

5G TECHNOLOGY

EMF exposure levels and health risk assessment

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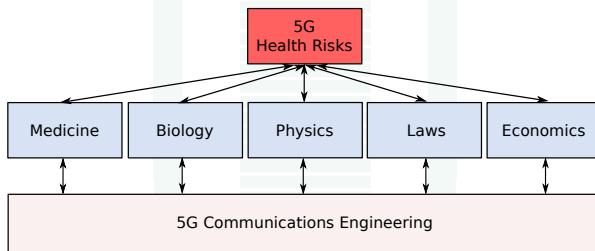
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Goal and Reference


Goal: we analyse the health risks of 5G exposure by adopting the perspective of communications engineering:



Reference material for this presentation (with literature overview and further analysis):

- L. Chiaraviglio, A. Elzanaty, and M.S. Alouini, "Health Risks Associated with 5G Exposure: A View from the Communications Engineering Perspective," arXiv preprint arXiv:2006.00944 (under review), June 2020.

- Health effects from 5G exposure;
- 5G exposure: metrics, regulations and compliance assessment;
- Health risks associated with 5G features;
- Risk mitigation techniques for 5G exposure;
- Conclusions and future works.



5G Exposure and Health Effects Allegations

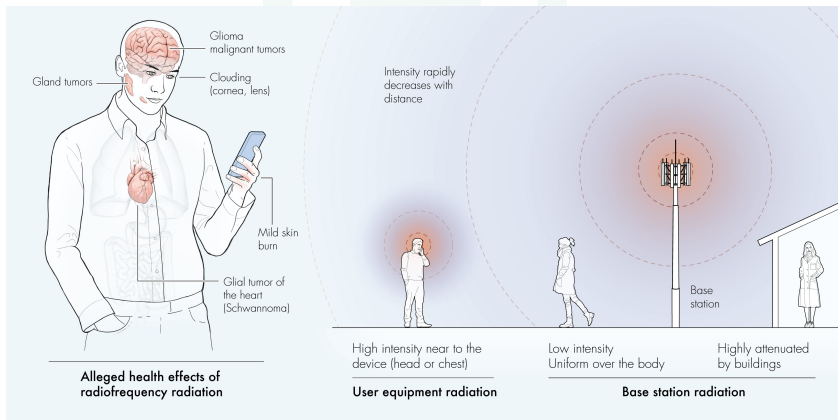
Basic Principles of RF Exposure

Electro Magnetic Field (EMF) exposure from Radio-Frequency (RF) devices (including 5G) belongs to non-ionizing category: waves DO NOT have enough energy to remove the electrons from the atoms in the living cell (ionization process).

Biological effects associated with RF exposure:

- thermal effects → prevented by EMF limits;
- non-thermal effects → no clear causal correlation between EMF exposure below limits defined by laws and emergence of long-term health diseases due to non-thermal effects.

Health Effects Allegations and 5G Exposure



(Illustration by Xavier Pita).

Other Health Effects Allegations

- 1 Triggered by high levels of RF exposure: skin effects, ocular effects, glucose metabolism → they can not be applied to 5G equipment operating below EMF limits;
- 2 Other controversial effects: male fertility, electromagnetic hypersensitivity → their connection with 5G exposure is not scientifically proven;
- 3 Fake theories: spreading of the COVID-19 disease, oxygen effects → they are based on hoaxes and pseudo-science.

Relevant medical studies in the context of 5G communications

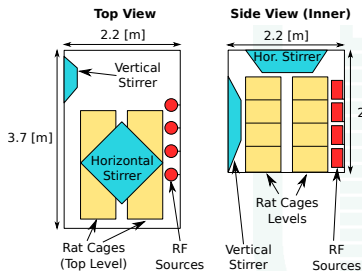
Mainly focused on long-term effects (cancer and tumors):

- Animal-based: National Toxicology Program (NTP) studies, Ramazzini Institute study;
- Population-based: INTERPHONE Study, Danish Cohort Study, Million Women Study, CEFALO Case-control study.

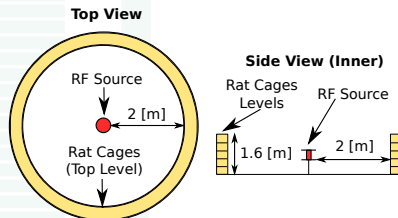
Animal-based studies: differences w.r.t. 5G communications

- Adopted frequencies;
- Test chambers vs. real 5G deployments;
- Maximum radiated power;
- Power management techniques;
- Electromagnetic fields exposure levels;
- Specific absorption rate levels;
- Transmission and modulation techniques.

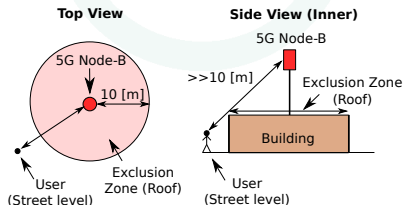
Test chambers vs. deployments



(a) NTP Test Chamber



(b) Ramazzini Test Chamber



(c) 5G Base Station Deployment

Maximum Radiated Power Comparison

Table: Maximum output power P_{MAX} for the different devices.

5G Device	Value
RF source - NTP	3800 [W] (65 [dBm])
RF source - Ramazzini Institute	100 [W] (50 [dBm])
5G macro Base Station	200 [W] (53 [dBm])
5G User Equipment	0.2 [W] (23 [dBm])

Electromagnetic Field Levels Comparison

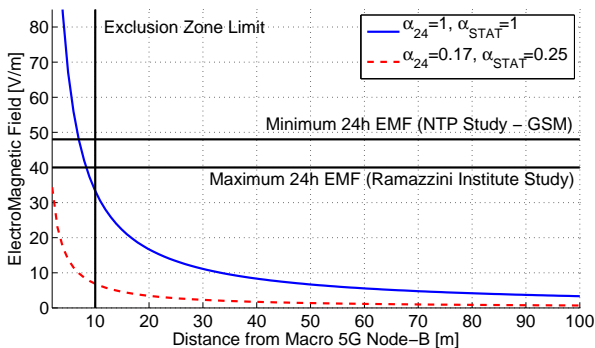



Figure: Electric Field strength (EMF) vs. distance for different settings of a 5G macro Base Station. The setting with $\alpha_{STAT} = 1$ and $\alpha_{24} = 1$ represents the worst-case. The setting with $\alpha_{STAT} = 0.25$ and $\alpha_{24} = 0.17$ is based on realistic considerations. The figure highlights also the positioning of the tests performed by NTP and Ramazzini Institute and the typical size of an exclusion zone for a 5G macro Base Station.

Animal-based studies: takeaways

- Many settings and/or assumptions in these studies appear to be very different and/or far from reality when compared to the ones adopted in 5G equipment.
- It is not possible to claim that the health effects observed in these studies may appear in a real 5G deployment.
- ICNIRP pointed out that such studies do not provide a consistent, reliable and generalizable body of evidence for revising the exposure guidelines.
- Further studies, tailored to address the aforementioned limitations, are needed.



5G Exposure: Metrics, Regulations and Compliance Assessment

Main exposure metrics relevant to 5G communications

- Electro-Magnetic Field (EMF) strength → 5G Base Stations, up to GHz frequencies;
- Power Density (PD) → 5G Base Stations / 5G User Equipment, all frequencies;
- Specific Absorption Rate (SAR) → (typically) 5G User Equipment, up to GHz frequencies.

International Regulations on 5G EMF Exposure

- Main organizations: ICNIRP, IEEE and FCC;
- Whole body vs. localized exposure;
- Occupational vs. general public limits;
- Exposure time and (for some metrics) mass.

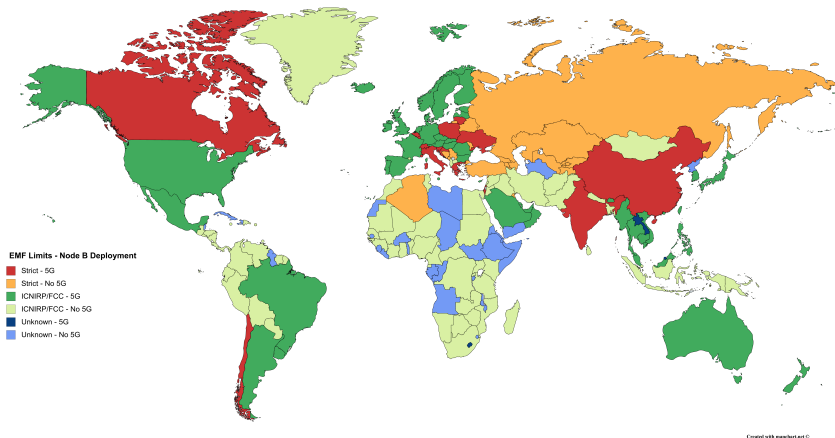
Example: EMF Strength Limits

	ICNIRP		IEEE C95.1		FCC-1997
	1998	2020	2005	2019	
General Public	28 [V/m], $10 < f \leq 400$ [MHz]	27.7 [V/m], $30 < f \leq 400$ [MHz]	27.5 [V/m], $30 < f \leq 400$ [MHz]		27.5 [V/m], $30 < f \leq 300$ [MHz]
	$1.375 \cdot f^{0.5}$ [V/m], $400 < f \leq 2000$ [MHz]		Power density limits,		Power density limits, $f > 300$ [MHz]
	61 [V/m], $2 < f < 300$ [GHz]	Power density limits, $2 < f < 300$ [GHz]	$f > 400$ [MHz]		
Occupational	61 [V/m], $10 < f \leq 400$ [MHz]	61 [V/m], $30 < f \leq 400$ [MHz]	61.4 [V/m], $30 < f \leq 400$ [MHz]		61.4 [V/m], $30 < f \leq 300$ [MHz]
	$3 \cdot f^{0.5}$ [V/m], $400 < f \leq 2000$ [MHz]		Power density limits,		Power density limits, $f > 300$ [MHz]
	137 [V/m], $2 < f < 300$ [GHz]	Power density limits, $2 < f < 300$ [GHz]	$f > 400$ [MHz]		
Time	6 [min], $f \leq 10$ [GHz]	30 [min]	30 [min] (General Public)	30 [min]	30 [min] (General Public)
	$68/f^{1.05}$ [min], $f > 10$ [GHz] (f in GHz)		6 [min] (Occupational)		6 [min] (Occupational)

5G Base Station exposure regulations:

- Many countries adopt ICNIRP 1998 or FCC 1997 limits;
- Other countries adopt limits STRICTER than ICNIRP/FCC (precautionary principle);
- Other countries do not adopt any limit;

5G Deployment and Base Station Exposure Limits



World map with countries colored according to the EMF limits on field strength (strict, ICNIRP/FCC, unknown) and Base Station deployment (5G, no 5G) - Most of micro states are omitted

5G Deployment and Base Station Exposure Limits: Takeaways

- Strong heterogeneity in terms of EMF limits and 5G adoption across the world;
- Countries with ICNIRP/FCC limits: 5G deployment possible, low health risks perceived;
- Countries with strict EMF limits: 5G deployment challenging, high health risks perceived;
- Countries without EMF limits: 5G deployment challenging, high health risks perceived;

Impact of EMF regulations stricter than ICNIRP/FCC limits

- No installation of 5G Base Stations where they are really needed;
- Strong negative impact on 5G services (throughput, latency);
- Increase of the exposure from UE (that currently represents the largest source of exposure);

EMF Compliance Assessment of 5G

- Compliance assessment: methodology to verify that the EMF radiated by a 5G device (Base Station or User Equipment) adheres to the limit.
- Type of compliance assessments: simulation vs. measurement.
- Main methodologies defined by IEEE, IEC, and ITU.
- Takeaways: these methodologies already include 5G devices.



Health risks associated with 5G features

- Extensive adoption of Massive MIMO and beamforming;
- Densification of 5G sites over the territory;
- Adoption of frequencies in the mm-Wave bands;
- Connection of millions of IoT devices;
- Coexistence of 5G with legacy technologies.

Extensive adoption of Massive MIMO and beamforming

- Increase of power and number of radiating elements → the expected exposure from 5G base stations will be in line (and in general lower) w.r.t. legacy technologies.
- Introduction of statistical exposure models → Used to estimate the exposure levels and the size of exclusion zones. Importance of being integrated inside the regulations.
- Measurement of exposure levels → Current studies demonstrate that the measured exposure levels are limited and in general lower than maximum theoretical values.

Densification of 5G sites over the territory

- Exponential increase of exposure due to 5G densification is NOT supported by scientific evidence
- Higher densification → lower power radiated by 5G Base Stations, and hence lower EMF exposure levels.
- In any case, EMF exposure has to be always lower than the limits defined by regulations, and hence guaranteeing safety for the population.

Adoption of frequencies in the mm-Wave bands

- Biological impact from mm-Waves already studied in the previous years (although not in the context of communications);
- WHO is currently preparing a review about health risks assessment of RF exposure (including mm-Waves), which will be completed by 2022;
- Deployment of Base Stations operating on mm-Waves will be initially limited (e.g., hot spots) w.r.t. deployment of sites operating in the mid-band and the sub-GHz band.

Connection of millions of IoT devices

- Current specifications impose very low values of maximum transmitted power by each IoT terminal (lower than smartphones);
- Exposure from IoT devices will be always below the limit defined by regulations;
- Big role played by the distance and obstacles between the user and the IoT device, as the exposure rapidly approaches negligible values.

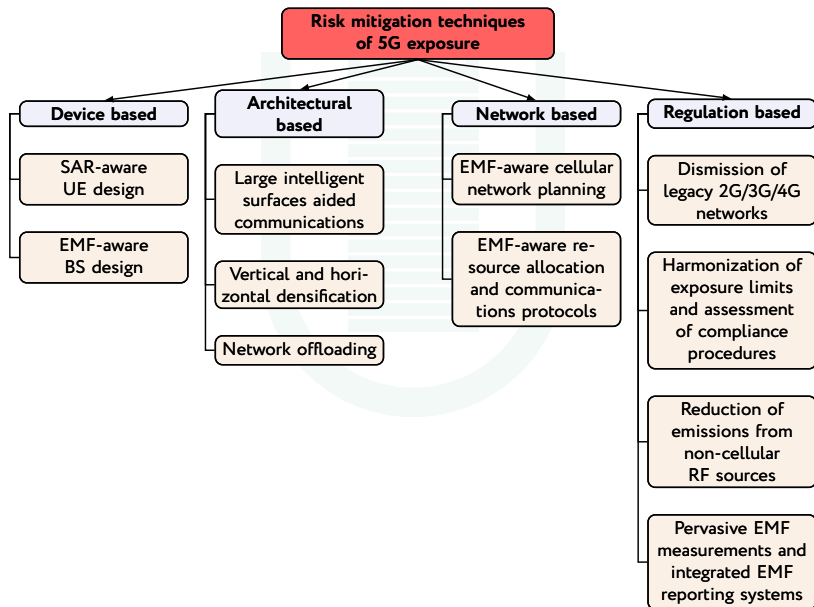
Coexistence of 5G with legacy technologies

- Saturation levels of legacy pre-5G networks → very critical for those countries adopting stringent EMF limits
- Impact of radio and TV broadcasting → underrated but important aspect, as Radio/TV repeaters radiate much more power than Base Stations;
- Interaction of 5G with weather satellites → controversial aspect, which depends on the actual deployment levels of mm-Wave Base Stations.

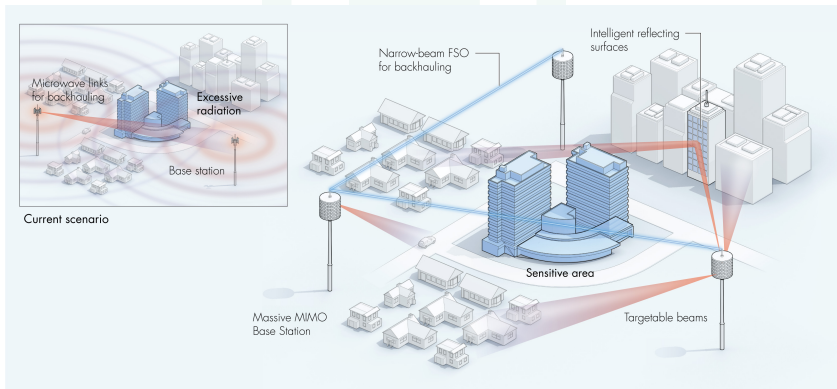


Risk Mitigation Techniques for 5G Exposure

Risks Mitigation Techniques: Overview



Impact of 5G and beyond 5G features



(Illustration by Xavier Pita).

- Health effects from 5G exposure → Claimed health effects about cancer/tumors due to RF radiation can not be applied to 5G;
- Metrics, regulations and compliance assessment → clear metrics, heterogeneous regulations across the world, clear assessment of compliance techniques;
- Health risks associated with 5G features → Such features do not represent in general a threat to the population health;
- Risk mitigation techniques → different promising avenues of research, with a fundamental role played by national governments in defining regulation-based solutions.

Conclusion and Future Works

- Health concerns about the deployment of 5G Base Stations are not supported by communications engineering evidence.
- No compelling motivation to stop the deployment of 5G networks (especially when precautionary principles are applied).
- Importance of continuing to research possible long-term health effects under realistic exposure patterns from 5G devices.
- Further research needed to design exposure-aware cellular networks for 5G and beyond 5G systems properly.

Contact and Paper Download



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<https://tinyurl.com/5g-health-risks-chiaraviglio>