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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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

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

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

What does 5G offer?

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

Applications:
- Enhanced Mobile Broadband
- Internet of Things
- 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

By 2023 connected farms will be standard practice

5G enabling smart agriculture and connected farms through:
- new IoT applications
- connecting everything
- low power long range sensors
- smart data management
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
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/m²
**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)

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

**EVALUATION OF DUT CHARACTERIZED BY MULTIPLE ANTENNAS & MULTIPLE TX**

- **Case I**: Antenna array, f > 6 GHz, 5G NR or WiGig
- **Case II**: Antenna/antenna array, f < 6 GHz, GSM, WCDMA, LTE, WiFi, etc
- **Case III**: Antenna array, f > 6 GHz, WiGig or NR (i.e. different technology compared with ‘green’ array)

Source – Ericsson presentation to IEC AHG10
5G Device Technical Report Overview

INTRODUCTION

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

Describes IEC TC106 plan > 6 GHz; defines scope

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
IEC Technical Report
Test methods

5G Device Compliance Assessment Method

‘NEAR-FIELD METHODS’

Power density evaluation based on E- and H-field (5.4.1)

Are both the E- and H-field (amplitude and phase) measured directly on the evaluation surface?

Yes

No

Making use of reconstruction algorithms

Power density on the evaluation surface is determined without the usage of reconstruction algorithms (5.4.1)

Power density on the evaluation surface is determined by means of reconstruction algorithms

Depending by the methodology, reconstruction algorithms can be used to:
- resolve the H-field from the E-field (or vice versa) when only one of the two is measured
- propagate, transform or project the electromagnetic field from the measurement surface to the evaluation surface when these do not coincide
- reconstruct field information from measured data (e.g. the phase if only amplitude is measured) (5.4.1 and Annex G)

E-field or H-field amplitude is measured on the evaluation surface to determine peak and/or spatial-average power density

The maximum peak and/or spatial-average power density on the evaluation surface are determined (5.4.1 and 5.4.2)

Spatial-average power density:

\[ S_{av} = \frac{1}{2\pi} \text{Re} \left( E \times H^* \right) \cdot \pi dA \]

Generic setup:
- evaluation surface
- DUT
- measurement surface
- probe
Two example robotic laboratory test systems were presented at the 2016 BioEM conference MMF 5G workshop - [http://www.bioem2016.org/mmf-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

- Calculations matched measurements using IEC 62232
- Verifies approach

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

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/m²
(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

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
THANK YOU