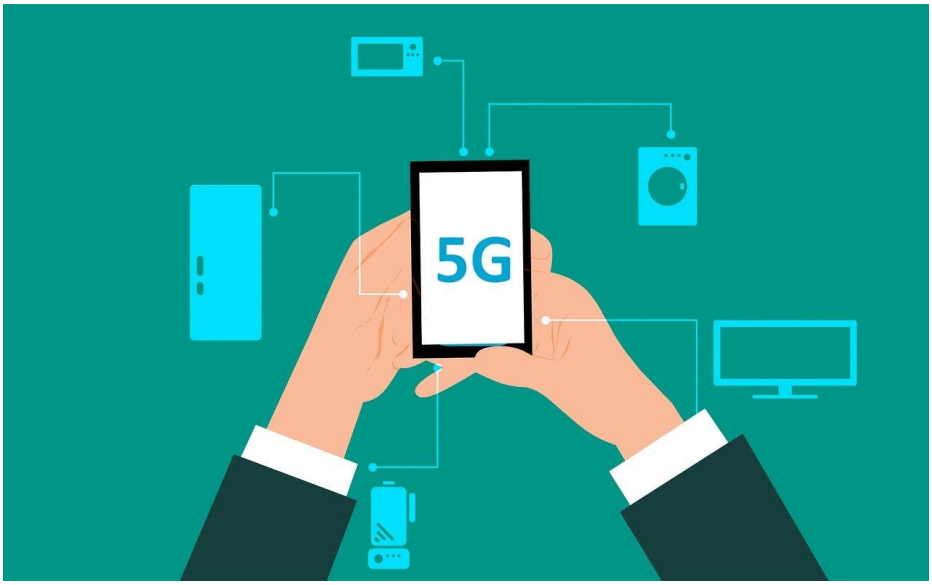
# TECHNOLOGIE 5G

## Bulletin de veille scientifique : Mai 2024




Objectifs : réaliser une veille scientifique sur la technologie 5G

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## Généralités

**The Advantage of the 5G Network for Enhancing the Internet of Things and the Evolution of the 6G Network.**

Gkagkas G, Vergados DJ, Michalas A, Dossis M. *Sensors (Basel)*. 2024 Apr 11;24(8).

The Internet of Things (IoT) is what we have as a great breakthrough in the 5G network. Although the 5G network can support several Internet of Everything (IoE) services, 6G is the network to fully support that. This paper is a survey research presenting the 5G and IoT technology and the challenges coming, with the 6G network being the new alternative network coming to solve these issues and limitations we are facing with 5G. A reference to the Control Plane and User Plane Separation (CUPS) is made with IPv4 and IPv6, addressing which is the foundation of the network slicing for the 5G core network. In comparison to other related papers, we provide in-depth information on how the IoT is going to affect our lives and how this technology is handled as the IoE in the 6G network. Finally, a full reference is made to the 6G network, with its challenges compared to the 5G network.

Lien vers l'article

### Performances et sécurité

**In Situ Assessment of Uplink Duty Cycles for 4G and 5G Wireless Communications.**

Vermeeren G, Verloock L, Aerts S, Martens L, Joseph W. *Sensors (Basel)*. 2024 May 9;24(10).

In this presented study, we measured in situ the uplink duty cycles of a smartphone for 5G NR and 4G LTE for a total of six use cases covering voice, video, and data applications. The duty cycles were assessed at ten positions near a 4G and 5G base-station site in Belgium. For Twitch, VoLTE, and WhatsApp, the duty cycles ranged between 4% and 22% in time, both for 4G and 5G. For 5G NR, these duty cycles resulted in a higher UL-allotted time due to time division duplexing at the 3.7 GHz frequency band. Ping showed median duty cycles of 2% for 5G NR and 50% for 4G LTE. FTP upload and iPerf resulted in duty cycles close to 100%.

Lien vers l'article

**Resource-Efficient Multicast URLLC Service in 5G Systems.**

Krasilov A, Lebedeva I, Yusupov R, Khorov E. *Sensors (Basel)*. 2024 Apr 15;24(8).

Many emerging applications, such as factory automation, electric power distribution, and intelligent transportation systems, require multicast Ultra-Reliable Low-Latency Communications (mURLLC). Since 3GPP Release 17, 5G systems natively support multicast functionality, including multicast Hybrid Automatic Repeat Request and various feedback schemes. Although these features can be promising for mURLLC, the specifications and existing studies fall short in offering guidance on their efficient usage. This paper presents the first comprehensive system-level evaluation of mURLLC, leveraging insights from 3GPP specifications. It points out (i) how mURLLC differs from traditional multicast broadband wireless communications, and (ii) which approaches to provide mURLLC require changing the paradigm compared with the existing solutions. Finally, the paper provides recommendations on how to satisfy strict mURLLC requirements efficiently, i.e., with low channel resource consumption, which increases the capacity of 5G systems for mURLLC. Simulation results show that proper configuration of multicast mechanisms and the corresponding algorithms for mURLLC traffic can reduce resource consumption up to three times compared to the baseline solutions proposed for broadband multicast traffic, which significantly increases the system capacity.

Lien vers l'article

**Application of the full consistency method (FUCOM) - Cosine similarity framework in 5G infrastructure investment planning: An approach for telecommunication quality improvements.**

Çodur S, Erkayman B, Alp SS, Özenir O, Pamucar D, Yıldız G, et al. *Heliyon*. 2024 May 15;10(9):e30664.

In the rapidly evolving telecommunications landscape, the shift towards advanced communication technologies marks a critical milestone. This transition promises to revolutionize connectivity by enabling seamless data downloads, high-quality video streaming, and instant access to applications. However, adapting to these advanced technologies poses significant challenges for infrastructure

expansion, requiring innovative investment and deployment strategies. These strategies aim not only to enhance service quality but also to ensure extensive network coverage. To address the need for systematic planning in infrastructure investment, this paper presents a novel methodology that combines the Full Consistency Method (FUCOM) with cosine similarity analysis. This integrated approach effectively prioritizes service areas for the deployment of 5G technology, emphasizing the importance of detailed planning in mobile strategy development. By leveraging FUCOM to determine the weights of various criteria and employing cosine similarity analysis to rank service areas, the methodology facilitates efficient resource allocation and service quality enhancements. Empirical validation using real data from a Turkish telecommunications company confirmed the effectiveness of the proposed algorithm. The results indicate that this integrated approach can significantly advance the telecommunications industry by providing essential insights for companies seeking to improve service quality amidst the transition to 5G and beyond. The successful implementation of the proposed algorithm demonstrates its effectiveness in addressing the challenges faced by telecommunications companies and underscores the importance of a data-driven approach in strategic decision-making and resource allocation. Furthermore, the findings suggest that the integrated FUCOM and cosine similarity analysis approach can offer a valuable tool for telecommunications companies worldwide, offering a systematic method for prioritizing infrastructure investments and enhancing network performance.

Lien vers l'article

**Measurement and Analysis of 4G/5G Mobile Signal Coverage in a Heavy Industry Environment.**

Polak L, Kufa J, Sotner R, Fryza T. *Sensors (Basel)*. 2024 Apr 15;24(8).

In the evolving landscape of Industry 4.0, the integration of advanced wireless technologies into manufacturing processes holds the promise of unprecedented connectivity and efficiency. In particular, the data transmission in a heavy industry environment needs stable connectivity with mobile operators. This paper deals with the performance study of 4G and 5G mobile signal coverage within a complex factory environment. For this purpose, a cost-effective and portable measurement setup was realized and used to provide long-term measurement campaigns monitoring and recording several key parameter indicators (KPIs) in 4G/5G downlink and upload. To support the reproducibility of the provided study and other research activities, the measured dataset is publicly available for download. Among others findings, the obtained results show how the performance of 4G/5G is influenced by a heavy industry environment and of the time of day on the network load.

Lien vers l'article

## Antennes

**Ni-Co Complex Ionic Synergistically Modifying Octahedron Lattice of Cordierite Ceramics for the Application of 5G Microwave-Millimeter-wave Antennas.**

Yao Y, Wang Y, Bafrooei HB, Mao M, Liu B, Lu Z, et al. *Inorg Chem*. 2024 May 27;63(21):10022-30.

In this work, phase-pure Mg(1.8)(Ni(1-x)Co(x))(0.2)Al(4)Si(5)O(18) ($0 \le x \le 1$) ceramics were synthesized by a high-temperature solid-state method. On the basis of Rietveld refinement data of X-ray powder diffraction and Phillips-Vechten-Levine theory, the atomic ionicity, lattice energy, and bond energy of the compound were calculated to explore their influence on the microwave dielectric properties of

ceramics. The Mg(1.8)Ni(0.1)Co(0.1)Al(4)Si(5)O(18) (x = 0.5) ceramic exhibited the best microwave dielectric properties: ε(r) = 4.44, Qf = 73 539 GHz@13 GHz, and τ(f) = -23.9 ppm/°C. (Ni(1-x)Co(x))(2+) complex ionic doping, compared with only Ni(2+) or Co(2+), is beneficial for improving the symmetry of [Si(4)Al(2)O(18)] hexagonal rings and reducing distortion. Subsequently, 8 wt % TiO(2) was added to Mg(1.8)Ni(0.1)Co(0.1)Al(4)Si(5)O(18), resulting in a near-zero τ(f) and high Qf values for the composite ceramic, with ε(r) = 5.22, Qf = 58 449 GHz@13 GHz, and τ(f) = -2.06 ppm/°C. Finally, a 5G millimeter-wave antenna with a central operating frequency of 25.52 GHz was designed and fabricated using the Mg(1.8)Ni(0.1)Co(0.1)Al(4)Si(5)O(18)-8 wt % TiO(2) ceramics. Operating in the 24.7-26.0 GHz range, it demonstrated favorable radiation characteristics with a simulated efficiency of 85.2% and a gain of 4.58 dBi. The antenna's performance confirms the high potential of the cordierite composite for application in 5G communication systems.

Lien vers l'article

**Development of Wearable Textile MIMO Antenna for Sub-6 GHz Band New Radio 5G Applications.**

Pradeep P, Basha MM, Gundala S, Syed J. *Micromachines (Basel)*. 2024 May 15;15(5).

In this paper, an irregular octagonal two-port MIMO patch antenna is designed specifically for New Radio (NR) 5G applications in the mid-band sub-6 GHz. The proposed antenna comprises an irregularly shaped patch antenna equipped with a regular 50-ohm feed line and a parasitic strip line antenna, and is partially grounded. Jeans material serves as a substrate with an effective dielectric constant of 1.6 and a thickness of 1 mm. This material is studied experimentally. The proposed antenna design undergoes analysis and optimization using the ANSYS HFSS tool. Furthermore, the design incorporates the influence of the slot on both the ground plane and the parasitic strip line to optimize performance, enhance isolation, and improve impedance matching among antenna elements. The dimensions of the jeans substrate are 40 mm × 50 mm. The simulated impedance bandwidth ranged from 3.6 GHz to 7 GHz and the measured bandwidth was slightly narrower, from 4.35 GHz to 7 GHz. The simulation results demonstrated an isolation level greater than 12 dB between antenna elements, while the measured results reached 28.5 dB, and the peak gain for this proposed antenna stood at 6.74 dB. These qualities made this proposed antenna suitable for various New Radio mid-band 5G wireless applications within the sub-6 GHz band, such as N79, Wi-Fi-5/6, V2X, and DSRC applications.

Lien vers l'article

**Broadband unidirectional twin-element MIMO antenna scheme for mid-band 5G and WLAN laptops.**

Luadang B, Janpangngern P, Pookkapund K, Dentri S, Krairiksh M, Phongcharoenpanich C. *Sci Rep*. 2024 Apr 27;14(1):9693.

This research proposes a broadband unidirectional twin-element multiple-input-multiple-output (MIMO) antenna scheme for mid-band 5G and WLAN applications. The twin-element antenna scheme comprises two single-element antennas, and each single-element antenna consists of a T-shaped hemispherical feeding patch, left- and right-arm radiating patches, and a conjoined triangular ground plane. The twin-element MIMO antenna scheme is integrated with a laptop model functioning as the reflector. The measured impedance bandwidth (|S(11)|, |S(22)|≤ - 6 dB) are 55.32%, covering 3.4-6.0 GHz, and the measured mutual coupling (|S(12)|) is less than - 15 dB. The measured gain at the center frequency (4.5 GHz) is 4.585 dBi. Besides, the measured xz- and yz-plane cross-polarization levels are below - 25 dB and - 15 dB, respectively. The half-power beamwidth (HPBW) in the xz-plane at 3.5, 4.5, and 5.5 GHz are 99°, 92.8°, and 84.2°, and the corresponding HPBW in the yz-plane are

102°, 78°, and 102°. The measured xz- and yz-plane back lobe levels are below - 15 dB across the entire operating frequency band (3.5-5.5 GHz). The radiation pattern of the twin-element MIMO antenna scheme is of unidirectionality. Furthermore, the envelope correlation coefficient and diversity gain of the twin-element antenna scheme are < 0.001 and > 9.99 dB, respectively. The proposed broadband unidirectional twin-element MIMO antenna scheme is thus operationally suitable for mid-band 5G/WLAN communication systems. Essentially, this research is the first to propose a broadband twin-element MIMO antenna scheme for mid-band 5G/WLAN applications.

Lien vers l'article

**A Dual-Band 8-Antenna Array Design for 5G/WiFi 5 Metal-Frame Smartphone Applications.**

Li H, Xiao S, He L, Cai Q, Liu G. *Micromachines (Basel)*. 2024 Apr 28;15(5).

This paper presents a dual-band 8-port multiple-input multiple-output (MIMO) antenna specifically designed for fifth-generation (5G) smartphones, featuring two open-slot metal frames. To enhance impedance matching and improve isolation between adjacent antenna elements, each antenna element employed a coupling feed. All simulation results in this paper come from Ansys HFSS. The operational frequency bands of the proposed antenna spanned 3.36-4.2 GHz for the lower band and 4.37-5.95 GHz for the higher band, covering 5G New Radio (NR) bands N78 (3.4-3.6 GHz) and N79 (4.4-4.9 GHz), as well as WiFi 5 (5.15-5.85 GHz). Notably, the antenna demonstrated outstanding isolation exceeding 16.5 dB within the specified operating bands. The exceptional performance positions the proposed antenna as a promising candidate for integration into 5G metal-frame smartphones.

Lien vers l'article

**Enhancing gain and isolation of a quad-element MIMO antenna array design for 5G sub-6 GHz applications assisted with characteristic mode analysis.**

Khan R, Sethi WT, Malik WA, Jan L, Tahseen MM, Almuhlafi AM, et al. *Sci Rep*. 2024 May 15;14(1):11111.

This paper presents a novel quad-element array with multiple inputs and multiple outputs (MIMO) designed for 5th generation sub-6 GHz applications. The MIMO system achieves a wide impedance bandwidth, high gain, and high isolation among its components, representing significant advancements in sub-6 GHz antenna applications. The single element, an elliptical resonator with a circular slot, is fed by a 50 Ω microstrip feedline, achieves a broad characteristic bandwidth from 3.7 to 5.7 GHz with a resonant frequency of 4.33 GHz and a gain of 1.81 dBi. Characteristic Mode Analysis (CMA) was employed to elucidate the evolution phases of this design. The quad-element MIMO antenna array maintains a compact size and broadband characteristics by arranging mirrored elements on the same ground plane. Implemented on a cost-effective FR-4 substrate measuring 44 × 44 × 1.6 mm(3), the recommended MIMO antenna array, enhanced with a partial ground plane and due to the introduction of a vertical strip, a high isolation of - 38.53 dB is achieved between MIMO components along with a realized gain of 3.01 dBi and a radiation efficiency of 71% in the 5G sub-6 GHz band. Noteworthy properties include high isolation, diversity gain (DG), and envelope correlation coefficient (ECC), verifying the appropriateness of the suggested MIMO scheme for 5G transmission and reception in sub-6 GHz applications.

Lien vers l'article

**Design of antipodal vivaldi antenna with patch and corrugations for 5G applications.**

Kumar S, Dixit AS, Choubey CK. *MethodsX*. 2024 Jun;12:102727.

A compact 1 × 4 antipodal Vivaldi antenna (AVA) array designed for 5 G applications is introduced in this study. An elliptical-shaped parasitic patch and corrugation are strategically employed to enhance gain and bandwidth, making it well-suited for 5 G applications. The resulting AVA array with corrugation and parasitic patch (AVA-PC) is designed and simulated on ANSYS HFSS, demonstrating a stable gain ranging from 10 dBi to 11.7 dBi over the frequency range of 23.45 GHz to 28.74 GHz. The antenna, with 25.8 mm x 22.4 mm x 0.5 mm dimensions, is implemented on Roger's RT/Duroid substrate 5880. •Design uses an antipodal Vivaldi antenna to build a 1 × 4 AVA.•The array employs corrugations and an elliptical patch as a performance enhancement technique.•Simulated results confirm the designed antenna's practical utility for 5 G applications in a band of 23.45 GHz to 28.74 GHz.

Lien vers l'article

**Author Correction: High isolation 16-port massive MIMO antenna based negative index metamaterial for 5G mm-wave applications.**

Musaed AA, Al-Bawri SS, Abdulkawi WM, Aljaloud K, Yusoff Z, Islam MT. *Sci Rep*. 2024 Apr 25;14(1):9492.

Lien vers l'article

## Architecture réseau

**A Comprehensive Overview of Network Slicing for Improving the Energy Efficiency of Fifth-Generation Networks.**

Lorincz J, Kukuruzović A, Blažević Z. *Sensors (Basel)*. 2024 May 20;24(10).

The introduction of fifth-generation (5G) mobile networks leads to an increase in energy consumption and higher operational costs for mobile network operators (MNOs). Consequently, the optimization of 5G networks' energy efficiency is crucial, both in terms of reducing MNO costs and in terms of the negative environmental impact. However, many aspects of the 5G mobile network technology itself have been standardized, including the 5G network slicing concept. This enables the creation of multiple independent logical 5G networks within the same physical infrastructure. Since the only necessary resources in 5G networks need to be used for the realization of a specific 5G network slice, the question of whether the implementation of 5G network slicing can contribute to the improvement of 5G and future sixth-generation networks' energy efficiency arises. To tackle this question, this review paper analyzes 5G network slicing and the energy demand of different network slicing use cases and mobile virtual network operator realizations based on network slicing. The paper also overviews standardized key performance indicators for the assessment of 5G network slices' energy efficiency and discusses energy efficiency in 5G network slicing lifecycle management. In particular, to show how efficient network slicing can optimize the energy consumption of 5G networks, versatile 5G network slicing use case scenarios, approaches, and resource allocation concepts in the space, time, and frequency

domains have been discussed, including artificial intelligence-based implementations of network slicing. The results of the comprehensive discussion indicate that the different implementations and approaches to network slicing pave the way for possible further reductions in 5G MNO energy costs and carbon dioxide emissions in the future.

Lien vers l'article

## Efficacité énergétique

**A Comprehensive Overview of Network Slicing for Improving the Energy Efficiency of Fifth-Generation Networks.**

Lorincz J, Kukuruzović A, Blažević Z. *Sensors (Basel)*. 2024 May 20;24(10).

The introduction of fifth-generation (5G) mobile networks leads to an increase in energy consumption and higher operational costs for mobile network operators (MNOs). Consequently, the optimization of 5G networks' energy efficiency is crucial, both in terms of reducing MNO costs and in terms of the negative environmental impact. However, many aspects of the 5G mobile network technology itself have been standardized, including the 5G network slicing concept. This enables the creation of multiple independent logical 5G networks within the same physical infrastructure. Since the only necessary resources in 5G networks need to be used for the realization of a specific 5G network slice, the question of whether the implementation of 5G network slicing can contribute to the improvement of 5G and future sixth-generation networks' energy efficiency arises. To tackle this question, this review paper analyzes 5G network slicing and the energy demand of different network slicing use cases and mobile virtual network operator realizations based on network slicing. The paper also overviews standardized key performance indicators for the assessment of 5G network slices' energy efficiency and discusses energy efficiency in 5G network slicing lifecycle management. In particular, to show how efficient network slicing can optimize the energy consumption of 5G networks, versatile 5G network slicing use case scenarios, approaches, and resource allocation concepts in the space, time, and frequency domains have been discussed, including artificial intelligence-based implementations of network slicing. The results of the comprehensive discussion indicate that the different implementations and approaches to network slicing pave the way for possible further reductions in 5G MNO energy costs and carbon dioxide emissions in the future.

Lien vers l'article

**Dynamic resource allocation for energy-efficient downlink NOMA systems in 5G networks.**

Abuajwa O, Mitani S. *Heliyon*. 2024 May 15;10(9):e29956.

Non-Orthogonal Multiple Access (NOMA) is a promising energy-efficient technology designed to satisfy the demands of future networks by efficiently sharing radio resources. In NOMA, the same radio resource is simultaneously assigned to two users at different power levels based on the NOMA-power domain. Resource allocation in NOMA presents a non-convex challenge, characterized as a non-deterministic polynomial (NP-hard) problem. This involves user and channel assignment and power allocation, making it an extraordinarily complex task to achieve an optimal solution. In this work, Simulated Annealing (SA) is proposed as an optimization technique for resource allocation in an energy-efficient downlink NOMA system. This resource allocation scheme addresses user and channel assignment, as well as power allocation, using SA as an efficient standalone approach to maximize

energy efficiency in NOMA. SA is utilized to execute the assignment of users to channels, distribute the necessary power for each channel, and determine the power ratio among users sharing the same channel. The results obtained demonstrate a significant improvement in energy efficiency, outperforming the existing numerical methods by 22 %. The proposed SA scheme not only achieves a close optimal solution but also in less computational time, offering sufficient reliability in terms of energy efficiency enhancement when compared to the existing numerical method.

Lien vers l'article

## Autres équipements

**Design and fabrication of a microstrip triplexer with wide flat channels for multi-band 5G applications.**

Yahya SI, Zubir F, Abdel Hafez M, Nkenyereye L, Chaudhary MA, Assaad M, et al. *PLoS One*. 2024;19(5):e0302634.

In this paper, a new microstrip triplexer is designed to work at 2.5 GHz, 4.4 GHz and 6 GHz for mid-band 5G applications. All channels are flat with three low group delays (GDs) of 0.84 ns, 0.75 ns and 0.49 ns, respectively. Compared to the previously reported works, the proposed triplexer has the minimum group delay. The designed triplexer has 18.2%, 13.7%, 23.6% fractional bandwidths (FBW%) at 2.5 GHz, 4.4 GHz and 6 GHz, respectively. The obtained insertion losses (ILs) are low at all channels. These features are obtained without a noticeable increase in the overall size. A novel and simple resonator is used to design the proposed triplexer, which includes two pairs of coupled lines combined with a shunt stub. A perfect mathematical analysis is performed to find the resonator behavior and the layout optimization. The type of shunt stub is determined mathematically. Also, the smallness or largeness of some important physical dimensions is determined using the proposed mathematical analysis. Finally, the designed triplexer is fabricated and measured, where the measurement results verify the simulations.

Lien vers l'article

**5G-enabled, battery-less smart skins for self-monitoring megastructures and digital twin applications.**

Lynch C, Adeyeye A, Abbara EM, Umar A, Alhendi M, Minnella C, et al. *Sci Rep*. 2024 May 1;14(1):10002.

With the current development of the 5G infrastructure, there presents a unique opportunity for the deployment of battery-less mmWave reflect-array-based sensors. These fully-passive devices benefit from having a larger detectability than alternative battery-less solutions to create self-monitoring megastructures. The presented 'smart' skin sensor uses a Van-Atta array design enabling ubiquitous local strain monitoring for the structural health monitoring of composite materials featuring wide interrogation angles. Proof-of-concept prototypes of these 'smart' skin millimeter-wave identification tags, that can be mounted on or embedded within common materials used in wind turbine blades, present a highly-detectable radar cross-section of - 33.75 dBsm and - 35.00 dBsm for mounted and embedded sensors respectively. Both sensors display a minimum resolution of 202 μ -strain even at 40 ◦ off-axis enabling interrogation of the fully-passive sensor at oblique angles of incidence. When interrogated from a proof-of-concept reader, the fully-passive, sticker-like mmID enables local strain monitoring of both carbon fiber and glass fiber composite materials. The sensors display a repeatable

and recoverable response over 0-3000 µ -strain and a sensitivity of 7.55 kHz/ µ -strain and 7.92 kHz/ µ -strain for mounted and embedded sensors, respectively. Thus, the presented 5G-enabled battery-less sensor presents massive potential for the development of ubiquitous Digital Twinning of composite materials in future smart cities architectures.

Lien vers l'article

### Applications industrielles

Aucun article dans ce bulletin.

### Applications médicales

**Feasibility and safety of dual-console telesurgery with the KangDuo Surgical Robot-1500 System using fifth-generation and wired networks: an animal experiment and sea-spanning clinical study.**

Xu L, Shen C, Li X, Zhao F, Huang W, Yang K, et al. *Minerva Urol Nephrol*. 2024 Apr;76(2):241-6.

BACKGROUND: To evaluate the feasibility and safety of dual-console telesurgery with the new KangDuo system in an animal experiment and clinical study. METHODS: Six canine models were performed radical prostatectomy with dual-console KanDuo surgical robot-1500 (KD-SR-1500-RARP). The perioperative outcomes, physical and mental workload of the surgeon were collected. Physical workload was evaluated with surface electromyography. Mental workload was evaluated with NASA-TLX. After conducting animal experiments to verify safety of dual-console KD-SR-1500-RARP, we conducted the clinical trial using 5G and wired networks. RESULTS: In the animal experiment, all surgeries were performed successfully. The operative time was 80.2±32.1 min. The docking time was 2.4±0.5 min. The console time was 49.7±25.3 min. There were no perioperative complications or equipment related adverse events. All dogs can micturate after catheter removal at one week postoperatively. The mental workload was at a low level (a scale ranging from 0 to 60), which scored 15.7±6.9. Among the eight recorded muscles, the fatigue degree of the right radial flexor and left biceps was the highest two (iEMG, resection, 299.8±344 uV, 109.9±16.9 uV; suture, 849.4±1252.5 uV, 423.1±621.3 uV, respectively). In the clinical study, the console time was 136 min. The mean latency time was ≤200 ms. The data pocket loss was <1%. The operation was successfully completed without malfunctions occurring throughout the entire process. CONCLUSIONS: Dual-console telesurgery with the KD-SR-1500 system was shown to be feasible and safe in radical prostatectomy using 5G and wired networks.

Lien vers l'article

**Effectiveness and feasibility of 5G-based remote interactive ultrasound training in critical care.**

Shen P, An Y, Hao C, Lyu J, Zhao H. *BMC Med Educ*. 2024 May 8;24(1):514.

BACKGROUND: Ultrasound has widely used in various medical fields related to critical care. While online and offline ultrasound trainings are faced by certain challenges, remote ultrasound based on the 5G cloud platform has been gradually adopted in many clinics. However, no study has used the 5G remote ultrasound cloud platform operating system for standardized critical care ultrasound training. This study aimed to evaluate the feasibility and effectiveness of 5G-based remote interactive ultrasound training for standardized diagnosis and treatment in critical care settings. METHODS: A 5G-based remote interactive ultrasound training system was constructed, and the course was piloted among critical care physicians. From July 2022 to July 2023, 90 critical care physicians from multiple

off-site locations were enrolled and randomly divided into experimental and control groups. The 45 physicians in the experimental group were trained using the 5G-based remote interactive ultrasound training system, while the other 45 in the control group were taught using theoretical online videos. The theoretical and practical ultrasonic capabilities of both groups were evaluated before and after the training sessions, and their levels of satisfaction with the training were assessed as well. RESULTS: The total assessment scores for all of the physicians were markedly higher following the training (80.7 ± 11.9) compared to before (42.1 ± 13.4) by a statistically significant margin ($P < 0.001$). Before participating in the training, the experimental group scored 42.2 ± 12.5 in the critical care ultrasound competency, and the control group scored 41.9 ± 14.3-indicating no significant differences in their assessment scores ($P = 0.907$). After participating in the training, the experimental group's assessment scores were 88.4 ± 6.7, which were significantly higher than those of the control group (72.9 ± 10.8; $P < 0.001$). The satisfaction score of the experimental group was 42.6 ± 2.3, which was also significantly higher than that of the control group (34.7 ± 3.1, $P < 0.001$). CONCLUSION: The 5G-based remote interactive ultrasound training system was well-received and effective for critical care. These findings warrant its further promotion and application.

Lien vers l'article

**5G-enabled smart hospitals: Innovations in patient care and facility management.**

Elendu C, Elendu TC, Elendu ID. *Medicine (Baltimore)*. 2024 May 17;103(20):e38239.

Smart hospitals represent the pinnacle of healthcare innovation, leveraging cutting-edge technologies to transform patient care and facility management. This article addresses the pressing need for effective implementation of 5G technology in smart hospitals, aiming to enhance connectivity, improve patient outcomes, and drive operational efficiency. The methodology employed involves a comprehensive review of existing literature, case studies, and expert insights to analyze the impact of 5G on various aspects of smart hospital operations. The article highlights the significance of 5G technology in enabling real-time data analytics, remote monitoring, and telemedicine, thus revolutionizing healthcare delivery. By providing high-speed, low-latency connectivity, 5G facilitates seamless communication and collaboration among healthcare providers, leading to more efficient diagnosis, treatment, and patient care. Additionally, the adoption of 5G enables smart hospitals to leverage artificial intelligence (AI)-based solutions for predictive analytics, personalized medicine and enhanced patient engagement. Furthermore, the article explores the potential of 5G-enabled smart hospitals in enhancing disaster preparedness and emergency response efforts. Case studies and examples demonstrate how 5G technology can improve situational awareness, coordinate resources, and deliver timely care during natural disasters and pandemics. Overall, this article underscores the transformative impact of 5G technology on smart hospitals and emphasizes the importance of embracing innovation to meet the evolving needs of patients and communities. By adopting 5G technology, smart hospitals can usher in a new era of healthcare delivery characterized by enhanced connectivity, improved patient outcomes, and unparalleled efficiency.

Lien vers l'article

**5G-Enabled Healthcare in Mobile Scenarios: Challenges and Implementation Considerations.**

Qureshi HN, Manalastas M, Farooq MUB, Imran A, Liu Y, Al Kalaa MO. *IEEE Netw*. 2023 Nov;37(6):141-9.

Wireless connectivity delay, disruption, or failure can significantly affect the performance of wireless-enabled medical devices, which in turn causes potential risks to the patient. Notably, the challenges related to connectivity provisioning are exacerbated in the fifth-generation (5G)-enabled healthcare use cases where mobility is utilized. In this article, we describe relevant 5G-enabled healthcare use cases involving mobility and identify the connectivity challenges that they face. We then illustrate practical implementation considerations, tradeoffs, and future research directions for enabling reliable 5G healthcare transmissions. This is done through simulation of connected ambulances as an example use-case.

Lien vers l'article

## Evaluation (Mesure des niveaux d'exposition)

### Méthodes d'évaluation

Aucun article dans ce bulletin.

### Evaluation population générale

**Electromagnetic field exposure monitoring of commercial 28-GHz band 5G base stations in Tokyo, Japan.**

Liu S, Tobita K, Onishi T, Taki M, Watanabe S. *Bioelectromagnetics*. 2024 May 22.

Fifth generation (5G) wireless communication is being rolled out around the world. In this work, the latest radio frequency electromagnetic field (EMF) exposure measurement results on commercial 28-GHz band 5G base stations (BSs) deployed in the urban area of Tokyo, Japan, are presented. The measurements were conducted under realistic traffic conditions with a 5G smartphone and using both omnidirectional and horn antennas. First and foremost, in all cases, the electric-field (E-field) intensity is much lower (<-38 dB) than the exposure limits. The E-field intensities for traffic-off cases do not show any significant difference between the two antennas with the maximum being 3.6 dB. For traffic-on cases, the omnidirectional antenna can undesirably capture the radio wave from the smartphone in some cases, resulting in a 7-13 dB higher E-field intensity than that using the horn antenna. We also present comparative results between 4G long term evolution BSs and sub-6-GHz band and 28-GHz band 5G BSs and provide recommendations on acquiring meaningful EMF exposure data. This work is a further step toward the standardization of the measurement method regarding quasi-millimeter/millimeter wave 5G BSs.

Lien vers l'article

### Risques professionnels

Aucun article dans ce bulletin.

### In silico

**Assessment of the potential threats to brain health posed by the radiation from 5G sub-6 GHz base stations in China using dosimetric methods.**

Lin J, Ding G, Liu X, Li J. *Environ Sci Pollut Res Int*. 2024 May;31(21):31015-27.

The 5G sub-6 GHz radio frequency (RF) electromagnetic fields (EMF) are the most widely used in China's communications. The public has expressed concerns about possible brain health effects of the higher frequency bands in 5G compared to 2G, 3G, and 4G bands. It is imperative to empirically investigate the potential health hazards of these novel frequency bands in 5G communication technology. This study evaluates the assessment of brain tissue dose coupling from sub-6 GHz band EMF emitted by base stations in China. Based on the 3D virtual human body model, the simulation environment was established. Dose including specific absorption rate (SAR) and internal electric field (IEF) between 2G, 3G, and 4G bands and 5G sub-6 GHz was investigated using normalized exposure values and exposure limits. The results indicate that the sub-6 GHz high-frequency band of 5G has the lowest dose value. It can be concluded that high-frequency electromagnetic radiation in 5G sub-6 GHz reduces the dose and health threats to the brain. This provides strong support for the promotion of 5G commutation in China and other regions.

Lien vers l'article

### In vitro

**1.7 GHz long-term evolution radiofrequency electromagnetic field with stable power monitoring and efficient thermal control has no effect on the proliferation of various human cell types.**

Goh J, Suh D, Park G, Jeon S, Lee Y, Kim N, et al. *PLoS One*. 2024;19(5):e0302936.

Long-term evolution (LTE) radiofrequency electromagnetic field (RF-EMF) is widely used in communication technologies. Thus, the influence of RF-EMF on biological systems is a major public concern and its physiological effects remain controversial. In our previous study, we showed that continuous exposure of various human cell types to 1.7 GHz LTE RF-EMF at a specific absorption rate (SAR) of 2 W/Kg for 72 h can induce cellular senescence. To understand the precise cellular effects of LTE RF-EMF, we elaborated the 1.7 GHz RF-EMF cell exposure system used in the previous study by replacing the RF signal generator and developing a software-based feedback system to improve the exposure power stability. This refinement of the 1.7 GHz LTE RF-EMF generator facilitated the automatic regulation of RF-EMF exposure, maintaining target power levels within a 3% range and a constant temperature even during the 72-h-exposure period. With the improved experimental setup, we examined the effect of continuous exposure to 1.7 GHz LTE RF-EMF at up to SAR of 8 W/Kg in human adipose tissue-derived stem cells (ASCs), Huh7, HeLa, and rat B103 cells. Surprisingly, the proliferation of all cell types, which displayed different growth rates, did not change significantly compared with that of the unexposed controls. Also, neither DNA damage nor cell cycle perturbation was observed in the 1.7 GHz LTE RF-EMF-exposed cells. However, when the thermal control system was turned off and the subsequent temperature increase induced by the RF-EMF was not controlled during continuous exposure to SAR of 8 W/Kg LTE RF-EMF, cellular proliferation increased by 35.2% at

the maximum. These observations strongly suggest that the cellular effects attributed to 1.7 GHz LTE RF-EMF exposure are primarily due to the induced thermal changes rather than the RF-EMF exposure itself.

Lien vers l'article

## Sur l'animal

**Intestinal microbiota via NLRP3 inflammasome dependent neuronal pyroptosis mediates anxiety-like behaviour in mice exposed to 3.5 GHz radiofrequency radiation.**

Zhou GQ, Wang X, Gao P, Qin TZ, Guo L, Zhang ZW, et al. *Sci Total Environ*. 2024 Jun 1;927:172391.

The rapid development of 5G communication technology has increased public concern about the potential adverse effects on human health. Till now, the impacts of radiofrequency radiation (RFR) from 5G communication on the central nervous system and gut-brain axis are still unclear. Therefore, we investigated the effects of 3.5 GHz (a frequency commonly used in 5G communication) RFR on neurobehavior, gut microbiota, and gut-brain axis metabolites in mice. The results showed that exposure to 3.5 GHz RFR at 50 W/m(2) for 1 h over 35 d induced anxiety-like behaviour in mice, accompanied by NLRP3-dependent neuronal pyroptosis in CA3 region of the dorsal hippocampus. In addition, the microbial composition was widely divergent between the sham and RFR groups. 3.5 GHz RFR also caused changes in metabolites of feces, serum, and brain. The differential metabolites were mainly enriched in glycerophospholipid metabolism, tryptophan metabolism, and arginine biosynthesis. Further correlation analysis showed that gut microbiota dysbiosis was associated with differential metabolites. Based on the above results, we speculate that dysfunctional intestinal flora and metabolites may be involved in RFR-induced anxiety-like behaviour in mice through neuronal pyroptosis in the brain. The findings provide novel insights into the mechanism of 5G RFR-induced neurotoxicity.

Lien vers l'article

**The effect of 6GHz radiofrequency electromagnetic radiation on rat pain perception.**

Emre M, Karamazi Y, Emre T, Avci Ç, Aydin C, Ebrahimi S, et al. *Electromagn Biol Med*. 2024 Apr 2;43(1-2):117-24.

This paper presents data on pain perception in rats exposed to 6 GHz radiofrequency electromagnetic radiation (RF-EMR). Rats were divided into two groups: control (n = 10, 4 replicates per test) and RF-EMR exposed group (n = 10, 4 replicates per test). Nociceptive responses of the groups were measured using rodent analgesiometry. Rats were divided into control and RF-EMR exposed groups. Nociceptive responses were measured using rodent analgesiometry. RF-EMR exposed rats had a 15% delay in responding to hot plate thermal stimulation compared to unexposed rats. The delay in responding to radiant heat thermal stimulation was 21%. We determined that RF-EMR promoted the occurrence of pressure pain as statistical significance by + 42% ($p < 0.001$). We observed that RF-EMR exposure increased nociceptive pain by + 35% by promoting cold plate stimulation ($p < 0.05$). RF-EMR exposure did not affect thermal preference as statistical significance but did support the formation of pressure pain perception.
In this study, we present data on pain perception in rats exposed to 6GHz RF-EMR. RF-EMR exposed rats showed delayed responses to hot plate and radiant heat thermal stimulation. RF-EMR increased

pressure and nociceptive pain as statistically significance. In particular, the effects of RF-EMR should be considered when assessing hyperalgesic and hypoalgesic symptoms in the clinic. The results of this study indicate the need to take precautions against the possible negative effects of RF-EMR on human health with the rise of 5G technology.

Lien vers l'article

**Review on the impact of cell phone radiation effects on green plants.**

Panda DK, Das DP, Behera SK, Dhal NK. *Environ Monit Assess*. 2024 May 21;196(6):565.

The aim of this review is to assess the impact of cell phone radiation effects on green plants. Rapid progress in networking and communication systems has introduced frequency- and amplitude-modulated technologies to the world with higher allowed bands and greater speed by using high-powered radio generators, which facilitate high definition connectivity, rapid transfer of larger data files, and quick multiple accesses. These cause frequent exposure of cellular radiation to the biological world from a number of sources. Key factors like a range of frequencies, time durations, power densities, and electric fields were found to have differential impacts on the growth and development of green plants. As far as the effects on green plants are concerned in this review, alterations in their morphological characteristics like overall growth, canopy density, and pigmentation to physiological variations like chlorophyll fluorescence and change in membrane potential etc. have been found to be affected by cellular radiation. On the other hand, elevated oxidative status of the cell, macromolecular damage, and lipid peroxidation have been found frequently. On the chromosomal level, micronuclei formation, spindle detachments, and increased mitotic indexes etc. have been noticed. Transcription factors were found to be overexpressed in many cases due to the cellular radiation impact, which shows effects at the molecular level.

Lien vers l'article

**The effect of exposure to RF-EMF from the laboratory simulator of 5G NR base station on physiological parameters and cognitive abilities of male wistar rats of different ages.**

Krivova NA, Kudabaeva MS, Zaeva OB, Borodina SV, Lepekhina TB, Pavlenko OA, et al. *Sci Rep*. 2024 May 4;14(1):10283.

In this article, the impact of radiofrequency electromagnetic field (RF-EMF) exposure from a simulated base station for the 5G New Radio (5G NR) telecommunication on rats was studied. The base station affects all age groups of the population, thus, for the first time, the experiment was conducted on male Wistar rats of three different ages (juvenile, adult, and presenile). The base station exposure parameters were chosen according to ICNIRP recommendations for limiting the exposure to radiofrequency electromagnetic field: frequency 2.4 GHz with an average specific absorption rate of 0.0076 W/kg and 0.0059 W/kg over the whole body of experimental animals. Throughout the experiment, body weight was examined weekly, and the dynamics of body weight gain was monitored. Rectal and skin surface temperature on the right hind limb was monitored weekly. Testing in the Morris water maze was performed during the last, Week 5, of RF-EMF exposure. After euthanasia, organ weights were determined in experimental and control animals. None of the investigated parameters did show any statistically significant differences between exposed and control animals of the same age. The data obtained can be used to assess the possible consequences of chronic exposure to RF-EMF from 5G NR base stations.
Lien vers l'article

## Sur l'homme

**Analysis of the metabolic profile of humans naturally exposed to RF-EM radiation.**

Rangesh NM, Malaisamy AK, Kumar N, Kumar S. *Metabolomics*. 2024 May 18;20(3):55.

INTRODUCTION: The world is experiencing exponential growth in communication, especially wireless communication. Wireless connectivity has recently become a part of everyone's daily life. Recent developments in low-cost, low-power, and miniature devices contribute to a significant rise in radiofrequency-electromagnetic field (RF-EM) radiation exposure in our environment, raising concern over its effect on biological systems. The inconsistent and conflicting research results make it difficult to draw definite conclusions about how RF-EM radiation affects living things. OBJECTIVES: This study identified two micro-environments based on their level of exposure to cellular RF-EM radiation, one with significantly less exposure and another with very high exposure to RF-EM radiation. Emphasis is given to studying the metabolites in the urine samples of humans naturally exposed to these two different microenvironments to understand short-term metabolic dysregulations. METHODS: Untargeted (1)H NMR spectroscopy was employed for metabolomics analyses to identify dysregulated metabolites. A total of 60 subjects were recruited with 5 ml urine samples each. These subjects were divided into two groups: one highly exposed to RF-EM (n = 30) and the other consisting of low-exposure populations (n = 30). RESULTS: The study found that the twenty-nine metabolites were dysregulated. Among them, 19 were downregulated, and 10 were upregulated. In particular, Glyoxylate and dicarboxylate and the TCA cycle metabolism pathway have been perturbed. The dysregulated metabolites were validated using the ROC curve analysis. CONCLUSION: Untargeted urine metabolomics was conducted to identify dysregulated metabolites linked to RF-EM radiation exposure. Preliminary findings suggest a connection between oxidative stress and gut microbiota imbalance. However, further research is needed to validate these biomarkers and understand the effects of RF-EM radiation on human health. Further research is needed with a diverse population.

Lien vers l'article

**The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies.**

Bosch-Capblanch X, Esu E, Oringanje CM, Dongus S, Jalilian H, Eyers J, et al. *Environ Int*. 2024 May;187:108612.

BACKGROUND: The technological applications of radiofrequency electromagnetic fields (RF-EMF) have been steadily increasing since the 1950s exposing large proportions of the population. The World Health Organization (WHO) is assessing the potential health effects of exposure to RF-EMF. OBJECTIVES: To systematically assess the effects of exposure to RF-EMF on self-reported non-specific symptoms in human subjects and to assess the accuracy of perceptions of presence or absence of RF-EMF exposure. METHODS: Eligibility criteria: experimental studies carried out in the general population and in individuals with idiopathic environmental intolerance attributed to EMF (IEI-EMF), in any language. INFORMATION SOURCES: Medline, Web of Science, PsycInfo, Cochrane Library, Epistemonikos, Embase and EMF portal, searched till April 2022. Risk of Bias (ROB): we used the RoB tool developed by OHAT adapted to the topic of this review. SYNTHESIS OF RESULTS: we synthesized studies using random effects meta-analysis and sensitivity analyses, where appropriate. RESULTS: Included studies: 41 studies were included, mostly cross over trials and from Europe, with a total of

2,874 participants. SYNTHESIS OF RESULTS: considering the primary outcomes, we carried out meta-analyses of 10 exposure-outcomes pairs. All evidence suggested no or small non-significant effects of exposure on symptoms with high (three comparisons), moderate (four comparisons), low (one comparison) and very low (two comparisons) certainty of evidence. The effects (standard mean difference, where positive values indicate presence of symptom being exposed) in the general population for head exposure were (95% confidence intervals) 0.08 (-0.07 to 0.22) for headache, -0.01 (-0.22 to 0.20) for sleeping disturbances and 0.13 (-0.51 to 0.76) for composite symptoms; and for whole-body exposure: 0.09 (-0.35 to 0.54), 0.00 (-0.15 to 0.15) for sleeping disturbances and -0.05 (-0.17 to 0.07) for composite symptoms. For IEI-EMF individuals SMD ranged from -0.19 to 0.11, all of them with confidence intervals crossing the value of zero. Further, the available evidence suggested that study volunteers could not perceive the EMF exposure status better than what is expected by chance and that IEI-EMF individuals could not determine EMF conditions better than the general population. DISCUSSION: Limitations of evidence: experimental conditions are substantially different from real-life situations in the duration, frequency, distance and position of the exposure. Most studies were conducted in young, healthy volunteers, who might be more resilient to RF-EMF than the general population. The outcomes of interest in this systematic review were symptoms, which are self-reported. The available information did not allow to assess the potential effects of exposures beyond acute exposure and in elderly or in chronically ill people. It cannot be ruled out that a real EMF effect in IEI-EMF groups is masked by a mix with insensitive subjects. However, studies on symptoms reporting and/or field perceptions did not find any evidence that there were particularly vulnerable individuals in the IEI-EMF group, although in open provocation studies, when volunteers were informed about the presence or absence of EMF exposure, such differences were consistently observed. INTERPRETATION: available evidence suggests that acute RF-EMF below regulatory limits does not cause symptoms and corresponding claims in the everyday life are related to perceived and not to real EMF exposure status.

Lien vers l'article

## Reproduction

**Radio frequency electromagnetic radiations interfere with the Leydig cell functions in-vitro.**

Jangid P, Rai U, Singh R. *PLoS One*. 2024;19(5):e0299017.

A growing threat to male infertility has become a major concern for the human population due to the advent of modern technologies as a source of radiofrequency radiation (RFR). Since these technologies have become an integral part of our daily lives, thus, it becomes necessary to know the impression of such radiations on human health. In view of this, the current study aims to focus on the biological effects of radiofrequency electromagnetic radiations on mouse Leydig cell line (TM3) in a time-dependent manner. TM3 cells were exposed to RFR emitted from 4G cell phone and also exposed to a particular frequency of 1800 MHz and 2450 MHz from RFR exposure system. The cells were then evaluated for different parameters such as cell viability, cell proliferation, testosterone production, and ROS generation. A considerable reduction in the testosterone levels and proliferation rate of TM3 cells were observed at 120 min of exposure as compared to the control group in all exposure settings. Conversely, the intracellular ROS levels showed a significant rise at 60, 90 and 120 min of exposure in both mobile phone and 2450 MHz exposure groups. However, RFR treatment for different time durations (15, 30, 45, 60, 90, and 120 min) did not have significant effect on cell viability at any of the exposure condition (2450 MHz, 1800 MHz, and mobile phone radiation). Therefore, our findings concluded with the negative impact of radiofrequency electromagnetic radiations on Leydig cell's physiological functions, which could be a serious concern for male infertility. However, additional studies are required to determine the specific mechanism of RFR action as well as its long-term consequences.

Lien vers l'article

## Dispositifs médicaux implantables

Aucun article dans ce bulletin.