Policy Brief

5G EXPOSURE OF EUROPEAN CITIZENS

Exposure to electromagnetic fields due to the transition to 5G

Introduction

As Europe rapidly advances toward the widespread adoption of 5G technology, there is a growing policy interest in understanding the implications of this shift for public health, particularly in terms of exposure to radiofrequency electromagnetic fields (RF-EMFs). The transition to 5G has introduced new frequencies, transmission patterns, and network architectures that alter how individuals are exposed in everyday settings. These changes build upon the continuous evolution of mobile networks, in which each successive generation has modified both the exposure originating from network base stations and the exposure associated with the use of personal devices, as a result of improved energy efficiency at both ends of the communication link.

Current research efforts across Europe, including large-scale measurement campaigns, are necessary to quantify these new exposure patterns and assess how they relate to network quality, user behaviour, population groups, and location. Moreover, studies on how the European population perceives exposure from different sources are also important to identify misconceptions on exposure and help to fill the gaps in risk communication. The results of such studies form the foundation for policy actions that safeguard public health, support evidence-based regulation, and ensure the responsible deployment of 5G and future wireless technologies.

Background

Key Concepts – What's new with 5G

Human exposure to RF-EMFs of mobile communications is the result of overlapping exposure scenarios. These can be distinguished by source, voluntariness, and spatial proximity to the source. The following categories are commonly used in RF-EMF exposure assessment and epidemiological studies.

- Involuntary downlink exposure

Involuntary or environmental downlink exposure refers to one's exposure from the fixed network infrastructure, primarily base stations, that provide the network coverage. Such fields are generally present regardless of individual mobile device use and typically expose the whole body. Contributors to environmental downlink exposure include periodically transmitted broadcast and control signals as well as traffic generated by mobile calls and data transfer (see also "Induced downlink exposure", below).

- Induced downlink exposure

When users actively generate traffic, a 5G serving base station may allocate additional resources to these users, which are transmitted via focused beams towards them. This targeted transmission increases the local incident power density near the users, meaning the user temporarily self-induces higher downlink exposure. Importantly, this increase affects not only the user who initiated the traffic but may also extend to other people in their surroundings (bystanders). Exposure from induced downlink exposure is transient but may constitute a relevant contribution to an individual's total exposure accumulated over a day.

- Induced uplink exposure

The uplink signal from a person's own device constitutes a significant exposure contribution, since this device is often used near the head or body. During activities such as mobile calls, file uploads, or tethering, localized absorption in tissues near the device can exceed contributions from all other sources. These activities are especially relevant for cumulative exposure metrics that integrate over time the electromagnetic power absorbed in tissue.

- Involuntary uplink exposure

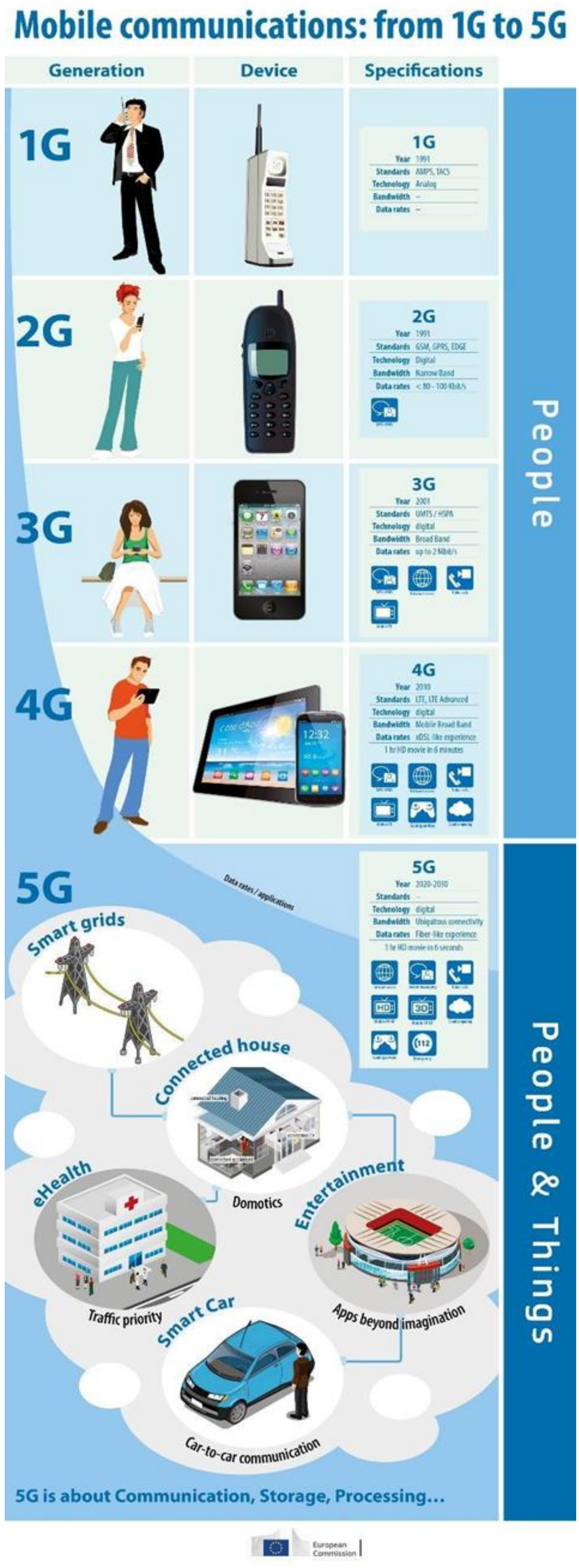
In crowded environments such as public transport, shopping centres, or stadiums, individuals may be exposed to uplink emissions from nearby users' devices. Poor network coverage (e.g., inside trains) makes mobile devices transmit at higher power. An increasing number of nearby users also leads to an increased involuntary uplink exposure.

Historical Perspective

The progression from first-generation (1G) analogue systems to fifth generation (5G) networks has been accompanied by substantial shifts in both the sources and characteristics of human exposure to RF-EMF. In the earliest systems, exposure was largely dominated by the uplink emissions of mobile handsets. Devices transmitted at relatively high powers, often up to two watts, and were typically held against the head during voice calls, leading to localized absorption in head tissues. At that time, infrastructure was sparsely deployed and consisted mainly of high-power macro base stations.

With the introduction of 2G and especially 3G, exposure patterns began to evolve. Power control techniques reduced the average transmitted power of mobile phones, which meant that exposure from the use of mobile phones was strongly reduced. This was especially the case when there was good network coverage. Simultaneously, network densification, additional operating frequencies, and the expansion of broadband services increased the network density relevant for environmental downlink fields. By the 3G era, cumulative exposure could no longer be described as solely uplink-driven, as it reduced overall and led to an increase of the relative contribution of downlink fields from base stations to total exposure.

The deployment of 4G LTE (Long Term Evolution) further accentuated this shift. Operating across a wider frequency range, with higher data throughput and carrier aggregation, LTE relied on denser infrastructure, including small cells and indoor solutions. As a result, downlink exposure from cellular networks has become more relevant relative to the uplink component,



while uplink exposure still prevailed in situations with poor network coverage or heavy upload traffic.

With the introduction of 5G, downlink exposures have changed. In the frequency bands that operate below 6GHz (also called FR1), exposures broadly resemble those in LTE. A new development was the introduction of MaMIMO (massive multiple-input multiple-output) antennas and dynamic beamforming, which has introduced high variability in the exposure. This means that a person can experience a very fast change of the exposure across very short time periods, or short distances. Downlink signals do no longer produce a steady background exposure but can fluctuate depending on user activity: a person’s own traffic may draw additional beams, while nearby users’ traffic can raise downlink levels for bystanders. In the millimetre-wave (mmWave) frequency range (FR2) – currently sparsely deployed in Europe – the situation changes again. Higher frequencies mean that absorption is largely confined to superficial tissues such as the skin and eyes, while higher path loss necessitates dense deployments of low-power small cells. Devices themselves employ directional antennas, leading to more localized and angularly dependent uplink exposures.

Taken together, the evolution from 1G to 5G has shifted the exposure proportion between uplink and downlink sources and has introduced new temporal and spatial dynamics.

Projects in the EMF and Health Cluster (CLUE-H) cluster aimed at quantifying the exposure situation of the population given that the nature of exposure to 5G signals is more complex, context-dependent, and heterogeneous, posing new challenges for measurement, and modelling. Furthermore, CLUE-H studies looked at how the European public perceives exposure to 5G signals in order to improve risk communication.

Current Evidence

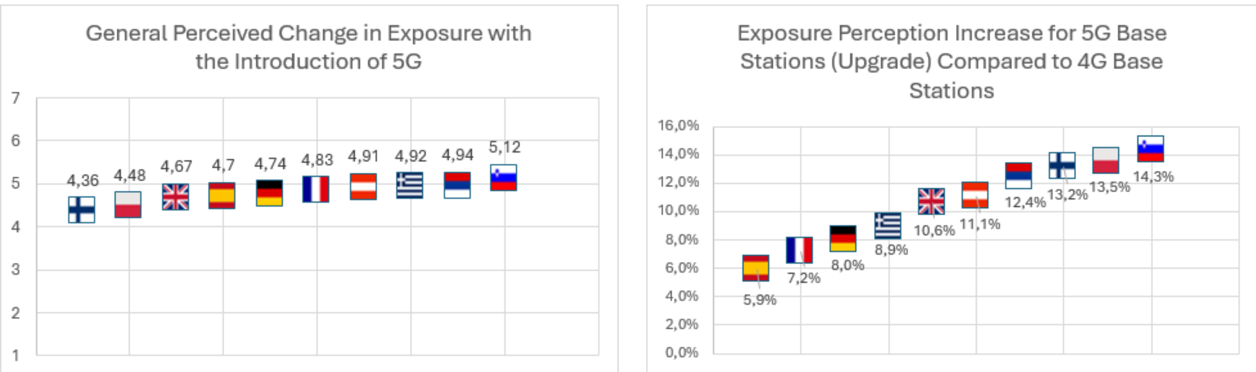
Perceived Exposure

A large online survey conducted jointly by the SEAWave and GOLIAT projects at the end of 2023 investigated how people in ten countries perceive their daily exposure to RF-EMF from 5G devices and infrastructure. Each country participated with a representative sample of about 1,000 respondents.

The key findings of the study were the following:

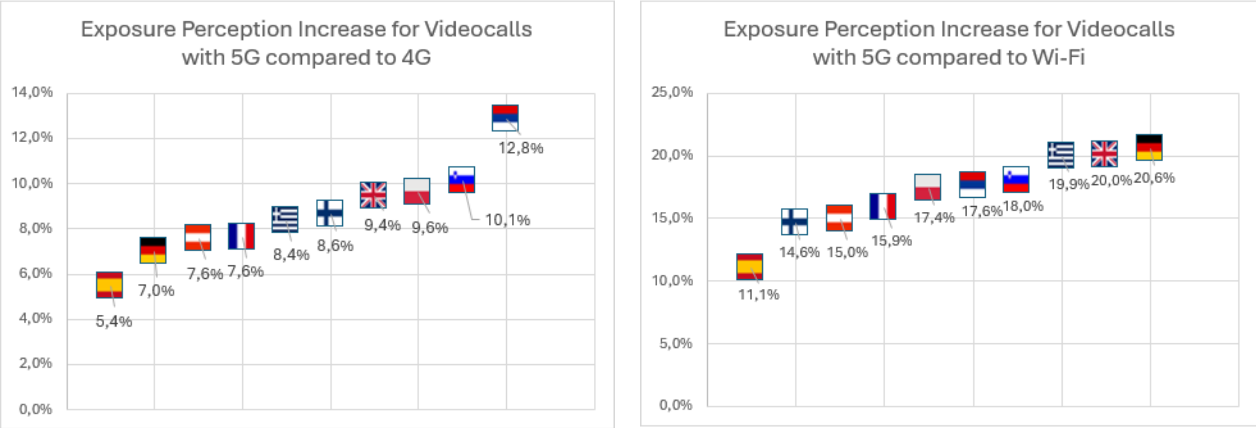
- Overall, respondents considered their daily RF-EMF exposure to be moderate, but expected it to increase with 5G, a pattern consistent across all countries. Perceived increases were lowest in Finland and highest in Slovenia (Figure 1a).
- Respondents also expected higher exposure from a mobile phone base station on the roof of a house if it were upgraded to 5G (Figure 1b).
- Respondents from all countries rated exposure from making a video call on a 5G smartphone as higher than on 4G (Figure 2a). Exposure from a 5G smartphone was perceived as higher than from Wi-Fi for the same activity, i.e., making a video call (Figure 2b).

In conclusion, people in Europe generally assume that 5G increases everyday RF-EMF exposure. The perceived increase is stronger in some countries (Slovenia, Serbia) than in others (Spain, Finland).



(a) (b)

Figure 1. (a) Perceived change in total daily exposure with introduction of 5G. Measured on a scale from 1 to 7 with 1 = very strong decrease, 4 = no change, 7 = very strong increase. (b) Increase in exposure perception for 5G base stations (upgraded from 4G) compared to 4G base stations. The increase percentages derive from comparison with the baseline images of 4G base stations shown to participants.



(a) (b)

Figure 2. (a) Increase in exposure perception for videocalls conducted with 5G compared to 4G. The increase percentages derive from comparison with the baseline images of 4G videocalls shown to participants. (b) Increase in exposure perception for videocalls conducted with 5G compared to Wi-Fi. The increase percentages derive from comparison with the baseline images of Wi-Fi videocalls shown to participants.

Measured Exposure

In the following we present results on exposure, as assessed by the measurement campaigns which have been taking place across Europe within the CLUE-H projects.

GOLIAT

The aim of the measurements in GOLIAT was to measure RF-EMF exposure from previous mobile phone technologies and from 5G in different microenvironments, across ten European countries (Austria, Belgium, France, Hungary, Italy, Netherlands, Poland, Spain, Switzerland and UK). Trained researchers performed microenvironmental surveys, by walking pre-defined routes in different urban and rural areas within each of the measured countries. Three scenarios of data transmission were performed to measure environmental levels (non-user scenario, i.e., involuntary downlink exposure), induced downlink exposure by continuously inducing downlink traffic (maximum downlink scenario) and induced uplink exposure by continuously generating uplink traffic (maximum uplink scenario).

The measurements showed that during the non-user scenario, the RF-EMF exposure levels were on average 80% lower in rural areas, compared to urban areas, and that overall exposure levels tended to be lower in countries with precautionary limits set in place (Belgium, Italy and Switzerland). During the non-user scenario, the downlink frequency bands from base stations were the main sources of exposure, in particular the 4G band at 1800 MHz (Figure 3). All measurements showed exposure levels substantially below regulatory limits in all countries.

For induced downlink exposure, the 5G band at 3.5 GHz was the primary contributor of exposure in various countries. For mobile device use, 4G uplink bands at 1800-2600 MHz and the 5G 3.5 GHz band contributed most to overall exposure. The transmitted power during the maximum uplink scenario was up to 64% higher in rural areas compared to urban areas, likely a result of the poorer network coverage compared to urban areas.

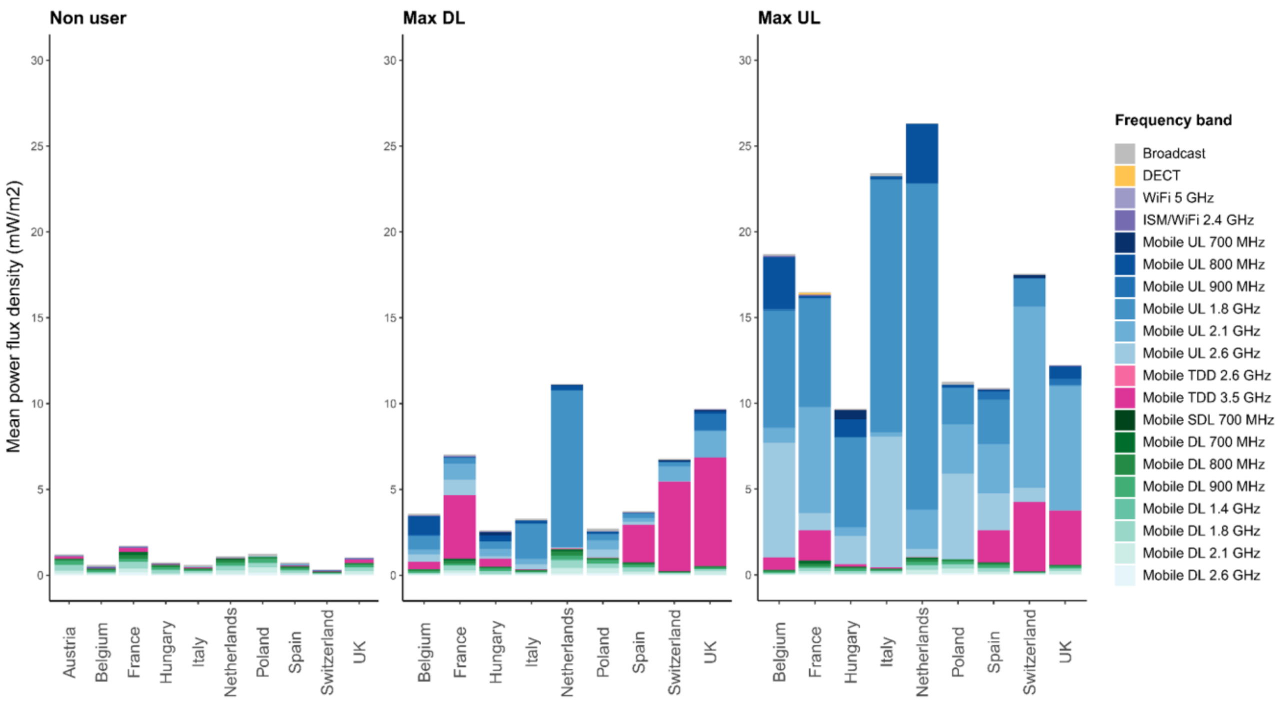


Figure 3. Mean power flux density (mW/m^2) levels measured in different frequency bands with the ExpoM-RF4 device. The graph is stratified per country and scenario of data transmission. Broadcast: contribution from digital terrestrial television, frequency modulation, digital audio broadcasting radio services and Tetrapol handsets/radio; DECT: Digital Enhanced Cordless Telecommunications; ISM: Industrial, Scientific and Medical; Wi-Fi: Wireless Fidelity; UL: uplink; TDD: time-division duplex; DL: downlink; SDL: supplementary downlink. (Source: Veludo *et al*, 2025).

ETAIN

The aim of the measurements in ETAIN was to better understand the relation between network signal quality indicator and output power of the mobile phones during various activities. To do so, a researcher has conducted measurements in six European countries (France, Germany, Switzerland, Greece, Netherlands, Spain) at various places during different mobile phone activities (calling, download or upload data) using 4G or 5G network. These measurements indicate that the higher the signal quality indicator the higher the downlink exposure from the own operator (Figure 4). Therefore, the aggregated signal quality indicators from all operators can be used as an approximate measure of environmental downlink exposure from these networks. Accordingly, this relation has been implemented in the 5G Scientist app. Second, the measurements demonstrated that output power of the phone was lower in conditions with good signal quality. This association tends to be stronger for applications with little data exchange compared to high data exchange but is relatively similar for 4G and 5G. This implies that when using mobile devices personal RF-EMF exposure is lower in areas with good network quality due to reduced output power, although environmental exposure is higher at such places.

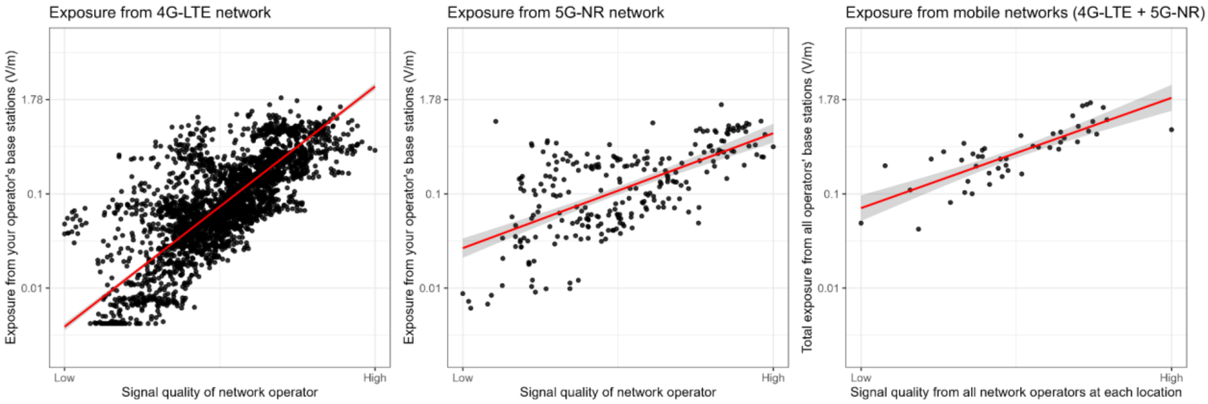


Figure 4. Relation between signal quality (horizontal axis) and environmental exposure in the corresponding frequency band (vertical axis). The left and middle panel figures refer to single user and their exposure from their operator separated for 4G and 5G. The right panel presents to the sum of all measurements per site from all available operators.

SEAWave

In SEAWave, measurement campaigns were conducted for all four categories of exposure (see “Key Concepts”, above) across six European countries (Belgium, France, Greece, Poland, Slovenia, Switzerland) and South Korea. Involuntary and induced exposure from downlink fields was assessed using mainly spot measurements. Induced uplink exposure was measured with three different commercial software tools used for testing network service quality, and with the DEVIN5G sensor developed during the project. All methods focused on evaluating the power emitted by smartphones in various usage scenarios. All exposure components were further assessed with personal exposimeters in diverse environments, ranging from open-air concerts to shopping malls and transportation hubs. Measurements in Greece have shown that involuntary exposure varies with population density: in rural areas where base stations are far from users, the uplink component dominates, while in urban areas, proximity to base stations leads to higher downlink exposure (Figure 5). Moreover, in line with other CLUE-H projects, it was observed that induced uplink exposure decreases under good signal conditions, particularly in communication modes with low data exchange rates, for both 4G and 5G.

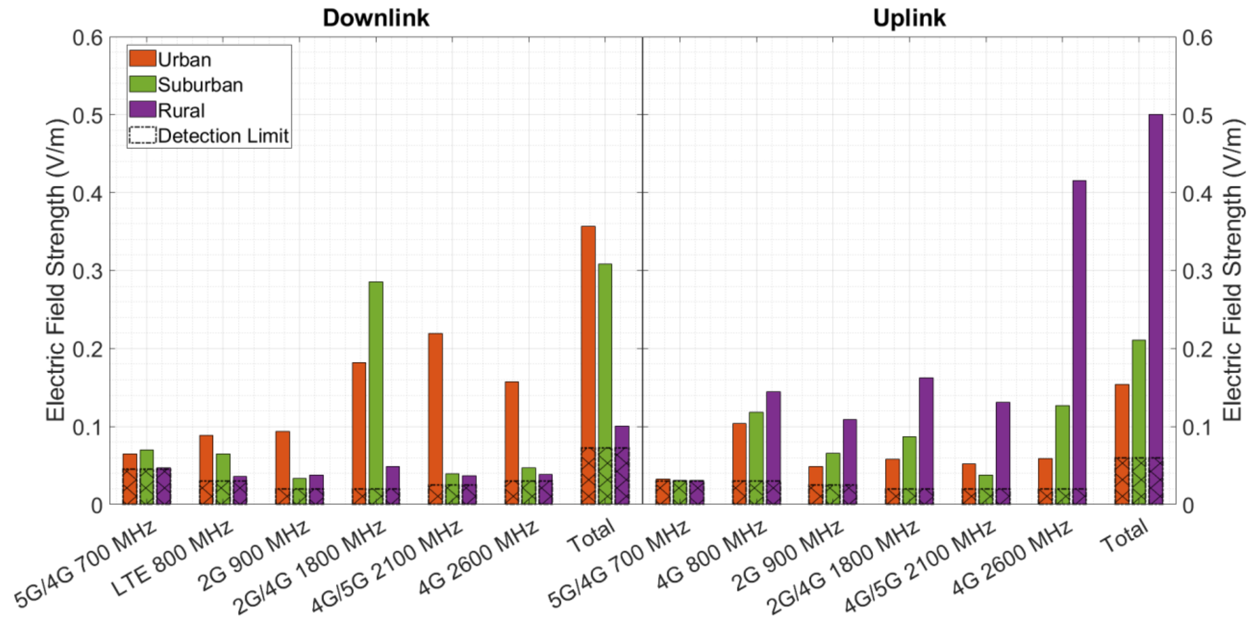


Figure 5. Mean electric field values in all cellular network frequency bands averaged over 76 microenvironments (16,990 measurement points in total) categorised in three macroenvironments (rural, suburban, urban) in Greece. The measurements were conducted without generating traffic through the device of the exposimeter operator. (Source: Delidimitriou *et al*, 2026).

NextGEM

One of the main pillars of NextGEM is measuring in real-world 5G systems for exposure assessment in both FR1 (sub-6GHz) and FR2 (mmWave) bands. Investigation has shown that FR2 deployments in Europe are limited. Based on this assessment, NextGEM performed FR2 measurements in both private (TU Delft Campus, the Netherlands) and commercial (Front-Torino, Italy) environments in Europe. The dedicated campaign in Front-Torino, at a commercial FR2 base station operating at 27 GHz, included body-worn sensors and on-site measurements. Measurements were performed both with wearable measurement devices developed within NextGEM, benchmarked against high-end handheld and laboratory signal analysers. Realistic beamforming conditions were induced using both hand-held and custom user equipment in line-of-sight scenarios. Preliminary results indicate that measured exposure levels in FR2, in the measurement conditions and test locations, remain well below the exposure limits defined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines (ICNRIP, 2020). In addition, when a non-user moves outside the beam attracted by a user, the non-user exposure level decreases sharply to negligible values.

Summary

Overall, the measurement campaigns that have been taking place in CLUE-H have shown that:

1. Environmental exposure is substantially below regulatory limits.
2. Whereas the majority of the public believes that environmental exposure has increased with the rollout of 5G in FR1, large scale measurement campaigns did not find noticeably increased environmental exposure levels.
3. The majority of people believe that video calls with 5G cause higher exposure than video calls using 4G or Wi-Fi. Measurements have shown that transmitted powers for 5G were generally about two-fold lower than for 4G (Stroobandt *et al*, 2025).
4. Environmental exposure tends to be higher in populated areas, where network quality is better. However, this also implies that exposure from one's own device use is lower.
5. A person's total exposure accumulated over a day is largely determined by their user behaviour. This includes the duration of device use and the distance between emitting devices and the body during use.
6. Deployment of FR2 5G networks in Europe is limited, with preliminary results showing exposure levels well below ICNIRP limits.

Policy Implications

Since measured exposure levels remain well below the technology-independent limits set by the Council Recommendation 1999/519/EC (CR, 1999), adverse health effects in the general population are not expected to occur. Nevertheless, to minimize inherent uncertainty about health risks from RF-EMF, the following policy recommendations are proposed:

1. In light of the rapid and ongoing development of communication technologies and increased use of AI, efforts should be made to maintain low exposure levels for the population in the future. Strategies should be established to consider RF-EMF exposure at an early stage in the development and design of future technologies. At this stage, exposure settings can be optimised with relatively little effort.
2. RF-EMF exposure should be considered in a comprehensive manner, encompassing not only environmental downlink exposures but also uplink exposure generated by users, as well as the interaction between downlink and uplink. Minimising downlink exposure may lead to reduced network quality. Consequently, data transmission may take longer and require higher output power from emitting devices, resulting in higher cumulative exposure for the user.
3. Given the expected on-going rapid development of the technology including deployment of 5G in the FR2 band, RF-EMF monitoring should be maintained after the CLUE-H projects have concluded. Such monitoring should focus on environmental exposures and RF-EMF-emitting devices, while also considering worst-case and typical exposure scenarios. Monitoring data remain essential for risk management and risk communication.
4. Public trust and adequate understanding are key to the implementation of any technology. Given the high level of misconception observed among the public regarding RF-EMF exposure, novel approaches to risk communication should be adopted.

References

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