



## Bulletin de veille Champs électromagnétiques N°10 - Février-Avril 2025

*La validation des informations fournies (exactitude, fiabilité, pertinence par rapport aux principes de prévention, etc.) est du ressort des auteurs des articles signalés dans la veille. Les informations ne sont pas le reflet de la position de l'INRS.*

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### Exposition professionnelle

**Assessment of exposure to RF-EMF among telecommunication tower workers in Kuwait,**  
Al-Sadi, N., Shehab, M. and Alzoughool, M., *Discover Public Health*, Feb 2025, Vol. 22, no. 1.

*Objective*The telecommunication industry has driven a global increase in teledensity, leading to reliance on wireless technologies such as Wi-Fi, phone calls, and signal transmissions. This study investigates the impact of electromagnetic field emissions from mobile telephone base stations on workers' exposure to non-ionizing radiation in Kuwait.  
*Methods*A cross-sectional study was conducted on 127 workers operating on or near telecommunication towers in Kuwait. Radiation exposure levels were measured across frequency bands from 900 to 3700 MHz, covering GSM 2G to 5G technologies. Participants were categorized by occupational roles and work experience. Data on health awareness and perceptions of radiation exposure were also collected.  
*Results*Despite Kuwait's stringent radiation safety benchmarks set at 10 microwatt/cm<sup>2</sup>-45 times below ICNIRP recommended limits-misconceptions about radiation exposure persist among workers.  
*Conclusion*Telecommunication infrastructure in Kuwait operates well within safe exposure limits. However, increased safety training and public awareness campaigns are needed to address

*misconceptions. Continuous monitoring and education can ensure workers' well-being.*

<https://doi.org/10.1186/s12982-025-00450-8>

### **Exposure to 5G mmWaves of a Base Station Operator: Dosimetric Study of the Influence of Posture**

Bellosono, L., D'agostino, S., Colella, M., Contessa, G. M., Polichetti, A., Liberti, M., Apollonio, F. and Ieee (2024). International Symposium on Electromagnetic Compatibility (EMC Europe), Bruges, BELGIUM.

*In this work, the electric field induced by plane wave exposure inside a human model is numerically investigated. The focus has been on workers exposed to electromagnetic fields at the frequency of 26 GHz, belonging to the FR2 band of 5G technology. The results were obtained adopting a human anatomical model, studying an exposure scenario corresponding to the reference levels for local occupational exposure. The analysis was conducted on a specific anatomical region, i.e., the wrist, in different positions of the arm. The results show how the induced electric field may depend on the posture of the exposed subject and their anatomical characteristics.*

<https://doi.org/10.1109/EMCEurope59828.2024.10722266>

### **High Magnetic Property and Toxicity of Particulate Matter Generated during Welding and Cutting Processes,**

Cui, W., Ma, Z. Z., Chen, Y. Z., Li, S. Y., Wu, D., Chen, X., Shao, Y. K., Liu, Y. Z., Li, Q. and Chen, J. M., *Environment & Health*, Mar 2024, Vol. 2, no. 6, p. 381-389.

*Magnetic particulate matter (PM) has raised increasing concern due to its abundant presence in ambient air and negative health impact. However, there is still a lack of comprehensive understanding of their emission sources and toxicities. We here report the observation of high magnetic property and toxicity of PM generated during typical welding and cutting processes. Magnetite, formed during high-temperature operation with less oxygen pressure, was revealed to be the major magnetic contributor. The averaged saturation magnetization and magnetic susceptibility values of fine PM (PM<sub>2.5</sub>) from welding processes are 1.4-4.2 times greater than those of PM emitted from other unintended emission sources, including iron and steel plants and brake wear, while they are 2.0-5.7 times greater for the cutting processes. Furthermore, PM<sub>2.5</sub> from welding and cutting processes are nearly 3.5-4.5 times more neurovirulent and 2.1-7.0 times more likely to induce oxidative stress than those from other magnetic sources in the nerve cells lines. Moreover, all of these magnetic PM<sub>2.5</sub> exhibit greater negative health effects than typical atmospheric PM<sub>2.5</sub> collected in Shanghai urban regions. These new findings suggest that appropriate occupational protection measures should be implemented for the welding and cutting process to reduce adverse health impacts.* <https://doi.org/10.1021/envhealth.4c00021>

### **Monitoring the head exposure of MRI workers around 3 T, 7 T, and 11.7 T scanners using smart goggles equipped with a network of magnetometers,**

Nicolas, H., Féry, C., Quirin, T., Weber, N., Oster, J., Felblinger, J., Vignaud, A. and Pascal, J., *Magnetic Resonance in Medicine*, Mar 2025.

*Purpose The aim of this paper is to introduce a new magnetic field exposimeter device that consists of goggles equipped with magnetic sensors for the assessment of the field exposure of MRI workers' heads. This is not possible with conventional pocket exposimeters. Hence, this device allows head-level field exposure to be measured, which can induce physiological effects on MRI workers, and which are required to be covered by managing the laboratory-related safety hazards directive 2013/35/EU. Methods Using on-chip monolithic three-axis Hall effect magnetometers, recently introduced on the market, we developed an exposimeter with unprecedented accuracy, which*

allows the measurement of the magnetic field closed to the organs which are the most impacted by strong magnetic fields: the brain, the eyes, and the tongue. Results The exposimeter prototypes were successfully tested around 3 T, 7 T, and 11.7 T MRI scanners on different workers and volunteers in real conditions. Comparisons with chest-level measurements lead typically to lower values than exposure recorded at the head-level, confirming the need for such head-level assessments. Exposure of the head above the limits established by the directive was also recorded (>2 T or >2.7 T/s). Conclusion This new exposimeter allows for a more accurate assessment of field exposure of MRI workers. Further improvements in the miniaturization and the usability of the exposimeter will allow us to disseminate the device and open the way to a larger-scale study. <https://doi.org/10.1002/mrm.30513>

**Protection of population and workers with cardiac implantable stimulators from 5G exposure. Part II: base station antennas exposure,**

Vivarelli, C., Calcagnini, G., Censi, F., Pavoncello, S., Franci, D., Burriesci, G. and Mattei, E., *European Physical Journal Plus*, Mar 2025, Vol. 140, no. 3.

The study investigates the potential risks of electromagnetic interference (EMI) from 5G signals on cardiac implantable electronic devices (CIED). Given the increasing prevalence of these devices and the widespread adoption of 5G technology, it is crucial to ensure the radiation protection of both workers and general population based on scientific evidence. The research introduces a novel measurement setup able to reproduce the actual signals adopted by 5G providers, focusing on the downlink scenario where the CIED is in proximity to a base station antenna. The study tested the pacing, sensing and high-voltage therapy delivery of 5 implantable defibrillators from major manufacturers under realistic exposure conditions and worst-case scenarios in terms of E-field level, timing and frequency characteristics of the 5G signal. 5G signals were generated at two frequencies (736 and 3680 MHz) and with three modalities (continuous wave, 5G full-traffic and 5G gated). A total of 90 measures were collected, and the results showed that the interfering signal generated according to the actual 5G protocol did not cause any EMI events. The proposed setup could also represent a useful tool for expressing the EMC immunity levels of CIEDs in terms of unperturbed E-field strength. This research demonstrates that 5G mobile terminals do not pose significant risks to PM/ICD wearers and provides important data, enhancing the current understanding of the EMI impact of 5G technology on critical medical devices. <https://doi.org/10.1140/epjp/s13360-025-06167-6>

## Etudes épidémiologiques

**Radiofrequency radiation and Alzheimer's disease: harmful and therapeutic implications,** Bektas, H. and Dasdag, S., *International Journal of Radiation Biology*, Mar 2025.

Purpose Alzheimer's disease (AD) is a neurodegenerative disorder characterized by memory loss and cognitive decline. The relationship between AD and radiofrequency (RF) radiation emitted by wireless devices remains under investigation. The aim of this review is to comprehensively explore the effects of RF radiation on AD by evaluating existing literature. This review used Web of Science, Scopus, and PubMed to find relevant studies on AD and RF radiation. This review evaluates a total of 81 studies, including animal models, human studies, and in vitro experiments, with results summarized in tables for clarity. Conclusion Some studies suggest RF aggravates AD by increasing oxidative stress, impairing blood-brain barrier integrity, and promoting amyloid-beta deposition. Conversely, other studies indicate RF may have protective benefits, such as enhancing brain mitochondrial functions and reducing amyloid-beta levels. Understanding the RF-AD relationship, including parameters like frequency and exposure time, is crucial for therapeutic strategies. The

studies reviewed highlight RF radiation's dual effects on AD, underscoring the need for a detailed approach. Further studies are required to clarify these effects and inform preventive and therapeutic measures. <https://doi.org/10.1080/09553002.2025.2481854>

**The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies - Part II: Less researched outcomes,**

Karipidis, K., Baaken, D., Loney, T., Blettner, M., Mate, R., Brzozek, C., Elwood, M., Narh, C., Orsini, N., Rösli, M., Paulo, M. S. and Lagorio, S., *Environment International*, Feb 2025, Vol. 196.

*Background:* In the framework of the World Health Organization assessment of health effects of exposure to radiofrequency electromagnetic fields (RF-EMF), we have conducted a systematic review of human observational studies on the association between exposure to RF-EMF and risk of neoplastic diseases. Due to the extremely large number of included exposure types/settings and neoplasm combinations, we decided to present the review findings in two separate papers. In the first one we addressed the most investigated exposure-outcome pairs (e.g. glioma, meningioma, acoustic neuroma in relation to mobile phone use, or risk childhood leukemia in relation to environmental exposure from fixed-site transmitters) (Karipidis et al., 2024). Here, we report on less researched neoplasms, which include lymphohematopoietic system tumours, thyroid cancer and oral cavity/pharynx cancer, in relation to wireless phone use, or occupational RF exposure. *Methods:* *Eligibility criteria:* We included cohort and case-control studies of neoplasia risks in relation to three types of exposure to RF-EMF: 1. exposure from wireless phone use; 2. environmental exposure from fixed-site transmitters; 3. occupational exposures. In the current paper, we focus on less researched neoplasms including leukaemia, non-Hodgkin's lymphoma and thyroid cancer in mobile phone users; lymphohematopoietic system tumours and oral cavity/pharynx cancer in exposed workers. We focussed on investigations of specific neoplasms in relation to specific exposure sources (termed exposure-outcome pair, abbreviated E-O pairs), noting that a single article may address multiple E-O pairs. *Information sources:* Eligible studies were identified by predefined literature searches through Medline, Embase, and EMF-Portal. *Risk-of-bias (RoB) assessment:* We used a tailored version of the Office of Health Assessment and Translation (OHAT) RoB tool to evaluate each study's internal validity. Then, the studies were classified into three tiers according to their overall potential for bias (low, moderate and high) in selected, predefined and relevant bias domains. *Data synthesis:* We synthesized the study results using random effects restricted maximum likelihood (REML) models. *Evidence assessment:* Confidence in evidence was assessed according to the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach. *Results:* We included 26 articles, which were published between 1988 and 2019, with participants from 10 countries, reporting on 143 different E-O pairs, including 65 different types of neoplasms. Of these, 19 E-O pairs satisfied the criteria for inclusion in quantitative syntheses of the evidence regarding the risks of leukaemia, nonHodgkin's lymphoma or thyroid cancer in relation to mobile phone use, and the risks of lymphohematopoietic system tumours or oral cavity/pharynx cancer following occupational exposure to RF-EMF. RF-EMF exposure from mobile phones (ever or regular use vs no or non-regular use) was not associated with an increased risk of leukaemia [meta-estimate of the relative risk (mRR) = 0.99, 95 % CI 0.91-1.07, 4 studies), nonHodgkin's lymphoma (mRR = 0.99, 95% CI = 0.92-1.06, 5 studies), or thyroid cancer (mRR = 1.05, 95% CI = 0.88-1.26, 3 studies). Long-term (10 + years) mobile phone use was also not associated with risk of leukaemia (mRR = 1.03, 95 % CI 0.85-1.24, 3 studies), non-Hodgkin lymphoma (mRR = 0.99, 95 % CI 0.86-1.15, 3 studies), or thyroid cancer (no pooled estimate given the small number of studies). There were not sufficient studies of any specific neoplasms to perform dose-response meta-analyses for either cumulative call time or cumulative number of calls; individual studies did not show statistically significant associations between lifetime intensity of mobile phone use and any specific neoplasm. Occupational RF-EMF

exposure (exposed vs unexposed) was not associated with an increased risk of lymphohematopoietic system tumours (mRR = 1.03, 95 % CI = 0.87-1.28, 4 studies) or oral cavity/pharynx cancer (mRR = 0.68, 95 % CI 0.42-1.11, 3 stu <https://doi.org/10.1016/j.envint.2025.109274>

### **Long-Term Impact of Using Mobile Phones and Playing Computer Games on the Brain Structure and the Risk of Neurodegenerative Diseases: Large Population-Based Study,**

Xiao, Y., Zhang, S. R., Ma, Y. Z., Wang, S. C., Li, C. Y., Liang, Y. and Shang, H. F., *Journal of Medical Internet Research*, Jan 2025, Vol. 27.

*Background: Despite the increasing popularity of electronic devices, the longitudinal effects of daily prolonged electronic device usage on brain health and the aging process remain unclear. Objective: The aim of this study was to investigate the impact of the daily use of mobile phones/computers on the brain structure and the risk of neurodegenerative diseases. Methods: We used data from the UK Biobank, a longitudinal population-based cohort study, to analyze the impact of mobile phone use duration, weekly usage time, and playing computer games on the future brain structure and the future risk of various neurodegenerative diseases, including all-cause dementia (ACD), Alzheimer disease (AD), vascular dementia (VD), all-cause parkinsonism (ACP), and Parkinson disease (PD). All the characteristics of using mobile phones and playing computer games were collected through face-to-face interviews at baseline, and outcomes were extracted from the algorithmic combinations of self-reported medical conditions, hospital admissions, and death registries. In addition, a group of participants underwent magnetic resonance imaging (MRI) at follow-up. Cox regression and linear regression were performed. Results: The study included over 270,000 participants for risk analysis, with a mean baseline age of approximately 55.85 (SD 8.07) years. The average follow-up duration was approximately 13.9 (SD 1.99) years. Lengthy mobile phone use was associated with a reduced risk of ACD (2-4 years: hazard ratio [HR] 0.815, 95% CI 0.729-0.912,  $P < .001$ ; 5-8 years: HR 0.749, 95% CI 0.677-0.829,  $P < .001$ ; >8 years: HR 0.830, 95% CI 0.751-0.918,  $P < .001$ ), AD (5-8 years: HR 0.787, 95% CI 0.672-0.922,  $P = .003$ ), and VD (2-4 years: HR 0.616, 95% CI 0.477-0.794,  $P < .001$ ; 5-8 years: HR 0.729, 95% CI 0.589-0.902,  $P = .004$ ; >8 years: HR 0.750, 95% CI 0.605-0.930,  $P = .009$ ) compared to rarely using mobile phones. Additionally, lengthy mobile phone use was linked to a decreased risk of ACP (5-8 years: HR 0.747, 95% CI 0.637-0.875,  $P < .001$ ; >8 years: HR 0.774, 95% CI 0.663-0.904,  $P = .001$ ) and PD (5-8 years: HR 0.760, 95% CI 0.644-0.897,  $P = .001$ ; >8 years: HR 0.777, 95% CI 0.660-0.913,  $P = .002$ ) in participants older than 60 years. However, higher weekly usage time did not confer additional risk reduction compared to lower weekly usage of mobile phones. The neuroimaging analysis involved 35,643 participants, with an average duration of approximately 9.0 years between baseline and neuroimaging scans. Lengthy mobile phone use was related to a thicker cortex in different areas of the brain. Conclusions: Lengthy mobile phone use is associated with a reduced risk of neurodegenerative diseases and improved brain structure compared to minimal usage. Our research provides valuable background knowledge for future studies on the impact of modern electronic devices on brain health.*

<https://doi.org/10.2196/59663>

## **Evaluation de l'exposition**

### **Electromagnetic Field Emissions by Electric Vehicles**

Cebulska, W., Hadryś, D. and Przytula, I. (2024). 20th Transport Systems Theory and Practice Conference, Katowice, POLAND.

*This article discusses the theory of electromagnetic field emissions, the impact on safety, and measures EMF emissions. The electromagnetic field emission of the Dacia Spring electric vehicle was measured in various driving conditions, i.e. in city and highway traffic and during charging. Values*

such as electric field strength, magnetic field strength and power density were measured. Measurements have shown that the emission of electric field, magnetic field and power density increases with the engine load. The highest electric field intensity recorded during charging was 5 V/m. Compliance with the Regulation of the Minister of Health (2020) indicates that emissions do not exceed permissible levels, ensuring safety. However, temporary symptoms may occur in the immediate vicinity of the vehicle. Continuous monitoring and establishment of exposure guidelines are necessary to reduce the potential health risks associated with electromagnetic fields. [https://doi.org/10.1007/978-3-031-81777-9\\_7](https://doi.org/10.1007/978-3-031-81777-9_7)

### **Electromagnetic Exposure Safety Assessment of Medical Implants in the Human Body for EV-WPT Considering Uncertainty,**

Chen, Y. Z., Yu, Q. Y., Zheng, Y., Wang, T. H. and Chi, Y. D., *Ieee Transactions on Vehicular Technology*, Feb 2025, Vol. 74, no. 2, p. 2105-2115.

*For humans exposed to electromagnetic fields, metal medical implants pose more safety issues. The objective of this article is to analyze the safety issues of human electromagnetic exposure containing implants in the electric vehicle wireless power transfer (EV-WPT). This article establishes an adult male human model with a coronary artery stent and hip joint implant and is exposed to the leakage magnetic field of an EV-WPT system. The EV-WPT system has a transmission power of 30 kW and a working frequency of 85 kHz. Fully considering the uncertainty of human exposure to the electromagnetic environment of the EV-WPT system, such as the distance between the human body and the EV-WPT system, the distance between the EV-WPT system coils, and the parameters of the compensation circuit, this article uses Bayesian Neural Networks to evaluate human electromagnetic safety. Bayesian neural networks can obtain accurate results with fewer training sets and have higher computational efficiency. The results showed that the probability of electromagnetic exposure levels significantly exceeding the standard limit in the human body with hip joint implants was almost 100%, while the probability of exceeding the standard limit in the human heart with coronary artery stents did not exceed 31.5%. Patients with medical implants may need to limit power when using the EV-WPT system. <https://doi.org/10.1109/tvt.2024.3349429>*

### **Network-Based Assessment of Actual EIRP of 5G Base Stations in a Stadium With 100 000 People and Implications on EMF Compliance,**

Di Paola, C., Joshi, P., Colombi, D., Xu, B., Bischoff, J. E., Zhekov, S. S. and Tornevik, C., *Ieee Antennas and Wireless Propagation Letters*, Jan 2025, Vol. 24, no. 1, p. 242-246.

*In this study, the actual time-averaged equivalent isotropic radiated power (EIRP) levels of nine 5G massive multiple-input-multiple-output base stations (BSs) located inside the Melbourne Cricket Ground were assessed. Measurements were conducted during the 2023 Australian Football League Grand Final with a full stadium capacity of over 100 000 attendees, under extreme mobile traffic and user density conditions. Precoding matrix indicator and time-averaged output power data of the BSs were collected using a network monitoring tool to obtain actual time-averaged EIRP statistics corresponding to the spatial distribution of power transmission in different beam directions. The results show that, even under exceptional traffic conditions, the actual time-averaged EIRP levels were significantly below the maximum, with the mean and 95 th percentile values being 7.6% and 9.5% of it, respectively. This corresponds to a reduction of the electromagnetic fields compliance distance by about 60% compared to the theoretical maximum exposure scenario. <https://doi.org/10.1109/lawp.2024.3493252>*

**6G RIS in Indoor Environments: Assessment of Exposure Variability in Human Users and Non-Users,**

Gallucci, S., Benini, M., Fiocchi, S., Tognola, G. and Parazzini, M., *Ieee Open Journal of Antennas and Propagation*, Apr 2025, Vol. 6, no. 2, p. 487-496.

*The aim of the present work is to assess the exposure of human users and non-users in indoor scenarios due to novel technology that will be integrated in 6G network in order to overcome the obstacles in NLOS area: Reconfigurable Intelligent Surface (RIS), here tuned in FR1-band. The exposure assessment was conducted in two simplified indoor scenarios, single room and office, where the transmission angle of the RIS were varied mimicking the RIS following the user, and the Specific Absorption Rate (whole-body and brain SAR) were calculated. Five human models from Virtual Population (ViP) were considered differing between each other for anatomical characteristics. SAR(wb) and SAR(brain) results, studied in terms of peak values, cumulative distribution functions (CDFs) and spatial maps, showed higher SAR(wb) values in adults compared to children, while SAR(brain) peaks were more pronounced in child models. The study also revealed that there are few cases in which the exposure of non-user could be higher than the user. Moreover, the CDFs demonstrated that, for all the considered models, the probability that very low SAR(brain) and SAR(wb) levels occur is noticeably high. However, in general all the results are well below the ICNIRP Guidelines limits. <https://doi.org/10.1109/ojap.2025.3529980>*

**Synthesis of the Report Pilot study on environmental exposure to Extremely Low Frequency Magnetic Fields (ELF-EMF). PHASE I,**

Marcos, F. V. and García, M. M., *Revista Espanola De Salud Publica*, Dec 2024, Vol. 98. <https://ojs.sanidad.gob.es/index.php/resp/article/download/943/1304/5343>

**Radiofrequency Electromagnetic Pollution of the Habitat Created by Mobile Communications,**

Mordachev, V., *Biology Bulletin*, Dec 2024, Vol. 51, no. 11, p. 3481-3495.

*The declared intensive development of 5G mobile communications, involving a significant increase in the mobile traffic area capacity and density of sources of electromagnetic radiation in a very wide frequency range can cause an unacceptable electromagnetic pollution of the habitat and a serious threat to public health. Effective management of these processes is impossible without the objective prediction of levels of electromagnetic background created at the implementation of the declared set of 5G scenarios and services. The aim of this paper is to present a practical technique for such prediction. The author has developed a technique for the assessment of integral levels of electromagnetic background created by wireless information services, based on the forecast of the average electromagnetic loading on area created by radiations of spatially distributed base stations and terminal devices of mobile communications. This loading created by 4G/5G systems can be defined on the base of the estimation of average area traffic capacity and available parameters of the equipment and topology of mobile communication networks. The author proposes expressions of acceptable complexity for estimating the electromagnetic background intensity created by stationary and mobile components of 4G/5G systems, and provides calculation results illustrating processes of electromagnetic background generation by these systems in different frequency ranges with different area traffic capacity and different sizes of base stations service areas, confirming the danger of unacceptable deterioration of electromagnetic ecology of the habitat at the further expansion of mobile communications. <https://doi.org/10.1134/s1062359024701863>*

**Comparative analysis of electromagnetic field exposure in a higher educational institution: a study before and after the COVID-19 pandemic,**

Singh, R., Singh, A. and Jangid, A., *Discover Public Health*, Mar 2025, Vol. 22, no. 1.

*The advancement and improvement of telecommunication technology has created worries about the effects of electromagnetic (EM) radiation on biotic systems. The COVID-19 pandemic has made extensive use of smartphones and other technologies that were both essential and unavoidable. In addition, this has resulted in humans being exposed to excessive microwave radiation from smartphones, particularly youngsters who have early access to these devices. In higher educational institutes, such as the Dayalbagh Educational Institute, the dependency on wireless communication has increased during the pandemic. In this work, we used SRM-3006 to evaluate the electric field, magnetic field, and power density for broad public exposure and compared the results to ICNIRP and FCC safety standards. Results of the measurements taken in the year 2023 have been compared with those of the pre-COVID measurements recorded in 2019, and their analysis has been performed. The findings indicate a significant increase in radiation levels in the post-COVID-19 scenario. <https://doi.org/10.1186/s12982-025-00484-y>*

**Auto-induced uplink 4G and 5G RF-EMF exposure assessment using a network monitoring application in different microenvironments across seven European countries,**

Stroobandt, B., Van Bladel, H., Veludo, A. F., Deprez, K., Aerts, S., Verloock, L., Thuróczy, G., Polittanski, P., Polanska, K., Tognola, G., Parazzini, M., Wiart, J., Guxens, M., Rösli, M. and Joseph, W., *Environmental Research*, Apr 2025, Vol. 270.

*The auto-induced uplink (a-UL) radio-frequency electromagnetic field (RF-EMF) exposure, often the dominant part of the total RF-EMF exposure, has not been included in previous microenvironmental studies. As 5G exposure depends more on mobile phone usage, monitoring typical transmit power levels is crucial towards more accurate personal exposure assessment. This study describes spatial differences in average mobile phone transmit power and investigates the influence of uplink duty cycles and frequency band usage. A novel methodology using the network monitoring application QualiPoc in fourth-generation (4G) and non-standalone fifth-generation (5G) networks was presented. For the first time, the assessment of 4G and 5G a-UL RF-EMF exposure was conducted simultaneously in a large-scale microenvironmental study in Europe. Measurements were performed along predefined routes in 282 different microenvironments (e.g., parks, residential areas) across seven European countries, during a maximum uplink usage scenario. The Netherlands had the highest average transmit powers per microenvironment (median 20.6 dBm). Transmit powers in villages were 0.6-2.1 dB higher than in big cities. The study suggested that base station density is a key predictor of a-UL exposure. Comparing technologies and frequency bands, average transmit powers for 5G were about 3.3 dB lower than for 4G and lowest for frequency bands with a time division duplexing (TDD) scheme due to the low uplink duty cycle (below 20%). This study provides crucial measurement data for epidemiologists and governments to enhance the understanding of the aUL component of personal RF-EMF exposure.*

<https://doi.org/10.1016/j.envres.2025.121029>

**The Numerical Assessment of RF Human Exposure to Microwave Ovens with Contact-Type Doors,**

Tian, R., Wei, J. C. and Lu, M., *Electronics*, Mar 2025, Vol. 14, no. 5.

*In complex electromagnetic environments, cardiac pacemakers may be interfered with easily. Microwave ovens, as common household appliances, may display electromagnetic leakage, which may pose risks to pacemaker wearers. This work evaluates the electromagnetic exposure of pacemaker wearers under various conditions. One involves different distances from the microwave oven to the human body, and the other involves a distinct oven door gap. This work uses COMSOL Multiphysics to establish a human thoracic cavity model with a heart and unipolar pacemaker, as well as a model of a microwave oven with contact-type doors. The results show that the specific*



absorption rate (SAR<sub>10g</sub>) and temperature increase in the thoracic cavity and heart tissue are inversely proportional to the distance from the microwave source. They are directly proportional to the oven door gap size. The induced electric field intensity, the temperature increase, and the induced voltage in the pacemaker show the same trend. When the human body is closest to the microwave oven with the largest door gap ( $D = 100$  mm,  $d = 0.3$  mm), the SAR<sub>10g</sub> and temperature increase of the thoracic cavity and heart tissue reach their maximum values, which are significantly below the safety standards recommended by ICNIRP. Similarly, the maximum value of the temperature increase and the induced electric field intensity in the pacemaker are below the safety standard recommended by ISO 14708-3 (+2 degrees C) and IEC 60601-1-2 (28 V/m). The maximum induced voltage at the pacemaker electrode is 5.322 mV, which exceeds the sensing sensitivity setting recommended by ISO 14117 (2 mV) for unipolar pacemakers. These findings demonstrate that microwave ovens with contact-type doors electromagnetic radiation do not threaten human health under normal usage conditions. However, the maximum value of the induced voltage exceeds the sensing sensitivity of some unipolar pacemakers, which may affect the operation of the unipolar pacemaker. This phenomenon requires attention from clinicians and patients. We still recommend that pacemaker wearers keep a distance from microwave ovens when using them.

<https://doi.org/10.3390/electronics14050873>

#### **Assessment of Global System for Mobile Communications - Railway (GSM-R) electromagnetic fields exposure along the railway lines in Lanzhou, China,**

Wang, Y. X. and Lu, M., *Environmental Research*, May 2025, Vol. 272.

*The rapid development of high-speed railways, coupled with the swift advancement of related wireless services, has raised public concerns about electromagnetic exposure, particularly for residents along railway lines. While numerous studies have examined radio exposure from mobile operators, broadcasting, and WLAN services, the electromagnetic exposure associated with railway communication services has primarily focused on occupational exposure for relevant personnel, with insufficient attention given to public exposure near railway lines. In this study, electromagnetic exposure levels along two railways in Lanzhou, China were assessed at two different dates using both vehicle-mounted data measurement and fixed-location measurement methods. It was observed that the maximum electromagnetic exposure caused by GSM-R occurs at distances of 1200 to 1500 m from the base station. The maximum values, 95 % values and mean values of the electromagnetic exposure for GSM-R were recorded respectively: 0.5755 V/m, 0.2265 V/m and 0.02483 V/m (Lanzhou- Xinjiang railway); 0.1376 V/m, 0.1107 V/m and 0.01722 V/m (Lanzhou-Lanzhou New District railway). The data collected at fixed locations during the same time period were 0.0313 V/m, 0.0303 V/m and 0.02517 V/m, respectively. The measurements also exhibited significant spatial variability, yet those taken on different dates showed high reproducibility. Additionally, a phenomenon of channel switching of GSM-R service was noted during the measurements. The vehicle-mounted data measurement method is highly efficient for assessing electromagnetic exposure levels over large areas. Integrating additional data, such as GIS (Geographic Information System) and base station information, allows for multi-dimensional analysis, uncovering more exposure-related insights. Our study, utilizing this approach, found that the variability of GSM-R exposure along the railway maybe related to the vertical directionality of the antennas. Furthermore, the electromagnetic exposure levels from the GSM-R service were found to comply with ICNIRP guidelines, indicating that these communication services present no significant health risks to the surrounding public.*

<https://doi.org/10.1016/j.envres.2025.121138>

## Toxicité

### **Multiple radiations and its effect on biological system - a review on in vitro and in vivo mechanisms,**

Balasubramanian, D., Agraharam, G., Girigoswami, A. and Girigoswami, K., *Annals of Medicine*, Dec 2025, Vol. 57, no. 1.

*Purpose*We are exposed to different types of radiation from natural sources or for biomedical diagnostic and therapeutic purposes at different doses or times. The dose, duration, and number of exposures can cause multiple effects both in vivo and in vitro. Several researchers have explored the effects of ionizing and non-ionizing radiation in cell lines and animal models. Macromolecules, such as DNA, RNA, and proteins, are the primary targets of damage and can lead to several diseases, including cancer and even cell death. Chronic low-dose exposure of cells to radiation can cause alterations in gene expression and can be deleterious to the fate of the cells. We aim to discuss the implications of multiple radiations on different biological systems, including how nanotechnology can facilitate the effects of radiation in therapeutics. *Conclusion*In this review, we discuss the in vitro and in vivo changes that occur due to exposure to different types of radiation used in diagnosis, therapeutics, and other means, such as radiation equipment operators and patients being exposed. The effects of ionizing and non-ionizing radiation have been discussed separately. We have also mentioned in detail about the human-caused accidents of Hiroshima and Chernobyl in this article. The application of nanotechnology in facilitating the effects of radiation in the therapy and management of radioresistance of cells has also been discussed. The radio resistance and method to improve the radiosensitivity have also been mentioned. This review article can reflect the recent developments in the various uses of ionizing and non-ionizing radiation in biomedical field and will open up new avenues to utilize radiation in a more prudent way. The role of nanotechnology in reducing the harmful effects of radiation is also discussed.

<https://doi.org/10.1080/07853890.2025.2486595>

### **The effects of radiofrequency radiation on male reproductive health and potential mechanisms,** Bektas, H. and Dasdag, S., *Electromagnetic Biology and Medicine*, Mar 2025.

*Recent studies have demonstrated that radiofrequency (RF) radiation emanating from devices such as mobile phones and Wi-Fi may have adverse effects on male reproductive health. This radiation can elevate testicular temperature, potentially compromising sperm quality and DNA integrity, and influence the specific absorption rate (SAR) across different body regions, leading to detrimental reproductive outcomes. Furthermore, exposure to RF radiation has been linked to conditions that could affect male reproductive function, such as oxidative stress, alterations in ion transitions across cell membranes, and inflammation. The article reviews research conducted on both humans and animal models regarding the effects of electromagnetic radiation on sperm quality, DNA damage, oxidative stress, hormone levels, and testicular function, suggesting that exposure to electromagnetic radiation could have harmful implications for male reproductive health. However, further research is necessary to fully understand the mechanisms and implications of non-ionizing electromagnetic radiation on male infertility.* <https://doi.org/10.1080/15368378.2025.2480664>

### **MRI noise and auditory health: Can one hundred scans be linked to hearing loss? The case of the Courtois NeuroMod project,**

Fortier, E., Bellec, P., Boyle, J. A. and Fuente, A., *Plos One*, Jan 2025, Vol. 20, no. 1.

*Magnetic resonance imaging (MRI) is one of the most commonly used tools in neuroscience. However, it implies exposure to high noise levels. Exposure to noise can lead to temporary or permanent hearing loss, especially when the exposure is long and/or repeated. Little is known about the hearing risks for people undergoing several MRI examinations, especially in the context of longitudinal studies. The goal of this study was to assess the potential impact of repeated exposure to MRI noise on hearing in research participants undergoing dozens of MRI scans. This investigation was made possible thanks to an unprecedented intensive MRI research data collection effort (the Courtois NeuroMod project) where participants have been scanned weekly (up to twice a week), with the use of hearing protection, since 2018. Their hearing was tested periodically, over a period of 1.5 years. First, baseline pure-tone thresholds and distortion product otoacoustic emission (DPOAE) amplitudes were acquired before the beginning of this study. Hearing tests were then scheduled immediately before/immediately after a scan and with a delay of two to seven days after a scan. Pure-tone thresholds and DPOAE amplitudes showed no scanner noise impact right after the scan session when compared to the values acquired right before the scan session. Pure-tone thresholds and DPOAE amplitudes acquired in the delayed condition and compared to the baseline showed similar results. These results suggest an absence of impact from MRI noise exposure. Overall, our results show that an intensive longitudinal MRI study like the Courtois NeuroMod project likely does not cause hearing damage to participants when they properly utilize adequate hearing protection. <https://doi.org/10.1371/journal.pone.0309513>*

**Patient's head position-dependent safety analysis of birdcage coil, loop array, and dipole array for applications at 300 MHz in magnetic resonance imaging based on hydrogen nuclei: Simulation study,**

Lee, E., Nam, T., Hernandez, D., Kim, D., Ryu, Y., Han, Y. and Kim, K. N., *Nuclear Engineering and Technology*, Feb 2025, Vol. 57, no. 2.

*The specific absorption rate (SAR) substantially contributes to the elevation of patient temperatures during magnetic resonance imaging (MRI) scans, potentially leading to tissue degeneration and damage. In particular, the relatively short wavelength of radio frequency (RF) used in ultra-high field (UHF)-MRI generates nonuniform RF excitation ( $|B_1^+|$ ) and electric ( $|E|$ )-fields within the body, with the potential to cause localized increases in tissue temperature. This study employs electromagnetic (EM) simulations to quantitatively assesses variations in SAR resulting from different patient's head positions across three types of RF coils (birdcage coil, loop array coil, and dipole array coil), frequently employed as transmission/reception (Tx/Rx) coils in 7 T MRI. Through analysis of 715 SAR values per RF coil, achieved by varying patient's head positions at 5 mm intervals within the maximum range of movement, the study shows substantial changes in SAR values averaged over 10 g of tissue (SAR<sub>10g</sub>). Notably, these changes reach a maximum difference of 339.89 % and 371.13 % in comparison to the iso-center (no change), concerning global- and local-SAR<sub>10g</sub>. Interestingly, the study identifies instances where SAR values surpass the standard SAR limit suggested by the safety guidelines, even when the distance between the RF coil and the patient exceeded 10 mm. <https://doi.org/10.1016/j.net.2024.08.048>*

**Mass attenuation coefficient of electromagnetic radiation for human tissues,**

Mohammed, S. I. and Taqi, A. H., *Journal of Radiation Research and Applied Sciences*, Mar 2025, Vol. 18, no. 1.

*This study aims to calculate the electromagnetic radiation attenuation coefficients for various tissues (16) of the human body (Skeleton cortical bone, Brain, Blood, Lung, Heart, Liver, Muscle, Ovary, Thyroid, Spleen, Kidney, Pancreas, Skin, Eye lens, Breast, and Adipose tissue) and also demonstrate the effect of changing an element of the chemical composition of these tissues on the*

gamma attenuation coefficients. Three programs were used to calculate the attenuation coefficients and note their differences. Phy-X/PSD, XCOM, and Geant4 were calculated in the energy range from 1 MeV to 100 GeV and compared with available experimental values of the adipose, brain, breast, kidney, liver, and lung tissues. The geant4 value is the most agreement with the experimental values. <https://doi.org/10.1016/j.jrras.2024.101255>

### **5G Radiofrequency Exposure Reduces PRDM16 and C/EBP $\beta$ mRNA Expression, Two Key Biomarkers for Brown Adipogenesis,**

Seewooruttun, C., Bouguila, B., Corona, A., Delanaud, S., Bodin, R., Bach, V., Desaillood, R. and Pelletier, A., *International Journal of Molecular Sciences*, Mar 2025, Vol. 26, no. 6.

*The widespread use of wireless technologies has raised public health concerns about the biological effects of radiofrequency (RF) exposure. Children have a higher specific absorption rate (SAR) of radiation energy compared to adults. Furthermore, brown adipose tissue (BAT) is more prevalent in infants and tends to decrease with age. Previous animal studies demonstrated a cold sensation in rats exposed to 900 MHz (second generation, 2G). UCP1-dependent thermogenesis and BAT hyperplasia are two fundamental adaptive mechanisms initiated in response to cold. This study investigated the impact of short-term exposure to 2G and fifth generation (5G) on key thermogenic and adipogenic markers related to these mechanisms while considering age and exposure duration. Juvenile and young adult Wistar rats were randomized into three subgroups: a 5G group (3.5 GHz), 2G group (900 MHz), and a control group (SHAM). They were exposed to their respective continuous-wave RF signals for 1 or 2 weeks at an intensity of 1.5 V/m, with two exposure sessions of 1 h per day. After the exposure period, a RT-qPCR was carried out to evaluate the genetic markers involved in BAT thermogenesis and adipogenesis. Two adipogenic biomarkers were affected; a fold change reduction of 49% and 32% was detected for PRDM16 ( $p = 0.016$ ) and C/EBP beta ( $p = 0.0002$ ), respectively, after 5G exposure, regardless of age and exposure duration. No significant RF effect was found on UCP1-dependent thermogenesis at a transcriptional level. These findings suggest that exposure to a 5G radiofrequency may partially disrupt brown adipocyte differentiation and thermogenic function by downregulating PRDM16 and C/EBP beta, possibly leading to higher cold sensitivity. <https://doi.org/10.3390/ijms26062792>*

### **Laptop and tablet use and their influence on total motile sperm count parameters: are laptops linked to infertility in Jamaican men?,**

Sterling, L., Carroll, K. and Harris, L. R., *Revista Internacional De Andrologia*, Dec 2024, Vol. 22, no. 4, p. 25-32.

*Background: This study aims to determine the impact of laptop and tablet use on total motile sperm count (TMSC) in men being investigated for assisted reproduction. Methods: A cross-sectional study was conducted on 156 men attending a fertility clinic in Jamaica. Routine semen analyses were performed and parameters specific to TMSC assessed. All data analyses were performed using SPSS Version 26. Logistic regression analyses were performed to independently predict the impact of quantifiable measures of laptop and tablet use. The main outcome measures were the parameters associated with TMSC. Results: Overall, 64% of the participants reported using laptops and 36% reported using tablets. There was a significant relationship seen with time spent on laptops and time trying to conceive ( $p = 0.015$ ). Regression analyses showed that persons who used their laptops for 2 to 5 h daily were approximately 16 times (adjusted Odds Ratio (aOR) = 15.9; 95% Confidence Interval (CI), 2.5-103.3,  $p = 0.004$ ) more likely to be diagnosed with low semen volume (hypospermia). Although no significant association was found between total motile sperm count (TMSC) and laptop use, a trend towards significance was observed with high laptop use ( $p = 0.052$ ), suggesting potential implications for TMSC as a predictor of pregnancy outcomes. Conclusions: Our*

findings highlight the need for clinicians to take into consideration wireless device usage in men undergoing fertility investigations. <https://doi.org/10.22514/j.androl.2024.027>

**Progress in the study of the effects of electromagnetic radiation on the mood and rhythm,**  
Zou, D. F., Li, Z. H., Liu, Y. B. and Wang, C. Z., *Electromagnetic Biology and Medicine*, Apr 2025, Vol. 44, no. 2, p. 212-227.

*The ever-expanding use of a large number of electrical appliances and mobile communication systems, which outnumber the global population, emit electromagnetic radiation through mobile telephones, power stations, transmission lines, radar, microwave ovens, televisions, refrigerators, therapeutic and other electronic devices. Electromagnetic radiation has been classified by the International Agency for Research on Cancer (IARC) as possibly carcinogenic to humans (Group 2B). A large number of research results show that short-term and long-term exposure to electromagnetic radiation can lead to anxiety, depression, decreased learning ability, memory loss, sleep rhythm disorders and other adverse effects. Sleep rhythm disorders affect many people worldwide and may be associated with psychiatric disorders such as anxiety and depression. In this review, we summarise key experiments related to the effects of electric field exposure on mood and rhythms in animal and cellular studies over the past decade, describe the effects of electromagnetic radiation on emotional behaviors and circadian rhythms in humans and mammals, and explore the relationship between electromagnetic radiation, mood and rhythms as well as its underlying mechanisms of action. Most animal studies suggest that electromagnetic radiation may affect the physiological organization and functioning of the brain, influence neurotransmitters and receptors, interfere with neuronal formation and structure, or alter associated endocrine hormones and free radicals, which may lead to the unfavorable development of psychiatric disorders and sleep rhythm disorders. This summary may provide researchers with better clues and ideas to develop therapeutic solutions with sleep disorders and depressive psychiatric disorders.*

<https://doi.org/10.1080/15368378.2025.2460971>

**Assessing the Antenna Performance (Radiated Power) and Electromagnetic Impact (SAR) on a User of a Wearable RF Communication Device, Involving Various Structured Models,**  
Zradzinski, P., Karpowicz, J. and Gryz, K., *Ieee Access*, 2025, Vol. 13, p. 19257-19265.

*The investigations focused on the significance of the structural design of models of a wearable device equipped with a wireless radiofrequency communication module (W-RFCD) operating at 2.45 GHz. Computer modeling was used to determine antenna performance (radiated power and related battery operating time), as well as the associated electromagnetic impact (SAR) in the user's head. The findings showed a potential reduction in battery life of 20-40% for body-worn devices when used near the head, compared to their performance in free space, while maintaining the same quality of wireless connection. In the exposure scenarios examined, results revealed that the 10g-SAR in the user's head could increase significantly: 1) by up to 65% when the RF module's battery was centered, versus when it was offset; and 2) by up to 240% with a 0 mm distance between the RF module and the battery, compared to a 2 mm distance. The use of a simplified model of W-RFCD may lead to incorrect conclusions about its performance and a substantial underestimation of the SAR values (10g-SAR values are up to double in the most complex exposure scenarios examined, compared to the most simplified). The antenna performance and SAR of W-RFCD developed using ready-made components can be optimized without altering antenna matching circuits or inserting additional physical structures.*

<https://doi.org/10.1109/access.2025.3528656>

### **Short-Term In Vitro Exposure of Human Blood to 5G Network Frequencies: Do Sex and Frequency Additionally Affect Erythrocyte Morphometry?**

Zura, N., Vince, S., Peric, P., Vilic, M., Malaric, K., Rimac, V., Cepulic, B. G., Vajdic, M., Jurak, I., Tur, S. M., Milas, N. P., Samardzija, M., Nemir, J., Telebuh, M. and Zaja, I. Z., *Biomedicines*, Feb 2025, Vol. 13, no. 2.

*Background/Objectives:* This study assessed the effects of 5G radiofrequency electromagnetic radiation (RF-EMR) at different frequencies (700 MHz, 2500 MHz, 3500 MHz) on the complete blood count (CBC), erythrocyte morphometry, and platelet activation after the short-term in vitro exposure of human blood. *Methods:* Blood samples from 30 healthy volunteers (15 men and 15 women, aged 25-40 years old) were collected at three intervals (14 days apart). For each collection, four tubes of blood were drawn per volunteer—two experimental and two controls. Experimental samples were exposed to 5G RF-EMR for 2 h at room temperature using a half-cone gigahertz transverse electromagnetic cell. The CBC was analysed via a haematology analyser, the erythrocyte morphometry was analysed using the SFORM program, and platelet activation was analysed via flow cytometry. *Results:* The CBC and platelet activation showed no significant differences between the experimental and control samples. However, the erythrocyte morphometry exhibited notable changes. At 700 MHz, the erythrocyte size, contour, and membrane roughness increased significantly for both sexes, with women's cells showing greater sensitivity. At 2500 MHz, women exhibited an increased contour index and a decreased solidity and form factor. At 3500 MHz, women showed an increased contour index and outline but a decreased solidity, elongation, and form factor. Cluster analysis identified two erythrocyte subpopulations: smaller, rounder cells with smooth membranes and larger cells with rougher membranes. *Conclusions:* These results indicate that 5G RF-EMR exposure significantly alters erythrocyte morphometry. The strongest effects were observed at 700 MHz, where men exhibited greater membrane roughness, and women showed larger and rounder erythrocytes. These findings suggest that short-term in vitro 5G RF-EMR exposure disrupts the cytoskeleton, increasing membrane permeability and deformability.

<https://doi.org/10.3390/biomedicines13020478>

## **Méthodes**

### **A Novel Method for Achieving Precision and Reproducibility in a 1.8 GHz Radiofrequency Exposure System That Modulates Intracellular ROS as a Function of Signal Amplitude in Human Cell Cultures**

Dahon, C., Aguida, B., Lebon, Y., Le Guen, P., Dangremont, A., Meyer, O., Citerne, J. M., Pooam, M., Raad, H., Thoradit, T., Jourdan, N., Bertagna, F. and Ahmad, M., *Bioengineering-Basel*, Mar 2025, Vol. 12, no. 3.

*Radiofrequency fields in the 1-28 GHz range are ubiquitous in the modern world, giving rise to numerous studies of potential health risks such as cancer, neurological conditions, reproductive risks and electromagnetic hypersensitivity. However, results are inconsistent due to a lack of precision in exposure conditions and vastly differing experimental models, whereas measured RF effects are often indirect and occur over many hours or even days. Here, we present a simplified RF exposure protocol providing a single 1.8 GHz carrier frequency to human HEK293 cell monolayer cultures. A custom-built exposure box and antenna maintained in a fully shielded anechoic chamber emits discrete RF signals which can be precisely characterized and modelled. The chosen amplitudes are non-thermal and fall within the range of modern telecommunication devices. A critical feature of the protocol is that cell cultures are exposed to only a single, short (15 min) RF exposure period, followed by detection of immediate, rapid changes in gene expression. In this way, we show that modulation of genes implicated in oxidative stress and ROS signaling is among the earliest cellular*

responses to RF exposure. Moreover, these genes respond in complex ways to varying RF signal amplitudes consistent with a hormetic, receptor-driven biological mechanism. We conclude that induction of mild cellular stress and reactive oxygen species (ROS) is a primary response of human cells to RF signals, and that these responses occur at RF signal amplitudes within the range of normal telecommunications devices. We suggest that this method may help provide a guideline for greater reliability and reproducibility of research results between labs, and thereby help resolve existing controversy on underlying mechanisms and outcomes of RF exposure in the general population. <https://doi.org/10.3390/bioengineering12030257>

#### **Recent Advances and Future Perspective in Computational Bioelectromagnetics for Exposure Assessments,**

Diao, Y. L., Joseph, W., Poljak, D., Giaccone, L., Kodera, S., Laakso, I., Yamazaki, K., Li, K., Sasaki, K., Tanghe, E., Cvetkovic, M., El Hajj, W., Hikage, T., Kaburcuk, F., Schmid, G., Nejasmic, A. S., Tarnaud, T., Anderson, V., Foster, K. R., Samaras, T., Tell, R. A., Watanabe, S., Chou, C. K. and Hirata, A., *Bioelectromagnetics*, Apr 2025, Vol. 46, no. 3.

*In the last few decades, extensive efforts have been dedicated to developing computational methods for modeling the interaction of the human body with electromagnetic fields (EMFs). These studies are crucial for the establishment of exposure limits in international standards and guidelines for human protection from EMF, as well as for advancing personalized dosimetry assessment for medical applications using EMF. To summarize the state-of-the-art knowledge in this field, the IEEE International Committee on Electromagnetic Safety (ICES) held an International Workshop on Computational Bioelectromagnetics in February 2024. This review summarizes the technical presentations and discussions from the workshop and was contributed by multiple authors, encompassing topics such as the tissue dielectric property measurement, low-frequency and radio-frequency bioelectromagnetic modeling methods, stochastic modeling in electromagnetic-thermal dosimetry, intercomparison studies, and computational uncertainties. The insights gained from this workshop will guide future research and aid in the development of more accurate and reliable exposure assessment methods.* <https://doi.org/10.1002/bem.70002>

#### **Continuous Monitoring and Modeling of High-Frequency EM Pollution Using Cutting-Edge Regression Techniques,**

Dikmen, I. C., *Ieee Access*, 2025, Vol. 13, p. 46627-46637.

*Electromagnetic (EM) sources have been of scientific interest for decades, primarily because of their intricate wave structures and the ways they travel through various media. Both national and international agencies regulate EM emissions across different frequency bands, making sure the public remains safe, mostly by setting limits on electric field intensity and power density. Here, we propose a precise predictive model for ongoing, high-frequency EM pollution, using data collected over six months in a mid-sized metropolitan area. Measurements were taken at a rate of 2 Hz, 24 hours a day. To forecast electric field intensity, we tested five regression models: Liquid Time-Constant Networks (LTC), Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM) Networks, Gated Recurrent Unit (GRU) Networks, and Kolmogorov-Arnold Networks (KAN). Among these, LTC achieved the top test accuracy of 97.95%, although the other models also proved highly reliable.* <https://doi.org/10.1109/access.2025.3548841>

#### **Fusion of Measurement and Simulation Technique for Electromagnetic Environment Analysis in Large-Scale Urban Areas,**

Gong, H. X., Wang, X., Liu, C. H., Zhao, Y. N., Liu, Y., Li, N. and Yang, W. L., *Ieee Transactions on Instrumentation and Measurement*, 2025, Vol. 74.

*Accurate analysis of electromagnetic environments, especially in large-scale urban areas, is essential to ensure the safety of urban electromagnetic spaces. This article presents a novel fusion technique that combines measurements from spectrum sensing sensors with an efficient hybrid algorithm that integrates parallel computation, higher order method of moments (HOMoM), and uniform geometrical theory of diffraction (UTD), to improve the accuracy of electromagnetic environmental analyses. The proposed technique addresses key challenges, including high costs associated with extensive measurements and poor accuracy in results fit from limited measurement data, as well as slow and imprecise simulation outcomes. By continuously updating the simulated electromagnetic field data with measured data, the technique improves simulation accuracy and enables efficient analysis of large urban areas. Experimental results from a 60-km<sup>2</sup> area in Xi'an demonstrated a root mean square error (RMSE) of less than 8 dB, with updates processed in under 8 s, making it a practical and efficient solution for large-scale urban electromagnetic environment analysis. <https://doi.org/10.1109/tim.2025.3552385>*

#### **Efficient Low-Frequency Human Exposure Assessment With the Maximum Entropy Snapshot Sampling,**

Stroka, S., Kasolis, F., Haubmann, N. and Clemens, M., *IEEE Transactions on Magnetics*, Dec 2024, Vol. 60, no. 12.

*Numerical dosimetry simulations of human exposure to low-frequency magnetic fields, according to International Commission on Non-Ionizing Radiation Protection (ICNIRP) recommendations, are typically computationally and memory-intensive. By employing reduced-order models (ROMs) for the high-fidelity linear systems to be solved, simulation efficiency can be significantly enhanced, thereby enabling a comprehensive numerical assessment of human exposure. For model generation, snapshot-based reduced basis methods (RBMs) as the proper orthogonal decomposition (POD), which rely on the singular value decomposition (SVD) of a matrix whose columns are the solution vectors of a high-fidelity system, are commonly used in the context of POD. Due to the recurrence of redundant information in most solution vectors, SVD becomes a computationally and memory-intensive step. With the maximum entropy snapshot sampling (MESS) strategy, the number of solution vectors can be efficiently reduced to the essential ones. This work presents a reduced basis for efficient human exposure assessment in a computationally and memory-efficient manner using this information-theoretic framework. <https://doi.org/10.1109/tmag.2024.3450187>*

#### **Fast In-Phantom Absorbed Power Density Evaluation at mmWaves Based on Infrared Measurements,**

Ziane, M., Boriskin, A. and Zhadobov, M., *IEEE Journal of Microwaves*, Mar 2025, Vol. 5, no. 2, p. 269-280.

*This article introduces a novel method for fast measurement of the absorbed power density (APD) induced by an electromagnetic field (EMF) emitting device operating near the human body at frequencies above 6 GHz, taking into account antenna/body interaction. The method employs an infrared (IR) thermography to remotely monitor the heat induced in a reflectivity-based skin equivalent phantom designed to reproduce the EMF scattering properties of human skin and the APD inside the human body. Such a phantom, implemented in the form of a thin planar solid dielectric structure, perturbs the device under test in a similar way as it would be perturbed by the presence of the human body, allowing the absorbed microwave energy to be effectively converted into an IR signal. The heat dynamics and the spatial temperature distribution on the phantom surface are measured by an IR camera and then converted to APD by postprocessing. To enhance the sensitivity of the method and to minimize the effect of heat conduction, spectral filtering is used.*



The proposed method is validated at 60 GHz using reference antennas (i.e. a cavity-fed dipole array and a pyramidal horn loaded with a slot array). The measured APD is compared with the reference APD simulated in human skin. The high accuracy and significant measurement time reduction, compared to conventional RF-based APD evaluation techniques, demonstrate a promising potential of the proposed IR-based method for fast EMF dosimetry and user exposure compliance testing of millimeter-wave (mmWave) 5 G and 6 G wireless devices.

<https://doi.org/10.1109/jmw.2025.3539871>

## Toxicité sur les animaux

### **Histopathologic effects of mobile phone radiation exposure on the testes and sperm parameters: a systematic literature review of animal studies,**

Assefa, E. M. and Abdu, S. M., *Frontiers in Reproductive Health*, Jan 2025, Vol. 6.

*Introduction: Male infertility, often attributed to insufficient production of healthy and active sperm, can be exacerbated by electromagnetic radiation emitted from mobile phones, which disrupts normal spermatogenesis and leads to a notable decline in sperm quality. The main targets of mobile phone-induced damage in the testes are Leydig cells, seminiferous tubules, and sperm cells. The aim of this systematic literature review is to identify histopathological changes in the testes due to mobile phone radiation exposure and to examine its effects on sperm parameters in experimental animals. Methods: In this systematic review, an extensive literature search was conducted across databases such as PubMed, ScienceDirect, Hinari, and Google scholar. Results: A total of 752 studies were identified for screening, and 18 studies were deemed eligible for data extraction. Studies have identified histopathological alterations in testicular tissue caused by mobile phone radiation, such as reduced seminiferous tubule diameter, tunica albuginea and germinal epithelial thickness, Leydig cell hypoplasia, and increased intertubular space. Consistent exposure to mobile phone radiation has been shown to significantly reduce sperm count, motility, and viability, while also increasing abnormal sperm morphology in male rats, mice, and rabbits. Conclusion: Animal studies indicate that electromagnetic radiation from mobile phones can negatively impact testicular tissue and sperm parameters, including sperm count, motility, viability, and morphology. As a precaution, preventive measures are recommended to minimize potential risks from mobile phone exposure, and further research is needed to fully understand its effects on human reproductive health.*

<https://doi.org/10.3389/frph.2024.1515166>

### **Interaction of 5G mid-band and mmWave electromagnetic fields with the murine fetus,**

Foroughimehr, N., Vilagosh, Z., Mcintosh, R., Wood, A. and Yavari, A., *Environmental Research*, Jun 2025, Vol. 274.

*Currently, fifth-generation (5G) systems are deploying in the mid-band (i.e., 3.5 GHz (GHz), with plans for standalone (SA) operation in the high-band (i.e., 26 GHz) soon. The literature reveals a lack of computational studies on flora and fauna. This study aims to address that gap and help validate experimental research on animal exposure to electromagnetic field (EMF). We aim to explore the radiofrequency (RF)-EMF absorbed by mouse fetuses through in silico analysis using the Finite Difference Time Domain (FDTD) technique. We utilize the commercial software XFDTD (Remcom) and conduct simulations at both 3.5 and 26 GHz. The investigation focuses on understanding the penetration depth to comprehend EMF absorption by the fetus. While the study indicates that RF-EMF absorption at 5G high-band frequencies is unlikely to pose significant risks to mouse uteruses and fetuses, there is a clear need for further investigation.*

<https://doi.org/10.1016/j.envres.2025.121188>

**Examining the effects of extremely low-frequency magnetic fields on cognitive functions and functional brain markers in aged mice,**

Hadzibegovic, S., Nicole, O., Andelkovic, V., De Gannes, F. P., Hurtier, A., Lagroye, I. and Bontempi, B., *Scientific Reports*, Mar 2025, Vol. 15, no. 1.

*Extremely low-frequency magnetic fields (ELF-MFs) are ubiquitously present in various environments of everyday life. While surveys from the World Health Organization (WHO) have not demonstrated the existence of ELF-MF-induced harmful consequences in healthy subjects, whether older adults are more vulnerable to the effects of residential and occupational ELF-MF exposure, and therefore may be at risk, remains unsettled. Here, we explored this potential health issue by investigating, in aged mice, the effects of chronic exposure to ELF-MFs (50 Hz ELF-MF at 1 mT for 8 h/day, 5 days/week for 12 consecutive weeks) on cognitive functions and expression profile of brain markers typically associated with aggravated aging or the development of Alzheimer's disease (AD). Sham-exposed mice showed a significant age-related decline in spatial memory functions compared to young adult mice. However, this expected pattern was neither exacerbated nor counteracted by chronic exposure to ELF-MFs. No difference in hippocampal expression of APP-695, A beta(1-42), S100b and GFAP proteins or in the pTau/Tau ratio was observed between sham- and ELF-MF-exposed aged mice, suggesting that chronic exposure to ELF-MFs does not aggravate aging and associated neuroinflammation, or promote pathological pathways involved in the initiation of AD. Because care should be taken in extrapolating these results to older adults with various comorbidities, applying current exposure limits to existing or new sensitive ELF-MF locations is recommended.*

<https://doi.org/10.1038/s41598-025-93230-y>

**The effect on rat peripheral nerve morphology and function of a 900-MHz electromagnetic field applied in the prenatal period,**

Hanci, H., Yenilmez, E., Demir, S., Yildirim, M., Gedikli, Ö. and Kaya, H., *Electromagnetic Biology and Medicine*, Mar 2025.

*The purpose of this study was to investigate the effects of a 900 megahertz (MHz) electromagnetic field (EMF) applied in the prenatal period on rat peripheral nerve morphology, nerve conduction velocity, and locomotor activity. Nine pregnant Sprague Dawley rats were assigned into three groups. No procedure was applied to the first group (control). The second (sham) group was placed inside an EMF cage for 1 h a day throughout the experiment (days 1-21 of pregnancy), but was not exposed to EMF. The third group (EMF) was placed inside the EMF cage for 1 h a day throughout the experiment (days 1-21 of pregnancy) and exposed to a 900 MHz EMF. No procedure was applied to the newborn pups until postnatal (PN) day 21, and new groups were constituted from among these. All the newly established groups were subjected to the open field and rotarod tests on PN days 21 and 60, after which electrophysiological measurements were performed on the groups in line with the study protocol. Sciatic nerves obtained from the animals sacrificed on PN day 60 were subjected to histopathological, histomorphometric, immunohistochemical, and biochemical analyses. In light of the study results, we concluded that prenatal application of a 900 MHz EMF adversely affects rat peripheral nerve development, and that these effects persist up to adulthood such as to be detectable in the sciatic nerve morphology, but that these morphological changes are not sufficiently severe to affect functional associated with the sciatic nerve.*

<https://doi.org/10.1080/15368378.2025.2479517>

**Repeated Head Exposures to a 5G-3.5 GHz Signal Do Not Alter Behavior but Modify Intracortical Gene Expression in Adult Male Mice,**

Lameth, J., Royer, J., Martin, A., Marie, C., Arnaud-Cormos, D., Levêque, P., Poirier, R., Edeline, J. M. and Mallat, M., *International Journal of Molecular Sciences*, Mar 2025, Vol. 26, no. 6.

*The fifth generation (5G) of mobile communications promotes human exposure to electromagnetic fields exploiting the 3.5 GHz frequency band. We analyzed behaviors, cognitive functions, and gene expression in mice submitted to asymmetrical head exposure to a 5G-modulated 3.5 GHz signal. The exposures were applied for 1 h daily, 5 days per week over a six-week period, at a specific absorption rate (SAR) averaging 0.19 W/kg over the brain. Locomotor activities in an open field, object location, and object recognition memories were assessed repeatedly after four weeks of exposure and did not reveal any significant effect on the locomotion/exploration, anxiety level, or memory processes. mRNA profiling was performed at the end of the exposure period in two symmetrical areas of the right and left cerebral cortex, in which the SAR values were 0.43 and 0.14 W/kg, respectively. We found significant changes in the expression of less than 1% of the expressed genes, with over-representations of genes related to glutamatergic synapses. The right cortical area differed from the left one by an over-representation of responsive genes encoded by the mitochondrial genome. Our data show that repeated head exposures to a 5G-3.5 GHz signal can trigger mild transcriptome alterations without changes in memory capacities or emotional state.*  
<https://doi.org/10.3390/ijms26062459>

#### **Experimental Study of Animal Behavior under the Influence of the Electromagnetic Field of the 5G Mobile Communication Standard,**

Nikitina, V. N., Kalinina, N. I., Dubrovskaya, E. N., Plekhanov, V. P. and Kovshov, A. A., *Biology Bulletin*, Dec 2024, Vol. 51, no. 11, p. 3473-3480.

*A pilot experimental study was carried out to assess the effect of unmodulated and modulated electromagnetic fields of the 5G mobile communication standard on the central nervous system of animals. Mature male Wistar rats were exposed to electromagnetic fields with a frequency of 4.9 GHz and an intensity of 250  $\mu$ W/cm<sup>2</sup> for 15 days for two hours a day. The animals of the two irradiated groups and the control group were in identical conditions in a semi-anechoic shielded chamber. The effect of the electromagnetic field on the functional state of the central nervous system was assessed by a comprehensive analysis of behavior patterns in the "open field" test before and after irradiation. The study did not reveal clear differences in animal behavior when exposed to unmodulated and modulated 5G electromagnetic fields. Statistically significant changes in animal behavior were recorded in the dynamics of the experiment in two irradiated and control groups, which may be due to a change in the natural electromagnetic background in a semi-anechoic shielded chamber.* <https://doi.org/10.1134/s1062359024701875>

#### **Neuromorphological Effects of Acute and Chronic Electromagnetic Radiation,**

Ushakov, I. B., Fedorov, V. P. and Davydov, B. I., *Biology Bulletin*, Dec 2024, Vol. 51, no. 11, p. 3445-3456.

*Morphological changes in the cerebral cortex have been studied in model experiments on three types of laboratory animals (mice, rats, and dogs) exposed to both acute and chronic electromagnetic radiation. It has been established that neurons are highly reactive and, at the same time, characterized by plasticity to the electromagnetic factor. Changes in neurons are more significant after general irradiation than after partial irradiation. The greatest response has been found from the structures of the protein-synthesizing system of neurons, as well as their interneuronal contacts. After 3 days of the recovery period, changes were recorded only at the ultrastructural level in the form of residues, decayed organelles, clusters of lysosomes, and local foci of brain edema. During chronic microwave impact with exposure at the "zero effect" level, the sensitivity of neurons to electromagnetic radiation was characterized by species differences and was inversely dependent on the animal body weight: mice were most sensitive, the structures of the rat*

nervous system were more resistant, and the nervous structures of dogs were least sensitive.

<https://doi.org/10.1134/s1062359024701899>

**The Impact of 9.375 GHz Microwave Radiation on the Emotional and Cognitive Abilities of Mice,** Wang, X. Y., Zhao, X. L., Xu, J., Li, M. H., Sun, B., Gao, A. N., Zhang, L. H., Wu, S., Liu, X. M., Zou, D. F., Li, Z. H., Dong, G. F., Zhang, C. G. and Wang, C. Z., *International Journal of Molecular Sciences*, Mar 2025, Vol. 26, no. 7.

*In recent years, high-power microwave (HPM) technology has developed rapidly. However, the current research mainly focuses on how to improve its performance and its impact on electronic devices, and there has been relatively little research on its effects on organisms. In particular, the research on the biological effects of HPMs in the X-band is even more limited. The purpose of this paper is to conduct a study on the effects of HPMs in the X-band with a frequency of 9.375 GHz on mood, learning, and cognitive abilities, as well as the antioxidant defense system. Upon observation, it was noted that the mice in the exposed groups, when compared to the control group, did not display significant signs of depression or anxiety. Furthermore, their learning capabilities, memory retention, and cognitive functions remained intact and were not adversely affected. The results of oxidative-stress-related indicators in serum and brain tissue showed increased levels of antioxidant enzymes including superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px), reduced levels of protein carbonyl (PCO) and malondialdehyde (MDA), and no significant changes in reactive oxygen species (ROS). In summary, acute exposure to 9.375 GHz HPM did not cause significant damage to the organisms, and the body could defend against the acute stress caused by HPMs through its own antioxidant system. This investigation provides substantial theoretical foundations and robust experimental evidence for establishing safety parameters and potential biomedical applications of microwave radiation within defined exposure limits.*

<https://doi.org/10.3390/ijms26072871>

## Actualité, société et mesures de prévention

**Self-diagnosing electromagnetic hypersensitivity-A case study,**

Ashton, D., *Frontiers in Public Health*, Mar 2025, Vol. 13.

<https://doi.org/10.3389/fpubh.2025.1535513>

**Could electrohypersensitivity be a specific form of high sensory processing sensitivity?**

Bordarie, J., Ledent, M., Dieudonné, M., Choisy, F. and De Clercq, E., *Frontiers in Public Health*, Feb 2025, Vol. 13.

*Introduction Electrohypersensitivity (EHS) refers to a syndrome in which individuals claim to suffer from a variety of symptoms that they attribute to electromagnetic fields. The characteristics of this specific hypersensitivity, particularly in terms of symptoms, are similar to those associated with high sensory processing sensitivity (HSPS). This article raises the question of the superposition of these two types of sensitivity and investigates the existence of a link between the two. Methods Participants (n = 100) completed a questionnaire measuring EHS and HSPS, as well as absorption, risk perception and avoidance strategies related to electromagnetic fields, and anxiety and depressive disorders. Results They showed an overrepresentation of highly sensitive people within the electrohypersensitive group. Furthermore, the results showed differences in terms of anxiety-depressive symptomatology and cognitive strategies (risk perception and avoidance strategies). Discussion The article discusses these results in the light of the literature and suggests avenues for future research and ways to help highly sensitive people, whether or not this condition is*

considered to be caused by electromagnetic radiation.

<https://doi.org/10.3389/fpubh.2025.1550427>

**Risks of electromagnetic fields from the perspective of general practitioners and pediatricians,**  
Forster, F., Riesmeyer, C., Ermel, L., Lüthy, K., Jung, R. Y. and Weinmann, T., *Bmc Primary Care*, Mar 2025, Vol. 26, no. 1.

*Background* Although there is little evidence for adverse health effects due to exposure to electromagnetic fields (EMF) below legal limits, worries regarding these effects are relatively frequent in the general population. For many individuals, general practitioners (GPs) and pediatricians are the first point of contact with the health system. Therefore, it is essential to understand their EMF risk perception. *Methods* We conducted a cross-sectional mixed methods study inviting 3,000 GPs and 2,000 pediatricians sampled from the German Federal Medical Registry, of which 614 (12.3%) participated in an online survey and 25 participated in focus groups. We estimated the prevalence of high risk perception, poor subjective knowledge regarding EMF, and the relevance of EMF in their everyday work correcting for non-response by Multilevel Regression and Poststratification. *Results* About a quarter of physicians indicated high risk perception regarding health and EMF. Relevance was low, with about 40% of GPs and about 20% of pediatricians reporting EMF-related consultations during the last year. About 60% of physicians had poor subjective knowledge. Many physicians said they could not rule out the possibility of adverse health effects of EMF due to insufficient knowledge and expressed a need for information to address this knowledge gap. *Conclusions* A substantial part of GPs and pediatricians with high risk perception are physicians with poor subjective knowledge regarding EMF who cannot completely rule out EMF below legal limits as a cause of unspecific, unclear symptoms, and who are therefore open to patients' suggestions of EMF as a potential cause. <https://doi.org/10.1186/s12875-025-02762-9>

**Research of the Biomedical Effects of Electromagnetic Field in Russia over 130 Years: Main Stages of Advances in Scientific Knowledge,**

Grigoriev, O. A., Ushakov, I. B. and Alekseeva, V. A., *Biology Bulletin*, Dec 2024, Vol. 51, no. 11, p. 3421-3433.

*We have analyzed the key stages of advances in the scientific history of research into the biomedical effects of electromagnetic field (EMF) in Russia over 130 years and proved the continuity of this scientific knowledge and its passage from one generation of scientists to the next due to scientific schools, systematic research, and national scientific coordination. The article focuses mainly on the period in which planned EMF health research was formed, the basic methodological principles were founded, and scientific principles were established for understanding the nature of the biological effects of EMF and their impact on health. The basic concepts on the part of Russian scientists about the mechanism underlying the biological effects of EMF and principles of their hygienic regulation are summarized.* <https://doi.org/10.1134/s1062359024701784>

**Electromagnetic shielding behavior of cut-protective workwear consisting of metallic core multicomponent hybrid yarn,**

Hasan, M. Z., Rathour, R., Das, A., Alagirusamy, R. and Kumar, N., *International Journal of Occupational Safety and Ergonomics*, Feb 2025.

*This study aims to enhance the electromagnetic barrier performance of conductive cut-protective fabrics by incorporating stainless steel filament fiber into the fabric. This was accomplished by combining high-performance polyethylene, polyester and stainless-steel filament fibers to produce cut-protective woven samples with different areal densities. The shielding efficiency values and the*

*correlation between input factors, such as frequency (100-1500 MHz), stainless steel (30-50  $\mu$  m) and areal density (150-250 g/m<sup>2</sup>), were computed empirically using surface response curves. Several noteworthy results and a strong correlation coefficient ( $R^2 = 0.97$ ) were observed, indicating the model's validity. Three-dimensional surface response curves were constructed to investigate how the independent factors affected the electromagnetic shielding efficacy. Furthermore, the optimal electromagnetic shielding effectiveness value of fabric made with distinct stainless-steel filament fiber diameters is apparent at varying measured frequencies. The diameter of metallic filament fibers strongly influences the fabric shielding effectiveness.*

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