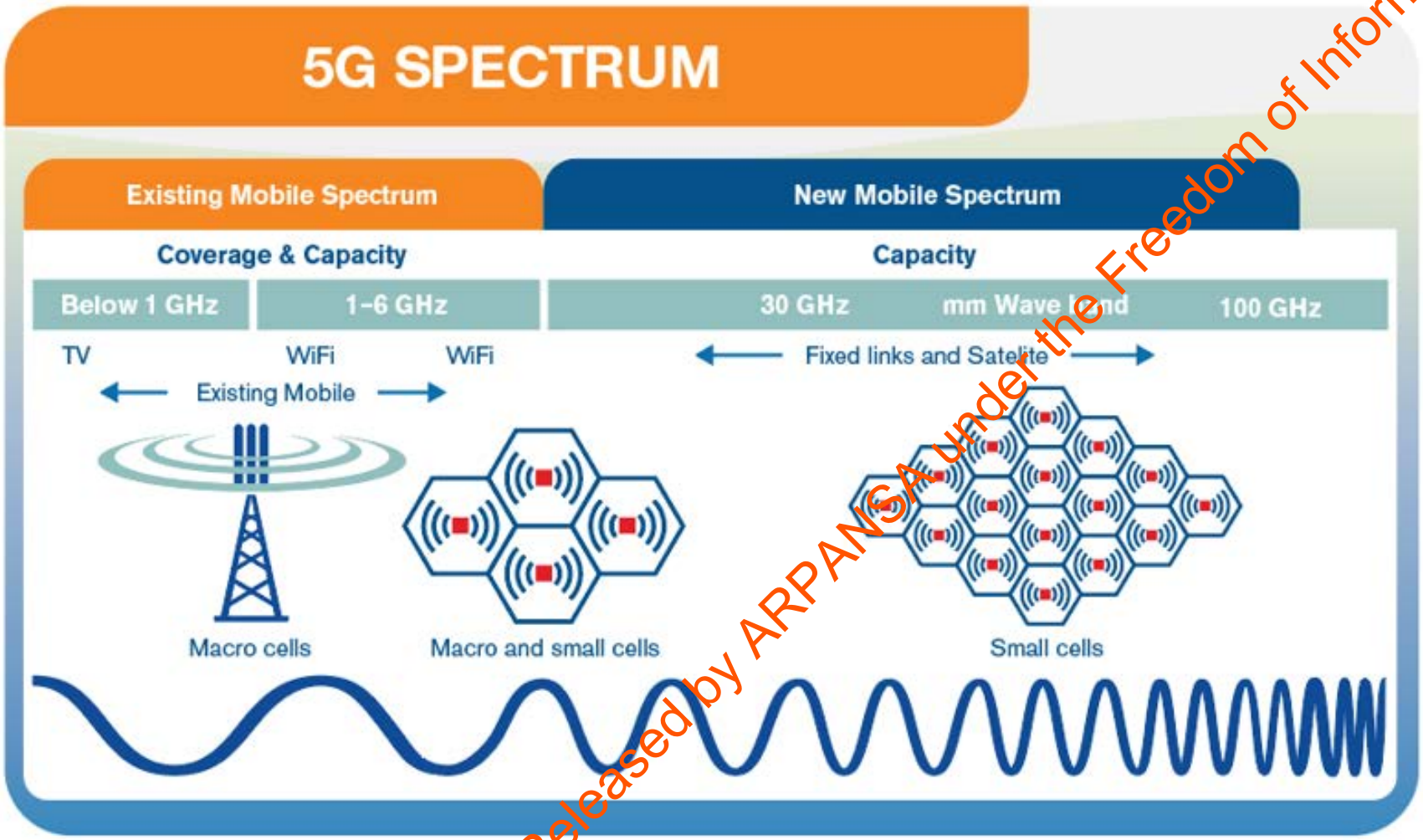
5G network architecture - illustrating 5G and 4G working together, with central and local servers providing faster content to users and low latency applications

Radio Access Network - small cells, towers, masts & dedicated in-building and home systems that connect mobile users and wireless devices to the core network

Core Network - mobile exchange and data network, manages mobile voice, data and internet connections. The 5G 'core network' is redesigned to better integrate with the internet and cloud based services, includes distributed servers across the network.

Network Slicing – smart way to segment network for separate applications – e.g. emergency services

How does 5G work - spectrum



Mobile spectrum showing the radio frequency range from 3-100 GHz with new 5G spectrum above 6GHz. Other radio services (TV, Wi-Fi, Fixed links & Satellite) are shown for reference

Frequency & Service

<1 GHz Coverage, IoT,

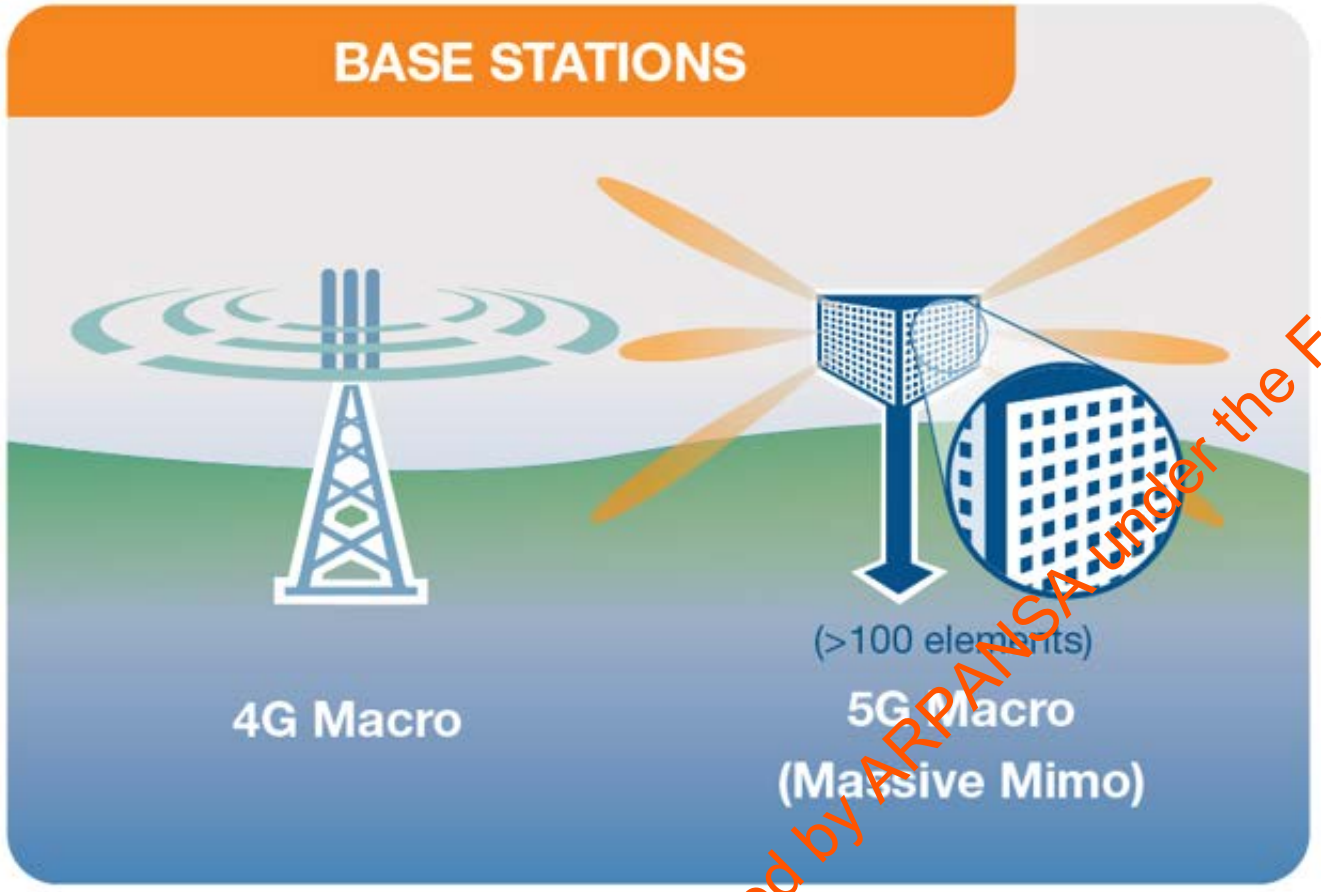
1-6 GHz Coverage, IoT, Capacity

> 6 GHz Capacity, extreme data rates

How does 5G work – technologies

MIMO = Multiple Input Multiple Output element Antenna

5G Technology – Advanced Antennas



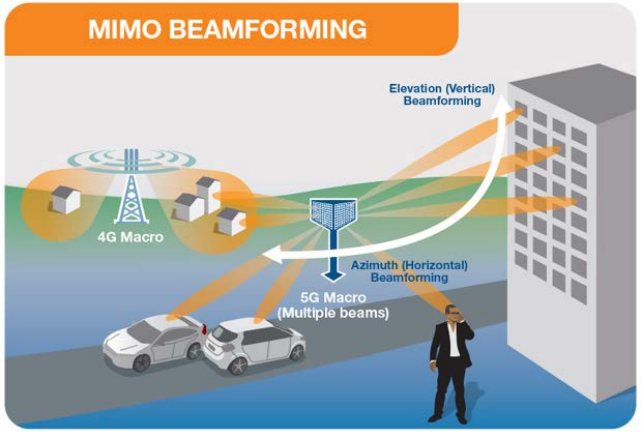
- Multiple Input, Multiple Output antenna elements
- "Massive" number of send/receive elements
- Provide multiple simultaneous connections
- More signal paths, more capacity
- Allows more users to connect at the same time
- Efficient use of radio spectrum

4G	Typically 2-8 antenna ports
5G	Large number of antenna elements (>100)

5G Technology - Beamforming

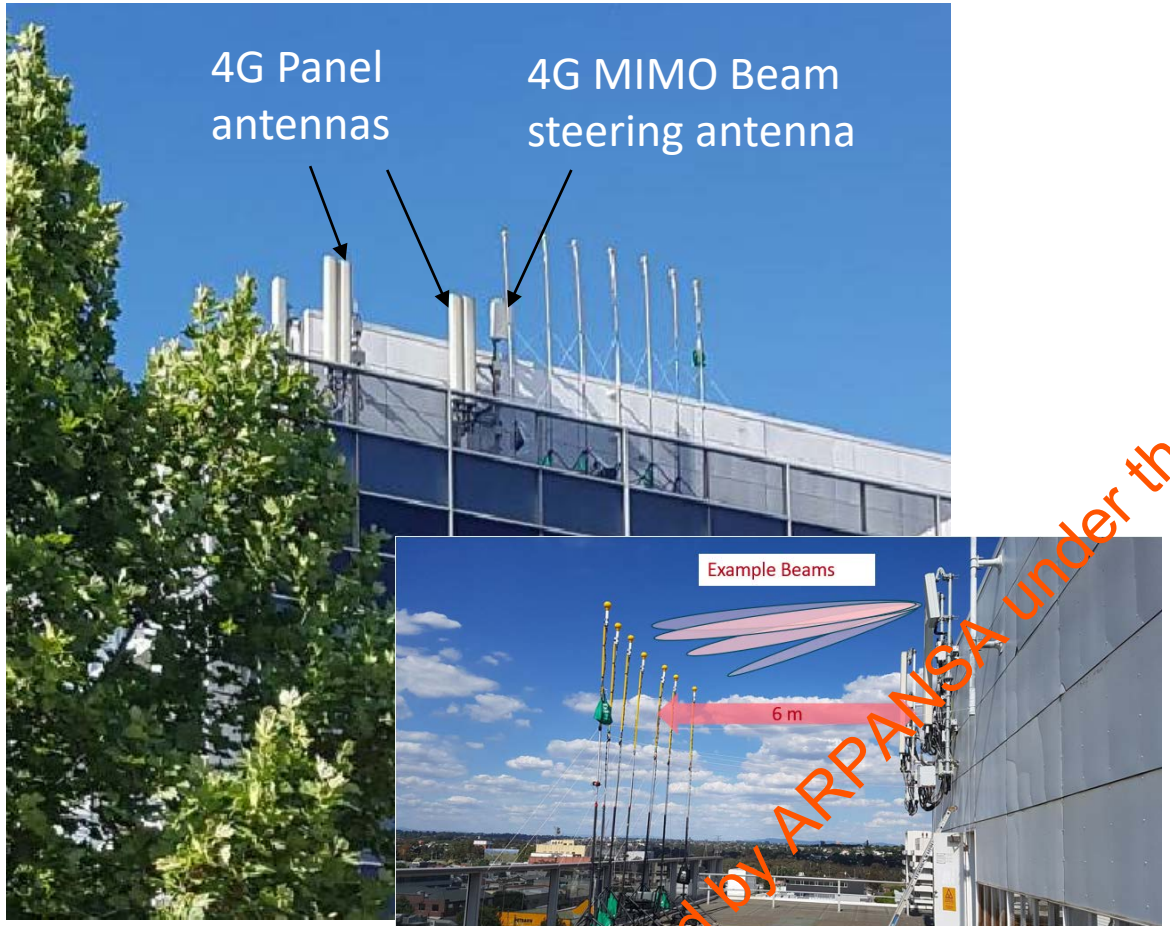
- Dedicated radio signal towards the user
  - A 4G signal is typically spread across a wide area
- Enabled by Massive MIMO technology
- Identifies most efficient signal path
- Improves connection reliability
- Reduces interference (unwanted signals)
- Efficient use of spectrum and power
- Allows more simultaneous data streams

5G Technology - Beamforming



Beamforming - Example from Telstra's 5G Trial in Melbourne 2016
green dots show active beams connected to 5G Van driving in carpark

Beamforming – live measurement of EME reduction



Beamforming EME Test

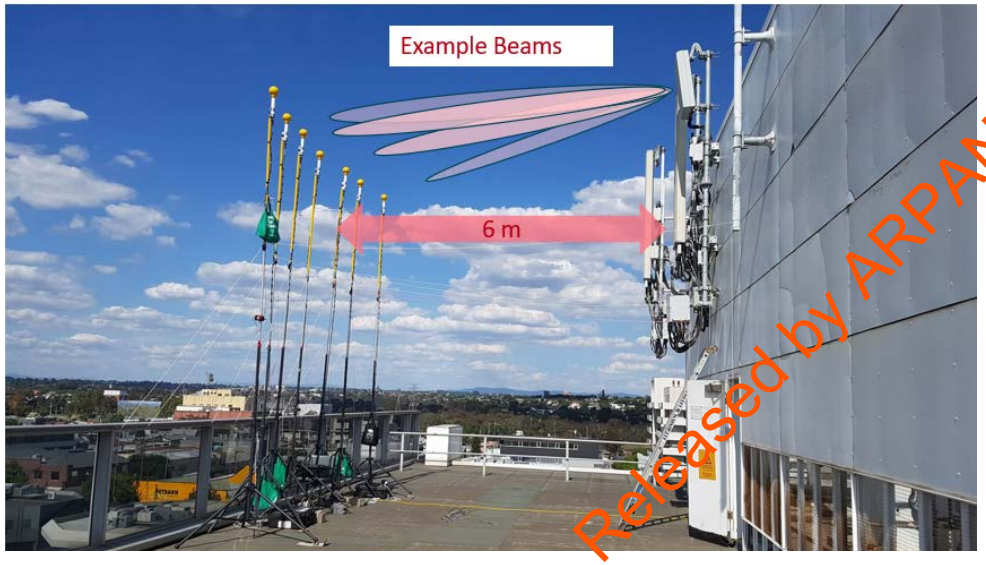
Optus 4G 2300MHz network in Melbourne with a MIMO beam steering antenna, 7 Narda SRM monitors measured the EME levels in front of the antenna with live traffic

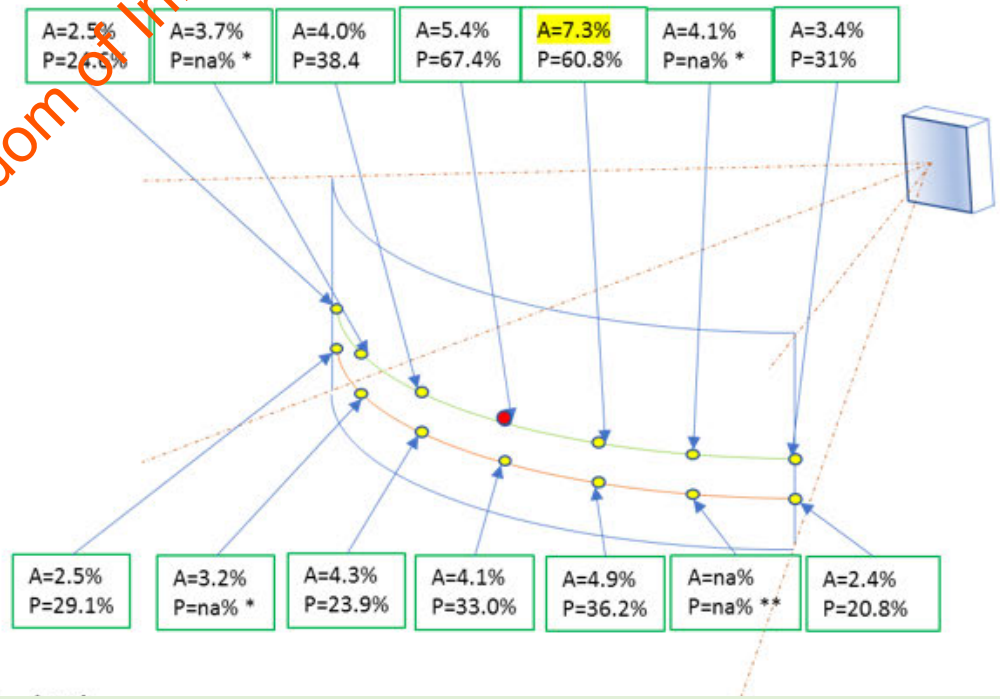
Results show approximate reduction in average EME levels of 10 times with beam steering compared to a normal antenna

Beamforming – live measurement of EME reduction

Measured results

- Highest observed values occurred close to bore site
  - 6 min EMF was 7.3% of Occ limit
  - The Computed value at this location was 116% of Occ limit

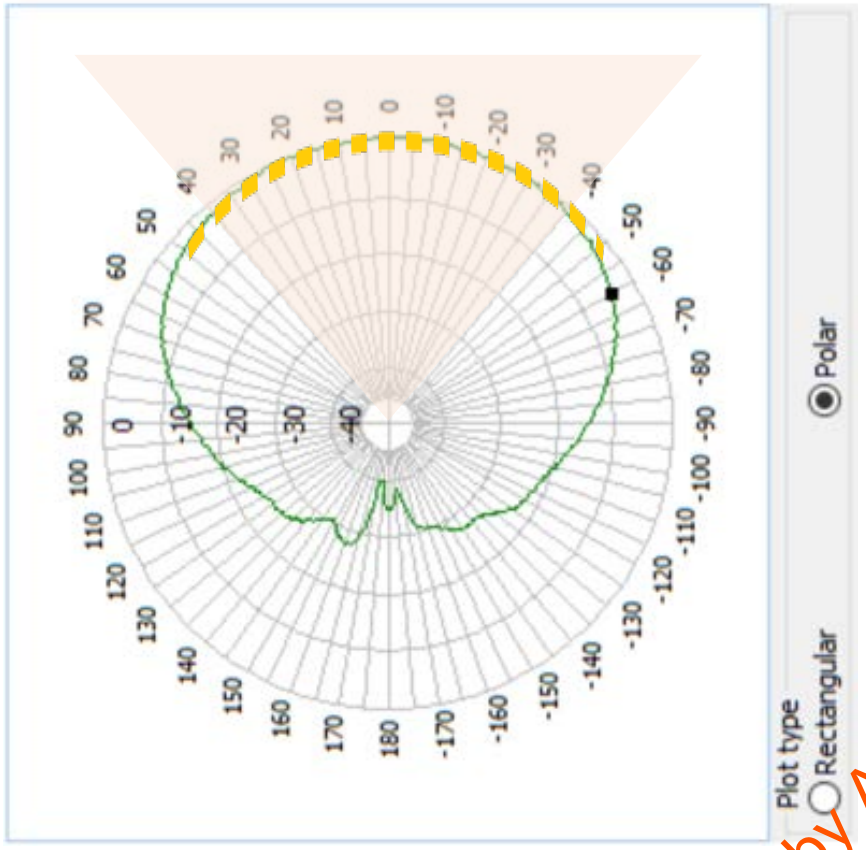


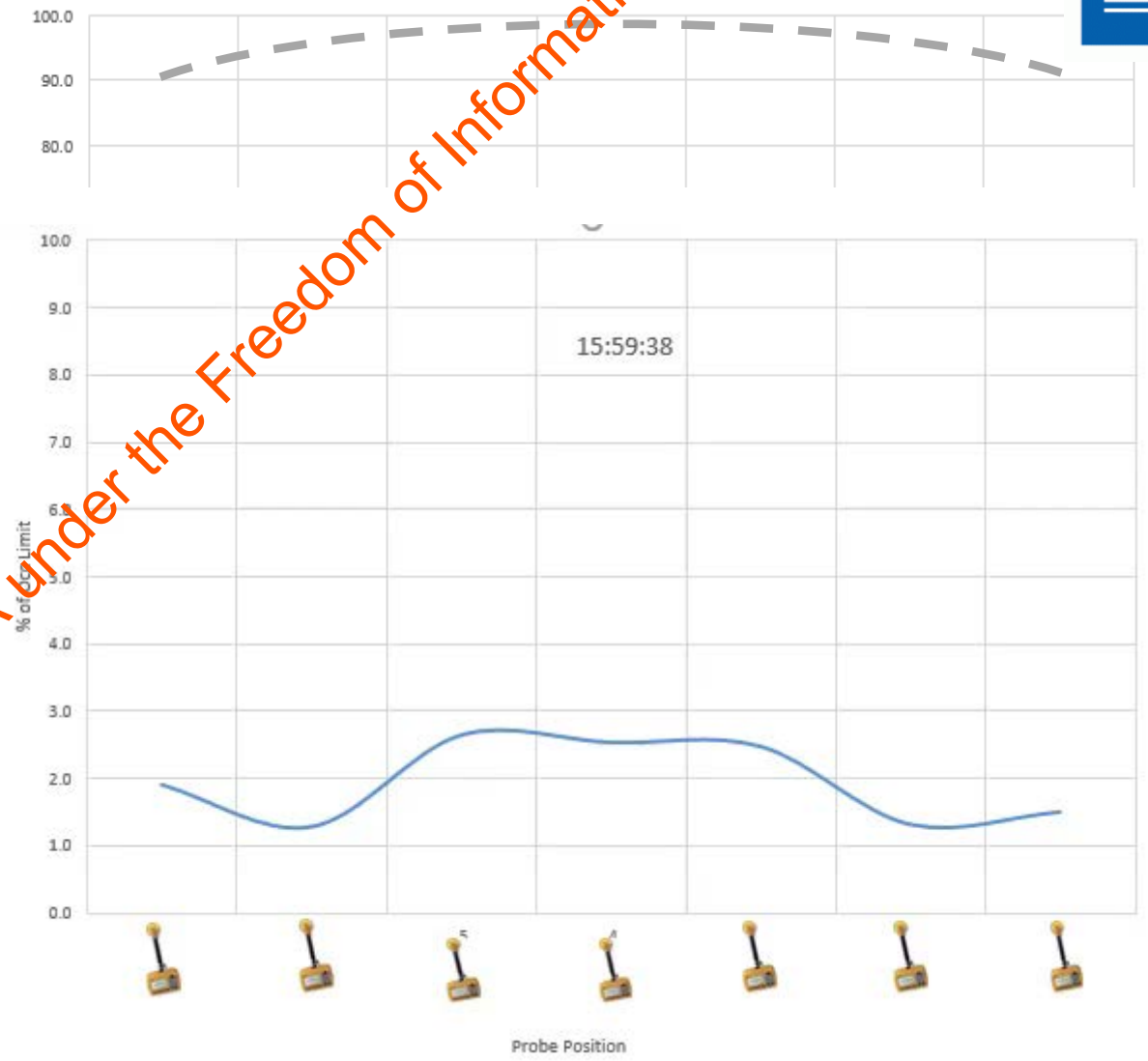


A= 6min Ave %Occ
P= Peak %Occ
● = Bore Site

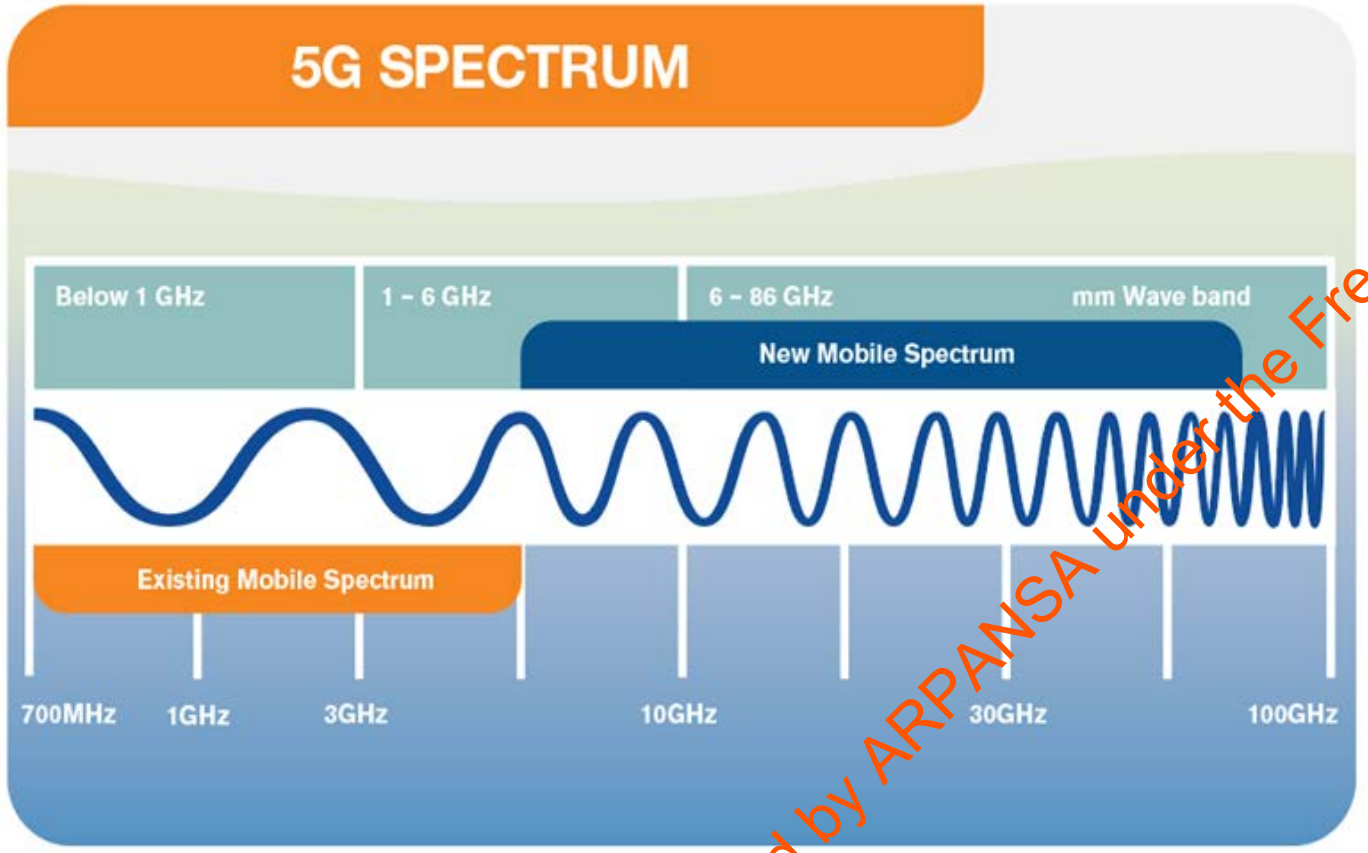
Results show reduction in average EME levels with beam steering compared to a normal antenna is consistent with published modelling **7% - 22% of the theoretical maximum** (Thors et al, 2017).

Beamforming – Actual Measured Beam Forming



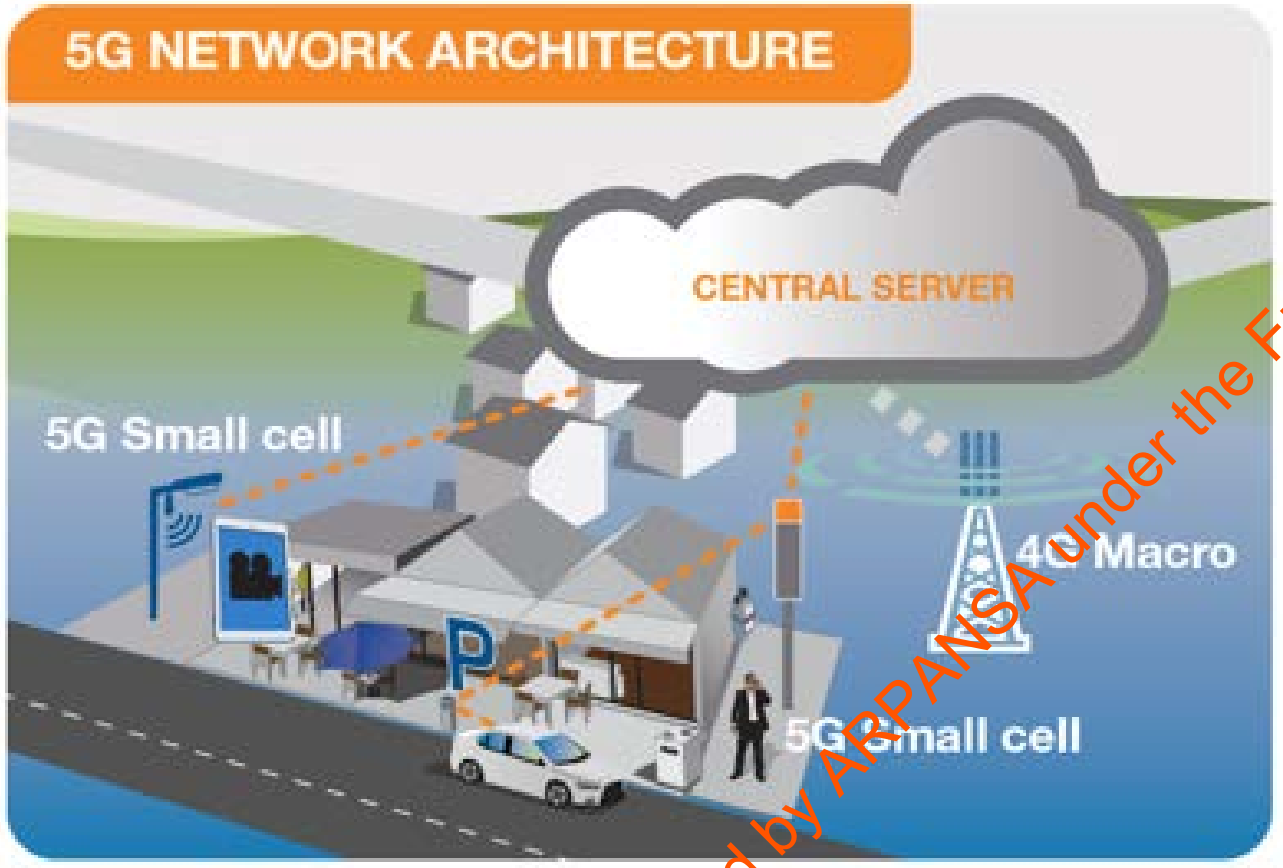


5G Technology – New Spectrum & Millimetre Waves



- New additional spectrum
- 5G uses frequencies from 600 MHz -100 GHz
- mmWaves start from 30 GHz
- Add significant bandwidth and capacity
- Maximise data throughput

5G Technology - Small Cells



- Small, low power mobile base stations
- Designed for very localised coverage
- Range 10 – 100's metres
- Complement macro base stations
- Fill in capacity & coverage gaps
- Reduce blackspots

5G Measurements – Using the IEC Standards

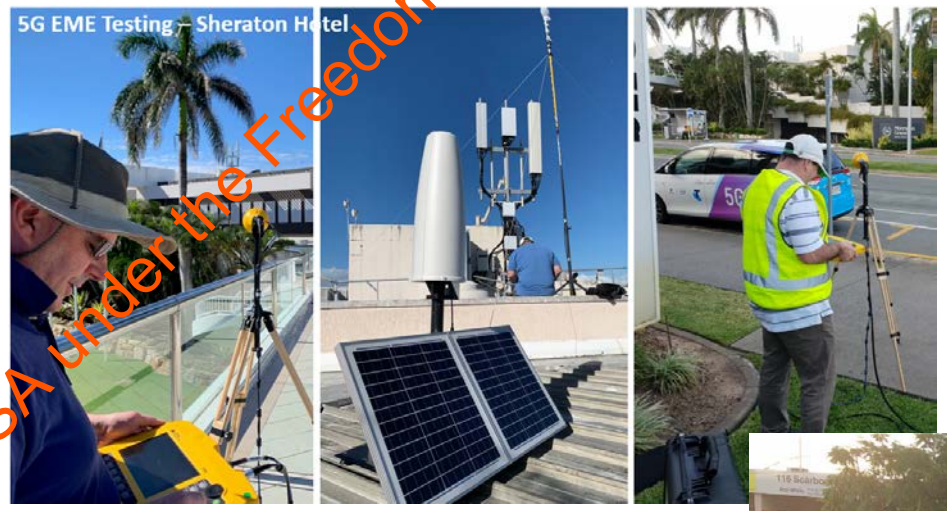
Telstra, Ericsson, Narda, & TRS have conducted extensive EMF testing of 5G on the trial 27GHz mmWave network in 2018 and the new 3.5GHz commercial network in 2019 in Australia

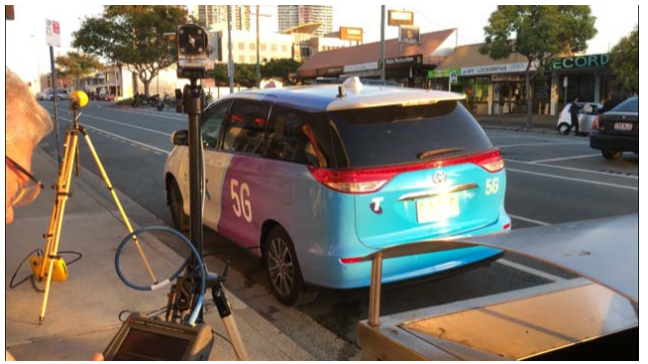
EMF tests included

- 27 GHz mmWave trial 5G network
  - indoor
  - outdoor

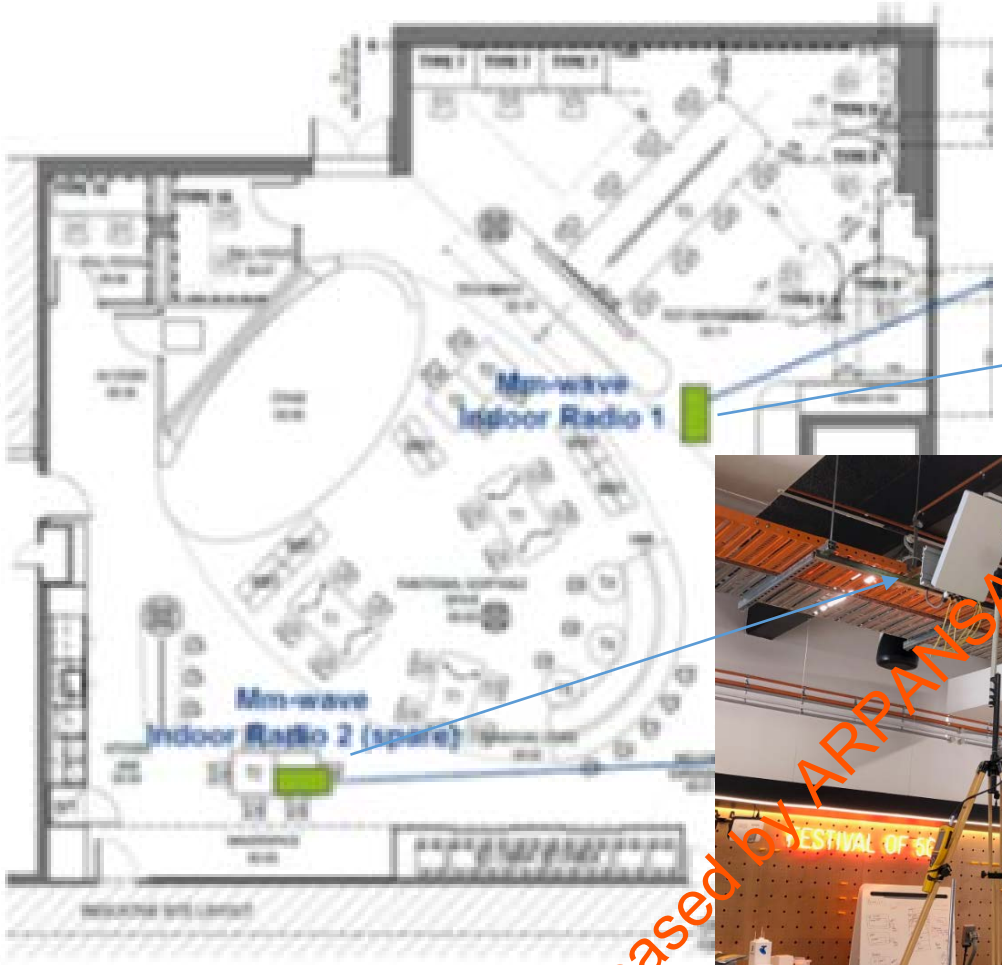
- 3.5GHz Commercial 5G Network

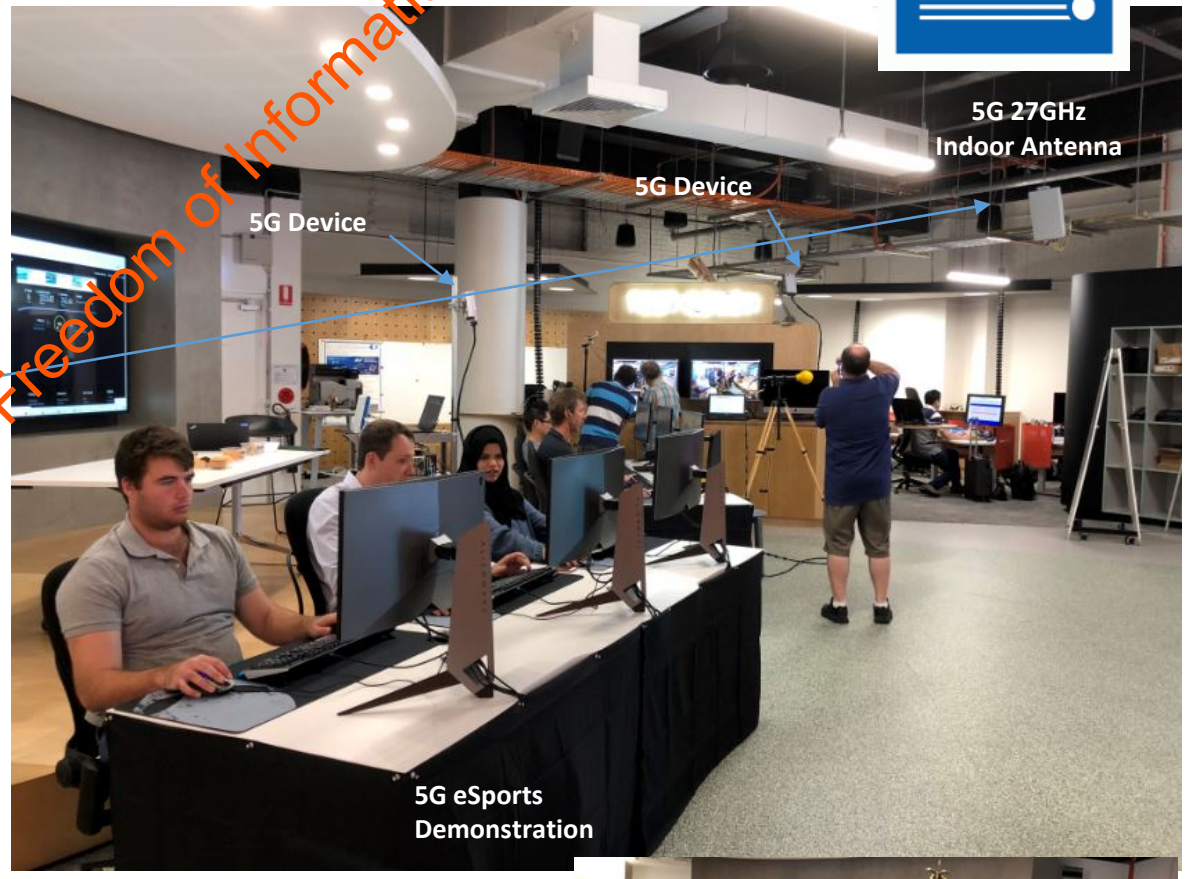
  - cafes
  - homes
  - schools
  - apartments
  - sporting fields
  - shopping centres



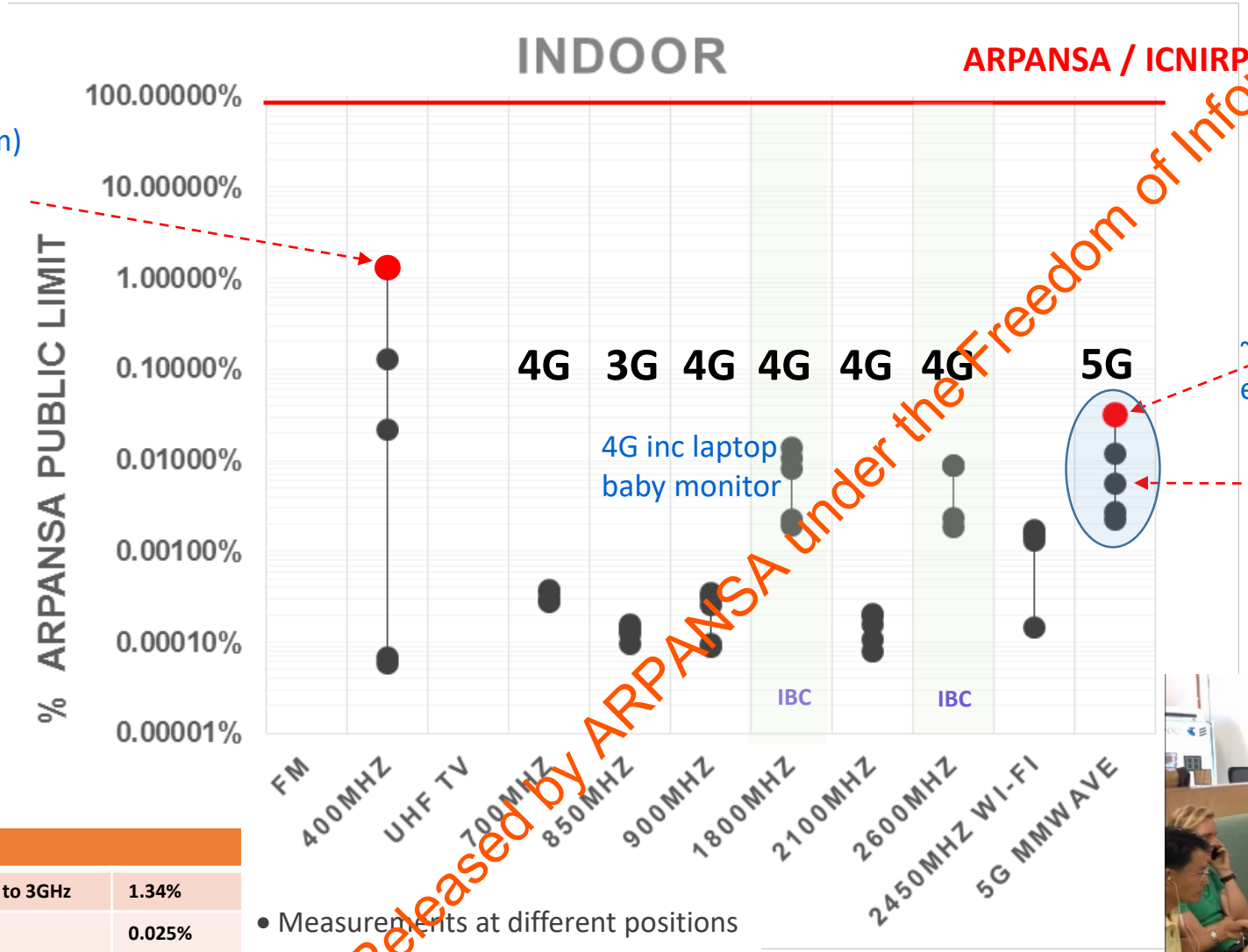


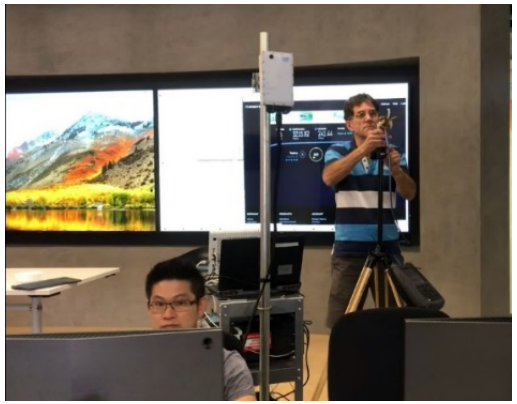
5G EME measurements – mmWave trial

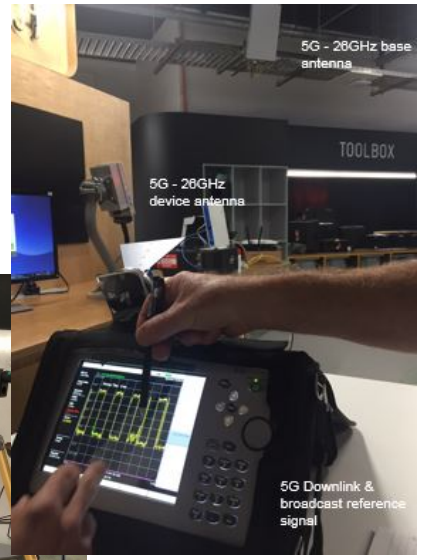


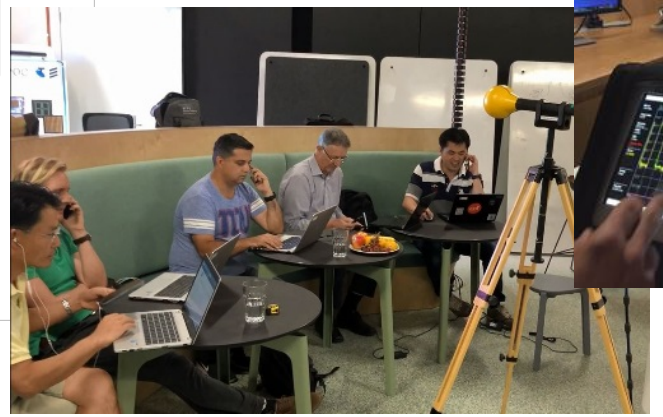


5G Environmental EME – mmWave trial









Highest exposure	
Cumulative: 27MHz to 3GHz	1.34%
3G, 4G, Wi-Fi	0.025%
5G (near UE antenna)	0.032%
5G (general environment)	0.012%

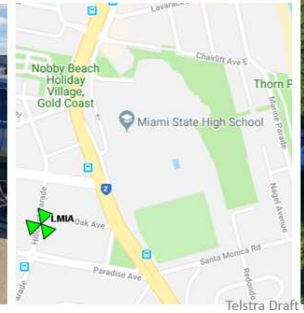
- Measurements at different positions

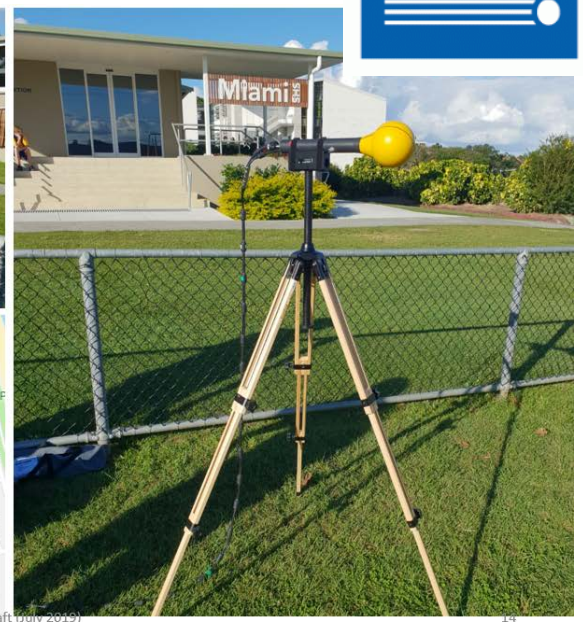
5G EMF Measurements – Gold Coast 2019





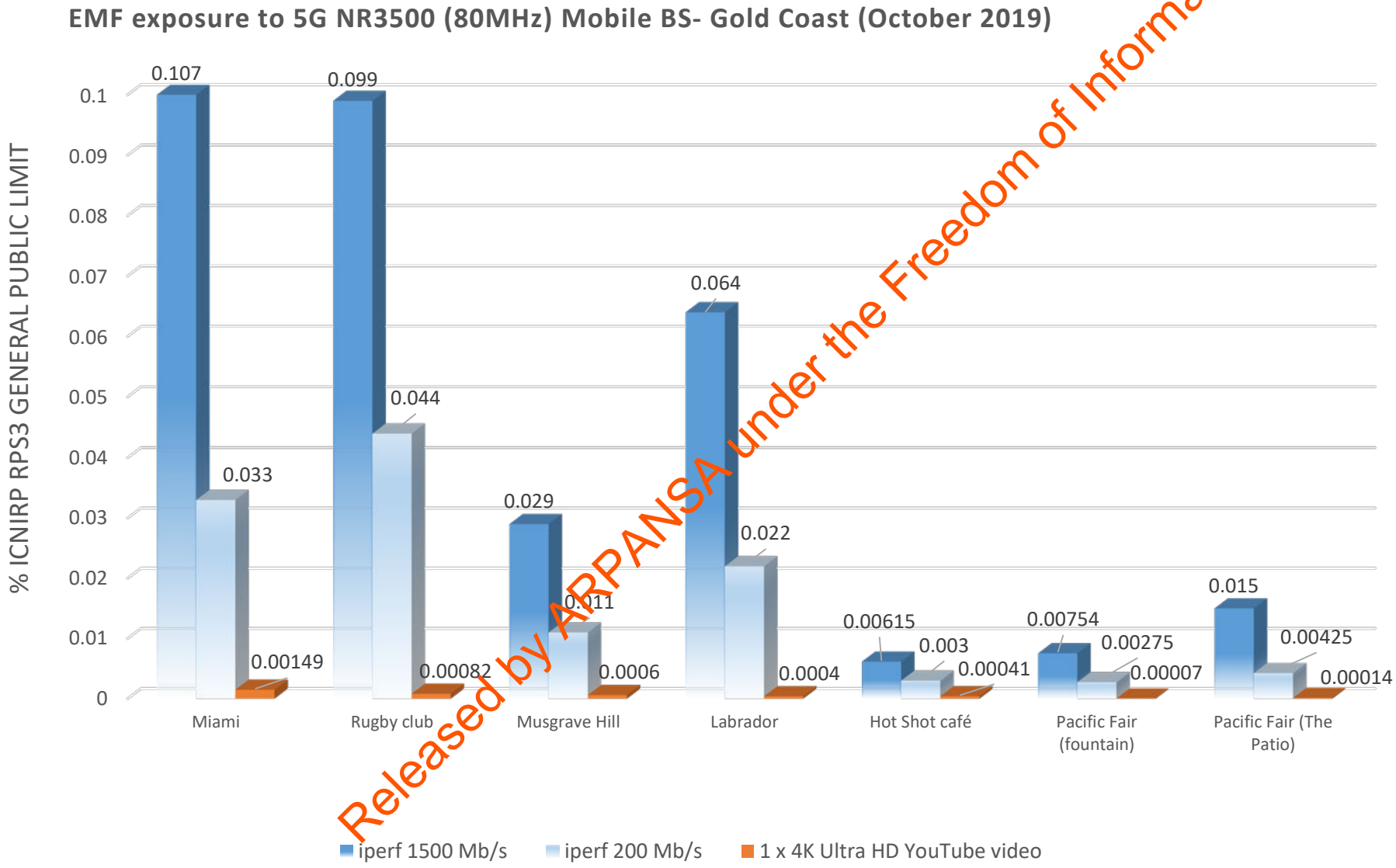

5G EME Testing – apartment with young engineers



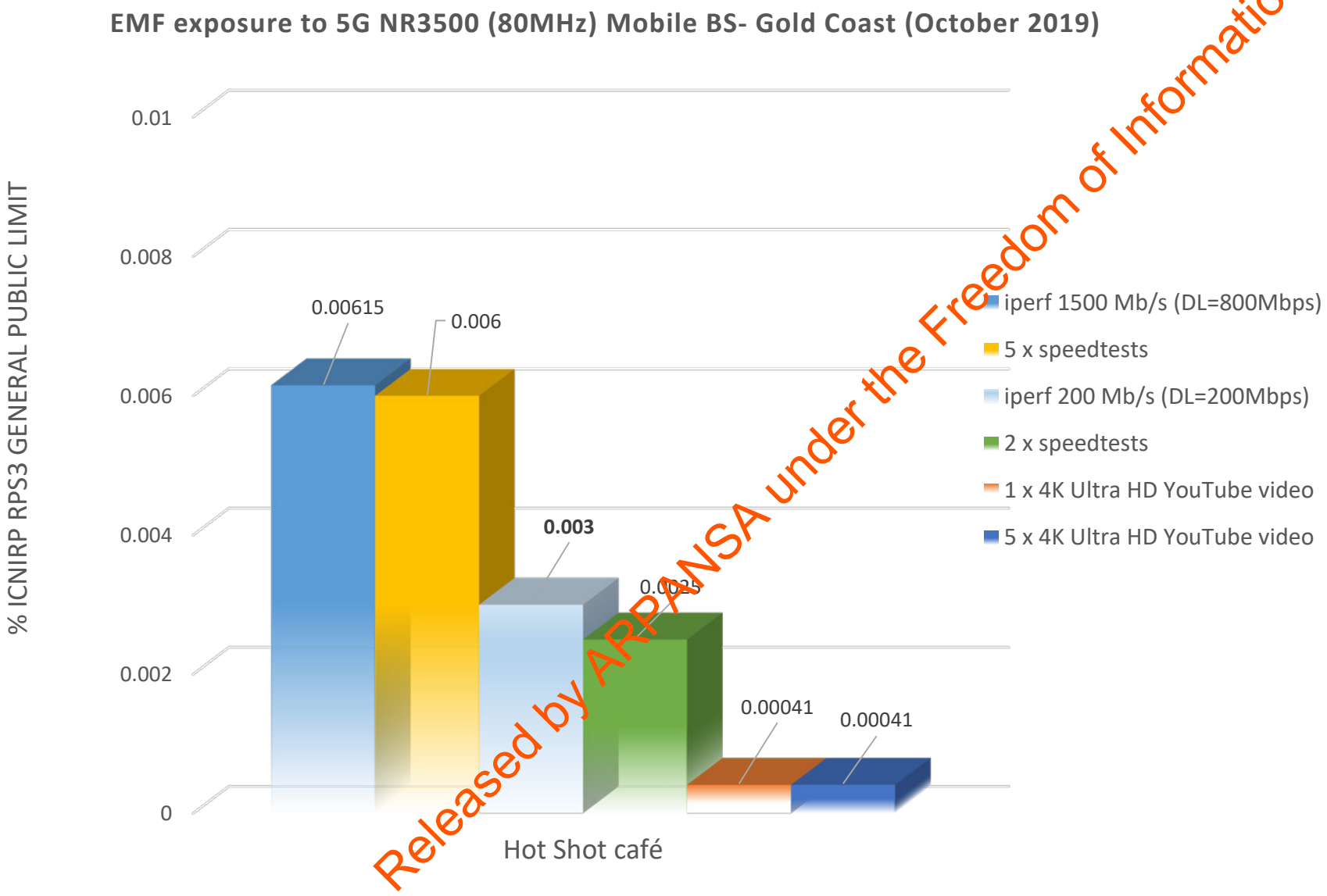


5G EMF Measurements – Gold Coast Oct 2019



5G Network configuration
80MHz / 160Watts
iPerf 1500 = near max pwr
iPerf 200 = 0.5 to 0.3 max pwr

5G EMF Measurements – Main Beach



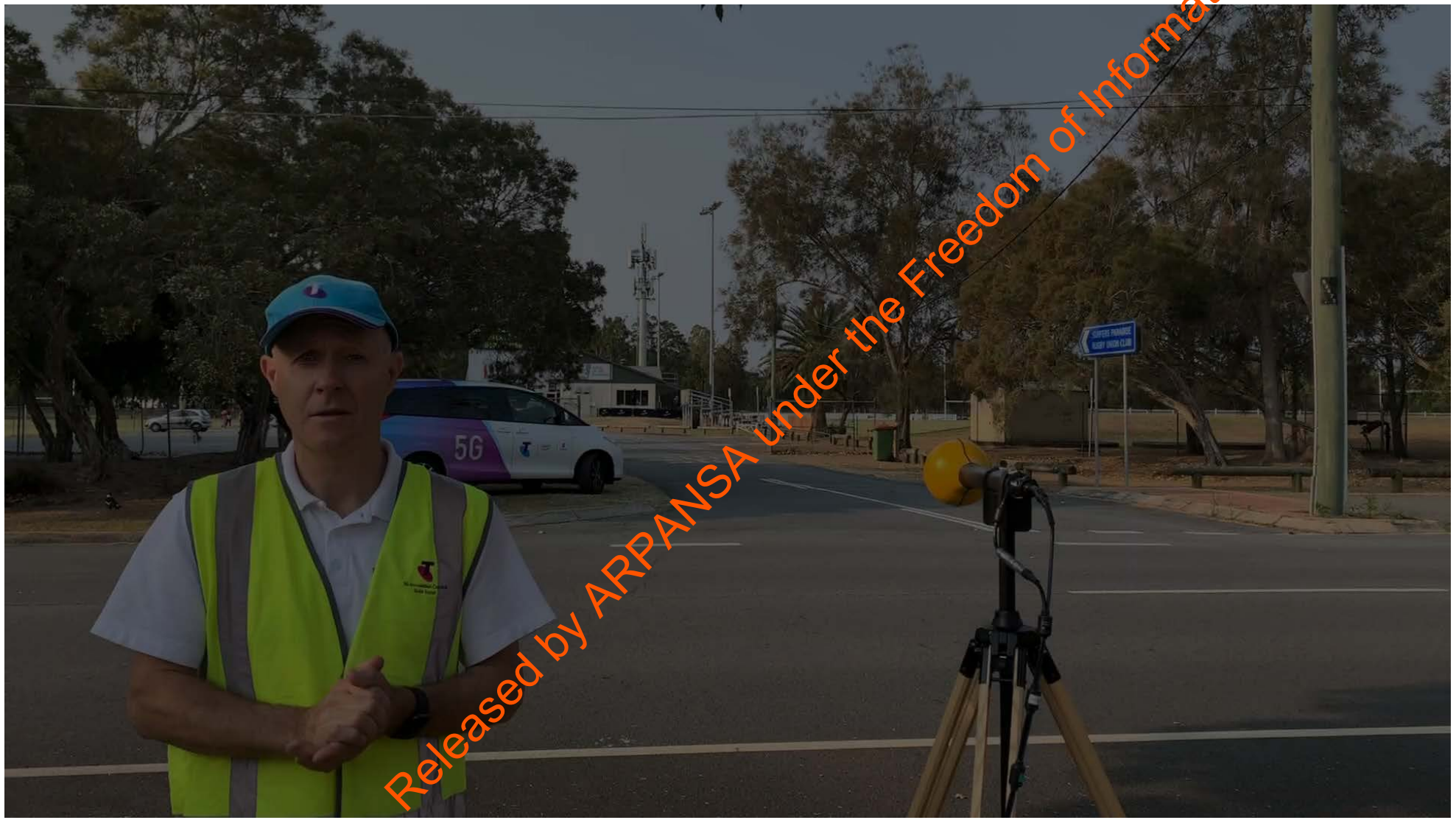
5G Network configuration
80MHz / 160Watts
iPerf 1500 = near max pwr
iPerf 200 = 0.5 to 0.3 max pwr

5G Technology – full load test indoors at max power

Speed test

iPerf load test

5G EMF Measurements – Gold Coast Oct 2019



IoT EMF & Connected Homes

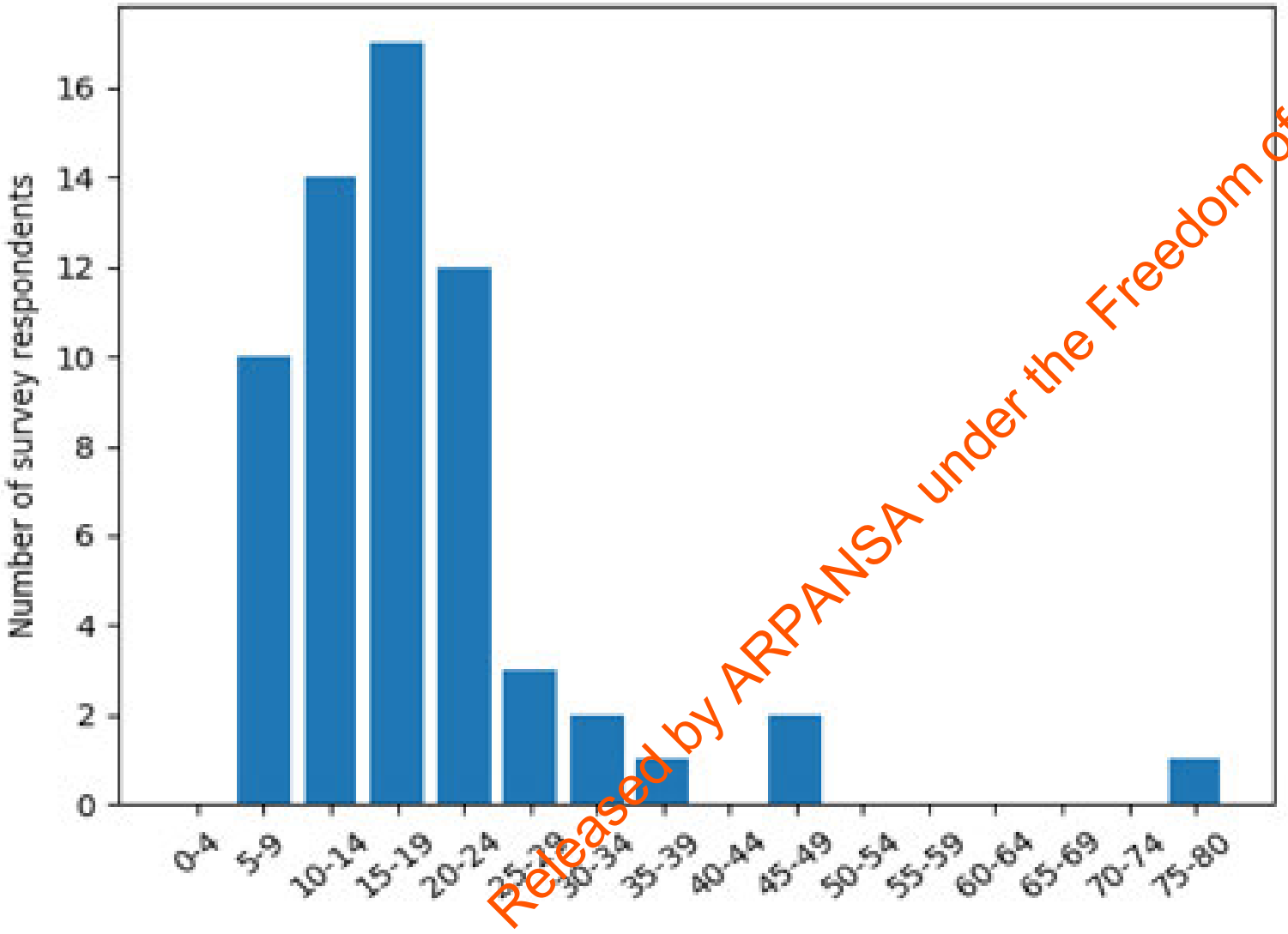
Telstra Smart Home EMF Survey

Aim:

Undertake RF measurements in residential homes to determine the electromagnetic energy (EME) levels from connected devices in the home

Following results were presented at the 2019 BioEM Conference by Telstra. The study is continuing.

IoT EMF & Connected Devices



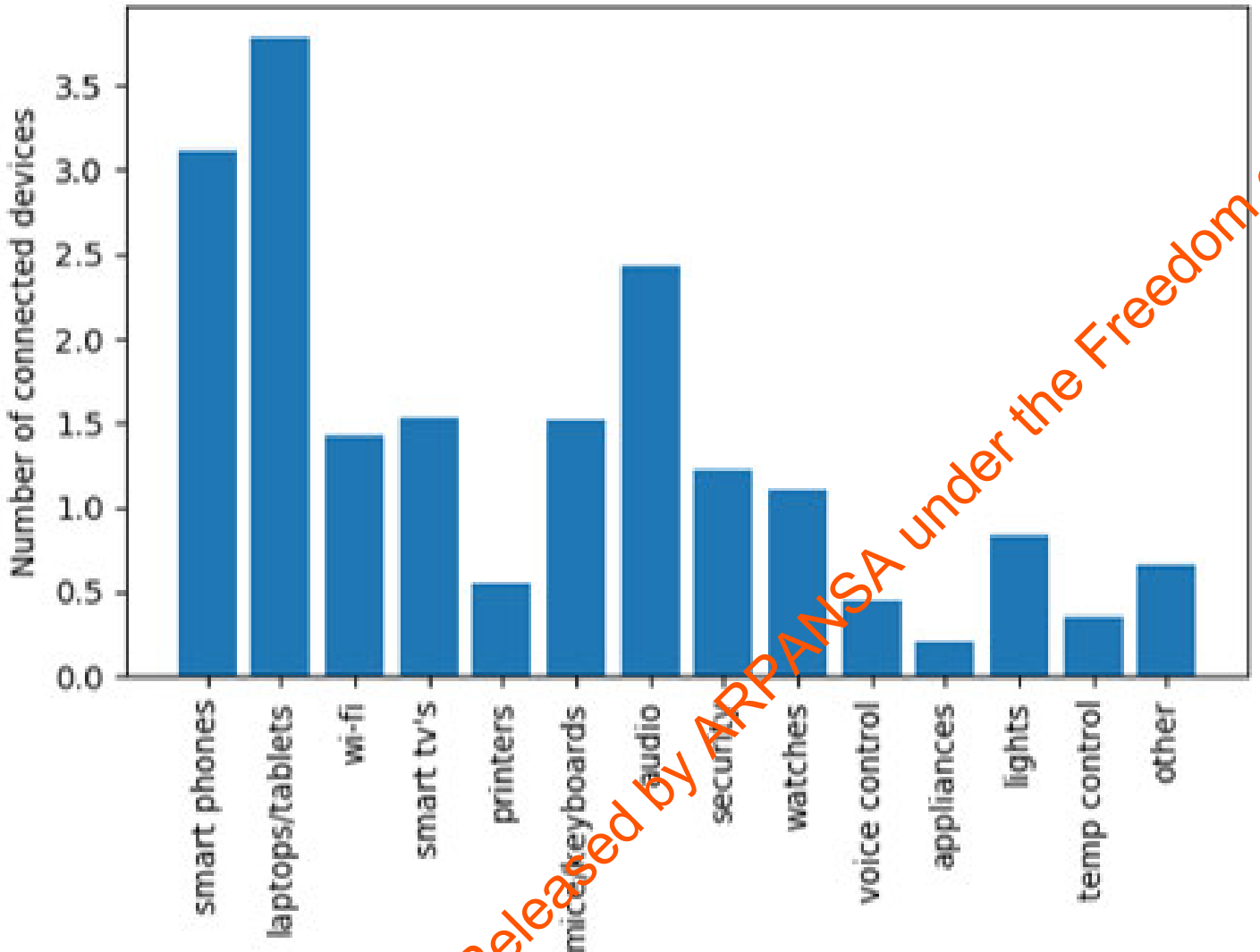
Average amount of device types from staff survey

Connected Devices

76 Telstra staff were surveyed to determine the average number and the types of connected devices people had in their homes.

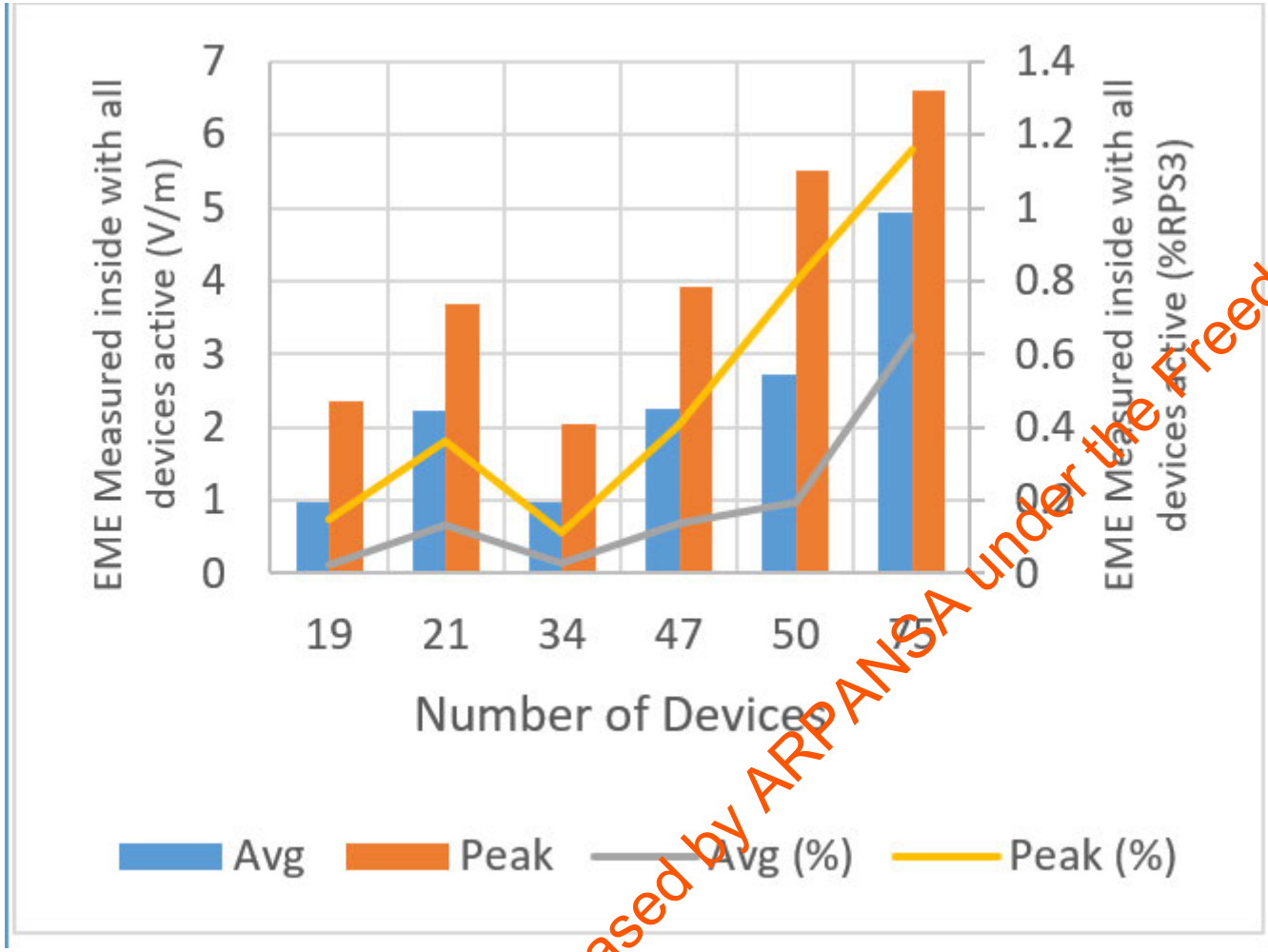
Devices ranged from phones, laptops and wireless headsets to smart lights, smart doorbells and smart home assistants

IoT EMF & Connected Device Types



Average amount of device types from staff survey

IoT EMF & Connected Homes



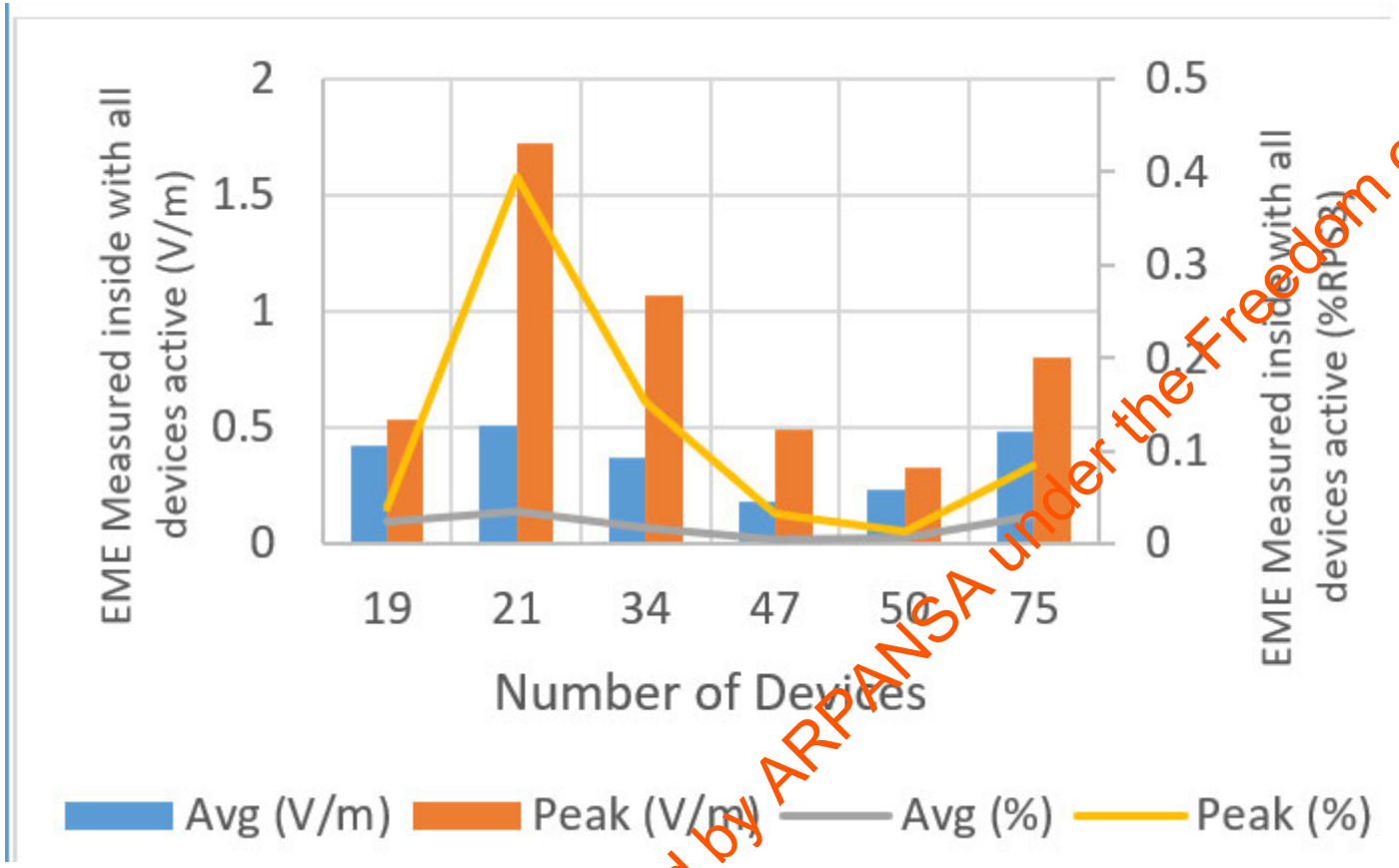
RELATIONSHIP BETWEEN THE NUMBER OF WIRELESS DEVICES AND THE EME MEASURED FROM THE WIFI ROUTER

Relationship between the number of devices in people's homes and the level of EME measured at 20cm from the Wi-Fi router

As expected a higher number of devices does correlate to a higher amount of EME.

However, even in the home with the highest number of devices, which was 75, the peak EME from the Wi-Fi router is 6.616 V/m which is 1.161% of the general public safety limit.

IoT EMF & Connected Homes



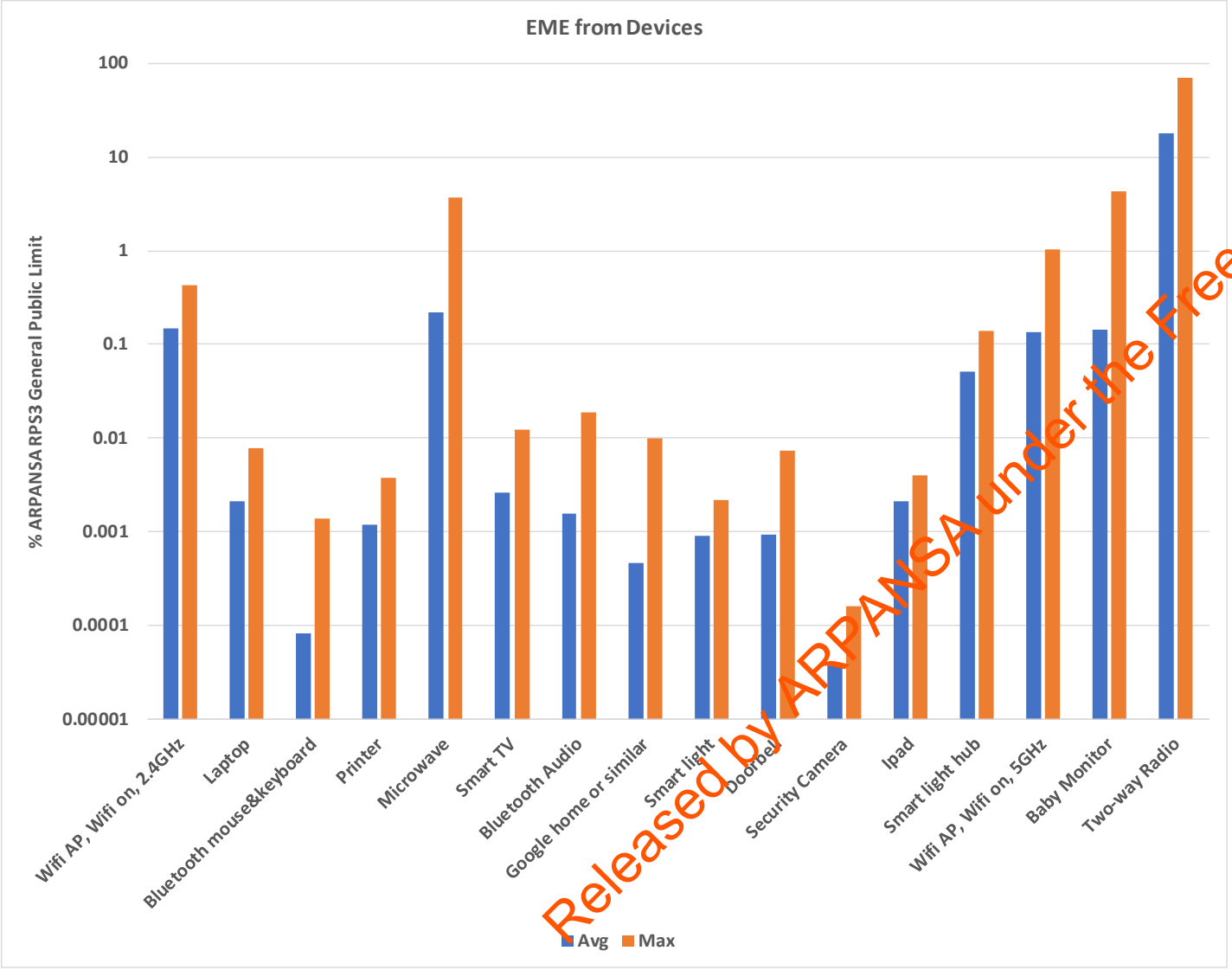
RELATIONSHIP BETWEEN THE NUMBER OF WIRELESS DEVICES AND THE EME LEVELS MEASURED IN THE HOME

Relationship between the number of devices in people's homes and the EME levels measured in the 'indoors, all devices on and active' scenario.

This suggests that even in homes with many devices the environmental EME level in the house is not a direct correlation

Area Monitor measuring EMF was located in the main living area

IoT EMF & Connected Devices



Device	% ARPANSA RPS3 GP Limit	
	Avg	Max
WIFI AP, Wifi on, 2.4GHz	0.1462	0.43
Laptop	0.0021	0.0079
Bluetooth mouse & keyboard	0.00008	0.0014
Printer	0.0012	0.0038
Microwave	0.22	3.73
Smart TV	0.0026	0.0125
Bluetooth Audio	0.0016	0.0188
Google home or similar	0.00046	0.0099
Smart light	0.0009	0.0022
Doorbell	0.00094	0.0073
Security Camera	0.000038	0.00016
iPad	0.0021	0.0041
Smart light hub	0.052	0.14
Wifi AP, Wifi on, 5GHz	0.14	1.02
Baby Monitor	0.14	4.31
Two-way Radio	17.61	70.45

Interim results from current testing

5G & EMF – How does it compare to EMF from the Sun

5G & EMF – Conclusions & Observations

- **5G Technology** - uses radio frequency like existing mobile technologies and other radio services inc TV, FM, emergency and commercial services, microwave links & satellite
- **5G EMF testing standards -** have been developed by the IEC / IEEE
- **5G EMF levels from base stations -** are similar to 3G, 4G and Wi-Fi.
- **5G EMF levels were found to be well below the ICNIRP exposure limits -** and in many cases over a thousand times lower.
- **IoT EMF levels are low -** and compliant with the ICNIRP exposure limits

Thank you - Questions ?