

TECHNOLOGIE 5G

Bulletin de veille scientifique : Février 2026



Objectifs : réaliser une veille scientifique sur la technologie 5G

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Généralités

Aucun article dans ce bulletin.

Technologie 5G

Performances et sécurité

AI-enabled cybersecurity framework for future 5G wireless infrastructures.

Alam A, Umer A, Ullah I, Alsayat A. *Sci Rep.* 2026 Feb 3;16(1):7055.

The deployment of fifth-generation (5G) wireless networks is transforming digital connectivity through ultra-low latency, high data rates, and massive device support. However, enabling technologies such as network slicing, virtualization, edge computing, and dense Internet of Things (IoT) integration significantly expand the attack surface, necessitating advanced cybersecurity strategies. This study proposes a comprehensive multi-layered cybersecurity framework tailored for 5G infrastructures. The framework incorporates device-level trust validation, secure network slice configuration and isolation, dynamic policy enforcement at the orchestration layer, and AI-driven threat detection to provide end-to-end protection across the 5G architecture. Unlike traditional reactive security models, the proposed approach adopts security-by-design principles to proactively mitigate threats. The framework's effectiveness is evaluated through extensive simulations and benchmarking against established standards, including the NIST Zero Trust Architecture and 3GPP TS 33.501. Results demonstrate a threat detection rate of up to 97.6%, low-latency performance under high-load and adversarial conditions, and scalable operation with large-scale device connectivity. Despite these results, challenges remain in ensuring consistent policy enforcement across distributed edge nodes, achieving interoperability among heterogeneous devices, and balancing performance with stringent security requirements. The study concludes by highlighting future research directions, including quantum-resilient cryptography and self-healing, AI-enhanced security mechanisms, to address evolving threats in future 6G networks.

[Lien vers l'article](#)

NIDD-enabled lightweight intrusion detection for effective DDoS mitigation in 5G and beyond.

Javid I, Khara S, Frnda J, Khanday SA, Wani NA, Bedi J, et al. *Sci Rep.* 2025 Nov 24;15(1):42207.

With the introduction of 5G technology, wireless communication is expected to undergo revolutionary changes that will allow high-speed connectivity and scalability. Though 5G networks have the potential to be revolutionary, they also pose new challenges in ensuring the security and integrity of data transfer, especially in Non-IP Data Delivery (NIDD) scenarios. The need for robust anomaly detection systems becomes even more critical in this scenario to safeguard IoT and other reliable networks. Anomaly detection has been the subject of much research in network contexts, as it is crucial for identifying hostile activity, system failures, and odd behavior. The growing dependence on technologies, particularly with the advent of 5G and its potential to connect nearly everything, has made it imperative to investigate intelligent and efficient techniques that ensure network availability, secrecy, and integrity. To address the botnet infiltration, DDoS mitigation, and other incursions in 5G networks, a novel lightweight intrusion detection model is proposed for 5G and beyond networks, which uses the 5GNIDD dataset in the experiments. The proposed model is powered by a robust preprocessing model, which uses Gini Importance for feature selection and state-of-the-art classifiers, namely, AdaBoost, Easy Ensemble, GRU, 1D-CNN, LSTM, and hybrid CNN-LSTM for classification. Two different case studies with k-best features are driven in experiments showcasing the effect of the curse

of dimensionality on precision. The model has obtained 99.64% accuracy and a 0.9830 precision using 1D-CNN and a hybrid LSTM-CNN model.

[Lien vers l'article](#)

Correction: NIDD-enabled lightweight intrusion detection for effective DDoS mitigation in 5G and beyond.

Javid I, Khara S, Frnda J, Khanday SA, Wani NA, Bedi J, et al. *Sci Rep.* 2026 Feb 18;16(1):6976.

The original version of this Article contains an error where the section 'Conclusion and Future Scope' was incorrectly removed.

[Lien vers l'article](#)

Secure Signal Encryption in IoT and 5G/6G Networks via Bio-Inspired Optimization of Sprott Chaotic Oscillator Synchronization.

Maamri F, Djellab H, Bououden S, Boumehrez F, Sahour A, Alawad MA, et al. *Entropy (Basel).* 2025 Dec 26;28(1).

The rapid growth of Internet of Things (IoT) devices and the emergence of 5G/6G networks have created major challenges in secure and reliable data transmission. Traditional cryptographic algorithms, while robust, often suffer from high computational complexity and latency, making them less suitable for large-scale, real-time applications. This paper proposes a chaos-based encryption framework that uses the Sprott chaotic oscillator to generate secure and unpredictable signals for encryption. To achieve accurate synchronization between the transmitter and the receiver, two bio-inspired metaheuristic algorithms-the Pachycondyla Apicalis Algorithm (API) and the Penguin Search Optimization Algorithm (PeSOA)-are employed to identify the optimal control parameters of the Sprott system. This optimization improves synchronization accuracy and reduces computational overhead. Simulation results show that PeSOA-based synchronization outperforms API in convergence speed and Root Mean Square Error (RMSE). The proposed framework provides robust, scalable, and low-latency encryption for IoT and 5G/6G networks, where massive connectivity and real-time data protection are essential.

[Lien vers l'article](#)

Antennes

Compact and low cross-polarization microstrip patch antenna for 5G Internet of Things applications.

Nguyen-Huy H, Tran H, Pham-Duy H, Dao-Duc T, Hussain N. *PLoS One.* 2026;21(2):e0341549.

This paper presents a miniaturization technique for microstrip patch antennas operating at the fundamental TM₀₁ mode based on a loading capacitor approach. Several gaps are inserted into the patch, and with the aid of shorting vias, coupled gaps are produced. These function as a slow-wave transmission line, and then, the operating frequency is significantly moved to a lower frequency range. The final radiating element with dimensions of approximately quarter-effective wavelength at 4.5 GHz

exhibits good matching performance in the frequency range from 4.48 to 4.52 GHz and broadside gain around 5.0 dBi. It is noted that the proposed design exhibits extremely low cross-polarization radiation of less than -40 dB, which is much lower than that of the conventional quarter-wavelength patch antenna. In comparison with the reported compact patch antennas in literature, the proposed miniaturized patch is one of the smallest design with the smallest cross-polarization level, while having comparable gain. Such operation characteristics demonstrate the suitability of the proposed antenna for compact Internet of Things (IoT) applications working at 5G New Radio n79 band.

[Lien vers l'article](#)

Implementation of smart metasurfaces for the Sub-6 GHz 5G wireless systems: design, optimization, and its synthesis for enhancing antenna's performance.

Behera BR, Paik H, Kumar JA, Alsharif MH, Saeed S, Yahya K. *Sci Rep.* 2026 Feb 25.

A broadened polarization bandwidth with a high-gain SADEA-driven metasurface antenna at 5 GHz is investigated for the sub-6 GHz 5G wireless applications. At first, a $\lambda_0/4$ linearly polarized printed monopole antenna is considered. In the next step, a metallic strip that serves as a dynamic switching mechanism is used to short one of the parasitic conducting strips with a partial ground plane to get circular polarization (CP). To make it suitable for the RF energy harvesting application, a crucial part of sub-6 GHz 5G communication, the motive is to achieve broadened performance for antenna gain, impedance (10-dB BW), and axial bandwidths (3-dB BW). It is attained by placing the SADEA-tuned metasurface layer as a parasitic patch at the height of $0.02\lambda_0$, below the radiator. With the usage of the SADEA optimization method, the process of the metasurface layer is depicted as more effective in performance and less complex towards its execution. It is printed on FR-4 of $1.33\lambda_0 \times 0.9\lambda_0 \times 0.02\lambda_0$, which offers a measured 58.23% 10-dB BW, 26.39% 3-dB BW, CP gain peak > 5.9 dBic, antenna efficiency > 75%, with a front-to-back ratio > -20 dBic in the sub-6 GHz 5G bands, a potential candidate for the next-generation wireless communication, especially for the RF energy harvesting systems.

[Lien vers l'article](#)

Dual-band composite high gain MIMO antenna for 5G NR applications employing shareable small cell radio unit.

Asadullah, Shoaib N, Khan MU, Ahmed A, Aburas AA, Abbasi QH. *Sci Rep.* 2026 Feb 15.

In this paper, a MIMO antenna is presented consisting of 4 composite elements. Each antenna element consists of a U-shaped conducting structure and a perturbed barrel Dielectric Resonator Antenna (PB-DRA) structure. The former is loaded with a bow-tie patch, and it is parasitically excited through the U-shaped microstrip element. The additional bow-tie structure is designed for the gain enhancement in the 5G NR frequency range 1 (FR1) band and frequency range 2 (FR2). The PB-DRA has a dielectric constant of 8, and it is excited in higher-order mode to achieve resonance in FR2. The composite structure offers dual-band resonance with 3.85 GHz resonant frequency in the FR1 band and 26.65 GHz in the FR2 band, giving a large frequency ratio radiation characteristic. The proposed antenna offers impedance bandwidth of 2.02 GHz in the FR1 band, and 5.3 GHz in the FR2 band. Achieving multi-band resonance with a large frequency ratio is essential for exploiting the true benefit of 5G communication, as it enables operation across widely separated bands and supports multi-operator radio access networks (MORAN). The peak gains observed in the FR1 and FR2 bands are 8.23 dB and 13.14 dB, respectively. The proposed antenna is specifically designed to meet the requirements of the Open RAN compliant shareable 5G small cell radio unit specifications, by offering resonance in n77/n78 and

n257/n261 bands, and end-fire radiation characteristics, ensuring sufficient coverage in the indoor and dense urban outdoor environment.

[Lien vers l'article](#)

Architecture réseau

Deep residual network enhanced with multilevel residual-of-residual for automatic classification of radio signals for 5G and beyond systems.

Jabeur R, Alaerjan A, Chikha HB. *Sci Rep.* 2026 Feb 2;16(1):7003.

Automatic Modulation Classification (AMC) plays a critical role in the design of intelligent receivers for next-generation wireless systems, particularly in the context of 5G and beyond networks characterized by diverse multicarrier waveform technologies. This paper proposes a novel AMC framework based on a Deep Residual Network (DRN) architecture enhanced with multilevel Residual-of-Residual (RoR) connections, specifically designed to classify advanced modulation formats across a wide spectrum of 5G candidate waveforms, namely Orthogonal Frequency Division Multiplexing (OFDM), Filtered-OFDM (FOFDM), Filter Bank Multi-Carrier (FBMC), Universal Filtered Multi-Carrier (UFMC), and Weighted Overlap-and-Add OFDM (WOLA), modulated using both 16-QAM and 64-QAM schemes. To the best of our knowledge, this is the first work applying DRN enhanced with multilevel RoR (DRN+RoR) specifically to OFDM, FOFDM, FBMC, UFMC, and WOLA with 16/64-QAM. The proposed architecture exploits the deep hierarchical learning capabilities of DRN+RoR to extract highly discriminative features, while employing Sequential Floating Forward Selection (SFFS) for feature optimization and dimensionality reduction. Extensive simulations are conducted under realistic wireless channel conditions, including time- and frequency-selective fading. Evaluation metrics such as classification accuracy, recall, precision, and F1-score demonstrate the superior performance of the proposed method over state-of-the-art machine learning baselines. In particular, our approach achieves higher robustness and classification accuracy across all tested SNRs and waveform types, outperforming recent deep learning-based baselines. We also assess the performance of the proposed algorithm under diverse 5G channel conditions, specifically TDL-A, TDL-B, and TDL-C models. The evaluation results indicate that our proposal maintains robust classification accuracy and strong generalization across all tested channel scenarios. These findings underscore the effectiveness of DRN+RoR as a robust and scalable solution for modulation recognition, offering substantial improvements in adaptive signal processing and enabling more reliable AMC in dynamically evolving 5G and beyond communication environments.

[Lien vers l'article](#)

Adaptive Quality Video Streaming Optimization: An Intelligent Multi-Neural Framework for Enhanced Quality of Experience in 5G and Beyond Networks.

Himaja T, Neeraja S, Chittineni S. *J Vis Exp.* 2026 Jan 27(227).

AQVSO (Adaptive Quality Video Streaming Optimization) is a new video streaming framework that aims to enhance video streaming quality and resource utilization in 5G & Beyond networks. The study proposes an end-to-end multi-neural network comprising four co-related modules that incorporate sparse convolutional networks with policy-driven encoders (SCN-PDE), a sparse graph attention convolutional network (SGA-ConvNet), adaptive spiking neural networks (ASNN), and deep belief networks with ant colony optimization (DBN-ACO). These elements dynamically adjust to network

changes based on a mathematical model that aims to strike a balance between quality and resource use. Experiments on the UCF-101 dataset show that AQVSO preserves SSIM scores similar to those of state-of-the-art algorithms BBA and BOLA (0.977), while requiring much less bandwidth (4,936/8,000 kbps). The framework can save 38% in bandwidth consumption while maintaining high perceptual quality (PSNR = 45.89 dB) and has nearly eliminated buffering occurrences. The system achieves 99.9% streaming certainty under mobile, CDN (Content Delivery Network), and enterprise conditions, providing an actual performance gain for video delivery systems in resource-limited situations. This is made possible by providing a manageable user experience and efficient use of network resources through adaptive, content-aware streaming decisions.

[Lien vers l'article](#)

Efficacité énergétique

Aucun article dans ce bulletin.

Autres équipements

High selective SIW bandpass filter with flexible bandwidth and transmission zero for 5G application.

Mishra GK, Pandey HK, Pathak NP. *Sci Rep.* 2026 Feb 21.

This paper presents a novel design of an electric coupling structure for a substrate-integrated waveguide (SIW) bandpass filter, which exhibits flexible characteristics, sharp roll-off, and high out-of-band rejection, making it suitable for 5G applications. The filter structure is designed with a rectangular slot with a metallic cylindrical via and a narrow propagating path. The proposed design creates a transmission zero (TZ) and shows flexibility in terms of TZ and bandwidth. This structure can be used for both inline and cross-line SIW topologies. Two filters are simulated and fabricated to validate the design. The first filter is designed at 27.12 GHz frequency with 4.98% fractional bandwidth (FBW) and one TZ at a higher stopband using an inline filter topology. The second filter is centered at 27.46 GHz frequency and 4.11% FBW with two TZ at both sides of the passband in crossline topology.

[Lien vers l'article](#)

Low-Cost Sensors in 5G RF-EMF Exposure Monitoring: Validity and Challenges.

Rathebe PC, Kholopo M. *Sensors (Basel).* 2026 Jan 13;26(2).

The deployment of 5G networks has transformed the landscape of radiofrequency electromagnetic field (RF-EMF) exposure patterns, shifting from high-power macro base stations to dense networks of small, beamforming cells. This review critically assesses the validity, challenges, and research gaps of low-cost RF-EMF sensors used for 5G exposure monitoring. An analysis of over 60 studies covering Sub-6 GHz and emerging mmWave systems shows that well-calibrated sensors can achieve measurement deviations of ± 3 -6 dB compared to professional instruments like the Narda SRM-3006, with long-term calibration drift less than 0.5 dB per month and RMS reproducibility around 5%. Typical outdoor 5G FR1 exposure levels range from 0.01 to 0.5 W/m² near small cells, while personal device use can

cause transient exposures 10-30 dB higher. Although mmWave (24-100 GHz) and Wi-Fi 7/8 (~60 GHz) are underrepresented due to antenna and component limitations, Sub-6 GHz sensing platforms, including software-defined radio (SDR)-based and triaxial isotropic designs, provide sufficient sensitivity for both citizen and institutional monitoring. Major challenges involve calibration drift, frequency band gaps, data interoperability, and ethical management of participatory networks. Addressing these issues through standardized calibration protocols, machine learning-assisted drift correction, and open data frameworks will allow affordable sensors to complement professional monitoring, improve spatial coverage, and enhance public transparency in 5G RF-EMF exposure governance.

[Lien vers l'article](#)

Applications médicales et industrielles de la 5G

Applications industrielles

Secure TPMS Data Transmission in Real-Time IoV Environments: A Study on 5G and LoRa Networks.

Niranjan DK, Supriya M, Tiberti W. *Sensors (Basel)*. 2026 Jan 6;26(2).

The advancement of Automotive Industry 4.0 has promoted the development of Vehicle to Vehicle (V2V) and Internet of Vehicles (IoV) communication, which marks the new era for intelligent, connected and automated transportation. Despite the benefits of this metamorphosis in terms of effectiveness and convenience, new obstacles to safety, inter-connectivity, and cybersecurity emerge. The tire pressure monitoring system (TPMS) is one prominent feature that senses tire pressure, which is closely related to vehicle stability, braking performance and fuel efficiency. However, the majority of TPMSs currently in use are based on the use of insecure and proprietary wireless communication links that can be breached by attackers so as to interfere with not only tire pressure readings but also sensor data manipulation. For this purpose, we design a secure TPMS architecture suitable for real-time IoV sensing. The framework is experimentally implemented using a Raspberry Pi 3B+ (Raspberry Pi Ltd., Cambridge, UK) as an independent autonomous control unit (ACU), interfaced with vehicular pressure sensors and a LoRa SX1278 (Semtech Corporation, Camarillo, CA, USA) module to support low-power, long-range communication. The gathered sensor data are encrypted, their integrity checked, source authenticated by lightweight cryptographic algorithms and sent to a secure server locally. To validate this approach, we show a three-node exhibition where Node A (raw data and tampered copy), B (unprotected copy) and C (secure auditor equipped with alerting of tampering and weekly rotation of the ID) realize detection of physical level threats at top speeds. The validated datasets are further enriched in a MATLAB R2024a simulator by replicating the data of one vehicle by 100 virtual vehicles communicating using over 5G, LoRaWAN and LoRa P2P as communication protocols under urban, rural and hill-station scenarios. The presented statistics show that, despite 5G ultra-low latency, LoRa P2P consistently provides better reliability and energy efficiency and is more resistant to attacks in the presence of various terrains. Considering the lack of private vehicular 5G infrastructure and the regulatory restrictions, this work simulated and evaluated the performance of 5G communication, while LoRa-based communication was experimentally validated with a hardware prototype. The results underline the trade-offs among LoRa P2P and an infrastructure-based uplink 5G mode, when under some specific simulation conditions, as opposed to claiming superiority over all 5G modes. In conclusion, the presented Raspberry Pi-MATLAB hybrid solution proves to be an effective and scalable approach to secure TPMS in IoV settings, intersecting real-world sensing with large-scale network simulation, thus enabling safer and smarter next-generation vehicular systems.

[Lien vers l'article](#)

Governing digital transformation in ports: Policy learning from the 5G-LOGINNOV project.

Catana E, Merlo F, Perboli G. *Open Res Eur*. 2025;5:362.

BACKGROUND: Seaports constitute strategic nodes in global supply chains and play a central role in the ongoing digital and green transition. Technologies such as 5G and artificial intelligence (AI) have the potential to enhance operational efficiency, safety, and environmental sustainability in logistics. However, their successful deployment depends not only on technological maturity but also on effective governance frameworks and coordinated stakeholder engagement. The 5G-LOGINNOV

project addressed this intersection between innovation and governance by linking technical experimentation with policy learning to support the transition toward smart ports. **METHODS:** The study employed an integrated methodological framework that combines the Collaborative Governance Regime (CGR) with the GUEST lean business methodology. This approach facilitates sustained multi-stakeholder collaboration and ensures that experimental outcomes are translated into validated business models and policy recommendations. Empirical evidence was collected from three Living Labs-Athens, Hamburg, and Koper-through workshops, interviews, and surveys involving private and public sector actors. **RESULTS:** The integrated CGR-GUEST approach led to the co-creation of policy frameworks guiding 5G deployment in ports and hinterland networks. It identified major implementation barriers-technical, infrastructural, regulatory, and organizational-and produced actionable recommendations to address them. The framework also enhanced the comparability of pilot results and supported the translation of innovation outcomes into policy-relevant insights. **CONCLUSIONS:** The findings demonstrate that 5G deployment in logistics is not merely a technological endeavor but a governance challenge. By integrating structured governance mechanisms with lean innovation tools, the proposed framework bridges experimentation and policy, offering a replicable model for aligning disruptive technologies with broader sustainability and competitiveness objectives.

[Lien vers l'article](#)

Applications médicales

Feasibility of telesurgery using fifth-generation wireless cellular technology and dedicated internet lines for cross-continental procedures: A pilot study.

Huang Q, Wang Y, Li Z, Breda A, Gaston RP, Pansadoro V, et al. *Chin Med J (Engl)*. 2026 Feb 4.

[Lien vers l'article](#)

5G-enabled XR live broadcasting of transoral robotic surgery (TORS): a feasibility study of an indoor small-cell architecture.

Goh LC, Ong HY, Abu Bakar MZ. *J Robot Surg*. 2026 Feb 11;20(1):238.

BACKGROUND: Live broadcasting of robotic surgery can expand access to specialist training and telementoring, but operating theatres can be difficult environments for stable, low-delay wireless connectivity. We evaluated a hospital-deployed fifth-generation (5G) indoor network to support extended-reality (XR) live viewing of transoral robotic surgery (TORS). **METHODS:** In a prospective, single-session feasibility study at a tertiary university hospital, a mid-band 5G New Radio (NR) indoor small-cell system was deployed in the operating theatre and linked to a dedicated Fixed Wireless Access (FWA) gateway. Video from a da Vinci robotic console was captured, encoded using an artificial-intelligence-assisted hardware encoder, and streamed in real time to XR head-mounted displays (Apple Vision Pro) and standard two-dimensional endpoints. Latency proxy metrics were logged throughout the broadcast, and remote viewers completed the System Usability Scale (SUS). **RESULTS:** The broadcast ran continuously for a 40-minute operative teaching segment with no reported workflow disruption or safety concerns. Mean signed latency offset was - 22 ms (absolute mean 22 ms) across the session. Twenty remote participants from seven countries joined the broadcast; 14/20 completed the SUS questionnaire, with a mean score of 72, indicating acceptable usability. **CONCLUSIONS:** A dedicated indoor 5G small-cell plus FWA configuration can deliver low-delay, XR-enabled live

broadcasting of robotic surgery using commercially available components. This reproducible workflow supports scalable surgical education and provides a platform for future clinical connectivity studies.

[Lien vers l'article](#)

Evaluation (Mesure des niveaux d'exposition)

Méthodes d'évaluation

Aucun article dans ce bulletin.

Evaluation population générale

Experimental and numerical assessment of near-field exposure of a 60 GHz communication antenna.

Vermeeren G, Debaille B, Kühn S, Torfs G, Kuster N, Demeester P, et al. *Radiat Prot Dosimetry*. 2026 Feb 3.

We simulated the mm-wave exposure of a real 60 GHz communication module and validated it using near-field measurements in terms of the incident power density. Next, we numerically evaluated the absorbed power density in a layered tissue model using the finite-difference time-domain technique. The worst-case and realistic exposures were compared with the latest guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and of the Institute of Electrical and Electronics Engineers (IEEE). The worst-case exposure complied with the exposure guidelines for a distance larger than 14.5 mm. Realistic exposure is application dependent and exceeded the limits specified by exposure guidelines for data-intensive applications with duty cycle of 90% at distances smaller than 10.6 mm.

[Lien vers l'article](#)

Risques professionnels

Aucun article dans ce bulletin.

Effets biologiques et sur la santé

In silico

Electromagnetic Exposure from RF Antennas on Subway Station Attendant: A Thermal Analysis.

Li J, Zhang Q, Lu M. *Sensors (Basel)*. 2026 Jan 21;26(2).

With the rapid development of wireless communication systems, the electromagnetic environment in subway stations has become increasingly complex, raising concerns about the long-term safety of station attendants who are chronically exposed to radiofrequency (RF) fields. At present, multiphysics analyses specifically addressing RF antenna exposure scenarios for subway attendants remain limited. To assess occupational electromagnetic exposure risks, this paper establishes a comprehensive electromagnetic-thermal coupling simulation model incorporating RF antennas, station-platform structures, and a realistic human model with organs including the brain, heart, and liver. Using the finite-element software COMSOL Multiphysics (v.6.3), numerical simulations are performed to calculate the specific absorption rate (SAR) in the trunk and major organs of the subway station attendant at RF antennas frequencies of 900 MHz, 2600 MHz, and 3500 MHz, as well as the temperature rise distribution of the human trunk and important tissues and organs under different initial temperatures of the environment. The results show that among the three frequencies, the maximum SAR of 5.55×10^{-4} W/kg occurs in the trunk at 3500 MHz. Tissue temperatures reach thermal steady state after 30 min of exposure, with the maximum temperature rises occurring in the brain at an ambient temperature of 18 °C and an operating frequency of 900 MHz, reaching 0.2123 °C. Across all simulated scenarios, both SAR values and temperature rises remain significantly below the occupational exposure limits established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These findings indicate that RF radiation generated by antennas in the subway station environment poses low health risks to female station attendants of similar physical characteristics to the Ella model. This study provides a scientific reference for the occupational RF protection of subway personnel and contributes data for the development of electromagnetic exposure standards in rail transit systems.

[Lien vers l'article](#)

Experimental and numerical assessment of near-field exposure of a 60 GHz communication antenna.

Vermeeren G, Debaille B, Kühn S, Torfs G, Kuster N, Demeester P, et al. *Radiat Prot Dosimetry*. 2026 Feb 3.

We simulated the mm-wave exposure of a real 60 GHz communication module and validated it using near-field measurements in terms of the incident power density. Next, we numerically evaluated the absorbed power density in a layered tissue model using the finite-difference time-domain technique. The worst-case and realistic exposures were compared with the latest guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and of the Institute of Electrical and Electronics Engineers (IEEE). The worst-case exposure complied with the exposure guidelines for a distance larger than 14.5 mm. Realistic exposure is application dependent and exceeded the limits specified by exposure guidelines for data-intensive applications with duty cycle of 90% at distances smaller than 10.6 mm.

[Lien vers l'article](#)

In vitro

5G RF-EMFs Mitigate UV-Induced Genotoxic Stress Through Redox Balance and p38 Pathway Regulation in Skin Cells.

Kim JH, Jin H, Jang KM, Lee JE, Na S, Jeon S, et al. *Antioxidants (Basel)*. 2026 Jan 19;15(1).

The biological effects of radiofrequency electromagnetic fields (RF-EMFs) remain an unresolved scientific issue with important societal relevance, particularly in the context of the global deployment of fifth-generation (5G) wireless technologies. The skin is continuously exposed to both RF-EMFs and ultraviolet (UV) radiation, a well-established inducer of oxidative stress and DNA damage, making it a relevant model for assessing combined environmental exposures. In this study, we investigated whether post-exposure to 5G RF-EMFs (3.5 and 28 GHz) modulates ultraviolet A (UVA)-induced genotoxic stress in human keratinocytes (HaCaT) and murine melanoma (B16) cells. Post-UV RF-EMF exposure significantly reduced DNA damage markers, including phosphorylated histone H2AX (γ H2AX) foci formation (by approximately 30-50%) and comet tail moments (by 60-80%), and suppressed intracellular reactive oxygen species (ROS) accumulation (by 56-93%). These effects were accompanied by selective attenuation of p38 mitogen-activated protein kinase (MAPK) phosphorylation (reduced by 55-85%). The magnitude of molecular protection was comparable to that observed with N-acetylcysteine treatment or pharmacological inhibition of p38 MAPK. In contrast, RF-EMF exposure did not reverse UV-induced reductions in cell viability or alterations in cell cycle distribution, indicating that its protective effects are confined to early molecular stress-response pathways rather than downstream survival outcomes. Together, these findings demonstrate that 5G RF-EMFs can facilitate recovery from UVA-induced molecular damage via redox-sensitive and p38-dependent mechanisms, providing mechanistic insight into the interaction between modern telecommunication frequencies and UV-induced skin stress.

[Lien vers l'article](#)

Sur l'animal

Single and combined microwave induced anxiety-like behavior via NLRP3 dependent neuronal pyroptosis in hippocampus and amygdala in mice.

Zhou G, Guo L, Qin T, Zhang Z, Gao P, Wang X, et al. *Ecotoxicol Environ Saf*. 2026 Jan 15;310:119818.

It was reported that exposure to microwave at a single frequency could induce behavioral changes, however, the effect of combined microwave exposure with multiple frequencies on behavior remain unclear. In this study, mice were exposed to either S-band (3.5 GHz) microwave (S group) or C-band (4.9 GHz) microwave (C group), or combined exposure to both S-band and C-band microwave (SC group), all for 5 weeks (1 h per day) at a power density of 50 W/m². Following exposure, anxiety-like, depression-like and cognitive behaviors were evaluated. The morphological structure of the hippocampus and amygdala were observed, along with levels of NLRP3 inflammasome dependent pyroptosis. Additionally, alterations in blood-brain barrier (BBB) and synapses in the amygdala were examined. The results showed that compared with Sham group, all three exposure groups exhibited increased anxiety-like behavior in mice. Compared with S group, the anxiety level in C group and SC groups were much higher. However, anxiety levels in the SC group were lower than those in C group.

Furthermore, NLRP3 inflammasome-dependent neuronal pyroptosis was observed in both the hippocampus and amygdala of all exposed mice, and the SC group exhibited the most severe brain damage in hippocampal CA3 region, whereas the C group exhibited the greatest amygdala pathology and BBB disruption. In summary, these findings suggest that NLRP3 inflammasome-mediated neuronal pyroptosis in the hippocampus and amygdala underlies microwave-induced anxiety, and amygdala-specific pyroptosis may play a more dominant role in driving anxiety-like behaviors than hippocampal damage under these exposure conditions. Additionally, combined microwave exposure may produce antagonistic biological effects.

[Lien vers l'article](#)

Effects of paternal 5G RFR exposure on health of male offspring mice.

Zhaowen Z, Ling G, Guiqiang Z, Jiajin L, Tongzhou Q, Jiangyi L, et al. *Reprod Toxicol*. 2026 Mar;140:109139.

With the widespread application of 5G communication technology, the potential health risks of radiofrequency radiation (RFR) have been paid much attention. Prior studies have demonstrated that the testes are highly sensitive to RFR, and notably, paternal epigenetic modifications can be transmitted to offspring, impacting their reproductive and neurobehavioral phenotypes. To investigate the intergenerational effects of paternal exposure to 5 G RFR on male offspring health, 7-8-week-old male C57BL/6 mice were randomly divided into Sham group and 4.9 GHz RFR group (16 mice per group). The mice in 4.9 GHz RFR group were exposed to 4.9 GHz RFR for 1 h/d over 42 consecutive days. Male offspring derived from exposed males and unexposed females were raised to adulthood. Anxiety and depression-like behaviors, learning and memory capabilities, sperm quality, and fertility in male offspring were assessed. Paternal testicular LRGUK gene (sperm motility-related) methylation, mRNA, and protein expression were detected. The results showed that paternal 5G RFR exposure induced anxiety-like behaviors and impaired sperm quality in F1 males, potentially associated with RFR-induced hypermethylation of paternal LRGUK gene and subsequent down regulation of its expression in offspring testes. No significant effects were observed on depression-like behaviors, cognitive performance, or fertility across F1-F2 generations. These findings indicated that paternal 5G RFR exposure induced intergenerational adverse effects on F1 males, potentially mediated by germ cell epigenetic modifications.

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