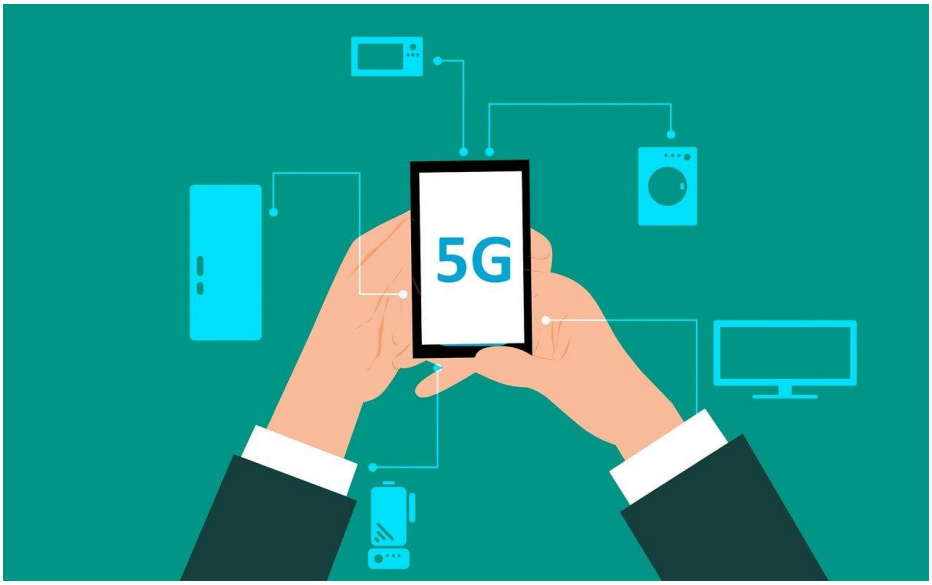
TECHNOLOGIE 5G

Bulletin de veille scientifique : Mars 2024



Objectifs : réaliser une veille scientifique sur la technologie 5G

La validation des informations fournies (exactitude, fiabilité, pertinence par rapport aux principes de prévention, etc.) est du ressort des auteurs des articles signalés dans la veille. Les informations ne sont pas le reflet de la position de l'INRS. Les éléments issus de cette veille sont fournis sans garantie d'exhaustivité. Les liens mentionnés dans le bulletin donnent accès aux documents sous réserve d'un abonnement à la ressource.

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Généralités

Personal exposure to radiofrequency electromagnetic fields: A comparative analysis of international, national, and regional guidelines.

Ramirez-Vazquez R, Escobar I, Vandenbosch GAE, Arribas E. *Environ Res*. 2024 Apr 1;246:118124.

A worldwide overview and analysis for the existing limits of human exposure to Radiofrequency Electromagnetic Fields (RF-EMF) is given in this paper. These reference levels have been established by different national and even regional governments, which can be based on the guidelines provided by the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the International Committee on Electromagnetic Safety of the Institute of Electrical and Electronics Engineers (IEEE), and even in the United States of the Federal Communications Commission (FCC), as well as, are based on the so-called precautionary principle. Explicit reference is made to the exposure limits adopted in countries or regions, such as Canada, Italy, Poland, Switzerland, China, Russia, France, and regions of Belgium (Brussels, Flanders, Wallonia), where the limits are much lower than the international standards. The limits are compared to a selected set of in-situ measurements. This clearly shows that the measured values are typically very small compared to the international standards but could be somewhat higher compared to the reduced limits. Based on this observation and the reasonable assumption that the sensitivity of people to Electromagnetic Fields (EMF) is the same everywhere (whole-body), we propose the idea to establish a worldwide reference limit for the general public, thus applicable in all countries, if the ICNIRP considers it appropriate. Research must continue to generate measurement data that demonstrate the levels of exposure to which we are really exposed, and with this, provide arguments to the organizations that established the guidelines, especially the ICNIRP, to evaluate whether the current limits are too much. High and can be modified when considered pertinent. To the best of our knowledge, at no time has the reference level for the general public been exceeded.

Lien vers l'article

Performances et sécurité

Compact and wideband nanoacoustic pass-band filters for future 5G and 6G cellular radios.

Giribaldi G, Colombo L, Simeoni P, Rinaldi M. *Nat Commun*. 2024 Jan 5;15(1):304.

Over recent years, the surge in mobile communication has deepened global connectivity. With escalating demands for faster data rates, the push for higher carrier frequencies intensifies. The 7-20 GHz range, located between the 5G sub-6 GHz and the mm-wave spectra, provides an excellent trade-off between network capacity and coverage, and constitutes a yet-to-be-explored range for 5G and 6G applications. This work proposes a technological platform able to deliver CMOS-compatible, on-chip multi-frequency, low-loss, wide-band, and compact filters for cellular radios operating in this range by leveraging the micro-to-nano scaling of acoustic electromechanical resonators. The results showcase the first-ever demonstrated low insertion loss bank of 7 nanoacoustic passband filters in the X-band. Most of the filters showcase fractional bandwidths above 3% and sub-dB loss per stage in an extremely compact form factor, enabling the manufacturing of filters and duplexers for the next generation of mobile handsets operating in the X-band and beyond.

Lien vers l'article

Author Correction: Compact and wideband nanoacoustic pass-band filters for future 5G and 6G cellular radios.

Giribaldi G, Colombo L, Simeoni P, Rinaldi M. *Nat Commun*. 2024 Mar 1;15(1):1913.

Lien vers l'article

Q-learning and fuzzy logic multi-tier multi-access edge clustering for 5g v2x communication.

Alagumani S, Natarajan UM. *Network*. 2024 Mar 6:1-24.

The 5th generation (5 G) network is required to meet the growing demand for fast data speeds and the expanding number of customers. Apart from offering higher speeds, 5 G will be employed in other industries such as the Internet of Things, broadcast services, and so on. Energy efficiency, scalability, resiliency, interoperability, and high data rate/low delay are the primary requirements and obstacles of 5 G cellular networks. Due to IEEE 802.11p's constraints, such as limited coverage, inability to handle dense vehicle networks, signal congestion, and connectivity outages, efficient data distribution is a big challenge (MAC contention problem). In this research, vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-pedestrian (V2P) services are used to overcome bandwidth constraints in very dense network communications from cellular tool to everything (C-V2X). Clustering is done through multi-layered multi-access edge clustering, which helps reduce vehicle contention. Fuzzy logic and Q-learning and intelligence are used for a multi-hop route selection system. The proposed protocol adjusts the number of cluster-head nodes using a Q-learning algorithm, allowing it to quickly adapt to a range of scenarios with varying bandwidths and vehicle densities.

Lien vers l'article

Stable route selection for adaptive packet transmission in 5G-based mobile communications.

Karuppiyan M, Subramani H, Kandasamy Raju S, Anthonymuthu Prakasam MM. *Network*. 2024 Mar 3:1-21.

The poor connectivity among mobile nodes introduces uncertainty in packet loss as the path link is not measured in this network. The focus is placed on communication cost to achieve valid packet transmission. Because the high-distance path selected for packet transmission incurs higher communication costs, it increases energy consumption and packet loss rate. So, the proposed dispersed path selection for communication (DPAC) method is constructed to obtain the best minimum distance routing path. This path operates with the help of queue variation is handled the data packets maintenance, and the time slot exceeds its limit. Packets are kept waiting to increase the packet broadcasting efficiency. A multipath jamming detection algorithm is constructed to provide a link-based path packet overload detection scheme to identify the packet overload. It also separates the path based on its characteristics to control overload. It reduces energy consumption and packet loss rate.

Lien vers l'article

Antennes

Advanced Dielectric Resonator Antenna Technology for 5G and 6G Applications.

Zhang Y, Ogurtsov S, Vasilev V, Kishk AA, Caratelli D. *Sensors (Basel)*. 2024 Feb 22;24(5).

We review dielectric resonator antenna (DRA) designs. This review examines recent advancements across several categories, specifically focusing on their applicability in array configurations for millimeter-wave (mmW) bands, particularly in the context of 5G and beyond 5G applications. Notably, the off-chip DRA designs, including in-substrate and compact DRAs, have gained prominence in recent years. This surge in popularity can be attributed to the rapid development of cost-effective multilayer laminate manufacturing techniques, such as printed circuit boards (PCBs) and low-temperature co-fired ceramic (LTCC). Furthermore, there is a growing demand for DRAs with beam-steering, dual-band functions, and on-chip alignment availability, as they offer versatile alternatives to traditional lossy printed antennas. DRAs exhibit distinct advantages of lower conductive losses and greater flexibility in shapes and materials. We discuss and compare the performances of different DRA designs, considering their material usage, manufacturing feasibility, overall performance, and applications. By exploring the pros and cons of these diverse DRA designs, this review provides valuable insights for researchers in the field.

Lien vers l'article

Architecture réseau

Aucun article dans ce bulletin.

Efficacité énergétique

5G and energy internet planning for power and communication network expansion.

Chen L, Wang J, Wu Z, Yu Y, Zhou M, Li G. *iScience*. 2024 Mar 15;27(3):109290.

Our research addresses the critical intersection of communication and power systems in the era of advanced information technologies. We highlight the strategic importance of communication base station placement, as its optimization is vital for minimizing operational disruptions in energy systems. Our study introduces a communications and power coordination planning (CPCP) model that encompasses both distributed energy resources and base stations to improve communication quality of service. This model facilitates optimal resource distribution, ensuring communication reliability over 96% and downlink transmission rates above 450 Mbps, enhancing network resilience and cost-effectiveness. Through case studies, we demonstrate CPCP's potential to significantly reduce planning costs, particularly with increased renewable energy integration, supporting the transition to low-carbon energy systems. Our findings contribute to a comprehensive understanding of the symbiotic relationship between communication and power networks, emphasizing the need for coordinated planning in building future-proof energy infrastructures.

Lien vers l'article

Autres équipements

5G NB-IoT System Integrated with High-Performance Fiber Sensor Inspired by Cirrus and Spider Structures.

Lu L, Hu G, Liu J, Yang B. *Adv Sci (Weinh)*. 2024 Mar 9:e2309894.

Real-time telemedicine detection can solve the problem of the shortage of public medical resources caused by the coming aging society. However, the development of such an integrated monitoring system is hampered by the need for high-performance sensors and the strict-requirement of long-distance signal transmission and reproduction. Here, a bionic crack-spring fiber sensor (CSFS) inspired by spider leg and cirrus whiskers for stretchable and weavable electronics is reported. Trans-scale conductive percolation networks of multilayer graphene around the surface of outer spring-like Polyethylene terephthalate (PET) fibers and printing Ag enable a high sensitivity of 28475.6 and broad sensing range over 250%. The electromechanical changes in different stretching stages are simulated by Comsol to explain the response mechanism. The CSFS is incorporated into the fabric and realized the human-machine interactions (HMIs) for robot control. Furthermore, the 5G Narrowband Internet of Things (NB-IoT) system is developed for human healthcare data collection, transmission, and reproduction together with the integration of the CSFS, illustrating the huge potential of the approach in human-machine communication interfaces and intelligent telemedicine rehabilitation and diagnosis monitoring.

Lien vers l'article

Applications médicales et industrielles de la 5G

Applications industrielles

Aucun article dans ce bulletin.

Applications médicales

Internet of medical things and blockchain-enabled patient-centric agent through SDN for remote patient monitoring in 5G network.

Rahman A, Wadud MAH, Islam MJ, Kundu D, Bhuiyan TMA, Muhammad G, et al. *Sci Rep*. 2024 Mar 4;14(1):5297.

During the COVID-19 pandemic, there has been a significant increase in the use of internet resources for accessing medical care, resulting in the development and advancement of the Internet of Medical Things (IoMT). This technology utilizes a range of medical equipment and testing software to broadcast patient results over the internet, hence enabling the provision of remote healthcare services. Nevertheless, the preservation of privacy and security in the realm of online communication continues to provide a significant and pressing obstacle. Blockchain technology has shown the potential to mitigate security apprehensions across several sectors, such as the healthcare industry. Recent advancements in research have included intelligent agents in patient monitoring systems by integrating blockchain technology. However, the conventional network configuration of the agent and blockchain introduces a level of complexity. In order to address this disparity, we present a proposed architectural framework that combines software defined networking (SDN) with Blockchain technology. This framework is specially tailored for the purpose of facilitating remote patient monitoring systems within the context of a 5G environment. The architectural design contains a patient-centric agent (PCA) inside the SDN control plane for the purpose of managing user data on behalf of the patients. The appropriate handling of patient data is ensured by the PCA via the provision of essential instructions to the forwarding devices. The suggested model is assessed using hyperledger fabric on docker-engine, and its performance is compared to that of current models in fifth generation (5G) networks. The performance of our suggested model surpasses current methodologies, as shown by our extensive study including factors such as throughput, dependability, communication overhead, and packet error rate.

Lien vers l'article

Evaluation (Mesure des niveaux d'exposition)

Méthodes d'évaluation

Design and Implementation of a Specialised Millimetre-Wave Exposure System for Investigating the Radiation Effects of 5G and Future Technologies.

Foroughimehr N, Wood A, McKenzie R, Karipidis K, Yavari A. *Sensors (Basel)*. 2024 Feb 26;24(5).

As the fifth-generation (5G) network is introduced in the millimetre-wave (mmWave) spectrum, and the widespread deployment of 5G standalone (SA) is approaching, it becomes essential to establish scientifically grounded exposure limits in the mmWave frequency band. To achieve this, conducting experiments at specific frequencies is crucial for obtaining reliable evidence of potential biological impacts. However, there is a literature gap where experimental research either does not utilise the mmWave high band (e.g., the 26 Gigahertz (GHz) band) or most studies mainly rely on computational approaches. Moreover, some experimental studies do not establish reproducible test environment and exposure systems. Addressing these gaps is vital for a comprehensive exploration of the biological implications associated with mmWave exposure. This study was designed to develop and implement a mmWave exposure system operating at 26 GHz. The step-by-step design and development of the system are explained. This specialised system was designed and implemented within an anechoic chamber to minimise external electromagnetic (EM) interference, creating a controlled and reproducible environment for experiments involving high-frequency EM fields. The exposure system features a 1 cm radiation spot size, enabling highly localised exposure for various biological studies. This configuration facilitates numerous dosimetry studies related to mmWave frequencies.

Lien vers l'article

Evaluation population générale

Electromagnetic exposure analysis of the subway passenger under the civil communication system radiation.

Zhou WY, Zhang XY, Lu M. *PLoS One*. 2024;19(3):e0300049.

In order to assess the electromagnetic exposure safety of passengers under the civil communication system of the subway, the radio-frequency (RF) electromagnetic environment of subway carriage is established by using COMSOL Multiphysics software, it includes a 1-1/4 " leaky coaxial cable (LCX1) and a 1-5/8" leaky coaxial cable (LCX2), which are designed to be the exposure sources, and twelve passengers at different position. The electromagnetic environment model has been verified through field measurement. The exposure dose distribution of twelve passengers is compared and analyzed, when LCX1 and LCX2 works respectively. The simulated results show that, to compare with LCX2, the electromagnetic dose absorbed by the passengers is reduced by 9.19% and 22.50% at 2100 MHz and 2600 MHz respectively. The specific absorption rate (SAR) of passengers obtains the maximum value of 1.91×10-4 W/Kg and the temperature rise to 0.214 K when the LCX1 works at 3400 MHz. By comparing with the public exposure limitation of the International Commission of Non-Ionizing Radiation Protection (ICNIRP), it demonstrates the electromagnetic exposure safety of the passengers under the civil communication system. More importantly, the proposed LCX1 not only could add the 5G signal cover but also lower the SAR absorbed by the passengers, which indicates that the public

electromagnetic exposure dose could be reduced by adjusting the radiation performances of exposure source, which provide a new way for electromagnetic protecting.

Lien vers l'article

Risques professionnels

Aucun article dans ce bulletin.

Effets biologiques et sur la santé

In silico

Aucun article dans ce bulletin.

In vitro

Investigation of the OAM EM wave tissue irradiation at millimeter-wave frequencies.

Fréq de 60 GhZ

Ilić A, Trajković JZ, Savić SV, Ilić MM. *Appl Radiat Isot*. 2024 May;207:111261.

Recently, there has been an increase of interest in the use of electromagnetic (EM) waves with helical wavefronts, known as the orbital angular momentum (OAM) waves. Applications in the field of biomedicine have been foreseen, such as medical imaging and diagnosis, deep-tissue imaging, biosensing, and communication with medical implants. Other possible applications include various localized tissue treatments or tissue ablation. The available references mainly study the interaction of OAM light with biological structures, offering some insights into the biophotonics effects, but without the investigation of how to plan tissue exposures or how to estimate the EM field parameters in a particular case of application. We use the previously developed short dipole modeling of OAM EM fields to study the above problems by altering the OAM beam parameters and the distance from the target tissue. The results could guide the design of components and devices based on OAM EM waves.

Lien vers l'article

Sur l'animal

Brain-implanted conductors amplify radiofrequency fields in rodents: Advantages and risks.

Vöröslakos M, Yaghmazadeh O, Alon L, Sodickson DK, Buzsáki G. *Bioelectromagnetics*. 2024 Apr;45(3):139-55.

Over the past few decades, daily exposure to radiofrequency (RF) fields has been increasing due to the rapid development of wireless and medical imaging technologies. Under extreme circumstances, exposure to very strong RF energy can lead to heating of body tissue, even resulting in tissue injury. The presence of implanted devices, moreover, can amplify RF effects on surrounding tissue. Therefore, it is important to understand the interactions of RF fields with tissue in the presence of implants, in order to establish appropriate wireless safety protocols, and also to extend the benefits of medical imaging to increasing numbers of people with implanted medical devices. This study explored the neurological effects of RF exposure in rodents implanted with neuronal recording electrodes. We exposed freely moving and anesthetized rats and mice to 950 MHz RF energy while monitoring their brain activity, temperature, and behavior. We found that RF exposure could induce fast onset firing of single neurons without heat injury. In addition, brain implants enhanced the effect of RF stimulation

resulting in reversible behavioral changes. Using an optical temperature measurement system, we found greater than tenfold increase in brain temperature in the vicinity of the implant. On the one hand, our results underline the importance of careful safety assessment for brain-implanted devices, but on the other hand, we also show that metal implants may be used for neurostimulation if brain temperature can be kept within safe limits.

Lien vers l'article

The impact of radiofrequency exposure on Aedes aegypti (Diptera: Culicidae) development.

Nik Abdull Halim NMH, Mohd Jamili AF, Che Dom N, Abd Rahman NH, Jamal Kareem Z, Dapari R. *PLoS One*. 2024;19(2):e0298738.

INTRODUCTION: Wireless communication connects billions of people worldwide, relying on radiofrequency electromagnetic fields (RF-EMF). Generally, fifth-generation (5G) networks shift RF carriers to higher frequencies. Although radio, cell phones, and television have benefitted humans for decades, higher carrier frequencies can present potential health risks. Insects closely associated with humans (such as mosquitoes) can undergo increased RF absorption and dielectric heating. This process inadvertently impacts the insects' behaviour, morphology, and physiology, which can influence their spread. Therefore, this study examined the impact of RF exposure on Ae. aegypti mosquitoes, which are prevalent in indoor environments with higher RF exposure risk. The morphologies of Ae. aegypti eggs and their developments into Ae. aegypti mosquitoes were investigated. METHODS: A total of 30 eggs were exposed to RF radiation at three frequencies: baseline, 900 MHz, and 18 GHz. Each frequency was tested in triplicate. Several parameters were assessed through daily observations in an insectarium, including hatching responses, development times, larval numbers, and pupation periods until the emergence of adult insects. RESULTS: This study revealed that the hatching rate for the 900 MHz group was the highest (79 ± 10.54%) compared to other exposures ($p = 0.87$). The adult emergence rate for the 900 MHz group was also the lowest at 33 ± 2.77%. A significant difference between the groups was demonstrated in the statistical analysis ($p = 0.03$). CONCLUSION: This work highlighted the morphology sensitivity of Ae. aegypti eggs and their developments in the aquatic phase to RF radiation, potentially altering their life cycle.

Lien vers l'article

Sur l'homme

The thermal sensation threshold and its reliability induced by the exposure to 28 GHz millimeter-wave.

Yuasa A, Uehara S, Ushizawa K, Kodera S, Arai N, Hirata A, et al. *Front Neurosci*. 2024;18:1331416.

The application of 28 GHz millimeter-wave is prevalent owing to the global spread of fifth-generation wireless communication systems. Its thermal effect is a dominant factor which potentially causes pain and tissue damage to the body parts exposed to the millimeter waves. However, the threshold of this thermal sensation, that is, the degree of change in skin temperature from the baseline at which the first subjective response to the thermal effects of the millimeter waves occurs, remains unclear. Here, we investigated the thermal sensation threshold and assessed its reliability when exposed to millimeter waves. Twenty healthy adults were exposed to 28 GHz millimeter-wave on their left middle fingertip at five levels of antenna input power: 0.2, 1.1, 1.6, 2.1, and 3.4 W (incident power density:

27-399 mW/cm(2)). This measurement session was repeated twice on the same day to evaluate the threshold reliability. The intraclass correlation coefficient (ICC) and Bland-Altman analysis were used as proxies for the relative and absolute reliability, respectively. The number of participants who perceived a sensation during the two sessions at each exposure level was also counted as the perception rate. Mean thermal sensation thresholds were within 0.9°C-1.0°C for the 126-399 mW/cm(2) conditions, while that was 0.2°C for the 27 mW/cm(2) condition. The ICCs for the threshold at 27 and 126 mW/cm(2) were interpreted as poor and fair, respectively, while those at higher exposure levels were moderate to substantial. Apart from a proportional bias in the 191 mW/cm(2) condition, there was no fixed bias. All participants perceived a thermal sensation at 399 mW/cm(2) in both sessions, and the perception rate gradually decreased with lower exposure levels. Importantly, two-thirds of the participants answered that they felt a thermal sensation in both or one of the sessions at 27 mW/cm(2), despite the low-temperature increase. These results suggest that the thermal sensation threshold is around 1.0°C, consistent across exposure levels, while its reliability increases with higher exposure levels. Furthermore, the perception of thermal sensation may be inherently ambiguous owing to the nature of human perception.

Lien vers l'article

Reproduction

Influence of radiofrequency electromagnetic fields exposure on sleep patterns in preterm neonates.

Besset D, Selmaoui B, Delanaud S, Bessarion L, Chardon K, de Seze R, et al. *Int J Radiat Biol*. 2024;100(3):427-32.

PURPOSE: The study objective was to assess the influence of radiofrequency electromagnetic fields (RF-EMF) exposure on sleep patterns in preterm newborns. We hypothesized that an increase in RF-EMF exposure levels would alter infants' sleep structure parameters. MATERIALS AND METHODS: Individual, continuous measurements of RF-EMF levels were performed in 29 hospitalized preterm newborns throughout the first 21 days after birth. The last day, overnight sleep structure was recorded by polysomnography. Relationships between both chronic (three-week period) and acute (polysomnographic period) RF-EMF levels with sleep parameters were computed. RESULTS: At median levels, the main chronic effect was an increase in indeterminate sleep with RF-EMF exposure. At the highest exposure levels found in our study, an increase in RF-EMF levels increased sleep fragmentation. No significant relationship was found between acute RF-EMF levels and sleep parameters. CONCLUSIONS: Despite no consolidated disruption in sleep structure, this study is the first to show that some sleep parameters seem to have a certain sensitivity to chronic - but not acute - RF-EMF exposure in preterm newborns. Further studies are needed to confirm our results and examine possible mid- to long-term, sleep-related cardiorespiratory and neurodevelopmental outcomes.

Lien vers l'article

Dispositifs médicaux implantables

Aucun article dans ce bulletin.