5G and the Internet of Things

Exposure Scenarios

Mike Wood - Chairman
International Electrotechnical Commission
Technical Committee 106
Presentation Overview

- 5G Timeline
- IEC 5G Standards
- How 5G Works
- 5G EMF Exposures – test results
- 3G, 4G, 5G EMF Exposures
- IoT devices in the home
- IoT EMF Exposures
- Discussion

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5G Timeline

- 2012: R&D projects (numerous)
- 2016-19: 5G Trials
- 2017-19: First 5G Standards Finalised
- 2019: Commercial Launch
- 2025: Mass 5G Adoption

5G is here now

**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 - Preparing for 5G

• IEC Strategic Business Plan – 5G focus
• Ensure Standards and Technical Reports are developed

5G Base Stations

<table>
<thead>
<tr>
<th>Standards</th>
<th>110MHz -100GHz – Aug 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 62232-2 Int Std</td>
<td></td>
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<tr>
<td>IEC 62669-2 Tech Report</td>
<td>6GHz -100GHz – April 2019</td>
</tr>
<tr>
<td>IEC 62232-3 Int Std</td>
<td>110MHz-330GHz –June 2020</td>
</tr>
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</table>

5G Devices

<table>
<thead>
<tr>
<th>Standards</th>
<th>6-100GHz – July 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC TR36170 Technical Report</td>
<td></td>
</tr>
<tr>
<td>IEC / IEEE 62704-5 Int Std (Calc)</td>
<td>6-100GHz – Dec 2020</td>
</tr>
<tr>
<td>IEC / IEEE 63195-1 Int Std (Meas)</td>
<td>6-100GHz – Dec 2020</td>
</tr>
</tbody>
</table>
IEC Standards - 5G Base Station Testing

Example: 5G site with massive MIMO
3.5 GHz and 28 GHz, actual maximum power

Actual maximum power = 25% of theoretical maximum
RF EMF exposure below ICNIRP limits in public areas
Case study to be included in IEC TR 62609 (2016) 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

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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

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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 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.

- 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

- Enhanced mobile broadband
  - Gigabytes in a second
  - 3D video, UHD screens
  - Work and play in the cloud
  - Augmented reality
  - Industry automation
  - Mission critical application
  - Self driving car

- Smart home/building
  - Voice

- Smart city

- Future IMT

- Massive machine type communications

- Ultra-reliable and low latency communications

Source Recommendation ITU-R M.2083-0

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# 5G Technical Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Data Rate</td>
<td>1 - 20 Gbps</td>
</tr>
<tr>
<td>User Experienced Data Rate</td>
<td>10 - 100 Mbps</td>
</tr>
<tr>
<td>Spectral Efficiency</td>
<td>×1 - ×3</td>
</tr>
<tr>
<td>Mobility</td>
<td>350 - 500 km/h</td>
</tr>
<tr>
<td>Latency</td>
<td>1 - 10 ms</td>
</tr>
<tr>
<td>Connection Density</td>
<td>10k – 1M devices / km²</td>
</tr>
<tr>
<td>Network Energy Efficiency</td>
<td>×1 - ×100</td>
</tr>
<tr>
<td>Area Traffic Capacity</td>
<td>0.1 - 10 Mbps / m²</td>
</tr>
<tr>
<td>Availability</td>
<td>99.999% (of time)</td>
</tr>
<tr>
<td>Reliability</td>
<td>99.999% (of packets)</td>
</tr>
<tr>
<td>Position accuracy</td>
<td>10m - &lt;1m</td>
</tr>
<tr>
<td>Security</td>
<td>Strong subscriber authentication, user privacy and network security</td>
</tr>
<tr>
<td>Battery life</td>
<td>10 years*</td>
</tr>
</tbody>
</table>

*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

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.

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

Frequency & Service

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

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.
How does 5G work – technologies

- Conventional Antennas (MIMO)
- Advanced Antennas (Massive MIMO/Beamforming)
- Small Cells
- Millimetre Waves

MIMO = Multiple Input Multiple Output element Antenna

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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
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.

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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

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

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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

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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

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5G Environmental EME – mmWave trial

Near (~0.45 m) Walkie Talkie

~0.3 m from 5G user equipment (UE)

5G levels inside

ARPANSA / ICNIRP public limit

INDOOR

4G inc laptop baby monitor

4G

3G

4G

4G

4G

5G

% ARPAESA PUBLIC LIMIT

100.00000%

10.00000%

1.00000%

0.10000%

0.01000%

0.00100%

0.00010%

0.00001%

FM

400MHz

UHF TV

700MHz

850MHz

900MHz

1800MHz

1900MHz

2100MHz

2600MHz

2450MHz

5G MMWA V

IBC

IBC

Measurements at different positions

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%

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5G EMF Measurements – Gold Coast 2019

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5G EMF Measurements – Gold Coast Oct 2019

EMF exposure to 5G NR3500 (80MHz) Mobile BS- Gold Coast (October 2019)

% ICNIRP RPS3 GENERAL PUBLIC LIMIT

- Miami: 0.107
- Rugby club: 0.099
- Musgrave Hill: 0.044
- Labrador: 0.029
- Hot Shot café: 0.011
- Pacific Fair (fountain): 0.015
- Pacific Fair (The Patio): 0.015

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

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5G EMF Measurements – Main Beach

EMF exposure to 5G NR3500 (80MHz) Mobile BS- Gold Coast (October 2019)

- iPerf 1500 Mb/s (DL=800Mbps)
- 5 x speedtests
- iPerf 200 Mb/s (DL=200Mbps)
- 2 x speedtests
- 1 x 4K Ultra HD YouTube video
- 5 x 4K Ultra HD YouTube video

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

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5G Technology – full load test indoors at max power

Speed test

iPerf load test
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.
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
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.
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

Interim results from current testing

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