INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

# EMF Standards for 5G technologies

**Human exposure compliance assessment procedures for mobile device and network equipment operating from 6-100 GHz**


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**Telecom ParisTech EMF Day**

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# Presentation Overview

- What is 5G?
- Benefits to society of 5G
- How does 5G work?
- 5G Standards Challenge
- EMF Standards for 5G
- 5G Compliance Assessment Methods
- 5G Device and Base Station Assessments
- Conclusions

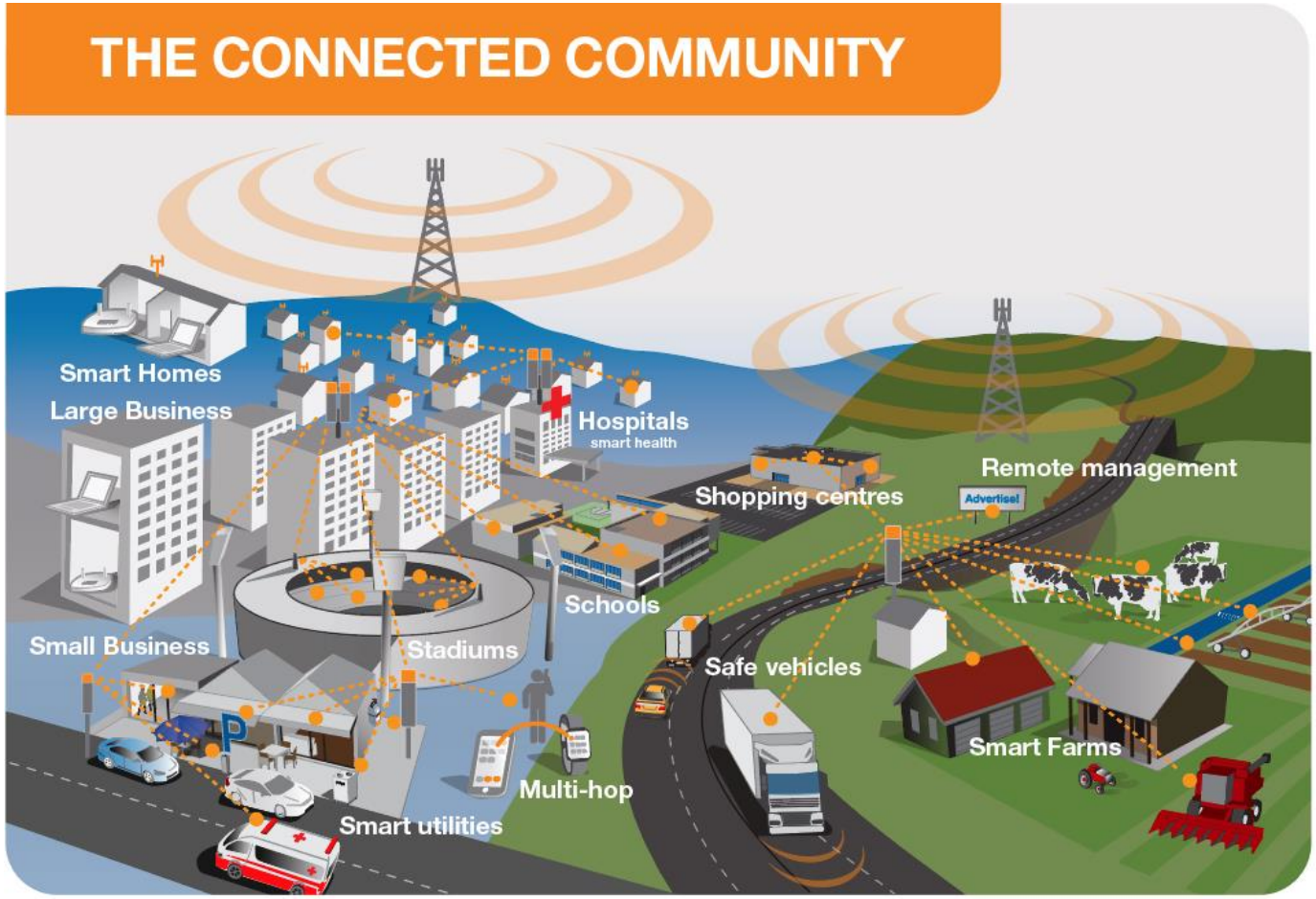
# What is 5G?

## 5G is the 5th generation of mobile

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

| 1G | 2G | 3G | 4G | 5G |
|---|---|---|---|---|
| 1980s | 1990s | 2000s | 2010s | 2020 |
| Analogue | Digital<br>SMS | Multimedia<br>Video Calling<br>Mobile internet | Mobile Broadband<br>Enhanced Video | Mobile Connected World<br>Enhanced Mobile Broadband<br>Low latency applications<br>Internet of Things<br>AR & VR |

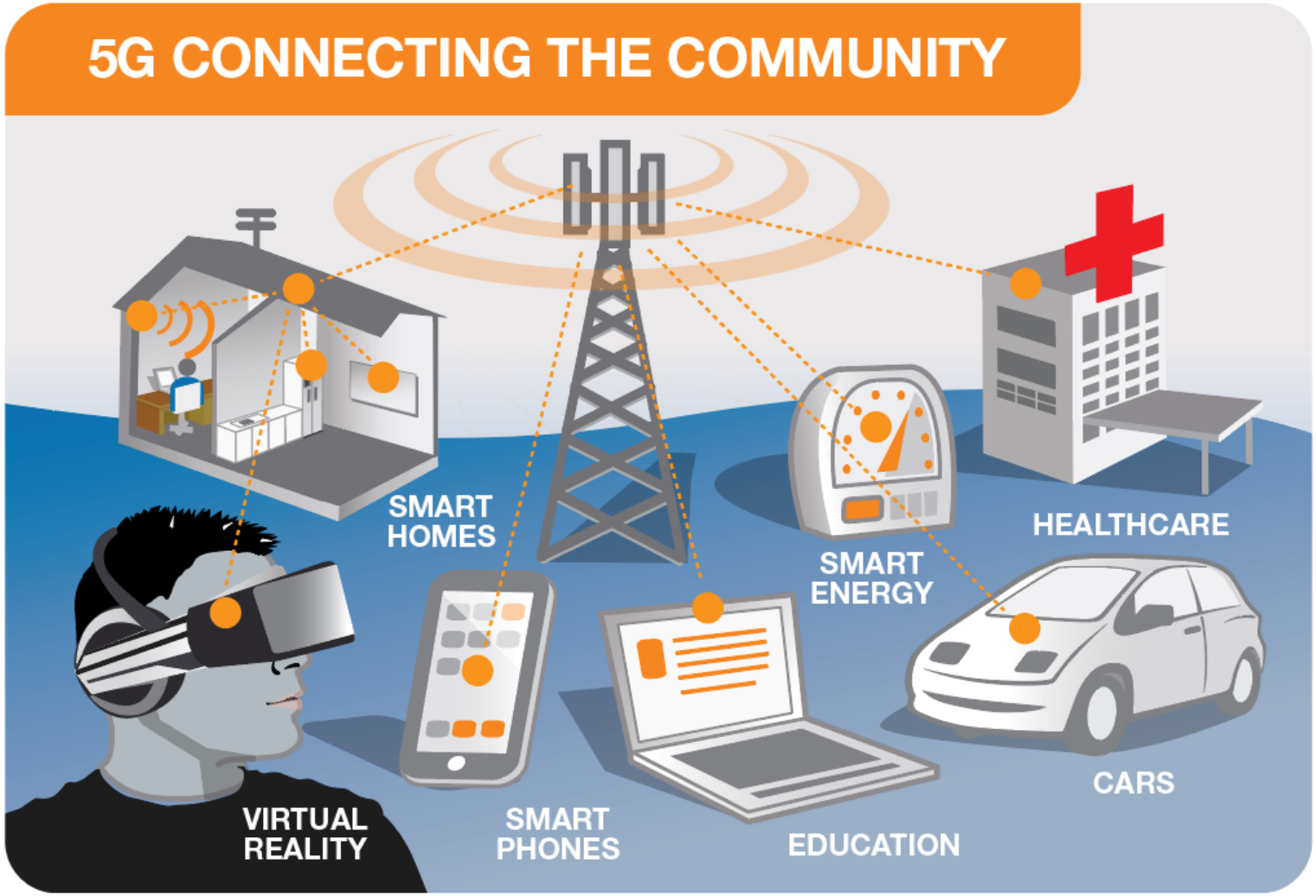
# 5G – Connecting the Community




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

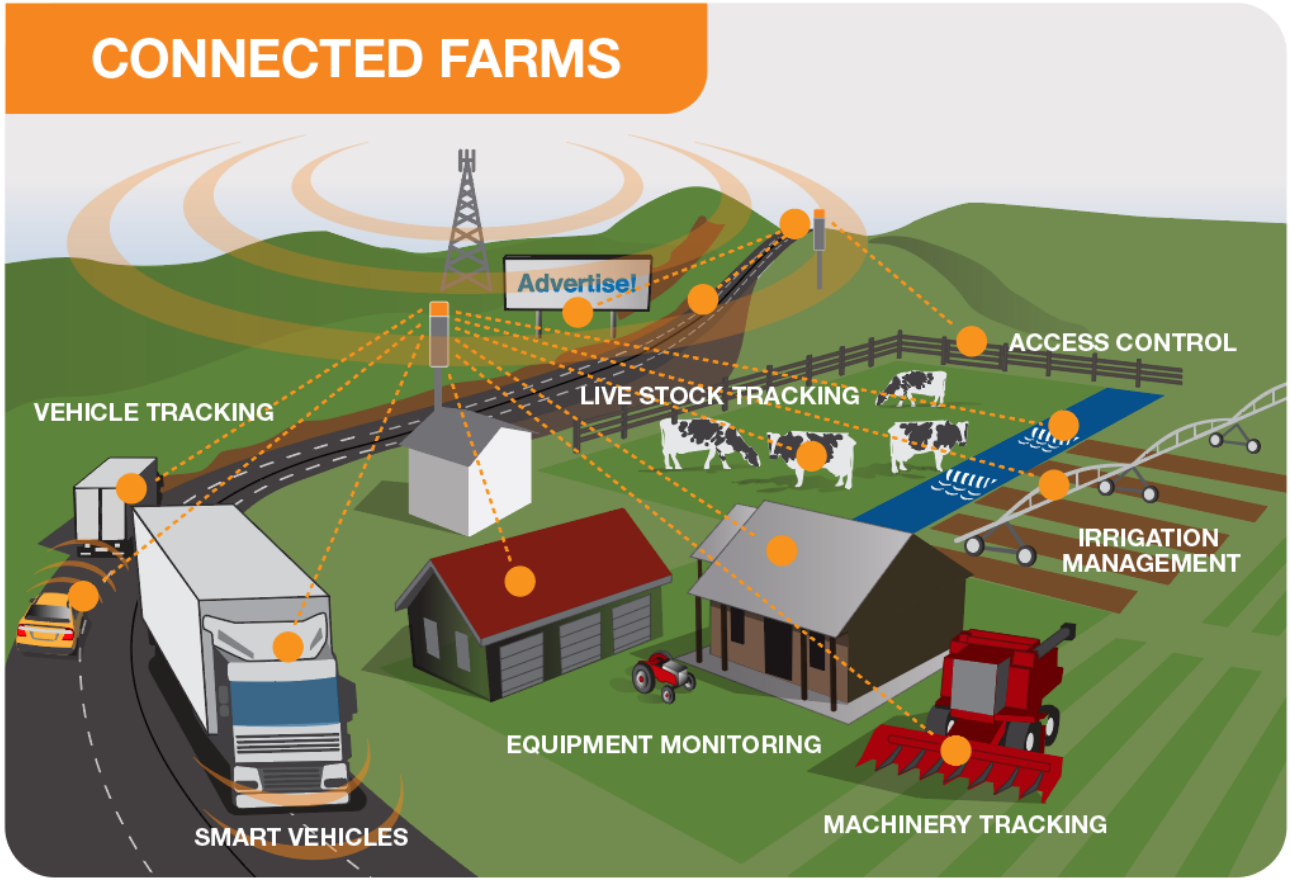
**5G uses radio waves or radio frequency (RF) energy to transmit and receive voice and data connecting our community.**

# Benefits to society




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

# Benefits to society – connected farms

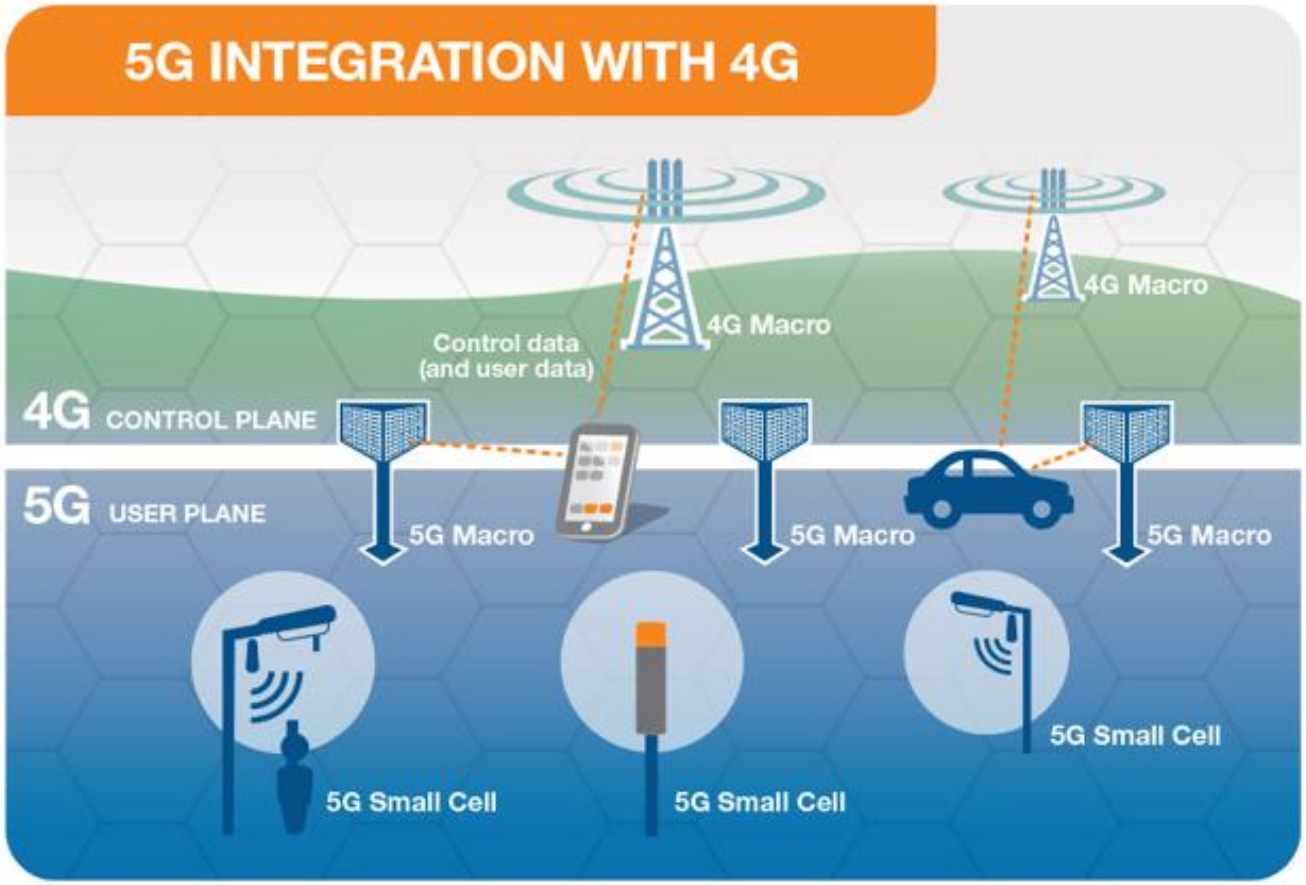



5G enabling smart agriculture and connected farms through

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

**By 2023 connected farms will be standard practice**

# How does 5G work?




5G works together with 4G (initially non standalone NSA)

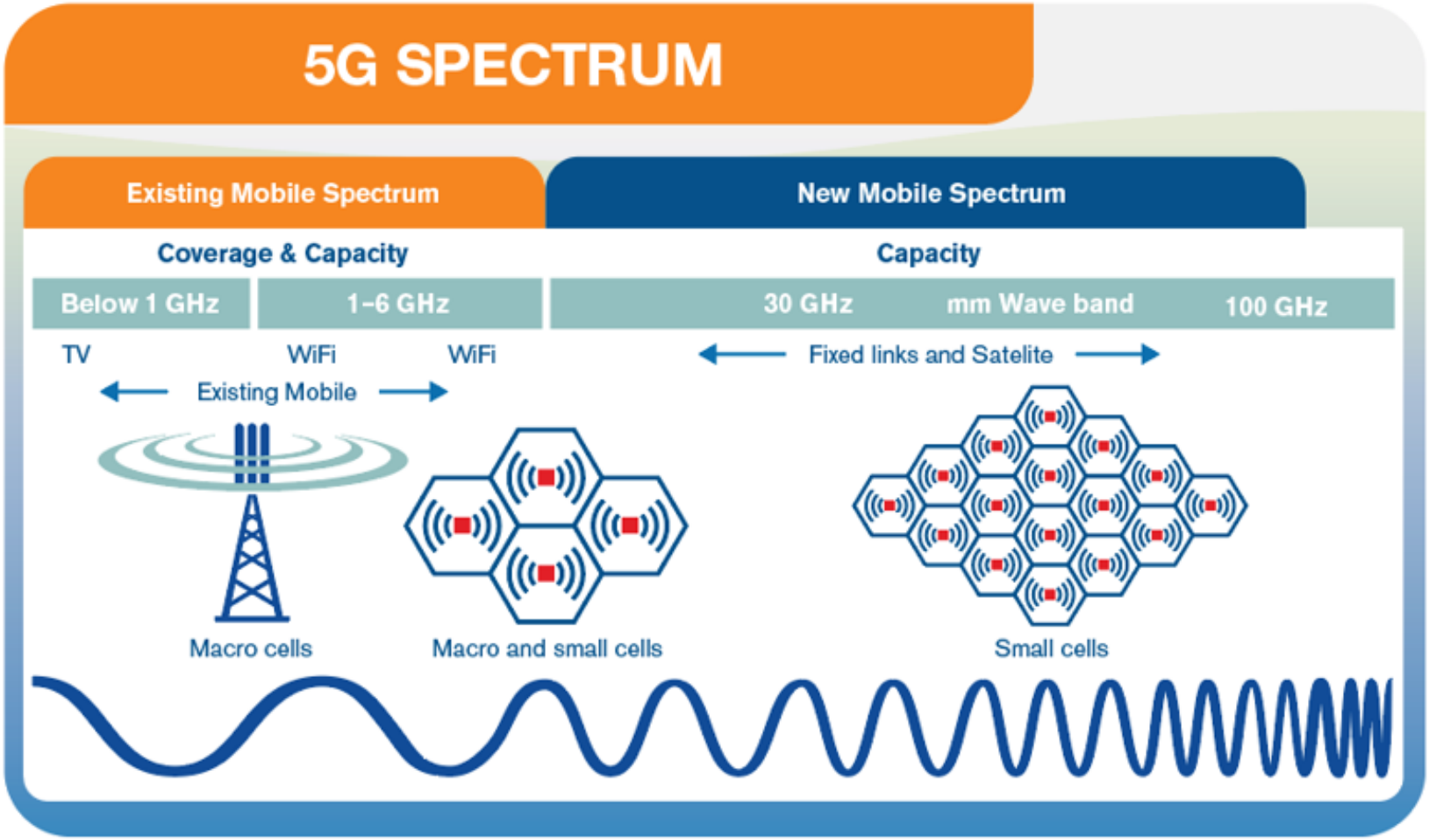
4G acts as control plane

5G acts as data/user plane

5G will operate stand alone in later releases

**Early 5G deployments will work together with 4G**

# How does 5G work - spectrum




<1 GHz Coverage, IoT,
1-6 GHz Coverage, IoT, Capacity
> 6 GHz Capacity, extreme data rates

# 5G Standards Overview

- There is a rapid development of new wireless technologies in the frequency range 6-100 GHz

- There is a requirement to ensure that human exposure compliance assessment procedures are developed for
  - devices used in close proximity to the head and body
  - base stations and network equipment

- Existing compliance assessment standards only go to 6GHz

- 2018 - 5G Test and Demonstration Networks
- 2019 - 5G Technology standards finalised
- 2020 - 5G Commercial Systems

**Challenge -** TC106 has responsibility to develop assessment standards for devices and networks to 100GHz (by 2018)

# EMF Standards for 5G

- Human Exposure Standards – set by Health Authorities & Governments
  (Global – ICNIRP/WHO, & Local - ARPANSA)

- Compliance Standards – set by International Standards Organisations
  (Global - IEC, ITU, & Local - Standards Australia)

**Key Point –** Global approach provides harmonised standards for communities, governments, industry and stakeholders

# 5G Exposure Limits

- Frequency bands available for 5G extend up to 100 GHz
- For frequencies above 10GHz, SAR is not a valid compliance assessment as the RF energy is only deposited into the skin and near body surface resulting in surface heating.
- The International (ICNIRP) exposure guidelines require the assessment of incident power density at frequencies above 10GHz.
- Likewise, the US exposure limits (IEEE standard C95.1 2005) requires the assessment of incident power density above 6 GHz.

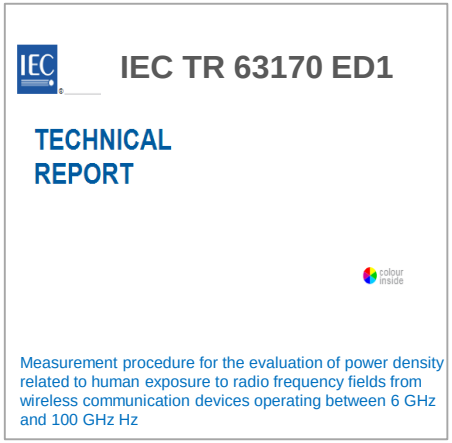
**ICNIRP Guidelines for Human Exposure**
Between 100 kHz and 10 GHz, basic restrictions on SAR are provided to prevent whole-body heat stress and excessive localized tissue heating; in the 100 kHz–10 MHz range, restrictions are provided on both current density and SAR. The localised head and body general public SAR limit is 2.0 W/kg

**Between 10 and 300 GHz,** basic restrictions are provided on incident power density to prevent excessive heating in tissue at or near the body surface. The localised head and body general public incident Power Density limit is 10W/m$^2$

# 5G Compliance Assessment Standards

**5G Devices** (e.g. handsets, hotspots, modems, sensors)

- IEC device testing procedure is required by 2018 for the 5G trials
- An IEC Technical Report was developed in 2017 that specifies the generic high level measurement requirements – (AdHoc Group 10)


IEC TR 63170 ED1

TECHNICAL REPORT

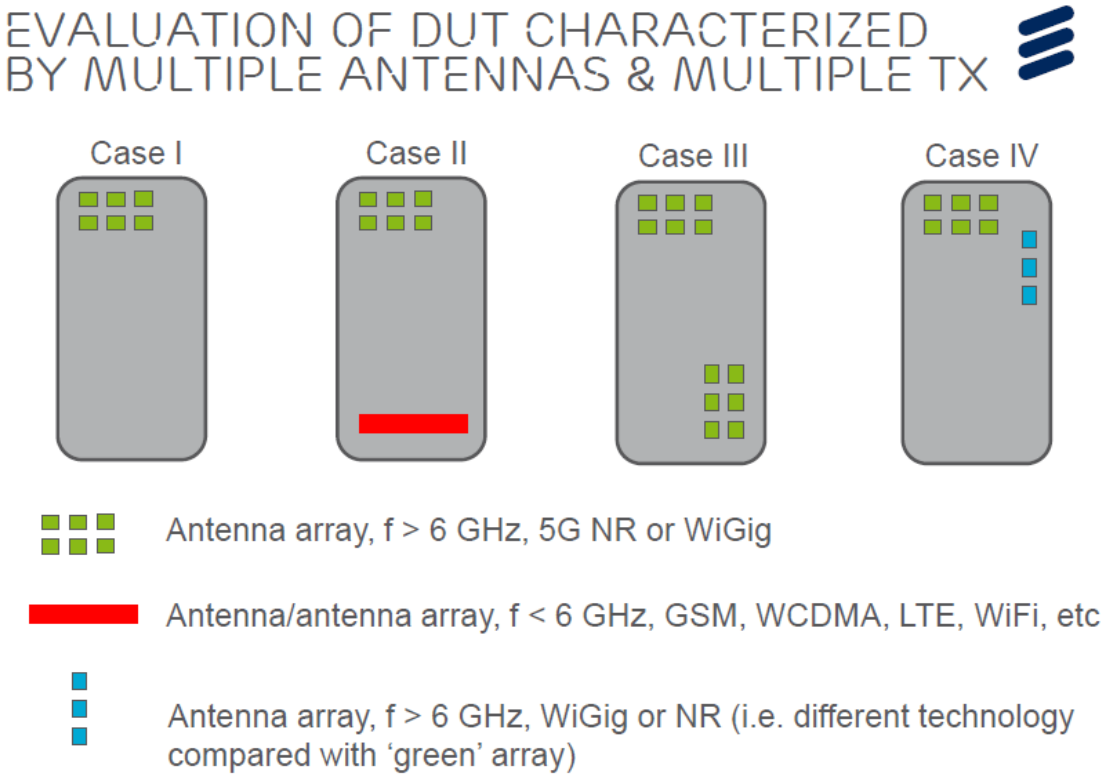
Measurement procedure for the evaluation of power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 100 GHz Hz

- An IEC International Standard to commence drafting in 2018 using the Technical Report as the starting point to be completed by 2020

  - Joint IEC/IEEE numerical assessment standard – lead by IEEE
  - Joint IEC/IEEE measurement assessment standard – lead by IEC

# 5G Compliance Assessment Standards

**5G Devices** – AHG10 evaluated the challenges of device measurements with multiple technologies and 5G New Radio




Source – Ericsson presentation to IEC AHG10

# 5G Device Technical Report Overview

## INTRODUCTION

- Describes IEC TC106 plan > 6 GHz; defines scope

## MAIN BODY

- general measurement procedure
- guidance on uncertainty
- reporting
- recommendation for future std. work

- Describes measurement approaches to conduct basic compliance assessment of portable devices (overview of measurement methodologies, operating modes, test frequencies, DUT positioning, evaluation surfaces, multiple tx, etc.)
- Provides recommendation for future standardization work related to EMF compliance assessment methodologies of wireless equipment (devices and base stations) including measurements and numerical approaches

## APPENDICES

- system check/validation and reference sources
- applicability of FF methods
- averaging shape
- reconstruction algorithms
- mixed numerical and experimental approach
- case studies

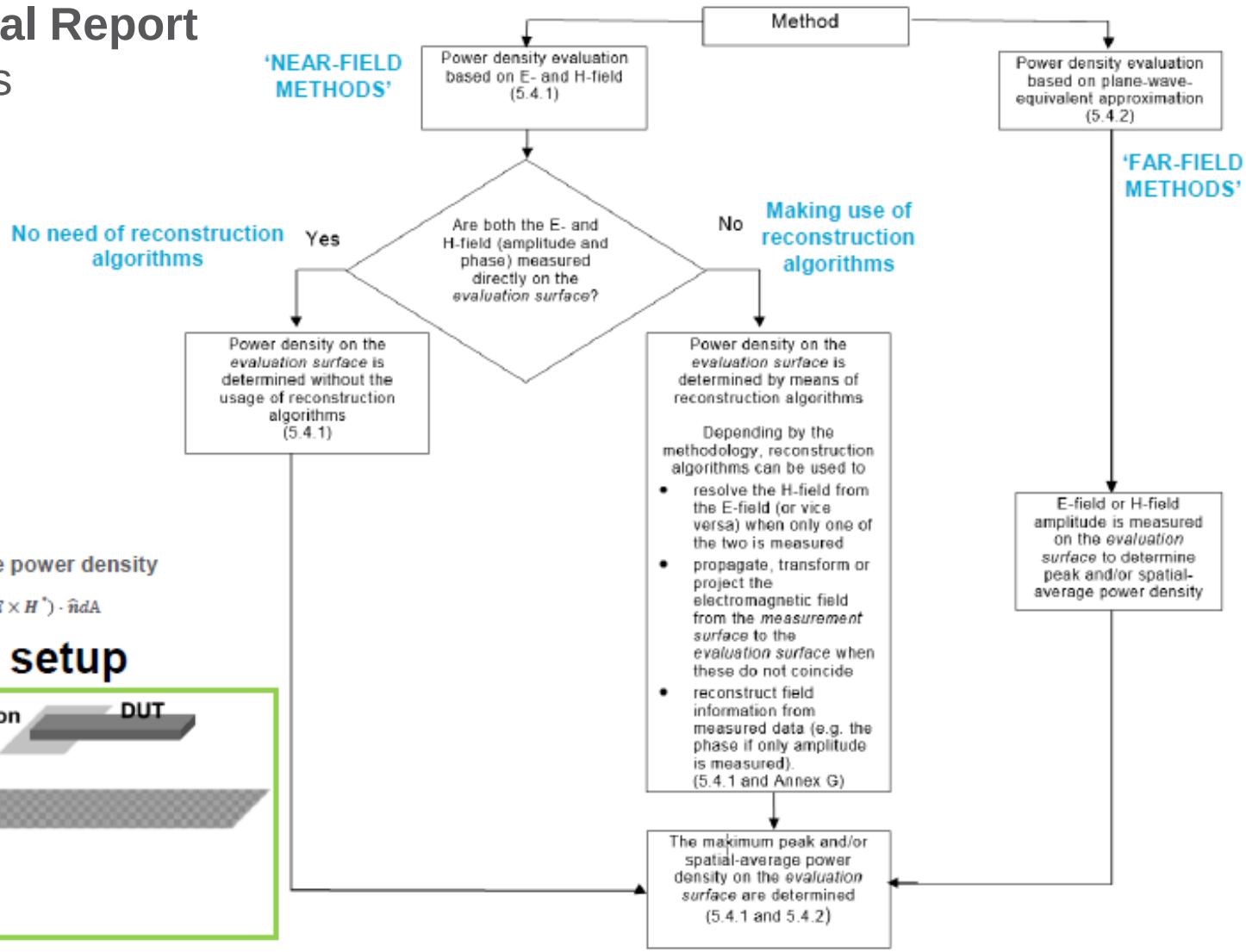
- Describes system check and validation procedures; provide examples of reference sources
- Provides insights on far-field measurement methods
- Provides insights on the power density averaging shape
- Provides info on reconstruction algorithms (e.g. field back-projection, phase retrieval, etc.)
- Describes an approach where measurements and simulations are used in combination to assess compliance for a WiGig device
- Provides exposure assessments examples based on realistic test scenarios

Source – Ericsson presentation to IEC AHG10

# 5G Device Compliance Assessment Method

## IEC Technical Report

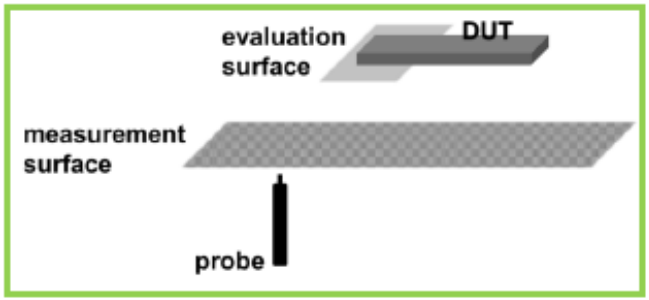
Test methods




Spatial-average power density

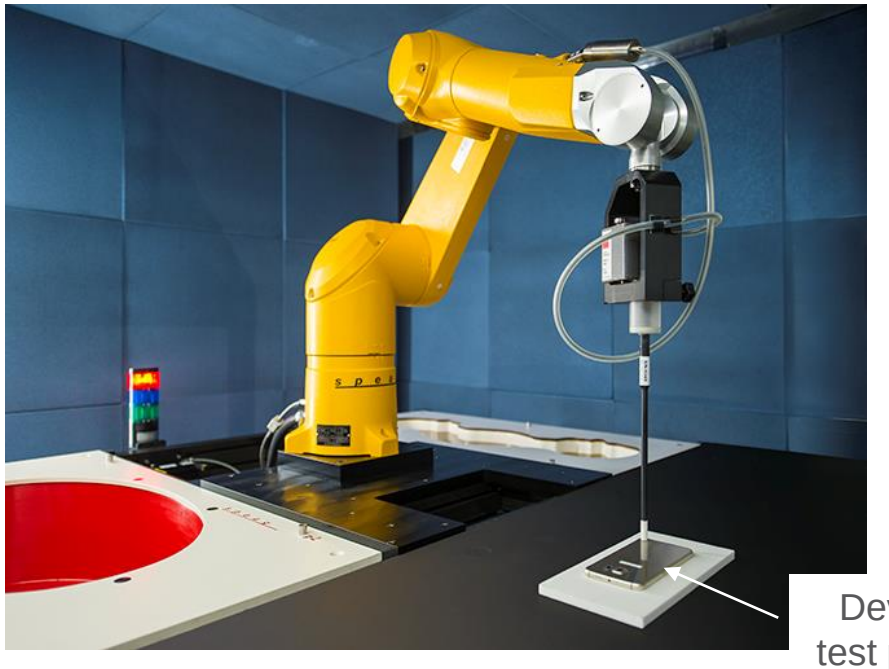
$$S_{av} = \frac{1}{2A}\mathrm{Re}\int(\boldsymbol{E}\times\boldsymbol{H}^{*})\cdot\hat{\boldsymbol{n}}dA$$

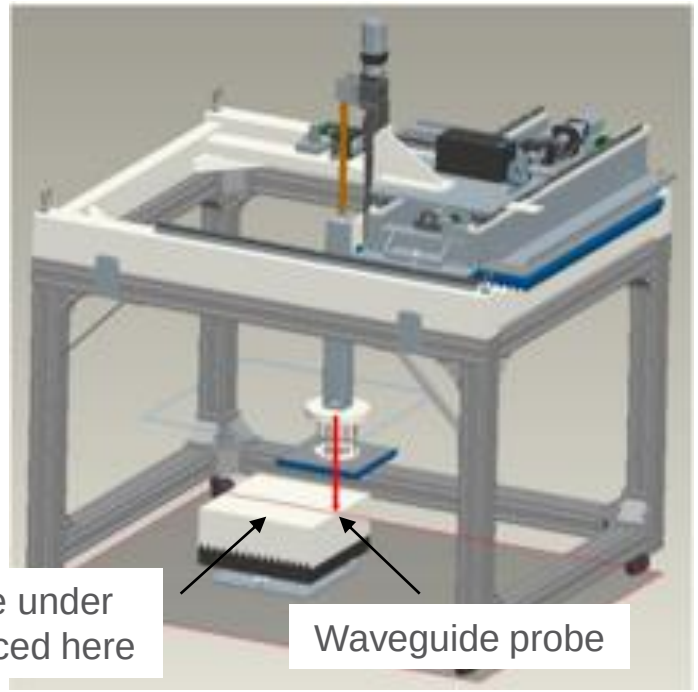
**Generic setup**



# 5G Device Test systems

Laboratory 5G device compliance test systems



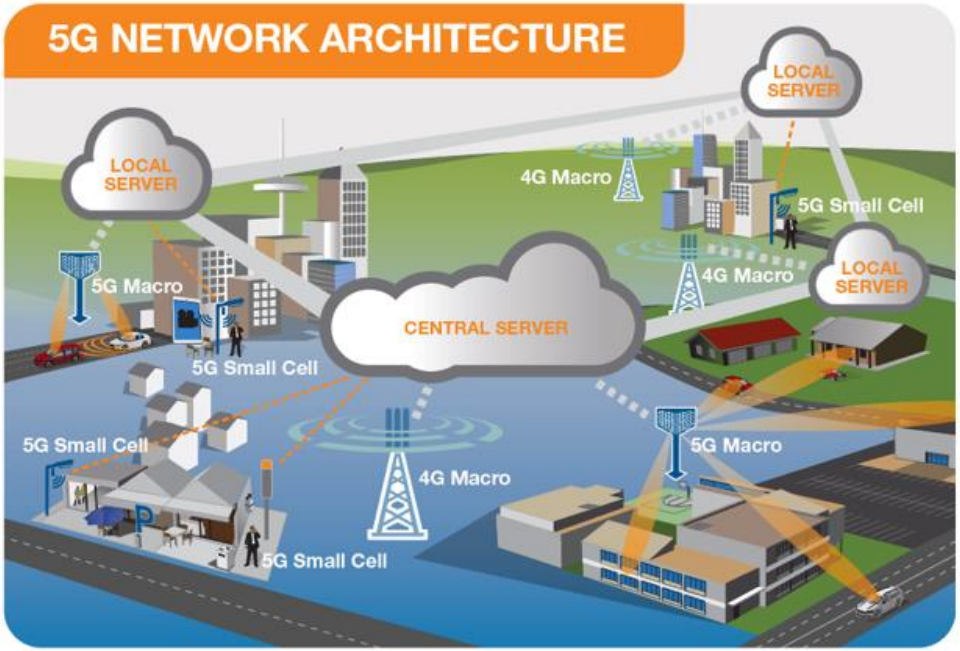

Two example robotic laboratory test systems were presented at the 2016 BioEM conference MMF 5G workshop - http://www.bioem2016.org/mmf-workshop

# 5G Compliance Assessment Standards

## 5G Networks & Radio Base Stations

- IEC62232 ED2 published in 2017 - extends to 100GHz (5G)
- A case studies Technical Report supporting IEC 62232 for 5G compliance assessment procedures is being developed
  - demonstrates base station assessment methods

Case studies
- Small cells
- Macro cells
- 3G,4G,5G Macro
- MIMO beam steering

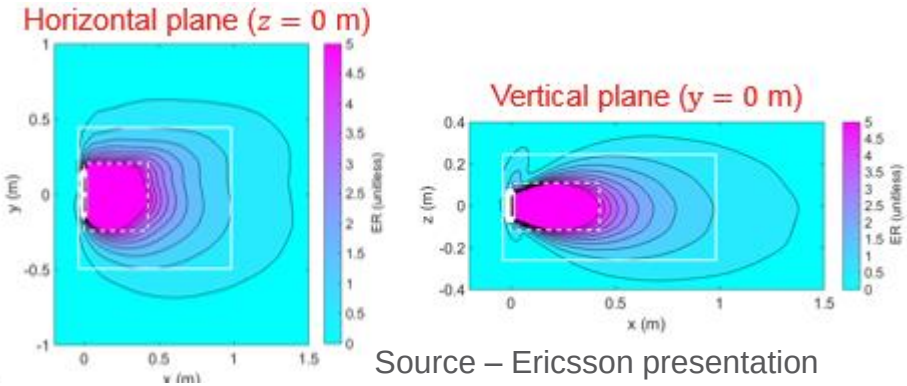



Source – Ericsson 5G and Health

# 5G Base Station – 15GHz Test Bed Assessment using IEC 62232

## EME Assessments for 5G Base Stations

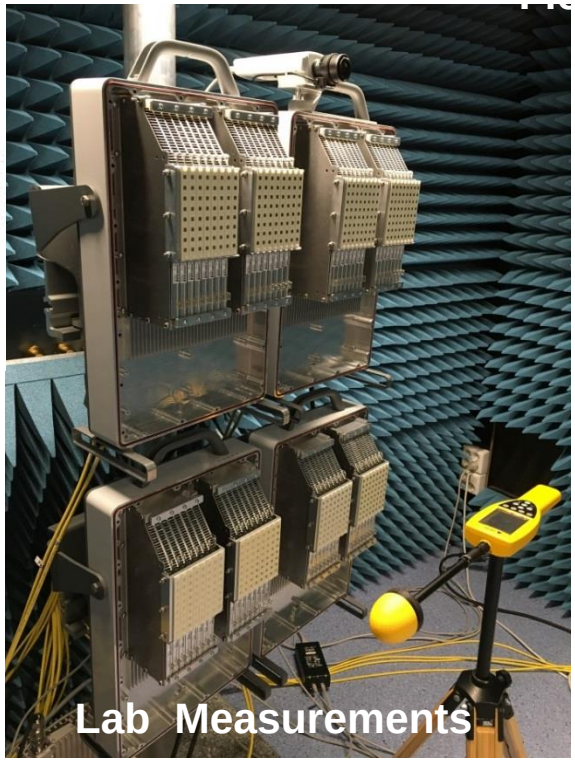
- Computer modelling
- Field Measurements
- Laboratory Measurements




Source – Ericsson presentation

- Calculations matched measurements using IEC 62232
- Verifies approach

- Public Exposure Limit = 1.0m
- Worker Exposure Limit = 0.4m

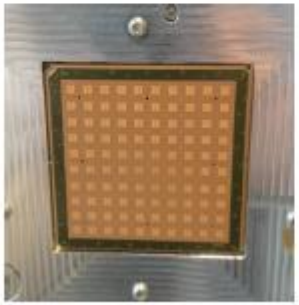



Phased antenna array at the Ericsson 5G Test Bed

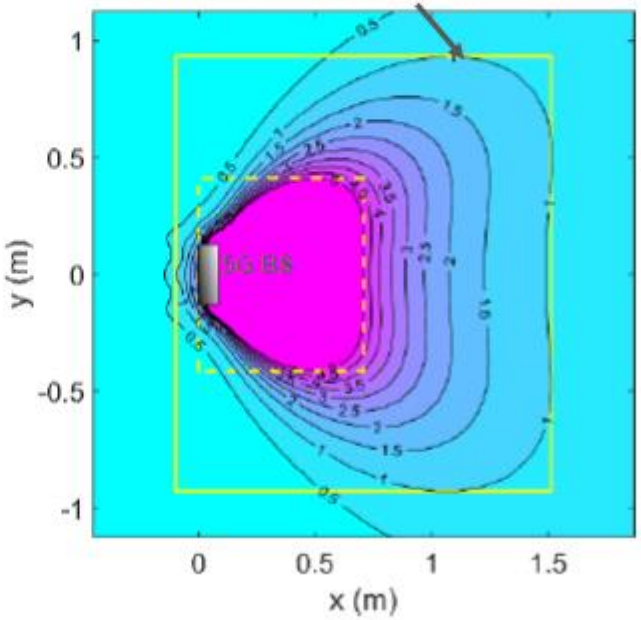
Note: The Broadband probe as shown here is mainly used for field measurements. This test was a laboratory check

# 28 GHz 5G massive MIMO small cell

**Ericsson AIR 5121**
28 GHz
512 antenna elements
8 beams
< 1 W total output power
24 dBi antenna gain
Beam steering: ± 60° (h), ± 15° (v)

Exclusion zone, 10 W/m$^2$
(ICNIRP power density limit for the general public)

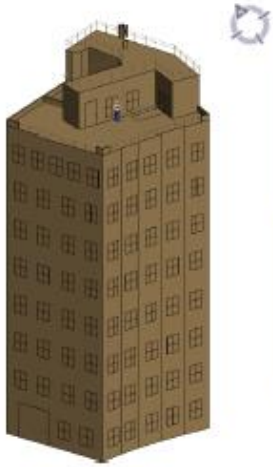


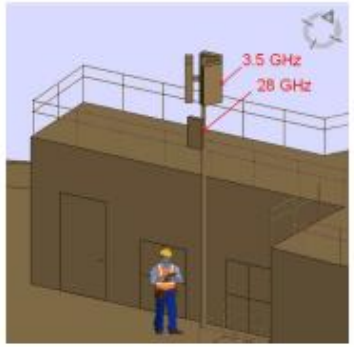

Computation assuming maximum power in all beam directions

# 5G Macro Cell Assessment using IEC 62232

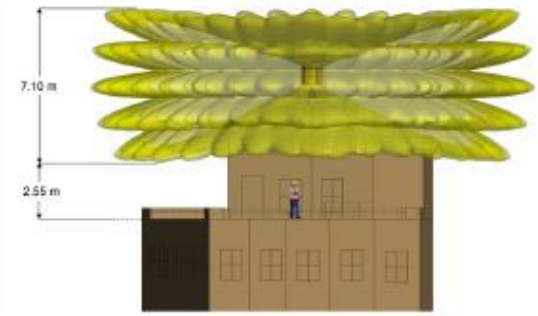
## Example: 5G site with massive MIMO

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

International standards IEC 62232 and ITU-T K.100 open up for use of actual maximum power to perform realistic EMF compliance assessments.

Statistical model to determine actual maximum power of 5G massive MIMO antennas has been developed: found to be around 25% of theoretical maximum power for 8x8 array antennas.

# Challenges for 5G & EMF Standards

- Globally harmonised EMF exposure limits
- Revised ICNIRP, IEEE, FCC exposure guidelines are critical esp for 5G devices >6GHz
- Development and implementation of new network and device testing procedures to meet technology evolution

# Conclusions

- **5G will unlock significant benefits for citizens, communities, industries, and countries**
- **Revised ICNIRP, IEEE, FCC guidelines are essential to enable harmonised global standards**
- **IEC/IEEE has implemented a strategy to ensure international test procedures are available for the 5G trial networks in 2018 and commercial deployments in 2020**

The IEC focus is to ensure EMF compliance assessment standards are ready to meet the deployment of 5G technology

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# THANK YOU