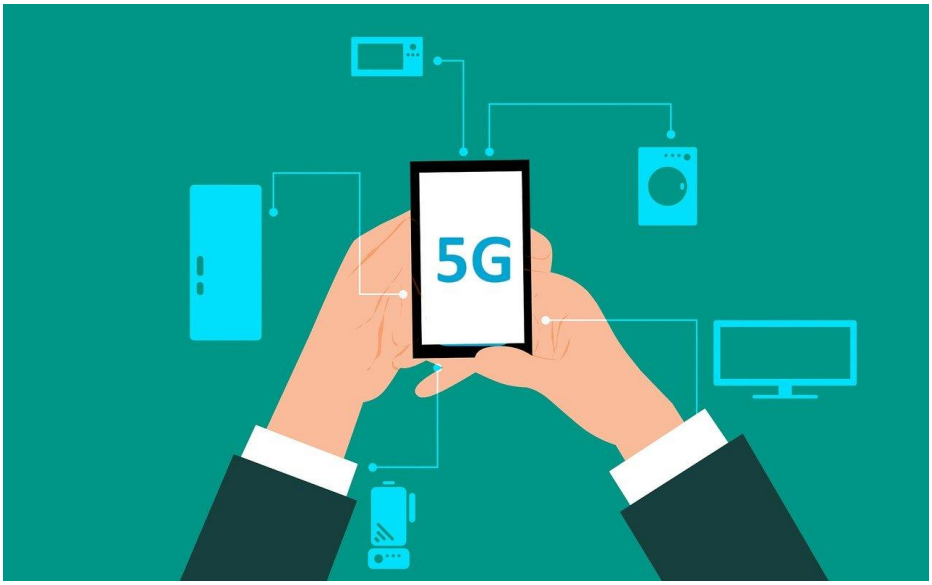
TECHNOLOGIE 5G

Bulletin de veille scientifique : Octobre 2025



Objectifs : réaliser une veille scientifique sur la technologie 5G

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Généralités

The WHO-commissioned systematic reviews on health effects of radiofrequency radiation provide no assurance of safety.

Melnick RL, Moskowitz JM, Héroux P, Mallery-Blythe E, McCredden JE, Herbert M, et al. *Environ Health*. 2025 Oct 2;24(1):70.

The World Health Organization (WHO) commissioned 12 systematic reviews (SR) and meta-analyses (MA) on health effects of exposure to radiofrequency electromagnetic fields (RF-EMF). The health outcomes selected for those reviews (cancer, electromagnetic hypersensitivity, cognitive impairment, birth outcomes, male fertility, oxidative stress, and heat-related effects) were based on a WHO-conducted international survey. The SR of the studies of cancer in laboratory animal studies was the only one that did not include a MA, because those authors considered it inappropriate due to methodological differences among the available studies, including differences in exposure characteristics (carrier frequency, modulation, polarization), experimental parameters (hours/day of exposure, duration of exposure, exposure systems), and different biological models. MAs in all the other SRs suffered from relatively few primary studies available for each MA (sometimes due to excessive subgrouping), exclusion of relevant studies, weaknesses in many of the included primary studies, lack of a framework for analyzing complex processes such as those involved in cognitive functions, and/or high between-study heterogeneity. Due to serious methodological flaws and weaknesses in the conduct of the reviews and MAs on health effects of RF-EMF exposure, the WHO-commissioned SRs cannot be used as proof of safety of cell phones and other wireless communication devices. However, the animal cancer SR, which was rated as "high certainty of evidence" for heart schwannomas and "moderate certainty of evidence" for brain gliomas, provided quantitative information that could be used to set exposure limits based on reducing cancer risk. The multiple and significant dose-related adverse effects found in the SRs on male fertility and pregnancy and birth outcome should also serve as the basis for policy decisions to lower exposure limits and reduce human reproductive risks. The report of harmful effects (e.g., cancer, reproductive toxicity, etc.) at doses below the adverse health effect threshold claimed by ICNIRP demonstrates that current exposure limits to RF-EMF, which were established by applying arbitrary uncertainty factors to their putative adverse threshold dose, lack scientific credibility.

Lien vers l'article

A multicriteria model for prioritizing 5G network deployment with Monte Carlo stability analysis: A case study in Magdalena, Colombia.

Martínez Abuabara R, Robles CA, Camargo LL. *PLoS One*. 2025;20(10):e0334781.

The global deployment of 5G mobile networks has followed a progressive and strategic approach, depending on regional characteristics. This study develops a reference framework to prioritize areas for deployment, considering technical, sociodemographic, geographic, and economic criteria. The methodology integrates multi-criteria decision-making techniques such as AHP, CRITIC, TOPSIS, and SAW to evaluate and prioritize alternatives. This framework was applied to the municipalities of the Magdalena department in Colombia. The AHP results indicate that technical criteria are the most relevant in the selection process, with a weight of 34.3%, followed by sociodemographic criteria at 33.6%, geographic criteria at 19.47%, and economic criteria at 12.63%. A high similarity in municipality prioritization was observed, with a correlation of ρ = 0.9897 according to Spearman's coefficient. Using TOPSIS and SAW, the municipality of Ciénaga ranks first, given that the sub-criteria of population size,

area, and 4G coverage hold the highest relevance in the selection process, with percentages of 13.13%, 12.16%, and 11.12%, respectively, while the municipalities of Fundación and Plato alternate between second and third place. On the other hand, La Zona Bananera ranks fourth and fifth. To assess the model's robustness against variability in the criterion weights, a sensitivity analysis was conducted using the Monte Carlo method with 10,000 iterations. The results indicate that the ranking remains stable, with an average correlation of $\rho = 0.9010$ between the rankings obtained with SAW and the final ranking using TOPSIS. The influence of high-weight and highly correlated sub-criteria was also assessed. Rankings from AHP-SAW and AHP-TOPSIS were compared with CRITIC-SAW and CRITIC-TOPSIS, yielding correlations of 0.98 and 0.76, respectively. It can be concluded that the deployment of 5G networks can be systematically prioritized based on the mentioned criteria, using a model that remains stable despite changes in criterion weights.

Lien vers l'article

Performances et sécurité

Indoor Localization with Extended Trajectory Map Construction and Attention Mechanisms in 5G.

Yang K, Yu C, Yao S, Jiang Z, Zhao K. *Sensors (Basel)*. 2025 Sep 17;25(18).

Integrated sensing and communication (ISAC) is considered a key enabler for the future Internet of Things (IoT), as it enables wireless networks to simultaneously support high-capacity data transmission and precise environmental sensing. Indoor localization, as a representative sensing service in ISAC, has attracted considerable research attention. Nevertheless, its performance is largely constrained by the quality and granularity of the collected data. In this work, we propose an attention-based framework for cost-efficient indoor fingerprint localization that exploits extended trajectory map construction through a novel trajectory-based data augmentation (TDA) method. In particular, fingerprints at unmeasured locations are synthesized using a conditional Wasserstein generative adversarial network (CWGAN). A path generation algorithm is employed to produce diverse trajectories and construct the extended trajectory map. Based on this map, a multi-head attention model with direction-constrained auxiliary loss is then applied for accurate mobile device localization. Experiments in a real 5G indoor environment demonstrate the system's effectiveness, achieving an average localization error of 1.09 m and at least 34% higher accuracy than existing approaches.

Lien vers l'article

Intelligent reflective surfaces in 5G and beyond: optimizing uplink satellite connectivity for IoT.

Obidiozor CO, Sait A, Al-Hadhrami T, Alkhammash EH, Saeed F. *PeerJ Comput Sci*. 2025;11:e2726.

In the evolving landscape of communication technologies, the integration of intelligent reflective surfaces (IRS) into uplink satellite communication for Internet of Things (IoT) ecosystems presents a promising solution to overcome traditional communication challenges. The purpose of this study is to explore the impact of IRS on enhancing signal quality and communication efficiency in satellite-supported IoT environments. This article adopts a simulation-based approach, using MATLAB and Simulink to model the uplink transmission of IoT devices to satellites with and without IRS assistance. The methodology focuses on analysing key performance metrics, including signal-to-noise ratio (SNR), spectral efficiency, signal strength, and interference mitigation. A reinforcement learning algorithm was employed to optimise IRS phase shifts and beamforming to maximise communication performance. The findings reveal that the integration of IRS leads to significant improvements in SNR, spectral efficiency, and overall signal quality, with a 2 dB increase in SNR and enhanced data transmission rates compared to non-IRS systems. IRS also mitigates interference and extends the coverage area of satellite networks. These results demonstrate the practical implications of IRS technology, which can be applied in scenarios such as smart cities, remote sensing, and disaster recovery, where reliable satellite communication is crucial. The study highlights the strategic importance of IRS in revolutionising IoT-satellite communication systems and sets the foundation for future work on scaling IRS technology for broader applications.

Lien vers l'article

Channel quality predictions assisted by new algorithms for high throughput satellite and 5G systems.

Al-Saegh AM, Ali EM, Abdalrazak MQ, Elmunim NA, Alibakhshikenari M, Virdee BS, et al. *Sci Rep*. 2025 Oct 5;15(1):34649.

Variations in rainfall patterns across different regions reduce the accuracy of existing satellite channel models. As satellite services and 5G applications continue to advance, the development of accurate rain-impairment-aware channel models has become essential. This paper presents a prediction model for rain-induced impairments in High Throughput Satellite (HTS) and 5G satellite-to-land communication channels. The proposed model integrates three novel algorithms designed to characterize and analyze rain-induced attenuation and channel quality. Specifically, these algorithms calculate rain-specific attenuation, effective slant path lengths through rainfall, overall rain-induced attenuation, signal carrier-to-noise ratios, and symbol error rates across three conventional modulation schemes. Additionally, the study introduces a new database detailing rain-induced attenuation on HTS channels, considering various frequencies and rainfall intensities. Results indicate substantial fluctuations in HTS-to-land fade levels and signal quality during rainfall events, which could lead to communication link outages, particularly at higher-order modulation schemes. This study provides practical methods to analyze channel characteristics using actual rainfall measurements, thereby facilitating the effective design and deployment of future HTS and 5G system.

Lien vers l'article

Local and Remote Digital Pre-Distortion for 5G Power Amplifiers with Safe Deep Reinforcement Learning.

Spano C, Badini D, Cazzella L, Matteucci M. *Sensors (Basel)*. 2025 Oct 3;25(19).

The demand for higher data rates and energy efficiency in wireless communication systems drives power amplifiers (PAs) into nonlinear operation, causing signal distortions that hinder performance. Digital Pre-Distortion (DPD) addresses these distortions, but existing systems face challenges with complexity, adaptability, and resource limitations. This paper introduces DRL-DPD, a Deep Reinforcement Learning-based solution for DPD that aims to reduce computational burden, improve adaptation to dynamic environments, and minimize resource consumption. To ensure safety and regulatory compliance, we integrate an ad-hoc Safe Reinforcement Learning algorithm, CRE-DDPG (Cautious-Recoverable-Exploration Deep Deterministic Policy Gradient), which prevents ACLR measurements from falling below safety thresholds. Simulations and hardware experiments demonstrate the potential of DRL-DPD with CRE-DDPG to surpass current DPD limitations in both local and remote configurations, paving the way for more efficient communication systems, especially in the context of 5G and beyond.

Lien vers l'article

Evaluating Transport Layer Security 1.3 Optimization Strategies for 5G Cross-Border Roaming: A Comprehensive Security and Performance Analysis.

Lastre JK, Ko Y, Kwon H, You I. *Sensors (Basel)*. 2025 Oct 4;25(19).

Cross-border Fifth Generation Mobile Communication (5G) roaming requires secure N32 connections between network operators via Security Edge Protection Proxy (SEPP) interfaces, but current Transport Layer Security (TLS) 1.3 implementations face a critical trade-off between connection latency and

security guarantees. Standard TLS 1.3 optimization modes either compromise Perfect Forward Secrecy (PFS) or suffer from replay vulnerabilities, while full handshakes impose excessive latency penalties for time-sensitive roaming services. This research introduces Zero Round Trip Time Forward Secrecy (0-RTT FS), a novel protocol extension that achieves zero round-trip performance while maintaining comprehensive security properties, including PFS and replay protection. Our solution addresses the fundamental limitation where existing TLS 1.3 optimizations sacrifice security for performance in international roaming scenarios. Through formal verification using ProVerif and comprehensive performance evaluation, we demonstrate that 0-RTT FS delivers 195.0 µs handshake latency (only 17% overhead compared to insecure 0-RTT) while providing full security guarantees that standard modes cannot achieve. Security analysis reveals critical replay vulnerabilities in all existing standard TLS 1.3 optimization modes, which our proposed approach successfully mitigates. The research provides operators with a decision framework for configuring sub-millisecond secure handshakes in next-generation roaming services, enabling both optimal performance and robust security for global 5G connectivity.

Lien vers l'article

Decoding 5G security: toward a hybrid threat ontology.

Paskauskas RA. *Open Res Eur*. 2024;4:34.

This Open Letter announces a new initiative, designed from the ground up, incorporating key cybersecurity standards while providing a novel framework for modelling hybrid threats in 5G infrastructure. The 5G Hybrid Threat Ontology is a structured framework designed to reduce risk and achieve sustainable resilience against hybrid threats targeting 5G infrastructure. As fifth-generation (5G) networks become integral to critical infrastructure, they introduce new vulnerabilities that adversaries can exploit through hybrid threats-multifaceted attacks spanning cyber, physical, and socio-political domains. Existing security approaches focus on specific technical vulnerabilities or predictive threat modelling but lack a unified framework to address hybrid threat scenarios systematically. This paper advances the study of 5G security by proposing an ontology-driven approach prioritising resilience through risk reduction rather than threat elimination or prediction. Developed using Semantic Web technologies, specifically the Resource Description Framework (RDF) in Turtle representation for structured threat modelling, the ontology ensures machine-readability, structured threat intelligence sharing, and validation through Shapes Constraint Language (SHACL). It integrates established frameworks, including the 5G Threat Taxonomy compiled by the European Union Agency for Cybersecurity (ENISA), the Structured Threat Information eXpression (STIX) standard, and other widely used cybersecurity standards. By formalising relationships between adversarial tactics, 5G vulnerabilities, and cascading risks, the ontology enables semantic reasoning using tools within the Protégé framework. Although still under development, the 5G Hybrid Threat Ontology demonstrates strong Description Logic (DL) expressivity, ensuring adaptability for evolving security challenges. This approach bridges high-level policy directives with operational cybersecurity needs, reinforcing a resilience-driven security posture. Future research will build on the phased development of the 5G Hybrid Threat Ontology to enhance adaptive threat modelling and dynamic risk assessment, ensuring that the ontology continues to evolve as a strategic tool for strengthening the resilience of 5G infrastructures against hybrid threats.

Lien vers l'article

A high isolated, high gain millimeter wave quad-port MIMO antenna array for wideband 5G new radio application.

Tiwari P, Rai JK, Dwivedi AK, Gahlaut V, Ranjan P, Chowdhury R, et al. *Sci Rep*. 2025 Oct 3;15(1):34484.

This paper introduces a high-performance quad-port Multiple-Input Multiple-Output (MIMO) antenna array for wideband 5G New Radio (NR) (n258, n257, n260, and n261) applications in the millimeter-wave (mmWave) spectrum. The target antenna structure employs a 1 × 2 element array design with microstrip line feeding and includes diamond-shaped slots along with defected ground geometry (DGG) to increase bandwidth, gain, and isolation independent of complicated decoupling components. Fabricated on low-loss Rogers RT/Duroid 5880 substrate (εr = 2.2, tanδ = 0.0009), the antenna has an ultrawide operation bandwidth of 24 GHz to 40 GHz with a 50% fractional bandwidth. The measured results show a peak gain of 18.2 dBi and outstanding inter-element isolation of over 44 dB, confirming the potential for interference-free MIMO operation of the antenna. The design also exhibits better diversity performance with an ECC of < 0.0005, diversity gain (DG) of 9.99 dB, and a CCL of < 0.3 bps/Hz, affirming its use in high-capacity, low-latency 5G mmWave systems. In addition, the compact form factor of the antenna (35 × 35 × 0.254 mm(3)), structural simplicity, and strong performance make it extremely suitable for integration within next-generation IoT platforms, indoor/outdoor wireless systems, and flexible mmWave-enabled communication devices. The present work aims to overcome challenging problems in the realization of wideband operation, high gain, and excellent isolation in compact MIMO configurations and presents a scalable and fabrication-friendly solution for future wireless networks.

Lien vers l'article

Pattern diversify patch antenna for sub-6 GHz 5G communication applications.

Iqbal K, Hassan A, Khan QU, Muddassir M, Althuwayb AA. *Sci Rep*. 2025 Sep 26;15(1):33155.

A dual-port single-layer pattern diversified microstrip patch antenna for sub-6 GHz 5G communication applications is proposed. The design consists of a notch-loaded annular ring with a separately excited slot-loaded circular patch within its aperture. The broadside radiation is achieved by exciting the dominant TM(11) mode of the circular patch while TM(31) mode of the annular ring is excited to obtain conical radiation patterns. The two modes of radiating elements operate at a frequency of 3.5 GHz which lies in the sub-6 GHz 5G frequency band. The measured results of the fabricated prototype are in good agreement with the simulated ones. The gain of the broadside beam is 7.2 dBi while the gain for the conical one is 4.6 dBi. The isolation between the two ports remains below - 28 dB.

Lien vers l'article

Design of an Ultra-Wideband MIMO Antenna with Open-Slot Structures for 5G Metal-Frame Smartphones.

Chen L, Bai J, Gu H. *Sensors (Basel)*. 2025 Sep 26;25(19).

This paper presents the design and implementation of an ultra-wideband MIMO antenna for sub-6 GHz 5G metal-frame smartphones. The proposed antenna array includes four pairs, each comprising a

slotted patch element and an open-slot structure on the metallic rim. The design achieves compactness by sharing the same aperture, critical for overcoming metal-frame smartphone constraints. It minimizes the required ground clearance to 40 × 0.7 mm(2) to fit the limited space of metallic bezels while maintaining high inter-element isolation. Specifically, one element operates at 2.5-3.8 GHz and 4.8-7.0 GHz, while the other provides continuous coverage from 2.5 to 6.5 GHz, supporting all global sub-6 GHz 5G frequency bands. Specifically, one element operates at 2.5-3.8 GHz and 4.8-7.0 GHz, while the other offers continuous coverage from 2.5 to 6.5 GHz, supporting all sub-6 GHz 5G frequency bands. The open-slot configuration enlarges the operational bandwidth and improves isolation, achieving more than 12.6 dB isolation between elements. A prototype was fabricated and experimentally tested. Measured results indicate that the antenna array maintains a total efficiency above 56% and an envelope correlation coefficient below 0.18 across the target bands. The measured and simulated results are in good agreement, confirming the effectiveness of the proposed design. The proposed antenna is a strong candidate for next-generation 5G smartphone applications due to its wideband performance, high isolation, and compact integration.

Lien vers l'article

Architecture réseau

Aucun article dans ce bulletin.

Efficacité énergétique

Aucun article dans ce bulletin.

Autres équipements

AI-Assisted Dynamic Port and Waveform Switching for Enhancing UL Coverage in 5G NR.

Villena-Rodríguez A, Martín-Vega FJ, Gómez G, Aguayo-Torres MC, Outes-Carnero J, Ng-Molina FY, et al. *Sensors (Basel)*. 2025 Sep 19;25(18).

The uplink of 5G networks allows selecting the transmit waveform between cyclic prefix orthogonal frequency division multiplexing (CP-OFDM) and discrete Fourier transform spread OFDM (DFT-S-OFDM) to cope with the diverse operational conditions of the power amplifiers (PAs) in different user equipment (UEs). CP-OFDM leads to higher throughput when the PAs are operating in their linear region, which is mostly the case for cell-interior users, whereas DFT-S-OFDM is more appealing when PAs are exhibiting non-linear behavior, which is associated with cell-edge users. Therefore, existing waveform selection solutions rely on predefined signal-to-noise ratio (SNR) thresholds that are computed offline. However, the varying user and channel dynamics, as well as their interactions with power control, require an adaptable threshold selection mechanism. In this paper, we propose an intelligent waveform-switching mechanism based on deep reinforcement learning (DRL) that learns optimal switching thresholds for the current operational conditions. In this proposal, a learning agent aims at maximizing a function built using available throughput percentiles in real networks. Said

percentiles are weighted so as to improve the cell-edge users' service without dramatically reducing the cell average. Aggregated measurements of signal-to-noise ratio (SNR) and timing advance (TA), available in real networks, are used in the procedure. In addition, the solution accounts for the switching cost, which is related to the interruption of the communication after every switch due to implementation issues, which has not been considered in existing solutions. Results show that our proposed scheme achieves remarkable gains in terms of throughput for cell-edge users without degrading the average throughput.

Lien vers l'article

Optically transparent on-glass frequency selective surface for 5G millimeter-wave dual-band manipulation with sub-6G compatibility.

Hu Q, Zhou J, Chen K, Zhao J, Feng Y. *Opt Lett*. 2025 Oct 15;50(20):6361-4.

An optically transparent on-glass frequency selective surface (FSS) is proposed with customized transmittivity of millimeter-wave (mm-wave) and sub-6G signals for 5G wireless communication. The presented FSS features a multi-resonant structure to selectively allow transmission of desired bands. With high optical transparency, the proposed FSS is formed through launching two metallic square loops and a hollowed patch onto a double-layer glass. Dual passbands covering 5G mm-wave n257/n258 and n260 bands are constructed, with sub-6G compatibility of an average in-band transmission of -2.42 dB. To verify the design principle, a proof-of-concept prototype is fabricated with an optical transparency of 62.1%. As experimental validation, transmission amplitudes above -3.2 dB are measured from 1.5 to 6 GHz, 23.5 to 30.7 GHz, and 36.1 to 40 GHz, with minimum insertion loss of 0.71 dB, 0.35 dB, and 0.97 dB, respectively, generally satisfying the requirement in 5G sub-6G, n257/n258, and n260 bands. The proposed approach delivers merits of bandpass filtering abilities across multiple 5G bands, high out-of-band rejection, high optical transparency, and low insertion loss, which may facilitate outdoor-to-indoor communication, confidential communication, and spectrum compatibility.

Lien vers l'article

Applications industrielles

Framework for assessing the implications of 5G technology on remote health library service provision.

Liu P, Azam M, Ahmad K. *Health Info Libr J*. 2025 Sep 30.

Technological advancements and emergence of 5G technology have significantly improved health library services. Although Wi-Fi offers many benefits in establishing smart libraries, the enhanced connectivity among a large number of devices reduces latency between input and output, and robust security demonstrates the enhanced potential for 5G technology in health libraries. In this paper, we highlight five dimensions to support health libraries in the development and evaluation of 5G technologies in facilitating remote health library and information services. The five dimensions are: technological infrastructure, technology integration into health libraries, remote health information services, user readiness, and external support.

Lien vers l'article

Applications médicales

5G remote robotic-assisted PKP is safe and effective for thoracolumbar vertebral compression fractures.

Zhang XL, Zhou LP, Dong XY, Liu A, Jia CY, Zhang HQ, et al. *World Neurosurg*. 2025 Sep 23:124498.

OBJECTIVE: 5G remote robotic-assisted (RRA) technology has been applied in percutaneous kyphoplasty (PKP) for the treatment of patients with thoracolumbar vertebral compression fractures. Although some cases of RRA have already been reported, the safety and effectiveness of this technology remain controversial. Meanwhile, the radiographic and clinical parameters of the RRA and conventional robotic-assisted (CRA) methods has not been compared for patients with thoracolumbar vertebral compression fractures. METHOD: This study aimed to compare the radiographic and clinical parameters of RRA versus the CRA technology for PKP in thoracolumbar vertebral compression fractures. A total of 95 patients with thoracolumbar vertebral compression fractures who received PKP using RRA (43 patients) and CRA (52 patients) techniques were retrospectively included. The radiographic parameters included vertebral height and local Cobb's angle. Meanwhile,the clinical parameters included bone cement leakage rate, pain indicators, surgical time, intraoperative blood loss and complications. RESULTS: In radiographic parameters, the preoperative and postoperative vertebral height,including anterior vertebral height (AVH), middle vertebral height (MVH), posterior vertebral height (PVH) of both groups showed similar statistical results, with no statistically significant differences(P>0.05).In addition, the preoperative and postoperative vertebral compression ratio including anterior vertebral compression ratio (AVCR), middle vertebral compression ratio (MVCR), posterior vertebral compression ratio (PVCR) of both groups showed similar statistical results, with no statistically significant differences(P>0.05).Besides, the parameters of two groups' preoperative and postoperative local Cobb's angle were almost the same(P>0.05). Furthermore,in terms of clinical parameters,the RRA technique showed a lower rate of bone cement leakage than the CRA method , but there was no significant difference between the two groups (P = 0.809).The preoperative and

postoperative pain scores calculated by visual analogue scale (VAS) and oswestry disability index (ODI) of both two groups shows approximate results.And the differences are not statistically significant.In addition,both the RRA and CRA group showed similar statistical results in terms of surgical time, intraoperative blood loss and complications with no statistically significant differences(P>0.05). CONCLUSIONS: RRA PKP for treating thoracolumbar compression fractures can effectively relieve patient pain, restore vertebral height, and improve local kyphosis while ensuring safety. The 5G remote robotic-assisted PKP is accurate and safe in clinical application.

Lien vers l'article

Design of AI-driven microwave imaging for lung tumor monitoring.

Singh A, Paul S, Gayen S, Mandal B, Mitra D, Augustine R. *Sci Rep*. 2025 Oct 1;15(1):34287.

The global incidence of lung diseases, particularly lung cancer, is increasing at an alarming rate, underscoring the urgent need for early detection, robust monitoring, and timely intervention. This study presents design aspects of an artificial intelligence (AI)-integrated microwave-based diagnostic tool for the early detection of lung tumors. The proposed method assimilates the prowess of machine learning (ML) tools with microwave imaging (MWI). A microwave unit containing eight antennas in the form of a wearable belt is employed for data collection from the CST body models. The data, collected in the form of scattering parameters, are reconstructed as 2D images. Two different ML approaches have been investigated for tumor detection and prediction of the size of the detected tumor. The first approach employs XGBoost models on raw S-parameters and the second approach uses convolutional neural networks (CNN) on the reconstructed 2-D microwave images. It is found that the XGBoost-based classifier with S-parameters outperforms the CNN-based classifier on reconstructed microwave images for tumor detection. Whereas a CNN-based model on reconstructed microwave images performs much better than an XGBoost-based regression model designed on the raw S-parameters for tumor size prediction. The performances of both of these models are evaluated on other body models to examine their generalization capacity over unknown data. This work explores the feasibility of a low-cost portable AI-integrated microwave diagnostic device for lung tumor detection, which eliminates the risk of exposure to harmful ionizing radiations of X-ray and CT scans.

Lien vers l'article

Real-Time Health Monitoring Using 5G Networks: Deep Learning-Based Architecture for Remote Patient Care.

Batool I. *JMIRx Med*. 2025 Oct 1;6:e70906.

BACKGROUND: Remote patient monitoring systems face critical challenges in real-time vital sign analysis and secure data transmission. OBJECTIVE: This study aimed to develop a novel architecture integrating deep learning with 5G networks for real-time vital sign monitoring and prediction. METHODS: A hybrid convolutional neural network-long short-term memory model with attention mechanisms was optimized for edge deployment using 5G ultrareliable low-latency communication. The system incorporated end-to-end encryption and HIPAA (Health Insurance Portability and Accountability Act) compliance. Performance was evaluated over 3 months using data from 1000 patients. RESULTS: The system demonstrated superior prediction accuracy and significantly reduced latency compared to existing solutions. Performance remained stable under adverse network conditions and across diverse patient populations, supporting thousands of concurrent monitoring sessions. CONCLUSIONS: This framework addresses security, scalability, and robustness requirements

for clinical implementation, potentially improving patient outcomes through early detection of deteriorating conditions.

Lien vers l'article

Evaluation (Mesure des niveaux d'exposition)

Méthodes d'évaluation

Aucun article dans ce bulletin.

Evaluation population générale

Temporal change of outdoor RF-EMF levels in four European countries: a microenvironmental measurement study.

Beláčková L, Veludo AF, Aminzadeh R, Van Bladel H, Griffon V, Cardis E, et al. *Environ Res*. 2025 Nov 15;285(Pt 1):122315.

INTRODUCTION: Over the past two decades, the amount of transmitted mobile data has increased rapidly. It is unknown whether the implementation of the new technologies enabling this has resulted in changes of outdoor radio-frequency electromagnetic fields (RF-EMF) exposure. Therefore, microenvironmental measurements were used to investigate temporal trends in RF-EMF exposure between 2016 and 2023, in the Netherlands, Switzerland, Belgium and Spain, following a similar protocol across campaigns. Microenvironmental measurements refer to exposure measurements performed at predefined small areas that have been differentiated with a specific function in that particular area. This allowed us to compare exposure trends between countries and years. METHODS: The data was collected as part of the ACCEDERA (2016-2018), ETAIN (2023), and GOLIAT (2023) projects, walking repeatedly the same routes with RF-EMF exposimeters. Identical microenvironments were identified in each country and measurements of the exposure from mobile base stations, mobile phones and the total exposure were compared across years. RESULTS: Comparing measurements between 6 and 14 unique microenvironments in each country, our data did not suggest significant changes in the exposure from the mobile base station origin (total downlink exposure) between baseline measurements in 2016 to follow up and 2023 for the four countries. Across all countries and years the median values of the mobile base station exposure ranged from 0.11 mW/m(2) (Switzerland, 2023) to 0.62 mW/m(2) (Netherlands, 2018). There was no consistent trend in the individual microenvironments across the countries. CONCLUSIONS: Our measurements of RF-EMF outdoor exposure levels across included microenvironment groups do not indicate change in exposure levels between 2016 and 2023 despite an increase in mobile data traffic by a factor of 8 in Western Europe(1).

Lien vers l'article

Risques professionnels

Aucun article dans ce bulletin.

In silico

Aucun article dans ce bulletin.

In vitro

Activating Transcription Factor 4 regulation of radiofrequency radiation-induced ferroptosis in osteoblasts.

Wang H, Zou W, Ding C, Cao Y. *Electromagn Biol Med*. 2025;44(4):551-65.

Given the ubiquitous presence of radiofrequency (RF) radiation sources in modern environments, concerns have been raised regarding their cytotoxic effects on osteoblasts and potential implications for skeletal health. This study investigated the molecular mechanisms underlying these effects, focusing on ferroptosis, a form of regulated cell death implicated in bone pathologies, and the role of Activating Transcription Factor 4 (ATF4). Through comprehensive bioinformatic analyses of public gene expression databases, we identified significant correlations between differentially expressed genes and biological processes associated with lipid metabolism and ferroptosis. MC3T3-E1 osteoblasts were subjected to systematic evaluation under four distinct experimental conditions: a sham-exposed control group and three treatment groups exposed to calibrated RF radiation intensities - low (LRF, 50μW/cm(2)), moderate (MRF, 150μW/cm(2)), and high (HRF,450μW/cm(2)). To elucidate the molecular mechanisms underlying RF-induced ferroptosis, both ATF4 knockdown and overexpression experiments were performed. The findings indicated that RF radiation at 150μW/cm(2) elicited the most pronounced effects, characterized by reduced osteoblast viability, elevated lipid peroxidation, disrupted redox balance, impaired mitochondrial function, and disturbances in iron homeostasis. Notably, Atf4 knockdown exacerbated these deleterious effects, while its overexpression conferred protection against RF radiation-induced cellular damage. This study demonstrates the crucial role of ATF4 modulation in RF radiation-induced ferroptosis in osteoblasts, a process potentially contributing to bone disorders such as osteoporosis and impaired fracture healing. These findings suggest that targeting ATF4 may represent a promising therapeutic approach to mitigate the effects of RF radiation on bone health, thereby opening new avenues for intervention in environmentally influenced skeletal disorders.

Lien vers l'article

Differential metabolic responses of mouse Leydig and spermatogonia cells to radiofrequency electromagnetic field exposure.

Miao X, Lin Y, Guo J, Lin J, Gao P, Zhang W, et al. *Front Public Health*. 2025;13:1623701.

INTRODUCTION: Although existing studies have shown that radiofrequency electromagnetic fields (RF-EMFs) have a variety of effects on living organisms, the specific impact of RF-EMFs on the metabolism of reproductive cells and their underlying mechanisms remain unclear.This study aims to explore the effects of RF-EMFs on the metabolism of mouse Leydig cells (TM3) and spermatogonia cells (GC-1)

through metabolomics analysis, revealing the potential mechanisms by which RF-EMFs affect reproductive health. METHODS: We employed liquid chromatography-mass spectrometry (LC-MS) to analyze the metabolomic profiles of TM3 and GC-1 cells under two irradiation modalities: continuous and intermittent RF-EMF exposure. The data were further analyzed using KEGG pathway analysis to identify significantly enriched metabolic pathways. The ELISA (Enzyme-Linked Immunosorbent Assay) was used to detect glutathione levels. RESULTS: Our results showed that continuous irradiation had a more pronounced impact on the metabolism of TM3 cells, primarily affecting amino acid metabolism, the citric acid cycle, ABC transporters, bile secretion, and glutathione metabolism. In contrast, intermittent irradiation mainly altered the levels of fatty acyls and purine nucleosides, with significant enrichment in purine metabolism, biosynthesis of unsaturated fatty acids, and fatty acid metabolism. Compared to TM3 cells, GC-1 cells exhibited lower sensitivity to RF-EMF irradiation. Both irradiation modalities affected purine metabolism and lysine degradation pathways in TM3 cells, suggesting that changes in ADP levels may serve as a key metabolic signature in the cellular response to RF-EMF exposure. CONCLUSION: Continuous irradiation significantly impacts TM3 cell metabolism, particularly amino acid and glutathione pathways, while intermittent irradiation mainly affects fatty acyls and purine metabolism. GC-1 cells show lower sensitivity to RF-EMF. ADP level changes may be a key metabolic signature of RF-EMF exposure.

Lien vers l'article

Effects of Simultaneous In-Vitro Exposure to 5G-Modulated 3.5 GHz and GSM-Modulated 1.8 GHz Radio-Frequency Electromagnetic Fields on Neuronal Network Electrical Activity and Cellular Stress in Skin Fibroblast Cells.

Hurtier A, Patrignoni L, Canovi A, Orlacchio R, Tjiou H, Gannes FP, et al. *Bioelectromagnetics*. 2025 Oct;46(7):e70026.

The widespread deployment of 5G wireless networks alongside existing GSM technologies has increased the need to assess potential biological effects of co-exposure to multiple radiofrequency electromagnetic fields (RF-EMF). This study evaluates the in-vitro impact of simultaneous exposure to 5G-modulated 3.5 GHz and GSM-modulated 1.8 GHz signals on neuronal electrical activity, mitochondrial reactive oxygen species (ROS) production, and cellular stress protein responses in neurons and skin fibroblasts. Primary cortical neurons and human immortalized skin fibroblasts were exposed to RF-EMF at specific absorption rates (SAR) of 1 or 4 W/kg for 15 min or 24 h, respectively. Neuronal activity was analyzed using multi-electrode arrays (MEAs), mitochondrial ROS production was measured using MitoSOX Red, and stress protein activity was assessed using bioluminescence resonance energy transfer (BRET) assays targeting RAS, PML, and HSF1 proteins. The results indicate no significant effects on the mean bursting rate (MBR) or mean firing rate (MFR) of cortical neurons, consistent with previous findings at similar SAR levels. Mitochondrial ROS production in fibroblasts also remained unaffected by RF-EMF co-exposure. BRET assays detected minor variations in the basal activity of RAS and PML and in the maximal efficacy of PMA and As_2O_3 to activate these pathways. However, these effects were small, near the detection threshold, and showed no consistent pattern across different tests or chemical treatments. No change was observed in HSF1 basal activity or responsiveness to MG132. These findings suggest that co-exposure to 5G- and GSM-modulated RF-EMF at SAR levels up to 4 W/kg does not produce conclusive evidence of marked biological effects under the tested conditions. Observed variations, when present, are of low amplitude and likely to fall within the range of experimental variability.

Lien vers l'article

Human Skin Model From 15 GHz to 110 GHz.

Christ A, Aeschbacher A, Tarigan B, Chitnis N, Fallahi A, Kühn S, et al. *Bioelectromagnetics*. 2025 Oct;46(7):e70025.

Compliance testing of wireless devices with absorbed power density (APD) limits requires body models that conservatively reproduce the absorption characteristics of human skin. Previous studies indicate that impedance-matching effects are caused by the stratum corneum (SC) layer. The objective of this study is to develop a single macroscopic dielectric model reproducing absorption of electromagnetic fields by the skin up to 110 GHz. The reflection coefficient of the skin of human volunteers was measured at frequencies of 15 to 43 GHz with open waveguide probes, complementing previous data from 45 to 110 GHz. The measurements were made at various regions of the body. The statistical analysis of the results shows that the reflection coefficient in dB follows normal distribution in regions with thin SC, which permits the development of a conservative skin model. In regions with thick SC, for example, the palms, the reflection coefficient is not normally distributed because the thickness of the SC depends on the mechanical stress the hands are exposed to. The measured data allow the derivation of dispersive two-layer models representing absorption and reflection at the skin surface with known uncertainty. The models can be used to conservatively demonstrate compliance with the APD limits of wireless devices in any of the 5G and 6G bands.

Lien vers l'article

Sur l'animal

Genotoxic and histopathological effects of 6 GHz radiofrequency electromagnetic radiation on rat liver tissue.

Ilgaz NS, Karamazı Y, Emre M, Toyran T, Karaoğlan Ö, Emre T, et al. *Electromagn Biol Med*. 2025;44(4):472-83.

In this study, the genotoxic and histopathological effects of 6 GHz (0.065 W/kg) Radiofrequency-Electromagnetic Radiation (RF-EMR) on rat liver tissue were investigated. Sham (control) and Radiofrequency Radiation (RFR) groups were formed with 10 adult male rats in each group. Rats in the sham group received no treatment. Rats in the RFR group were exposed to 6 GHz RF-EMR for 4 h/day for 42 days. Immediately after the completion of the exposure, the rats in both groups were sacrificed and liver tissues were removed. Comet Test was performed to determine the genotoxic effect in the samples. Masson Trichrome and Hematoxylin Eosin staining methods were applied histopathologically. According to the Comet Analysis results, the genetic damage index (GDI) and damaged cell percentage (DCP) of the RFR group were higher than the sham group, but this difference was not statistically significant ($p > 0.05$). In histopathologic examinations, portal inflammation, single cell necrosis, vascularity and congestion were more prominent in the RFR group compared to the sham group. In our study, it was shown that 6 GHz RF-EMR can cause histopathologic and DNA level changes in rat liver tissue. As a result of the literature review, no prior studies have specifically examined the genotoxic and histopathological effects of 6 GHz RF-EMR. This makes our study important as it addresses the biological impacts of the 6 GHz frequency band.

Lien vers l'article

Protective effects of quercetin against 3.5 GHz RF radiation-induced thyroid dysfunction and oxidative stress in rats.

Bektas H, Bese Akgun BB, Cakir S, Dogu S, Ahnas B. *Electromagn Biol Med*. 2025;44(4):449-60.

The global expansion of 5 G communication networks has heightened concerns about the biological effects of high-frequency radiofrequency (RF) radiation, particularly on endocrine organs such as the thyroid gland. This study investigated the effects of 3.5 GHz RF radiation on thyroid hormone levels and oxidative stress markers in male Wistar rats and assessed the potential protective role of quercetin, a natural antioxidant. Twenty-eight rats were randomly assigned to four groups: Sham, RF, Quercetin, and RF + Quercetin. RF exposure was administered at 3.5 GHz (2 W) for 2 hours/day, 5 days/week, for 30 days. Quercetin (20 mg/kg) was administered intraperitoneally. Serum levels of T3, T4, and TSH, as well as thyroid tissue levels of TAS, TOS, GSH, and MDA, were analyzed using ELISA. RF exposure significantly decreased T3 and T4, increased TSH, elevated MDA and TOS, and reduced TAS and GSH levels. Quercetin treatment showed trends toward reversing some of these effects, although not all changes reached statistical significance. SAR simulations confirmed higher energy absorption in the thyroid region (average SAR: 1.128 W/kg). These findings suggest that 3.5 GHz RF radiation may impair thyroid function and redox homeostasis, and that quercetin may exert limited biochemical protection, though further studies are needed to confirm its efficacy. Further long-term molecular studies are warranted to elucidate the mechanisms involved.

Lien vers l'article

Effects of 2100 MHz radio-frequency fields on brain tissues and plasma of normal rats and obese rats.

Günay S, Delen K, Özkan ET, Kuzay Aksoy D, Sırav Aral B. *Electromagn Biol Med*. 2025;44(4):418-24.

The use of mobile phones, one of the popular recent sources of radio-frequency fields (RFF), is increasing. It has been shown thatRFF exposure can increase free radical levels and oxidative stress.Obesity is an important risk factor for many diseases such as cancer, cardiovascular diseases, and diabetes, and has been shown to increase oxidative stress. In this study, rats were exposed to 2100 MHz RFF(electric field 15 V/m) for 15 minutes daily and 4 hours daily for 3 weeks. It aims to investigate the effects of 2100 MHz RFF on brain tissue and plasma of normal and obese rats. The rats were divided into eight groups (n = 6):control, Sham1, Sham2, RFF1, RFF2, High Fat Diet (HFD), Sham+HFD, andHFD+RFF. The inflammatory and oxidative effects on brain tissue and plasma were analyzed using the GraphPad 9 macOS package program. WhenTOS levels in brain tissue were compared between Sham2 and RFF1 andall groups, a significant difference was found in the RFF2 group. TASlevel was significantly different in the HDF+RFF group compared to the control group, Sham and all groups. When pro-inflammatory and anti-inflammatory parameters were evaluated in brain tissue, significant differences were found in different exposure groups. Inplasma, TOS levels were significantly different in the RFF2 groupcompared to Sham2 and RFF1, but TAS levels were not different.According to the data obtained, obesity may be protective against the oxidative and inflammatory effects of RFF.

Lien vers l'article

3.5GHz radiofrequency electromagnetic fields (RF-EMF) on metabolic disorders in Drosophila melanogaster.

Wang Y, Zhang Z, Zhang L, Liao Y, Cai P. *Ecotoxicol Environ Saf*. 2025 Oct 6;304:119132.

The widespread implementation of fifth-generation (5 G) technology has raised concerns regarding its impact on biosafety. This study aims to uncover metabolic alterations in Drosophila melanogaster in response to electromagnetic radiation through metabolomics under 3.5 GHz radiofrequency electromagnetic fields (RF-EMF) conditions. Newborn male flies were continuously exposed to 3.5 GHz RF-EMF at intensities of 0.1 W/m(2), 1 W/m(2), and 10 W/m(2) throughout their entire life cycle under 24-hour constant darkness. Metabolomic analysis was performed on Drosophila samples after long-term exposure. The results indicate that long-term exposure to RF-EMF leads to disruptions in four metabolic pathways - alanine, aspartate and glutamate metabolism, tryptophan metabolism, ascorbate and aldehyde metabolism, and purine metabolism - as well as 34 differential metabolites across various power density in Drosophila melanogaster. Notably, the most significant metabolites (GABA, glucose-6-phosphate, AMP, N-formylglycinamide nucleotide, LPC, and MG) exhibited high sensitivity to RF-EMF showing significant decreases. The suggests that long-term exposure to electromagnetic wave treatment may reduce the overall metabolic levels in fruit fly. These findings provide valuable insights into the metabolic disturbance induced by RF-EMF and enhance our understanding of the potential health effects associated with 5 G radiation.

Lien vers l'article

Sur l'homme

Effects of radiofrequency electromagnetic fields on cognitive function in elderly subjects (60+ years)-Results of an experimental randomized sham controlled double-blind cross-over study in women and in men.

Sauter C, Dorn H, Bueno-Lopez A, Eggert T, Schmid G, Danker-Hopfe H. *Environ Res*. 2025 Nov 15;285(Pt 3):122479.

BACKGROUND: During the regular use of digital communication devices, the human head is exposed to different levels of radiofrequency electromagnetic fields (RF-EMF). Several experimental human studies on possible effects of RF-EMF from different technical systems on cognitive performance over the last decades show contradictory results. Most of the results come from studies with young male participants. OBJECTIVES: The present study examined whether cognitive functions of older women and men are more vulnerable and therefore may react differently to RF-EMF exposure than younger individuals. METHODS: Sixty healthy women (30) and men (30) between the ages of 60 and 80 years took part in a double-blind randomized sham-controlled experimental study. All participants completed four different attentional tasks in nine separate sessions, separated by two weeks, while being exposed to either RF-EMF of Global System for Mobile Communications (GSM 900 MHz), Terrestrial Trunked Radio (TETRA 385 MHz) signals, or sham in three sessions each. RESULTS: Two performance outcome measures out of 16 were statistically significantly affected by exposure in women only: accuracy in an n-back task was worse under GSM exposure in the easier version and under TETRA exposure in the highest level of the task. Performance of women and men did not differ significantly. Only one significant sex-exposure interaction effect was observed under TETRA exposure, indicating a better performance in men, and a worse performance in women as compared to sham. DISCUSSION: Overall, cognitive performance of healthy elderly participants was not affected by short-term RF-EMF exposure, which corresponds to the results of the most recent comprehensive meta-

analyses for the non-elderly population. No conclusion can be drawn for older adults with health-related restrictions or disorders, or effects from long-term exposure.

Lien vers l'article

Greater prevalence of symptoms associated with higher exposures to mobile phone base stations in a hilly, densely populated city in Mizoram, India.

Sailo L, Laldinpuii, Zosangzuali M, Weller S, Varte CL, Tochhawng L, et al. *Electromagn Biol Med*. 2025;44(4):385-404.

Members of the scientific community and the general public are raising concerns about the potential health and environmental effects of radio-frequency electromagnetic fields (RF-EMF) for those living nearby mobile phone base stations (MPBS). This study examined the impact of RF-EMF (900-1900 MHz) on symptoms spanning four health categories: mood-energy, cognitive-sensory, inflammatory, and anatomical issues. A questionnaire identifying health symptoms within these categories, was given to 183 highly exposed and 126 reference residents, matched on demographics. While years of residing near the MPBS influenced the prevalence of some symptoms, proximity to the base station and higher levels of exposure (measured using power density) influenced the prevalence of many of the symptoms. A higher proportion of symptoms was found in residents who were either living within 50 meters of a MPBS or who were exposed to power densities of 5-8 mW/m(2), for all four health categories. This relationship between exposure level and symptom prevalence was further influenced by age, daily mobile phone use (over 5 h per day), and lifestyle factors, for certain symptoms. Hierarchical regression analysis revealed that level of exposure (power density) was the only factor contributing to the number of symptoms experienced by residents, for all four health categories. An unexpected finding was that among the more highly exposed residents, the younger individuals (under 40 years) reported more inflammation related issues than older individuals. These results underscore the need to inform policymakers regarding the benefits of adopting a precautionary approach to potential risks associated with RF-EMF exposures from MPBS.

Lien vers l'article

Review of the biological effects due to high-power microwaves exposure.

Gao A, Dong G, Wang C. *Electromagn Biol Med*. 2025;44(4):581-600.

High power microwaves (HPMs), characterized by frequencies spanning from 1 GHz to 300 GHz and peak power exceeding 100 MW, have numerous applications but also pose considerable health hazards. This review discusses the biological effects of HPMs on various human and animal cells, tissues, organs, and systems. Notably, HPMs can damage brain structures, particularly the hippocampus, causing oxidative stress and DNA damage, which in turn contribute to cognitive impairment. The immune system is subject to dual effects from HPMs, exhibiting both stimulatory and suppressive immune responses contingent on the specifics of exposure details. In the reproductive system, HPMs are observe to diminish male fertility by interfering with spermatogenesis and semen quality, although antioxidants may mitigate these effects. Furthermore, HPMs may exacerbate skin conditions, such as atopic dermatitis, and potentially accelerate the onset of skin cancer. With regard to cardiovascular health, these effects are usually transient, mainly affecting blood pressure and heart rate, but ultimately not impairing them. Furthermore, HPMs in agricultural production, sterilization and other beneficial effects have been found. This review provides valuable references for the

investigation of the biological effects and the underlying mechanisms of HPM, as well as for the revision of related standards and guidelines.

Lien vers l'article

Correction to "Autonomous nervous system responses to environmental-level exposure to 5G's first deployed band (3.5 GHz) in healthy human volunteers".

Exp Physiol. 2025 Oct 13.

The original article should have included a section titled ‘Funding information’, with the following text: ‘This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101057262. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or the Health and Digital Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.’ We apologize for this error.

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