Bulletin de veille
Champs électromagnétiques
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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 liens mentionnés dans le bulletin donnent accès aux documents sous réserve d'un abonnement à la ressource.

Exposition professionnelle

Protocols of electromagnetic fields measurement for workers exposure evaluation in rehabilitation centers

BURRIESCI G., L. M. ROCCA, G. RUBONELLO, M. COMELLI, M. VALENTINI and IEEE (2024). 4th URSI Atlantic Radio Science Meeting (AT-RASC), Meloneras, SPAIN.

The goal of the present work is to develop precise and user-friendly protocols to apply during electromagnetic fields exposure evaluation. This subject, in fact, is characterized by a lack of simple and standardized procedures compromising work of the experts involved in these evaluations. For this project, several physio kinesitherapy equipment have been selected due to their complex signals emission able to cause overexposure to the workers. With the aim of testing the developed protocols, a monitoring campaign has been conducted on several devices normally used in these working places, i.e. three tecar therapy, three magneto therapy and one radar therapy apparatuses. All the rehabilitation centers chosen to validate the protocols are internal to our institute (INAIL - National Institute for Insurance against Accidents at Work) and are located in the south of Italy. Despite the complexity of the measured variables, all the planned goal are achieved in terms of both procedures and exposure evaluation. https://www.emf-portal.org/en/article/55235

Experimental evaluation of electromagnetic compatibility of cardiac active implantable medical devices in the work environment of beauty and physiotherapy centers
CENSI F., C. VIVARELLI, E. MATTEI, G. CALCAGNINI, A. BOGI, M. COMELLI, N. ZOPPETTI, G. BURRIESCI, S. D'AGOSTINO, R. FALSAPERLA and IEEE (2024). 4th URSI Atlantic Radio Science Meeting (AT-RASC), Meloneras, SPAIN.
Occupational health and safety framework identifies workers with active implantable medical devices (AIMD) as a particularly sensitive risk group that must be protected against the dangers caused by the interference of electromagnetic fields (EMF). Among the work environments in which EMF levels potentially exceed the Guidelines limits there are the beauty and physiotherapy centers. The aim of this paper is to investigate the potential risk for cardiac AIMD holders when exposed to four EMF sources that can be encountered in the work environment of aesthetic and/or physiotherapy centers. https://ieeexplore.ieee.org/document/10584753

Computational dosimetry on military crew exposed to HF vehicular antenna in near field condition
COLELLA M., M. BISCARINI, G. PELLEGRINO, M. DE MEISO, M. CAVAGNAROO, F. APOLLONIO, M. LIBERTIO and IEEE (2024). 4th URSI Atlantic Radio Science Meeting (AT-RASC), Meloneras, SPAIN.
Within the context of evaluating occupational exposure to Electromagnetic (EM) fields, the military scenario presents interesting and unexplored area of research. In this study, we examined the near-field exposure of military personnel to a vehicular antenna in a realistic setting. The objective was to enhance our understanding of the induced electric (E-) field and Specific Absorption Rate (SAR) within the human body (Duke, ViP, v.3) when positioned partially outside an armored vehicle. This is a crucial aspect to investigate, especially when the E-field intensities radiated by the antenna may overcome the recommended limits, as in the case herein evaluated. The dosimetric analysis was carried out at different frequencies within the antenna working band (i.e., 35.5 MHz and 85.5 MHz). https://www.emf-portal.org/en/article/55248

Technological developments in protection from non-ionizing radiation: instrumental procedures and software to support operators
COMELLI M., N. ZOPPETTI, G. BURRIESCI, S. D'AGOSTINO, A. BOGI, R. DI LIBERTO and IEEE (2024). 4th URSI Atlantic Radio Science Meeting (AT-RASC), Meloneras, SPAIN.
This study aims to address the limitations identified in the risk assessment procedure, associated with exposure to various sources of electromagnetic fields. The authors promote the utilization of an online procedure designed to enhance the evaluation of occupational exposure. These quantities include, e.g., clearance distances and weighted peak indices, particularly for non-sinusoidal signals. The study also presents a detailed case study focusing on magnetic resonance imaging (MRI). https://www.emf-portal.org/en/article/55237

Approach for assessment and reduction of occupational exposure in transcranial magnetic stimulation treatments
D'AGOSTINO S., S. CAMPIONI, R. FALSAPERLA, M. LIBERTI, F. APOLLONIO and IEEE (2024). 4th URSI Atlantic Radio Science Meeting (AT-RASC), Meloneras, SPAIN.
Transcranial Magnetic Stimulation (TMS) treatments have gained widespread acceptance in clinical practice due to their recognized significance in diagnosing and treating of various brain diseases. Nevertheless, to date, the exposure of the operator that performs the treatment remains an open issue in the framework of the occupational exposure evaluation, especially considering their daily close exposure prolonged in time. Therefore, in conjunction with the lack of a technical standard for the device's safe usage, we conducted a numerical assessment of occupational exposure, with a

particular emphasis on local exposure analysis and studying methods to possibly mitigate exposure, especially concerning the upper limb. https://www.emf-portal.org/ja/article/55257

MRI exposure assessment: an overview of Italian research activity
FALSAPERLA R., G. M. CONTESSA, S. D'AGOSTINO, N. TOSETTI, L. BIAGI, N. ZOPPETTI and IEEE (2024). 4th URSI Atlantic Radio Science Meeting (AT-RASC), Meloneras, SPAIN.
In this work, the authors report some results of previous studies conducted for assessing occupational exposure in magnetic resonance imaging (MRI) related to gradient magnetic fields and movement in the static magnetic field. To do this some measurement campaigns were carried out and a procedure approach was developed with the aim of providing and testing an efficient method for exposure assessment. https://www.emf-portal.org/de/article/55254

Challenges and opportunities from the out-of-band sensitivity of data loggers in a (quasi)autonomous evaluation of electromagnetic exposure
GRYZ K., J. KARPOWICZ, P. ZRADZINSKI and IEEE (2024). IEEE International Symposium on Measurements and Networking (M and N), Rome, ITALY.
The investigations examined the applicability of radiofrequency (RF) electromagnetic field (EMF) data loggers (DL), readily available on the market, for assessing worker exposure to the strong EMF (i.e. near its sources) in the microenvironment where strong and complex (in the frequency domain) exposure may exist - at frequencies within the DL's declared measurement frequency band and outside of it (outof-band frequency), e.g. exposure to RF and also 50 Hz (out-ofband) EMF. The results of laboratory tests and field studies show that, based on: (i) the real RF-DL metrological parameters (including its out-of-band sensitivity) and (ii) the frequency pattern of EMF in a microenvironment under question, as anticipated from previous tests, a possible false detection that it is a highly RF-exposed environment may be reinterpreted into the relevant evaluating of exposure to the out-of-band frequency EMF component. Using the approach of three-step exposure evaluation (including: (1) laboratory tests on the out-of-band sensitivity of available RF-DL; (2) environmental tests of real frequency pattern of exposure in the microenvironment under question; (3) expert-assisted interpretation of the results of RF-DL measurements), may technically allow the extension of the frequency range of workers' EMF exposure (beyond measurement frequency ranges declared for DLs available on the market), which may be (quasi)autonomously monitored in a real working environment with respect to its timing and level.
https://doi.org/10.1109/mn60932.2024.10615926

The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies - Part I: Most researched outcomes,
KARIPIDIS K., D. BAAKEN, T. LONEY, M. BLETTNER, C. BRZOZEK, M. ELWOOD, C. NARH, N. ORSINI, M. RÖÖSLI, M. S. PAULO and S. LAGORIO, *Environment International* 191 (Sep 2024),
Background: The objective of this review was to assess the quality and strength of the evidence provided by human observational studies for a causal association between exposure to radiofrequency electromagnetic fields (RF-EMF) and risk of the most investigated neoplastic diseases. Methods: Eligibility criteria: We included cohort and case-control studies of neoplasia risks in relation to three types of exposure to RF-EMF: near-field, head-localized, exposure from wireless phone use (SR-A); far-field, whole body, environmental exposure from fixed-site transmitters (SR-B); near/far-field occupational exposures from use of hand-held transceivers or RF-emitting equipment in the workplace (SR-C). While no restrictions on tumour type were applied, in the current paper we focus on incidence-based studies of selected "critical" neoplasms of the central nervous system (brain, meninges, pituitary gland, acoustic nerve) and salivary gland tumours (SR-A); brain tumours and leukaemias (SR-B, SR-C). We focussed on investigations of

specific neoplasms in relation to specific exposure sources (i.e. E-O pairs), noting that a single article may address multiple E-O pairs. Information sources: Eligible studies were identified by literature searches through Medline, Embase, and EMF-Portal. Risk-of-bias (RoB) assessment: We used a tailored version of the Office of Health Assessment and Translation (OHAT) RoB tool to evaluate each study's internal validity. At the summary RoB step, studies were classified into three tiers according to their overall potential for bias (low, moderate and high). Data synthesis: We synthesized the study results using random effects restricted maximum likelihood (REML) models (overall and subgroup meta-analyses of dichotomous and categorical exposure variables), and weighted mixed effects models (dose-response meta-analyses of lifetime exposure intensity). Evidence assessment: Confidence in evidence was assessed using the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach. Results: We included 63 aetiological articles, published between 1994 and 2022, with participants from 22 countries, reporting on 119 different E-O pairs. RF-EMF exposure from mobile phones (ever or regular use vs no or non-regular use) was not associated with an increased risk of glioma [meta-estimate of the relative risk (mRR) = 1.01, 95 % CI = 0.89-1.13), meningioma (mRR = 0.92, 95 % CI = 0.82-1.02), acoustic neuroma (mRR = 1.03, 95 % CI = 0.85-1.24), pituitary tumours (mRR = 0.81, 95 % CI = 0.61-1.06), salivary gland tumours (mRR = 0.91, 95 % CI = 0.78-1.06), or paediatric (children, adolescents and young adults) brain tumours (mRR = 1.06, 95 % CI = 0.74-1.51), with variable degree of across-study heterogeneity (I-2 = 0 %-62 %). There was no observable increase in mRRs for the most investigated neoplasms (glioma, meningioma, and acoustic neuroma) with increasing time since start (TSS) use of mobile phones, cumulative call time (CCT), or cumulative number of calls (CNC). Cordless phone use was not significantly associated with risks of glioma [mRR = 1.04, 95 % CI = 0.74-1.46; I-2 = 74 %) meningioma, (mRR = 0.91, 95 % CI = 0.70-1.18; I-2 = 59 %), or acoustic neuroma (mRR = 1.16; 95 % CI = 0.83-1.61; I-2 = 63 %). Exposure from fixed-site transmitters (broadcasting antennas or base stations) was not associated with childhood leukaemia or paediatric brain tumour risks, independently of the level of the modelled RF exposure. Glioma risk was not significantly increased following occupational RF exposure (ever vs never), and no differences were detected between increasing categories of modelled cumulative exposure levels. Discussion: In the sensitivity analyses of glioma, meningioma, and acoustic neuroma risks in relation to mobile phone use (ever use, TSS, CCT, and CNC) the presented results were robust and not affected by changes in study aggregation. In a leave-one-out meta-analyses of glioma risk in relation to mobile phone use we identified one influential study. In subsequent meta-analyses performed after excluding this study, we observed a substantial reduction in the mRR and the heterogeneity between studies, for both the contrast Ever vs Never (regular) use (mRR = 0.96, 95 % CI = 0.87-1.07, I-2 = 47 %), and in the analysis by increasing categories of TSS ("<5 years": mRR = 0.97, 95 % CI = 0.83-1.14, I-2 = 41 %; "5-9 years ": mRR = 0.96, 95 % CI = 0.83-1.11, I-2 = 34 %; "10+ years": mRR = 0.97, 95 % CI = 0.87-1.08, I-2 = 10 %). There was limited variation across studies in RoB for the priority domains (selection/attrition, exposure and outcome information), with the number of studies evenly classified as at low and moderate risk of bias (49 % tier-1 and 51 % tier-2), and no studies classified as at high risk of bias (tier-3). The impact of the biases on the study results (amount and direction) proved difficult to predict, and the RoB tool was inherently unable to account for the effect of competing biases. However, the sensitivity meta-analyses stratified on bias-tier, showed that the heterogeneity observed in our main meta-analyses across studies of glioma and acoustic neuroma in the upper TSS stratum (I-2 = 77 % and 76 %), was explained by the summary RoB-tier. In the tier-1 study subgroup, the mRRs (95 % CI; I-2) in long-term (10+ years) users were 0.95 (0.85-1.05; 5.5 %) for glioma, and 1.00 (0.78-1.29; 35 %) for acoustic neuroma. The time-trend simulation studies, evaluated as complementary evidence in line with a triangulation approach for external validity, were consistent in showing that the increased risks observed in some case-control studies were incompatible with the actual incidence rates of glioma/brain cancer observed in several countries and over long periods. Three of these simulation studies consistently reported that RR estimates >

1.5 with a 10+ years induction period were definitely implausible, and could be used to set a "credibility benchmark". In the sensitivity meta-analyses of glioma risk in the upper category of TSS excluding five studies reporting implausible effect sizes, we observed strong reductions in both the mRR [mRR of 0.95 (95 % CI = 0.86-1.05)], and the degree of heterogeneity across studies (I-2 = 3.6 %). Conclusions: Consistently with the published protocol, our final conclusions were formulated separately for each exposure-outcome combination, and primarily based on the line of evidence with the highest confidence, taking into account the ranking of RF sources by exposure level as inferred from dosimetric studies, and the external coherence with findings from time-trend simulation studies (limited to glioma in relation to mobile phone use). For near field RF-EMF exposure to the head from mobile phone use, there was moderate certainty evidence that it likely does not increase the risk of glioma, meningioma, acoustic neuroma, pituitary tumours, and salivary gland tumours in adults, or of paediatric brain tumours. For near field RF-EMF exposure to the head from cordless phone use, there was low certainty evidence that it may not increase the risk of glioma, meningioma or acoustic neuroma. For whole-body far-field RF-EMF exposure from fixed-site transmitters (broadcasting antennas or base stations), there was moderate certainty evidence that it likely does not increase childhood leukaemia risk and low certainty evidence that it may not increase the risk of paediatric brain tumours. There were no studies eligible for inclusion investigating RF-EMF exposure from fixed-site transmitters and critical tumours in adults. For occupational RF-EMF exposure, there was low certainty evidence that it may not increase the risk of brain cancer/glioma, but there were no included studies of leukemias (the second critical outcome in SR-C). The evidence rating regarding paediatric brain tumours in relation to environmental RF exposure from fixed-site transmitters should be interpreted with caution, due to the small number of studies. Similar interpretative cautions apply to the evidence rating of the relation between glioma/brain cancer and occupational RF exposure, due to differences in exposure sources and metrics across the few included studies.
https://doi.org/10.1016/j.envint.2024.108983

Health risks for medical personnel due to magnetic fields in magnetic resonance imaging, KÖNIG A. M., A. PÖSCHKE and A. H. MAHNKEN, *Rofo-Fortschritte Auf Dem Gebiet Der Rontgenstrahlen Und Der Bildgebenden Verfahren* (2024 Jul 2024),
Background The current state of medical and scientific knowledge on the effects of exposure to electromagnetic fields on workers in the field of clinical magnetic resonance imaging (MRI) is summarized here. Method A systematic literature search was conducted to analyze the health risks to medical personnel from magnetic fields in MRI. A total of 7273 sources were identified, with 7139 being excluded after screening of the title and abstract. After full-text screening, 34 sources remained and were included in this paper. Conclusion There are a number of scientific publications on the occurrence of short-term sensory effects such as vertigo, metallic taste, phosphenes as well as on the occurrence of neurocognitive and neurobehavioral effects. For example, short-term exposure to clinical magnetic fields has been reported to result in a 4% reduction in speed and precision and a 16% reduction in visual contrast sensitivity at close range. Both eye-hand precision and coordination speed are affected. The long-term studies concern, among other things, the influence of magnetic fields on sleep quality, which could be linked to an increased risk of accidents. The data on the exposure of healthcare workers to magnetic fields during pregnancy is consistently outdated. However, it has been concluded that there are no particular deviations with regard to the duration of pregnancy, premature births, miscarriages, and birth weight. Epidemiological studies are lacking. With a focus on healthcare personnel, there is a considerable need for high-quality data, particularly on the consequences of long-term exposure to electromagnetic fields from clinical MRI and the effects on pregnancy. https://doi.org/10.1055/a-2296-3860

Prediction of health impacts of exposure to electromagnetic field on the immunity system of power plants workers using fuzzy decision-making rules,
KORENEVSKIY N. A., R. T. AL-KASASBEH, A. SHAQADAN, M. A. MYASOEDOVA, Z. AL-QODAH, S. N. RODIONOVA, Y. ELTOUS, S. FILIST and I. MAKSIM, *International Journal of System Assurance Engineering and Management* 15, no. 10 (Oct 2024): 4853-4873,
This study aims to enhance health assessments in environments with industrial risk factors by incorporating oxidative status indicators, such as lipid peroxidation levels and antioxidant activity, into prognostic and diagnostic models. A novel approach was developed to quantitatively evaluate the body's protection level by synthesizing hybrid fuzzy decision rules that integrate oxidative status indicators. The methodology was validated through a case study focusing on predicting ischemic heart disease in locomotive crew drivers, who are at high risk for disability and mortality due to their occupational environment. The incorporation of oxidative status into prognostic decision rules significantly improved the accuracy and efficiency of disease prediction. In particular, fuzzy mathematical models were also developed to predict and diagnose immune system diseases in electric power industry workers exposed to electromagnetic fields and other risk factors. Statistical tests revealed that the decision rules achieved a prediction accuracy greater than 0.85, with early-stage detection accuracy reaching 0.95. These findings provide occupational pathology specialists with a valuable tool for enhancing the precision of disease prediction and diagnosis in industrial settings. The integration of oxidative status indicators into prognostic models offers a promising approach to improving health outcomes for workers exposed to industrial risk factors. https://doi.org/10.1007/s13198-024-02489-3

People with Implants: A Neglected Population by EM Exposure Regulation?
KRANOLD L., J. T. XI, T. GOREN, N. KUSTER and IEEE (2024). IEEE MTT-S International Microwave Biomedical Conference (IMBioC), Montreal, CANADA.
Electromagnetic (EM) safety guidelines and standards are designed to protect both workers and the general public from risks posed by exposures to routine or occupational (i.e. non-medical) EM sources. In this research, we investigate whether people with implants, a growing portion of the population, are also protected by these guidelines. We review the current limits and restrictions of EM safety standards, and study the local field enhancement around generic implants in average body tissues over a wide range of frequencies from 10 kHz to 1 GHz. Especially at low frequencies, enhancements in the order of 50 dB can be observed. We also exposed a high fidelity human anatomical model with generic implants to a generic electric vehicle wireless charging coil at 85 kHz. One active and one passive implant were considered at 36 charging coil positions, and we observed the basic restrictions of International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2010 guidelines at this frequency being exceeded by almost 20 dB. Assessment of the EM safety of low-frequency high-power wireless power transfer systems for persons with conductive implants must be considered carefully. https://doi.org/10.1109/imbioc60287.2024.10590577

Research on the safety risks of microwave irradiation on motion balance perception in electric power environments,
QIN J. F., H. CHEN, Q. L. QIAO, W. ZHANG, C. L. ZHU, J. J. CHENG, X. Y. LIU and A. G. SONG, *Science of the Total Environment* 952 (Nov 2024),
To the microwave irradiation safety hazards caused by the co-construction of towers in smart grids, this paper investigates the effects of microwave irradiation in the power environment on the biological motion balance perception function. Firstly, simulation of microwave signals in the electric power environment, i.e., lowfrequency harmonics and high-frequency carriers, were realized by signal modulation and applied in four types of behavior testing scenarios. Then, determining rats as target organisms to replace workers and randomly dividing into groups in proportion: open field, rotating rod fatigue, beam walking and forced swimming. Configuring radar

with various parameters to match the electric power irradiation scene and stimulate rats, monitoring the abnormal behavior by image processing module, including posture, motion trajectory, distance, and other features. The experimental result showed that exposed to microwaves induce rats motor ability decline, balance perception imbalance, together with paralysis within long-term exposure, and its locomotor activity, coordination, posture control and reaction time all exhibit varying degrees of weakening. These findings indicate that microwave irradiation in electric power environment may pose significant health and safety risks for worker. https://doi.org/10.1016/j.scitotenv.2024.175936

Flexible Electromagnetic Phantom with Electrotextile Backing
RIZZO R., G. SACCO, M. ZHADOBOV and IEEE (2024). 4th URSI Atlantic Radio Science Meeting (AT-RASC), Meloneras, SPAIN.
This paper introduces the first flexible skin-equivalent phantom operating in the millimeter-wave (mmW) range. Its thin and flexible structure makes it suitable for the performance testing of human-centered wireless devices, where mechanical reconfigurability of a planar or conformal surface representing the human body is needed. It consists of a homogeneous layer of carbon powder mixed with silicone, backed by an electrotextile on one side. The thickness and composition of the dielectric layer are optimized to reproduce the reflection coefficient at the air/skin interface around 60 GHz. The maximum relative error between the reflection coefficient of the phantom and the one of human skin is within 3.5% in magnitude and 16.2% in phase. https://www.emf-portal.org/ja/article/55260

Numerical assessment of induced electric fields in a worker's hand with commonly used metallic implants under exposure to low frequency magnetic fields,
SCHMID G., P. SCHNEEWEISS, R. HIRTL, T. JHALA and T. SAMARAS, *Journal of Radiological Protection* 44, no. 3 (Sep 2024),
The European Union's Workers' Directive 2013/35/EU on the minimum health and safety requirements regarding the exposure of workers to electromagnetic fields specifies action levels (ALs) for external electric and magnetic fields, which should protect against induced tissue-internal electric field strength E i above the exposure limit values, the latter being defined in order to prevent tissue stimulation at low frequencies. However, although 2013/35/EU explicitly calls for the protection of 'workers at particular risk' (including workers with metallic implants), the AL specified in the Directive have been derived under the assumption that there are no metallic parts present inside the body. Therefore, in the present work, we analysed the situation of a worker's hand and forearm bearing metallic implants (Herbert screw and volar radius plate) used for osteosynthesis after the most common bone fractures of the hand/forearm, exposed to low frequency magnetic fields. The uniform exposure of the whole hand and forearm as well as the exposure to a specific and widely used device, a deactivator for single-use labels of acousto-magnetic electronic article surveillance systems, were considered based on numerical computations using a high-resolution anatomical hand and forearm model. The results obtained indicated that the maximum induced electric field strength averaged in a volume of 2 mm x 2 mm x 2 mm cube was higher in the presence of the metallic implants by a factor of up to 4.2 for bone tissue and 2.3 for soft tissue compared with the case without an implant. Hence, it is obvious that the local induced electric field strengths may be substantially increased by the implants. The extent of this increase, however, is highly dependent on the implant's position inside the body, the implant's geometry, and the field distribution and orientation with respect to the anatomical structure and the implant.
https://doi.org/10.1088/1361-6498/ad66dc

Comparison of a radiofrequency electric and magnetic field source-based job-exposure matrix with personal radiofrequency exposure measurements,

TURUBAN M., H. KROMHOUT, J. VILA, F. DE VOCHT, M. VALLBONA-VISTÓS, I. BALDI, E. CARDIS and M. C. TURNER, *Annals of Work Exposures and Health* (2024 Sep 2024),
Objectives: Assessing occupational exposure to radiofrequency electromagnetic fields (RF-EMF) presents significant challenges due to the considerable variability in exposure levels within and between occupations. This spatial and temporal variability complicates the reliable evaluation of potential health risks associated with RF-EMF exposure in the workplace. Accurate assessment methods are crucial to understand the extent of exposure and to evaluate potential health risks, especially given the potential for higher exposures in occupational settings compared to the general population. This study compares the historical RF-EMF exposure estimates in the INTEROCC RF-EMF job-exposure matrix (RF-JEM) with recent personal measurement data collected in 2 countries as part of the OccRF-Health study, to assess the broader applicability of the RF-JEM. Methods: Weighted kappa (k (w)) coefficients and Spearman rank correlation tests were performed to assess the alignment between RF-JEM estimates and measurements for 8 h time-weighted average exposure intensity and prevalence estimates across various occupations. The comparisons were mainly based on 22 jobs having >= 5 measured workers in the OccRF-Health study. Results: Poor agreement was found for both exposure prevalence and intensity between both methods (k (w) < 0.1). RF-JEM values likely overestimated exposure levels for both electric (E) and magnetic (H) fields (mean percentage difference >194%) compared to current personal measurements. Conclusions: Findings suggest that the INTEROCC-JEM likely overestimates current exposure intensity levels in the measured jobs. Adopting a semiquantitative JEM could also mitigate misclassification errors due to exposure variability, improving accuracy in exposure assessment. These findings indicate the need for more targeted personal measurements, including among highly exposed workers, and for potentially considering new exposure metrics to more accurately assess occupational RF-EMF exposures in occupational epidemiological research. https://doi.org/10.1093/annweh/wxae072

Occupational exposure to radiofrequency electromagnetic fields and brain tumor risk: Application of the INTEROCC job-exposure matrix,
TURUBAN M., H. KROMHOUT, J. VILA, M. VALLBONA-VISTÓS, F. DE VOCHT, I. BALDI, L. RICHARDSON, G. BENKE, D. KREWSKI, M. E. PARENT, S. SADETZKI, B. SCHLEHOFER, J. SCHÜZ, J. SIEMIATYCKI, M. VAN TONGEREN, A. WOODWARD, E. CARDIS and M. C. TURNER, *International Journal of Cancer* (2024 Sep 2024),
Radiofrequency electromagnetic fields (RF-EMF, 100 kHz to 300 GHz) are classified by IARC as possibly carcinogenic to humans (Group 2B). This study evaluates the potential association between occupational RF-EMF exposure and brain tumor risk, utilizing for the first time, a RF-EMF job-exposure matrix (RF-JEM) developed in the multi-country INTEROCC case-control study. Cumulative and time-weighted average (TWA) occupational RF-EMF exposures were estimated for study participants based on lifetime job histories linked to the RF-JEM using three different methods: (1) by considering RF-EMF intensity among all exposed jobs, (2) by considering RF-EMF intensity among jobs with an exposure prevalence >= the median exposure prevalence of all exposed jobs, and (3) by considering RF-EMF intensity of jobs of participants who reported RF-EMF source use. Stratified conditional logistic regression models were used, considering various lag periods and exposure time windows defined a priori. Generally, no clear associations were found for glioma or meningioma risk. However, some statistically significant positive associations were observed including in the highest exposure categories for glioma for cumulative and TWA exposure in the 1- to 4-year time window for electric fields (E) in the first JEM application method (odds ratios [ORs] = 1.36, 95% confidence interval [95% CI] 1.08, 1.72 and 1.27, 95% CI 1.01, 1.59, respectively), as well as for meningioma for cumulative exposure in the 5- to 9-year time window for electric fields (E) in the third JEM application method (OR = 2.30, 95% CI 1.11, 4.78). We did not identify convincing associations between occupational RF-EMF exposure and risk of glioma or meningioma. https://doi.org/10.1002/ijc.35182

Risk Assessment for Workers with Wearable Medical Devices Exposed to Electromagnetic Fields, VIVARELLI C., F. CENSI, G. CALCAGNINI, R. FALSAPERLA and E. MATTEI, *Health Physics* 127, no. 2 (Aug 2024): 269-275,
The exponential diffusion of wearable medical devices (WMD) in recent years has involved people of all ages, including workers. Workers who use WMDs should be considered at a particular risk from electromagnetic fields, and in accordance with EU Directive 2013/35/EU, they require an individual risk assessment. Currently, there is no international standard that provides specific guidance on how to perform such a risk assessment. This paper focuses on the effects of electromagnetic fields on WMDs and does not consider the direct effects on human body tissues. It aims to offer practical recommendations to employers and/or health physicists for the risk assessment of workers with WMDs. Focusing on EU countries, we first describe the requirements outlined by the technical standard for the electromagnetic compatibility (EMC) of medical electrical equipment EN 60601-1-2. Then, some general guidelines on how to perform the risk assessment are provided. The assessment can be conducted by comparing the field values measured in the workplace with the immunity test levels specified in the technical standards of medical electrical equipment. If the measured values are lower than the immunity test levels indicated in the standard and the distance from the electromagnetic source is greater than the distance used by the manufacturer during the EMC (electromagnetic compatibility) tests (typically 30 cm), the risk for the worker may be considered acceptable. However, if the measured values exceed the immunity test levels or the distance criteria, a specific evaluation based on a case-by-case analysis is required.
https://doi.org/10.1097/hp.0000000000001798

Impact of high (1950 MHz) and extremely low (50 Hz) frequency electromagnetic fields on DNA damage caused by occupationally relevant exposures in human derived cell lines, WOREL N., M. MISÍK, M. KUNDI, F. FERK, H. P. HUTTER, A. NERSESYAN, G. WULTSCH, G. KRUPITZA and S. KNASMUELLER, *Toxicology in Vitro* 100 (Oct 2024),
Epidemiological studies indicate that electromagnetic fields (EMF) are associated with cancer in humans. Exposure to mobile phone specific high frequency fields (HF-EMF) may lead to increased glioma risks, while low frequency radiation (LF-EMF) is associated with childhood leukemia. We studied the impact of HF-EMF (1950 MHz, UMTS signal) on DNA stability in an astrocytoma cell line (1321N1), and the effect of LF-EMF (50 Hz) in human derived lymphoma (Jurkat) cells. To find out if these fields affect chemically induced DNA damage, coexposure experiments were performed. The cells were exposed to HF-EMF or LF-EMF and treated simultaneously and sequentially with mutagens. The compounds cause DNA damage via different molecular mechanisms, i.e. pyrimidine dimers which are characteristic for UV light (4-nitroquinoline 1-oxide, 4NQO), bulky base adducts (benzo[a]pyrene diolepoxide, BPDE), DNA-DNA and DNA-protein cross links and oxidative damage (NiCl2, CrO3). DNA damage was measured in single cell gel electrophoresis (comet) assays. We found a moderate reduction of basal and 4NQO-induced DNA damage in the astrocytoma line, but no significant alterations of chemically induced DNA migration by the HF and LF fields under all other experimental series. The biological consequences of the moderate reduction remain unclear, but our findings indicate that acute mobile phone and power line specific EMF exposures do not enhance genotoxic effects caused by occupationally relevant chemical exposures.
https://doi.org/10.1016/j.tiv.2024.105902

Etudes épidémiologiques

A review on the consequences of molecular and genomic alterations following exposure to electromagnetic fields: Remodeling of neuronal network and cognitive changes,
ABTIN S., F. SEYEDAGHAMIRI, Z. AALIDAEIJAVADI, A. M. FARROKHI, F. MOSHREFI, T. ZIVEH, M. I. ZIBAII, H. ALIAKBARIAN, M. REZAEI-TAVIRANI and A. HAGHPARAST, *Brain Research Bulletin* 217 (Oct 2024),
The use of electromagnetic fields (EMFs) is essential in daily life. Since 1970, concerns have grown about potential health hazards from EMF. Exposure to EMF can stimulate nerves and affect the central nervous system, leading to neurological and cognitive changes. However, current research results are often vague and contradictory. These effects include changes in memory and learning through changes in neuronal plasticity in the hippocampus, synapses and hippocampal neuritis, and changes in metabolism and neurotransmitter levels. Prenatal exposure to EMFs has negative effects on memory and learning, as well as changes in hippocampal neuron density and histomorphology of hippocampus. EMF exposure also affects the structure and function of glial cells, affecting gate dynamics, ion conduction, membrane concentration, and protein expression. EMF exposure affects gene expression and may change epigenetic regulation through effects on DNA methylation, histone modification, and microRNA biogenesis, and potentially leading to biological changes. Therefore, exposure to EMFs possibly leads to changes in cellular and molecular mechanisms in central nervous system and alter cognitive function.
https://doi.org/10.1016/j.brainresbull.2024.111090

Link between Wi-Fi, cordless devices, mobile phone usage patterns, and behavioral problems among Japanese children: A prospective cohort study,
AJMAL A., K. YAMAZAKI, N. TAMURA, Y. A. BAMAI, T. YOSHIKAWA, T. HIKAGE, A. IKEDA and R. KISHI, *Environmental Research* 261 (Nov 2024),
Background: With the recent advent of technology, it is important to confirm the health and safety of the youth. This study aimed to prospectively evaluate the relationship between Wi-Fi, cordless phones, and mobile phone usage patterns and behavioral problems. Methods: This study involved 2465 children aged 8-17 years from the Hokkaido Study on Environment and Children's Health from October 2020 to January 2021, with a follow-up from September 2021 to March 2022. The mother-child dyad provided information on the presence of residential Wi-Fi and cordless phones, cordless phone call duration, and mobile phone usage pattern (duration of calls using mobile network and internet, online audio streaming, online video streaming, and playing online games) via a baseline questionnaire. Based on the scores on Strength and Difficulties Questionnaire at baseline and follow-up, the children were categorized into four groups: normal, persistent, improved, and concurrent. Results: No significant association was found between Wi-Fi, mobile phone calls via mobile networks, and behavioral problems. Cordless phone at home had higher odds for improvement in total difficulty scores, and cordless phone for calling more than 4 min per week had lower odds of persistent problematic prosocial behavior. Longer duration of mobile phone calling via the internet (>40 min/week) had higher odds of concurrent total difficulties. Mobile phone calling via mobile network for <5 min per week had higher odds for improved total difficulty scores. Audio streaming via mobile phones for 60-120 min had lower odds of persistent total difficulties. Conclusion: Our results showed sporadic findings between residential RF-EMF indoor sources and mobile phone usage pattern. These observed findings could be affected by residual confounding and chance findings. Ongoing follow-up studies are necessary to further explore this association through detailed exposure assessment and addressing the potential limitations of our study. https://doi.org/10.1016/j.envres.2024.119715

The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies,
BOSCH-CAPBLANCH X., E. ESU, C. M. ORINGANJE, S. DONGUS, H. JALILIAN, J. EYERS, C. AUER, M. MEREMIKWU and M. RÖÖSLI, *Environment International* 187 (May 2024),
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
https://doi.org/10.1016/j.envint.2024.108612

Evaluation of electric field (E) exposure levels and its relationship with the sleep quality of residents around the BTS antennas in Sabzevar, Iran,
MALVANDI H., M. FALLAHI, M. H. SAGHI and N. HASSANZADEH, *Radiation Protection Dosimetry* 200, no. 15 (Aug 2024): 1405-1415,
Mobile devices and base transceiver station (BTS) are the main sources of human exposure to radio frequency electromagnetic fields (RF-EMFs). Therefore, the aim of the present study was to evaluate the levels of exposure to RF-EMF in three different time intervals and three different distances from BTS antennas in Sabzevar. Additional goals were to investigate the electric field (E) difference between different microenvironments, between the suburbs and downtown, and evaluating the sleep quality of residents around BTS antennas at different distances. The results showed significant differences between the values of E (Avg) and E (max Avg) at different times (T1, T2, and T3), different distances (50, 100, and 300 m) from BTS antennas, and between BTS antennas located in the suburbs and downtown. No significant differences were observed between the values of E (Avg) and E (max Avg) in terms of microenvironments. Poor sleep quality (>5) was recorded in the residents around the BTS antennas at different distances, and a significant difference was observed between the sleep quality of the residents at a distance of <100 m

compared to the residents at a distance of >300 m. The recorded levels of E in all places and times were below the human safety limits set by the Iranian National Standardization Organization, the Information and Communication Technologies Authority and the International Commission on Non-Ionizing Radiation Protection, indicating the absence of potential risk due to exposure to E in the study area. https://doi.org/10.1093/rpd/ncae180

General population EMF exposure evolution in anticipation of 5G: a study at 5 years difference
PETRITA T., D. B. DEACONESCU, S. MICLAUS and IEEE (2024). IEEE International Symposium on Measurements and Networking (M and N), Rome, ITALY.
Using data from Romania's NRA, ANCOM, we assess the modification of the EMF exposure in general population. Our study includes 12 EMF monitoring stations placed in populated areas, i.e. city centers. This study catches the mobile networks evolution, including the introduction of 5G technology, after spectrum auction held in November 2021. While the deployment of the networks can still be seen as immature at the end of 2023, we are extrapolating the effects of 5G evolution and traffic shift towards data with wideband EMF sensors measurements.
https://doi.org/10.1109/mn60932.2024.10615901

The effect of exposure to radiofrequency electromagnetic fields on cognitive performance in human experimental studies: Systematic review and meta-analyses,
POPHOF B., J. KUHNE, G. SCHMID, E. WEISER, H. DORN, B. HENSCHENMACHER, J. BURNS, H. DANKER-HOPFE and C. SAUTER, *Environment International* 191 (Sep 2024),
Background: The objective of this review is to evaluate the associations between short-term exposure to radio- frequency electromagnetic fields (RF-EMF) and cognitive performance in human experimental studies. Methods: Online databases (PubMed, Embase, Scopus, Web of Science and EMF-Portal) were searched for studies that evaluated effects of exposure to RF-EMF on seven domains of cognitive performance in human experimental studies. The assessment of study quality was based on the Risk of Bias (RoB) tool developed by the Office of Health Assessment and Translation (OHAT). Random effects meta-analyses of Hedges's g were conducted separately for accuracy- and speed-related performance measures of various cognitive domains, for which data from at least two studies were available. Finally, the certainty of evidence for each identified outcome was assessed according to Grading of Recommendations Assessment, Development, and Evaluation (GRADE). Results: 57,543 records were identified and 76 studies (80 reports) met the inclusion criteria. The included 76 studies with 3846 participants, consisting of humans of different age, sex and health status from 19 countries, were conducted between 1989 and 2021. Quantitative data from 50 studies (52 reports) with 2433 participants were included into the meta-analyses. These studies were performed in 15 countries between 2001 and 2021. The majority of the included studies used head exposure with GSM 900 uplink. None of the meta-analyses observed a statistically significant effect of RF-EMF exposure compared to sham on cognitive performance as measured by the confidence interval surrounding the Hedges's g or the significance of the z-statistic. For the domain Orientation and Attention, , subclass Attention - Attentional Capacity RF-EMF exposure results in little to no difference in accuracy (Hedges's g 0.024, 95 % CI [-0.10; 0.15], I-2 = 28 %, 473 participants). For the domain Orientation and Attention, , subclass Attention - Concentration / Focused Attention RF-EMF exposure results in little to no difference in speed (Hedges's g 0.005, 95 % CI [-0.17; 0.18], I-2 = 7 %, 132 participants) and probably results in little to no difference in accuracy; it does not reduce accuracy (Hedges's g 0.097, 95 % CI [-0.05; 0.24], I-2 = 0 %, 217 participants). For the domain Orientation and Attention, , subclass Attention - Vigilance RF-EMF exposure probably results in little to no difference in speed and does not reduce speed (Hedges's g 0.118, 95 % CI [-0.04; 0.28], I-2 = 41 %, 247 participants) and results in little to no difference in accuracy (Hedges's g 0.042, 95% CI, [-0.09; 0.18], I-2 = 0%, 199 participants).
https://doi.org/10.1016/j.envint.2024.108899

Evaluation de l'exposition

Facing Challenges in Zero-Span Measurements of 5G mm-Wave EMF Power in LoS and NLoS Propagation,
ADDA S., V. BOTTURA, S. D'ELIA, N. PASQUINO, R. SUMAN and M. VACCARONO, *Ieee Transactions on Instrumentation and Measurement* 73 (2024),
We present a methodology for on-site zero-span (ZS) measurement of incident power generated by 5G base stations (BSs) that operate at millimeter-waves (mm-waves), analyzing the challenges offered by the new frequency band and nonline-of-sight (NLoS) propagation, which is the most common situation for mobile network users. We also investigate the impact of omnidirectional and directional measurement antennas. This is the first research on this topic available in scientific literature. Our results reveal that the measurement method designed for frequencies below 6 GHz in line-of-sight (LoS) conditions is also applicable in the mm-wave range. At the same time, in NLoS, mitigation strategies are suggested to measure signals accurately. That is, an omnidirectional antenna is recommended since a directional one requires an initial assessment to align the probe with the direction of the strongest signal. In addition, directional antennas under NLoS conditions do not guarantee that the power density coming from different directions due to reflections is measured entirely. This study holds significant importance for international standardization bodies focusing on establishing measurement methods to evaluate exposure originating from mobile network BSs. https://doi.org/10.1109/tim.2024.3457966

Comprehensive Analysis of Magnetic Flux Density and RF-EMF Exposure in Electric Buses: A Case Study from Samsun, Turkey,
ALBAYRAK Z. E., C. KURNAZ, T. KARADAG and A. A. CHEEMA, *Sensors* 24, no. 17 (Sep 2024),
This study investigates magnetic flux density (B) and radiofrequency electromagnetic field (RF-EMF) measurements on electric buses operating in Samsun, Turkey, focusing on two bus routes (called E1 and E4) during the morning and evening hours. Measurements were taken under diverse operational conditions, including acceleration, cruising, and braking, at locations of peak passenger density. Along the E1 route, the magnetic field intensity varied significantly based on the bus position, road slope, and passenger load, with notable increases during braking. In contrast, the E4 route showed a lower magnetic field intensity and RF-EMF values due to its straighter trajectory and reduced operational stops. The highest RF-EMF measurement recorded was 6.01 V/m, which is below the maximum levels established by the ICNIRP guidelines. In 11 out of the 12 different band-selective RF-EMF measurements, the highest contribution came from the downlink band of the base stations, while in only one measurement, the highest contribution originated from the uplink bands of the base stations. All data were subject to the Anderson-Darling test, confirming the generalized extreme value distribution as the best fit for both B and RF-EMF measurements. Additionally, the study assessed B levels inside and outside the bus during charging, revealing heightened readings near the pantograph. These findings significantly contribute to our understanding of electromagnetic field exposure in electric bus environments, highlighting potential health implications and informing the development of targeted mitigation strategies. https://doi.org/10.3390/s24175634

Measurement of the electric field of mobile telephone base station antennas in Riobamba (Ecuador), to determine the specific absorption rate (SAR) in the human body,
CASTILLO-HEREDIA L., P. INFANTE-MOREIRA, E. M. PEÑAFIEL, M. VINUEZA-MORALES, R. O. HUGO and E. AVILÉS-LUNA, *Results in Engineering* 23 (Sep 2024),

Exposure to electromagnetic and radio frequency fields generated by communication technologies such as mobile phones has raised concerns about electromagnetic pollution and its possible health effects. The objective of the study was to measure the electric field coming from cell phone base station antennas and determine through simulation in virtual anatomical models the maximum and average SAR in the whole body and in 10 g in different parts of the human body. The measurements were carried out with a selective non-ionizing electromagnetic radiation meter at 10 sites in the city of Riobamba, Ecuador. The highest maximum and average SAR for whole body was 3.045x10-7 and 3.923 x10-8 W/kg, respectively. While, at 10 g, the maximum SAR reached up to 8.52x10-9 W/kg in arms and the average SAR 2.13x10-9 W/kg in legs. All results are well below the limits established by the ICNIRP, suggesting a low risk of exposure. This work provides valuable information on the levels of exposure to electric fields from mobile telephone base stations and the results collected in this research could serve as a reference for future research, since the sampling method used could be reproduced to study the temporal variation of electric field levels in the city and conduct more comprehensive studies of SAR distribution in the human body. https://doi.org/10.1016/j.rineng.2024.102554

50 Hz Temporal Magnetic Field Monitoring from High-Voltage Power Lines: Sensor Design and Experimental Validation,
DEPREZ K., T. VAN DE STEENE, L. VERLOOCK, E. TANGHE, L. GOMMÉ, M. VERLAEK, M. GOETHALS, K. VAN CAMPENHOUT, D. PLETS and W. JOSEPH, *Sensors* 24, no. 16 (Aug 2024),
A low-cost, tri-axial 50 Hz magnetic field monitoring sensor was designed, calibrated and verified. The sensor was designed using off-the-shelf components and commercially available coils. It can measure 50 Hz magnetic fields originating from high-voltage power lines from 0.08 mu T to 364 mu T, divided into two measurement ranges. The sensor was calibrated both on-board and in-lab. The on-board calibration takes the circuit attenuation, noise and parasitic components into account. In the in-lab calibration, the output of the developed sensor is compared to the benchmark, a narrowband EHP-50. The sensor was then verified in situ under high-voltage power lines at two independent measurement locations. The measured field values during this validation were between 0.10 mu T and 13.43 mu T, which is in agreement with other reported measurement values under high-voltage power lines in literature. The results were compared to the benchmark, for which average deviations of 6.2% and 1.4% were found, at the two independent measurement locations. Furthermore, fields up to 113.3 mu T were measured in a power distribution sub-station to ensure that both measurement ranges were verified. Our network, four active sensors in the field, had high uptimes of 96%, 82%, 81% and, 95% during a minimum 3-month interval. In total, over 6 million samples were gathered with field values that ranged from 0.08 mu T to 45.48 mu T. This suggests that the proposed solution can be used for this monitoring, although more extensive long-term testing with more sensors is required to confirm the uptime under multiple circumstances. https://doi.org/10.3390/s24165325

Sustainable Maintenance of Conductors in Transmission/Distribution Networks Using Complex Magnetic Field Analysis,
DINA L. A., V. VOICU, I. DUMBRAVA, P. M. MIRCEA and I. D. NICOLAE, *Sustainability* 16, no. 15 (Aug 2024),
This study presents issues related to electromagnetic pollution and the level of magnetic field radiation occurring around conductors used for electricity transmission and distribution. The fact that modeling and simulation are the most efficient methods of optimization, considering the cost-benefit ratio, was the premise of this work. This paper proposes the performance of a complex analysis, carried out in a comparative manner, which includes physical tests and simulations in the existing field around transmission and distribution cables used in transformer substations. In the first stage, the level of the magnetic field existing near the conductor carried by an electric current

was tested (measured), and a virtual model was then designed to simulate the field in conditions similar to those of the test. The results obtained from the simulation were analyzed in comparison with those obtained by testing. The maximum permissible limits of exposure to an electromagnetic field, which are regulated by Government Decision HG 520/2016 of 20 July 2016 and Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013, were used as the reference to formulate conclusions for both situations considered. These comparisons were intended to determine the level of exposure to electromagnetic fields existing in places where electricity transmission/distribution conductors are located. Energy sustainability exists due to the versatile properties of the conductors, with the energy transmission and distribution network being functional regardless of the source of energy production. https://doi.org/10.3390/su16156659

A Comparative Study of In Situ Methodologies for Assessment of RF EMF Exposure From a 5G FR2 Base Station,
GOEGEBEUR S., K. DEPREZ, D. COLOMBI, J. E. BISCHOFF, C. DI PAOLA, B. STROOBANDT, L. VERLOOCK, S. AERTS, C. TÖRNEVIK and W. JOSEPH, *Ieee Access* 12 (2024): 132552-132564,
In this work, in situ measurements of the radio frequency electromagnetic field exposure have been conducted for an indoor massive MIMO 5G base station operating at 26-28 GHz. Measurements were performed at six different positions (at distances between 9.94 and 14.32 m from the base station), of which four were in line-of-sight and two were in non-line-of-sight. A comparison was performed between the measurements conducted with an omnidirectional probe and with a horn antenna, for scenarios with and without a user equipment used to actively create an antenna traffic beam from the base station towards the measurement location. A maximum exposure of 171.9 mW/m2 was measured at a distance of 9.94 m from the base station. This is below 2% of the ICNIRP reference level. Moreover, the feasibility to measure the power per resource element of the Synchronization Signal Block - which can be used to extrapolate the maximum exposure level - with a conventional spectrum analyzer was shown by comparison with a network decoder.
https://doi.org/10.1109/access.2024.3424262

Evaluation of the Exposition Human to Electromagnetics Field at 5G and 6G Frequencies
TAYBI C., J. ASSAHSAH, A. KARKRI, M. A. MOUTAOUEKKIL, B. ELMAGROUD and A. ZIYYAT (2023). International Conference on Electrical Systems & Automation (ICESA), Al Hoceima, MOROCCO.
This chapter aims to study the problems related to human exposure to electromagnetic fields at the frequencies of the fifth and sixth generation of mobile networks, particularly in the millimeter frequency band (mmW). In our study, a cubic voxel of 2 mm has been illuminated by a perfect plane wave and it has been analyzed under Altair FEKO with the MLFMM method. The ElectroMagnetic Field EMF, the power density, the simulation time, and the memory occupation were studied at said frequencies for, first, a homogeneous voxel and a heterogeneous voxel composed of a layer of skin, fat, muscle, and bone. The results obtained show, first, that the frequency of the reflected EMF fields is double that of the incident EMF fields, and on the other hand, that the calculation time and the occupation of the memory increase according to the frequency and the phantom type. https://doi.org/10.1007/978-3-031-51796-9_35

Instantaneous vs Theoretical Maximum Exposure under Real Traffic Conditions: Example in the City of Valencia
VILLAESCUSA-TEBAR A., A. NAJERA, J. GONZALEZ-RUBIO, C. GARCIA-PARDO and IEEE (2024). 18th European Conference on Antennas and Propagation (EuCAP), Glasgow, SCOTLAND.
With the ongoing deployment of the fifth generation (5G) mobile telecommunications, there is an increasing need for standardized methodologies to assess human exposure to radiofrequency electromagnetic fields from 5G base stations. Thus, the development of proper assessment methodologies will impact the adequate deployment of 5G systems as well as ensure the safe

operation of devices for people. This work focuses on comparing total exposure and theoretical maximum exposure levels in commercial 5G operational networks in the City of Valencia for the frequency band below 6 GHz. This study is based on results from measurements using a code-selective methodology as well as a personal exposimeter in addition to an omnidirectional antenna and one-user equipment (UE) to measure the downlink exposure in a real scenario. https://ieeexplore.ieee.org/document/10500944

Proximity Sensing of Stationary Human Body Using FMCW Radar
YOO K., D. CHOI, H. KIM, J. SUH, J. KIM, O. ELIEZER, S. YOO and IEEE (2024). IEEE Texas Symposium on Wireless and Microwave Circuits and Systems (WMCS), Baylor Res & Innovat Collaborat, Waco, TX.
A body proximity sensing (BPS) algorithm based on FMCW radar is proposed for regulatory compliance in mobile wireless devices, having the ability to distinguish a human target from other objects even when stationary. The proposed algorithm consists of a calibration step that considers the characteristics of the surrounding environment, and a subsequent detection step that is capable of detecting the human body present in that environment. In several realistic test environments, the proposed algorithm, realized in a 60 GHz commercially available FMCW radar system, demonstrated a 100% detection probability up to a distance of 20 cm from the human body, and effectively suppressed false alarm instances in the absence of the human body within the range of detection of interest. https://doi.org/10.1109/wmcs62019.2024.10619029

Toxicité

Induced electric fields in MRI settings and electric vestibular stimulations: same vestibular effects?,
BOUISSET N. and I. LAAKSO, *Experimental Brain Research* 242, no. 11 (Nov 2024): 2493-2507,
In Magnetic Resonance Imaging scanner environments, the continuous Lorentz Force is a potent vestibular stimulation. It is nowadays so well known that it is now identified as Magnetic vestibular stimulation (MVS). Alongside MVS, some authors argue that through induced electric fields, electromagnetic induction could also trigger the vestibular system. Indeed, for decades, vestibular-specific electric stimulations (EVS) have been known to precisely impact all vestibular pathways. Here, we go through the literature, looking at potential time varying magnetic field induced vestibular outcomes in MRI settings and comparing them with EVS-known outcomes. To date, although theoretically induction could trigger vestibular responses the behavioral evidence remains poor. Finally, more vestibular-specific work is needed. https://doi.org/10.1007/s00221-024-06910-y

Effects of 5G radiofrequency electromagnetic radiation on indicators of vitality and DNA integrity of in vitro exposed boar semen,
BUTKOVIC I., S. VINCE, M. LOJKIC, I. FOLNOZIC, S. MILINOVIC, M. VILIC, K. MALARIC, V. BERTA, M. SAMARDZ, M. KRESZINGER and I. Z. ZAJA, *Theriogenology* 230 (Dec 2024): 243-249,
The effects of radiofrequency electromagnetic radiation (RF-EMR) on semen quality have been in the spotlight in recent years, though research results to date have been contradictory. The effects of RF-EMR amongst others depend upon frequency, and there is currently no literature concerning the influence of 5G frequencies on both DNA integrity and spermatozoa vitality in males. The aim of this study was to investigate the effect of 5G RF-EMR on sperm membrane integrity, mitochondrial potential, and DNA integrity of in vitro exposed semen of breeding boars. The study included semen samples of eight breeding boars of the Pietren breed and four breeding boars of the German Landrace breed, from 1.5 to 3.5 years in age. Freshly diluted semen of each boar was divided into a

control (n = 12) and experimental group (n = 12). The samples of the experimental group were exposed for 2 hours to continuous RF-EMR at a single frequency (700 MHz, 2500 MHz and 3500 MHz) and an electromagnetic field strength of 10 V/m using a transverse gigahertz electromagnetic cell. Sperm DNA fragmentation was assessed using a Halomax (R) kit and sperm membrane integrity and mitochondrial potential was assessed using a PI/SYBR-14 LIVE/DEAD viability kit with JC-1. A significantly higher proportion of spermatozoa with DNA fragmentation was found in exposed semen samples for all frequencies compared to the control group. The highest DNA damage was recorded in semen samples exposed to 5G RF-EMR at 2500 MHz ($p < 0.01$) and 3500 MHz ($p < 0.05$) vs. control semen samples. A significantly higher proportion of spermatozoa with damaged cell membrane and good mitochondrial potential was recorded in semen samples exposed with 3500 MHz. In vitro exposure of breading boar semen to 5G RF-EMR significantly increases the proportion of DNA fragmentation. The harmful effect of 5G RF-EMR on the proportion of spermatozoa with damaged DNA was frequency dependent. The 3500 MHz frequency displayed the most harmful effects due to significant impacts on DNA integrity and spermatozoa vitality indicators. https://doi.org/10.1016/j.theriogenology.2024.09.025

Effect of sequential delivery of 1-and 2-MHz bipolar microneedling radiofrequency energy on thermal tissue reactions in a minipig model,
CHO S. B., S. Y. KANG, Y. J. LEE, M. CHOI, B. KIM and J. C. AHN, *Skin Research and Technology* 30, no. 9 (Sep 2024),
BackgroundBipolar microneedling radiofrequency (RF) treatment generates different patterns of thermal reactions, depending on the skin impedance and RF treatment parameters, including the frequency, power, conduction time, settings of sub-pulse packs, and penetrating depth and type of microneedles used. We compared the effect of sequential delivery of 1- and 2-MHz bipolar RF energy to in vivo minipig skin on thermal tissue reaction.MethodsRF treatments at frequencies of 1 and 2 MHz were sequentially delivered to minipigs' skin in vivo. A histological study was performed to analyze RF-induced skin reactions at 1-h and at 3-, 7-, and 14-days post-treatment.ResultsThe skin specimens demonstrated that the two different frequencies of RF treatment generated mixed patterns of the peri-electrode coagulative necrosis (PECN) according to the experimental settings and tissue impedance. In the PECN zone, the tissue coagulation induced by the first RF treatment was surrounded by the effect of the later RF treatment at the other RF frequency. In the inter-electrode non-necrotic thermal reaction zone, the effect of the latter RF treatment was widespread and deep through the dermis, which had received RF treatment at the other frequency first. The delivery of pulsed-type RF energy at sub-pulse packs of 6 or 10 provided effective RF delivery over long conduction time without excessive thermal damage of the epidermis. Nonetheless, by sequential delivery of two different RF frequencies, RF-induced tissue reactions were found to be markedly enhanced.ConclusionThe sequential delivery of 1- and 2-MHz RF energy induces novel histological patterns of tissue reactions, which can synergistically enhance the thermostimulatory effects of each RF setting. Moreover, variations in patterns of tissue reactions can be generated by regulating the order of frequencies and the number of sub-pulse packs of RF used.
https://doi.org/10.1111/srt.13898

Electromagnetic Exposure Levels of Electric Vehicle Drive Motors to Passenger Wearing Cardiac Pacemakers,
DONG X. W., Y. D. QIAN and M. LU, *Sensors* 24, no. 13 (Jul 2024),
The number of individuals wearing cardiac pacemakers is gradually increasing as the population ages and cardiovascular disease becomes highly prevalent. The safety of pacemaker wearers is of significant concern because they must ensure that the device properly functions in various life scenarios. Electric vehicles have become one of the most frequently used travel tools due to the gradual promotion of low-carbon travel policies in various countries. The electromagnetic

environment inside the vehicle is highly complex during driving due to the integration of numerous high-power electrical devices inside the vehicle. In order to ensure the safety of this group, the paper takes passengers wearing cardiac pacemakers as the object and the electric vehicle drive motors as the exposure source. Calculation models, with the vehicle body, human body, heart, and cardiac pacemaker, are built. The induced electric field, specific absorption rate, and temperature changes in the passenger's body and heart are calculated by using the finite element method. Results show that the maximum value of the induced electric field of the passenger occurs at the ankle of the body, which is 60.3 mV/m. The value of the induced electric field of the heart is greater than that of the human trunk, and the maximum value (283 mV/m) is around the pacemaker electrode. The maximum specific absorption rate of the human body is 1.08 x 10-6 W/kg, and that of heart positioned near the electrode is 2.76 x 10-5 W/kg. In addition, the maximum temperature increases of the human torso, heart, and pacemaker are 0.16 x 10-5 degrees C, 0.4 x 10-6 degrees C, and 0.44 x 10-6 degrees C within 30 min, respectively. Accordingly, the induced electric field, specific absorption rate, and temperature rise in the human body and heart are less than the safety limits specified in the ICNIRP. The electric field intensity at the pacemaker electrode and the temperature rise of the pacemaker meet the requirements of the medical device standards of ICNIRP and ISO 14708-2. Consequently, the electromagnetic radiation from the motor operation in the electric vehicle does not pose a safety risk to the health of passengers wearing cardiac pacemakers in this paper. This study also contributes to advancing research on the electromagnetic environment of electric vehicles and provides guidance for ensuring the safe travel of individuals wearing cardiac pacemakers. https://doi.org/10.3390/s24134395

Modeling methods in overlapping electroporation treatments: Pulse number effects on tissue conductivity and ablation area,
GUO F., X. H. GOU, J. G. SUN, J. HONG and Y. P. ZHANG, *Electrochimica Acta* 503 (Nov 2024),
Irreversible electroporation (IRE) is a non-thermal tissue ablation technique that utilizes high-voltage pulses between electrode pairs to destroy tissue. Numerical models are essential for predicting treatment outcomes and aiding in treatment planning. This paper studies a nonlinear conductivity model (NC) and a multiparametric nonlinear conductivity model (MPNC) to investigate overlapping electroporation treatments using a three- needle electrode configuration. The NC model accounts for the effects of the electric field and temperature on tissue conductivity during multiple pulsed electric field applications. The MPNC model incorporates the influence of pulse number, alongside electric field and temperature, on tissue conductivity. Results indicate that in the MPNC model, tissue conductivity is significantly higher in regions where the electric field intensity is below the threshold for irreversible electroporation, with the maximum difference reaching 0.4 . 4 S/m. In contrast, tissue conductivity is slightly lower in regions where the electric field intensity exceeds the IRE threshold. Additionally, the MPNC model predicts a smaller area of irreversible electroporation and a larger area of reversible electroporation, with these differences becoming more pronounced as the distance between electrode needles increases. These findings underscore the importance of considering pulse number effects in numerical models to enhance the accuracy of treatment planning for irreversible electroporation-based therapies.
https://doi.org/10.1016/j.electacta.2024.144883

Ubiquitous extremely low frequency electromagnetic fields induces anxiety-like behavior: mechanistic perspectives,
HOSSEINI E., *Electromagnetic Biology and Medicine* (2024 Jul 2024),
Anxiety is an adaptive condition characterized by heightened uneasiness, which in the long term can cause complications such as reducing the quality of life and problems related to the mental and physical health. Concerns have been raised regarding the potential dangers of extremely low frequency electromagnetic fields (ELF-EMF) ranging from 3 to 3000 Hz, which are omnipresent in

our daily lives and there have been studies about the anxiogenic effects of these fields. Studies conducted in this specific area has revealed that ELF-EMF can have an impact on various brain regions, such as the hippocampus. In conclusion, studies have shown that ELF-EMF can interfere with hippocampus-prefrontal cortex pathway, inducing anxiety behavior. Also, ELF-EMF may initiate anxiety behavior by generating oxidative stress in hypothalamus and hippocampus. Moreover, ELF-EMF may induce anxiety behavior by reducing hippocampus neuroplasticity and increasing the NMDA2A receptor expression in the hippocampus. Furthermore, supplementation with antioxidants could serve as an effective protective measure against the adverse effects of FLF-FMF in relation to anxiety behavior. In the modern world, the use of electric devices is inevitable and our living environment is full of these devices that create waves called electromagnetic fields. A group of these waves have extremely low frequencies, and many researches have been done on their effects on the behavior of laboratory animals such as rats and mice. Many of these studies indicate that these types of waves are anxiogenic, and a number of human studies also confirm this effect. In this study, we decided to search for the possible mechanisms behind this effect. Our review of the studies conducted in this field determined that the main effect of extremely low frequency fields which can have on different parts of the brain, causing anxiety behavior, is oxidative stress. Of course, studies show that the use of antioxidants, can prevent the oxidative effects of this type of waves. https://doi.org/10.1080/15368378.2024.2380305

Effect of terahertz radiation on drug activity in bacterial cells,
KAKIKAWA M., R. MATSUZUKA and Y. YAMAGUCHI, *Journal of Electromagnetic Waves and Applications* 38, no. 13 (Sep 2024): 1514-1522,
Terahertz (THz) waves have been reported to change membrane permeability and induce conformational changes in protein molecules. Drugs action on cells involves membrane permeability, and we therefore investigated the effect of THz waves on the activity of the cytotoxic drug bleomycin on Escherichia coli. 0.46 THz radiation with an average power of 2.5 W/cm2 was noncytotoxic to E. coli cells. However, 0.46 THz radiation enhanced the cytotoxic activity of bleomycin in E. coli cells, and the drug-enhancing effect depended on the power density of the THz waves. Then, the activity of the drug remaining in the culture medium after THz radiation did not differ from that remaining after non-radiation. This indicates that THz radiation does not affect the bacterial cell-membrane permeability to bleomycin. Thus, these results suggest that 0.46 THz radiation enhances the cytotoxicity of bleomycin to E. coli cells and may influence the mechanism of bleomycin action within cells rather than affecting drug uptake.
https://doi.org/10.1080/09205071.2024.2380386

Do mobile phones and laptop computers really impact sperm?,
KAVOUSSI P. K. and S. K. KAVOUSSI, *Arab Journal of Urology* (2024 Jul 2024),
Over the past few decades, the male population's fertility has decreased as demonstrated by an overall worsening of semen analysis parameters. Environmental variables are undoubtedly contributing elements. The technology that people rely on to enhance their quality of life and efficiency in many facets of daily life may also have pathologic consequences on the testicles and affect semen characteristics. Mobile phones and laptop computers are two frequently hypothesized sources of electromagnetic radiation and heat that can interfere with male fertility. These are two of the most widely utilized devices available today, and the majority of men use one or the other of them for the majority of their work.Understanding these consequences, as well as their possible influence and severity on male reproductive capacity, is the aim of this review of the medical literature. A thorough analysis of the most recent research in medicine, including original investigations, systematic reviews, and meta-analyses, was carried out by searching PubMed for publications on the relationship between male fertility and laptops and cell phones. A definitive understanding of the impact remains elusive due to contradicting data in the medical literature,

despite some studies suggesting a possible negative influence of laptop computers and cell phones on male fertility.Based on the available data in the medical literature, it is debatable whether laptop computers and cell phones have a negative effect on a man's fertility. Nevertheless, men who want to be cautious and rule out any potential factors that can affect fertility may decide to reduce or avoid these exposures. https://doi.org/10.1080/20905998.2024.2381957

Effects of High Temperature and High Humidity on the Degree of Ocular Damage Caused by 60 GHz Millimeter Wave Exposure,
KOJIMA M., T. TASAKI, T. KAMIJO, A. HADA, Y. SUZUKI, M. IKEHATA and H. SASAKI, *Health Physics* 127, no. 5 (Nov 2024): 557-564,
Millimeter waves (MMW) are pervasive in society; however, studies on the biological effects of MMW exposure are usually performed in laboratory settings not reflecting global environmental diversity. We investigated the effects of a 6-min exposure to 60 GHz MMW (wavelength, 5.0 mm) at incident power densities of 200 and 300 mW cm-2 in eyes (exposed right eyes vs. unexposed left eyes) under various ambient temperature/relative humidity environments (24 degrees C/50%, 45 degrees C/20%, and 45 degrees C/80%) using an in vivo rabbit model. Correlations were examined with adverse ocular events, including corneal epithelial damage (assessed using fluorescein staining), corneal opacity (evaluated by slit-lamp microscopy), and corneal thickness (measured via optical coherence tomography). Our findings indicate that higher temperatures and humidity tend to exacerbate MMW-induced ocular damage, albeit not significantly in the present study. Further research with a larger sample size is warranted. Incident power density emerged as a factor that was directly linked to the ocular damage threshold. High ambient temperature and humidity tended to exacerbate ocular damage from MMW exposure, although the effect was secondary. Ocular damage in a high-temperature (45 degrees C), high-humidity (80%) environment was increased to the same extent as that by incident power density increased by approximately 100 mW cm-2 in an ocular damage model in a standard environment (24 degrees C, 50%). In a high-humidity environment, the internal ocular tissue temperature increased at a high ambient temperature of 45 degrees C, suggesting that the eyeball may respond differently compared to other tissues. https://doi.org/10.1097/hp.0000000000001843

Redox cell signalling triggered by black carbon and/or radiofrequency electromagnetic fields: Influence on cell death,
LÓPEZ-MARTIN E., R. SUEIRO-BENAVIDES, J. M. LEIRO-VIDAL, J. A. RODRÍGUEZ-GONZÁLEZ and F. J. ARES-PENA, *Science of the Total Environment* 953 (Nov 2024),
The capacity of environmental pollutants to generate oxidative stress is known to affect the development and progression of chronic diseases. This scientific review identifies previously published experimental studies using preclinical models of exposure to environmental stress agents, such as black carbon and/or RF-EMF, which produce cellular oxidative damage and can lead to different types of cell death. We summarize in vivo and in vitro studies, which are grouped according to the mechanisms and pathways of redox activation triggered by exposure to BC and/or EMF and leading to apoptosis, necrosis, necroptosis, pyroptosis, autophagy, ferroptosis and cuproptosis. The possible mechanisms are considered in relation to the organ, cell type and cellularsubcellular interaction with the oxidative toxicity caused by BC and/or EMF at the molecular level. The actions of these environmental pollutants, which affect everyday life, are considered separately and together in experimental preclinical models. However, for overall interpretation of the data, toxicological studies must first be conducted in humans, to enable possible risks to human health to be established in relation to the progression of chronic diseases. Further actions should take pollution levels into account, focusing on the most vulnerable populations and future generations. https://doi.org/10.1016/j.scitotenv.2024.176023

Thermodynamic Considerations on the Biophysical Interaction between Low-Energy Electromagnetic Fields and Biosystems,
LUCIA U. and G. GRISOLIA, *Membranes* 14, no. 8 (Aug 2024),
A general theory explaining how electromagnetic waves affect cells and biological systems has not been completely accepted yet; nevertheless, extremely low-frequency electromagnetic fields (ELF-EMFs) can interfere with and modify several molecular cellular processes. The therapeutic effect of EMFs has been investigated in several clinical conditions with promising results: in this context a better understanding of mechanisms by which ELF-EMF influences cellular events is necessary and it could lead to more extended and specific clinical applications in different pathological conditions. This paper develops a thermodynamic model to explain how ELF-EMF directly interferes with the cellular membrane, inducing a biological response related to a cellular energy conversion and modification of flows across cell membranes. Indeed, energy, irreversibly consumed by cellular metabolism, is converted into entropy variation. The proposed thermodynamic model views living systems as adaptative open systems, analysing the changes in energy and matter moving in and out of the cell. https://doi.org/10.3390/membranes14080179

Study of genotoxic and cytotoxic effects induced in human fibroblasts by exposure to pulsed and continuous 1.6 GHz radiofrequency,
MASSARO L., S. DE SANCTIS, V. FRANCHINI, E. REGALBUTO, G. ALFANO, C. FOCACCETTI, M. BENVENUTO, L. CIFALDI, A. SGURA, F. BERARDINELLI, J. MARINACCIO, F. BARBATO, E. ROSSI, D. NARDOZI, L. MASUELLI, R. BEI and F. LISTA, *Frontiers in Public Health* 12 (Jul 2024),
Background The widespread use of radiofrequency (RF) sources, ranging from household appliances to telecommunications devices and military equipment, raises concerns among people and regulatory agencies about the potential health risks of RF exposure. Consequently, several in vitro and in vivo studies have been done to investigate the biological effects, in particular non-thermal, of this non-ionizing radiation. To date, this issue is still being debated due to the controversial results that have been reported. Furthermore, the impact of different RF signal modulations on biological systems remains poorly investigated. The present in vitro study aims to evaluate the cytotoxicity and genotoxicity of continuous or pulsed 1.6 GHz RF in human dermal fibroblasts (HDF).Methods HDF cultures were exposed to continuous and pulsed 1.6 GHz RF, for 2 h, with Specific Absorption Rate (SAR) of 0.4 W/kg. The potential biological effects of 1.6 GHz RF on HDF were assessed with a multi-methodological approach, analyzing the effects on cell cycle, ultrastructure, protein expression, mitotic spindle, CREST stained micronuclei, chromosome segregation and gamma-H2AX/53BP1 foci.Results 1.6 GHz RF exposure modified proteins expression and morphology of HDF. Specifically, the expression of different heat-shock proteins (HSP) (i.e., HSP-90, HSP-60, and HSP-25) and phospho-AKT were affected. In addition, both continuous and pulsed RF modified the cytoskeletal organization in HDF and increased the number of lysosomes, while the formation of autophagosomes was observed only after pulsed RF exposure. Mitotic spindle anomalies were also found after exposure. However, no significant effect was observed on cell cycle, chromosome segregation, CREST-stained micronuclei and gamma-H2AX/53BP1 foci.Conclusion The results of the present study show the absence of genotoxic damage in 1.6 GHz RF exposed HDF and, although mitotic spindle alterations were observed, they did not have an aneugenic effect. On the other hand, changes in some proteins expression and cell ultrastructure in exposed HDF suggest that RF can potentially induce cell alterations at the morphological and molecular levels. https://doi.org/10.3389/fpubh.2024.1419525

Uptake of substances into living mammalian cells by microwave induced perturbation of the plasma membrane,
MILDEN-APPEL M., M. PARAVICINI, J. P. MILDEN, M. SCHÜSSLER, R. JAKOBY and M. C. CARDOSO, *Scientific Reports* 14, no. 1 (Sep 2024),

Delivering foreign molecules and genetic material into cells is a crucial process in life sciences and biotechnology, resulting in great interest in effective cell transfection methods. Importantly, physical transfection methods allow delivery of molecules of different chemical composition and are, thus, very flexible. Here, we investigated the influence of microwave radiation on the transfection and survival of mammalian cells. We made use of an optimized microwave-poration device and analyzed its performance (frequency and electric field strength) in comparison with simulations. We, then, tested the effect of microwave irradiation on cells and found that 18 GHz had the least impact on cell survival, viability, cell division and genotoxicity while 10 GHz drastically impacted cell physiology. Using live-cell fluorescence microscopy and image analysis, we tested the uptake of small chemical substances, which was most efficient at 18 GHz and correlated with electric field strength and frequency. Finally, we were able to obtain cellular uptake of molecules of very different chemical composition and sizes up to whole immunoglobulin antibodies. In conclusion, microwave-induced poration enables the uptake of widely different substances directly into mammalian cells growing as adherent cultures and with low physiological impact. https://doi.org/10.1038/s41598-024-71401-7

Mobile telephony radiation exerts genotoxic action and significantly enhances the effects of gamma radiation in human cells,
PANAGOPOULOS D. J., *General Physiology and Biophysics* 43, no. 2 (2024): 103-120,
I previously reported chromosomal damage in human peripheral blood lymphocytes (HPBLs) induced by: a) mobile telephony (MT) electromagnetic fields (EMFs)/electromagnetic radiation (EMR), b) a high caffeine dose, and c) the combination of the two stressors. HPBLs from the same subjects exposed to gamma radiation at doses 0.1, 0.3, or 0.5 Gy, displayed more aberrations than those exposed to MT EMFs or the high caffeine dose in a dose-dependent manner. When the cells exposed to these gamma radiation doses were pre-exposed to a single 15-min MT EMF exposure, the number of aberrations increased significantly more than the sum number of aberrations induced by the individual stressors in all subjects. Thus, MT EMF exposure at a power density similar to 136 times below the latest International Commission on Non-Ionizing Radiation Protection (ICNIRP) exposure limit, apart from the fact that it is genotoxic by itself, significantly enhanced the genotoxic action of gamma radiation. Since gamma radiation at similar doses is applied for diagnostic and therapeutic purposes, people should be aware of the increased risk during treatment periods. Comparison of the genotoxic action between MT EMF and gamma radiation shows that the ICNIRP limits are, at least, similar to 4.5x10(4) times less stringent than the limits for gamma radiation. https://doi.org/10.4149/gpb_2023036

Stimulus effects of extremely low-frequency electric field exposure on calcium oscillations in a human cortical spheroid,
SAITO A., T. SHIINA and Y. SEKIBA, *Bioelectromagnetics* (2024 Aug 2024),
High-intensity, low-frequency (1 Hz to 100 kHz) electric and magnetic fields (EF and MF) cause electrical excitation of the nervous system via an induced EF (iEF) in living tissue. However, the biological properties and thresholds of stimulus effects on synchronized activity in a three-dimensional (3D) neuronal network remain uncertain. In this study, we evaluated changes in neuronal network activity during extremely low-frequency EF (ELF-EF) exposure by measuring intracellular calcium ([Ca2+]i) oscillations, which reflect neuronal network activity. For ELF-EF exposure experiments, we used a human cortical spheroid (hCS), a 3D-cultured neuronal network generated from human induced pluripotent stem cell (hiPSC)-derived cortical neurons. A 50 Hz sinusoidal ELF-EF exposure modulated [Ca2+]i oscillations with dependencies on exposure intensity and duration. Based on the experimental setup and results, the iEF distribution inside the hCS was estimated using high-resolution numerical dosimetry. The numerical estimation revealed threshold values ranging between 255-510 V/m (peak) and 131-261 V/m (average). This indicates that

thresholds of neuronal excitation in the hCS were equivalent to those of a thin nerve fiber. Neuronal Network Assessment: Using human cortical spheroids, we measured changes in neuronal network activity using [Ca2+]i oscillations. Electrical Stimulation Thresholds: Thresholds for electrical stimulation were determined under exposure to 50 Hz sinusoidal wave extremely low-frequency electric fields, revealing sensitivity patterns. Quantified Exposure Levels: Peak and average exposure levels were identified, providing quantifiable insights into the effects of induced electric field stimulation on neuronal network activity. https://doi.org/10.1002/bem.22521

Protective effect of radiofrequency exposure against menadione-induced oxidative DNA damage in human neuroblastoma cells: The role of exposure duration and investigation on key molecular targets,
SANNINO A., M. ALLOCCA, M. R. SCARFI, S. ROMEO and O. ZENI, *Bioelectromagnetics* (2024 Sep 2024),
In our previous studies, we demonstrated that 20 h pre-exposure of SH-SY5Y human neuroblastoma cells to 1950 MHz, UMTS signal, at specific absorption rate of 0.3 and 1.25 W/kg, was able to reduce the oxidative DNA damage induced by a subsequent treatment with menadione in the alkaline comet assay while not inducing genotoxicity per se. In this study, the same cell model was used to test the same experimental conditions by setting different radiofrequency exposure duration and timing along the 72 h culture period. The results obtained in at least three independent experiments indicate that shorter exposure durations than 20 h, that is, 10, 3, and 1 h per day for 3 days, were still capable to exert the protective effect while not inducing DNA damage per se. In addition, to provide some hints into the mechanisms underpinning the observed phenomenon, thioredoxin-1, heat shock transcription factor 1, heat shock protein 70, and poly [ADP-ribose] polymerase 1, as key molecular players involved in the cellular stress response, were tested following 3 h of radiofrequency exposure in western blot and qRT-PCR experiments. No effect resulted from molecular analysis under the experimental conditions adopted. RF exposure of human neuroblastoma cells at 1950 MHz, UMTS signal, does not induce genotoxicity per se at 0.3 and 1.25 W/kg SAR. RF exposure reduces the MD-induced genotoxicity in several time windows along the 72 h cell culture period at both SAR levels. RF exposure does not alter protein and gene expression of key molecular players involved in cellular stress response in the assay conditions adopted. https://doi.org/10.1002/bem.22524

Studies on the thermal sensitivity of lung cancer cells exposed to an alternating magnetic field and magnesium-doped maghemite nanoparticles,
SIKORSKA M., G. DOMANSKI, M. BAMBUROWICZ-KLIMKOWSKA, A. KASPRZAK, A. M. NOWICKA, M. RUZYCKA-AYOUSH and I. P. GRUDZINSKI, *Cancer Nanotechnology* 15, no. 1 (Dec 2024),
Background: Magnetic fluid hyperthermia (MFH) represents a promising therapeutic strategy in cancer utilizing the heating capabilities of magnetic nanoparticles when exposed to an alternating magnetic field (AMF). Because the efficacy and safety of MFH treatments depends on numerous intrinsic and extrinsic factors, therefore, the proper MFH setups should focus on thermal energy dosed into the cancer cells. Methods: In this study, we performed MFH experiments using human lung cancer A549 cells (in vitro) and NUDE Balb/c mice bearing human lung (A549) cancer (in vivo). In these two experimental models, the heat was induced by magnesium-doped iron(III) oxide nanoparticles coated with mPEG-silane (Mg-0.1-gamma-Fe2O3(mPEG-silane)(0.5)) when exposed to an AMF. Results: We observed that the lung cancer cells treated with Mg-0.1-gamma-Fe2O3(mPEG-silane)(0.5) (0.25 mg<middle dot>mL(-1)) and magnetized for 30 min at 14.4 kA<middle dot>m(-1) yielded a satisfactory outcome in reducing the cell viability up to ca. 21% (in vitro). The activation energy calculated for this field strength was estimated for 349 kJ<middle dot>mol(-1). Both volumetric measurements and tumor mass assessments confirmed by magnetic resonance imaging (MRI) showed a superior thermal effect in mice bearing human lung cancer

injected intratumorally with Mg-0.1-gamma-Fe2O3(mPEG-silane)(0.5) nanoparticles (3 mg<middle dot>mL(-1)) and subjected to an AMF (18.3 kA<middle dot>m(-1)) for 30 min four times at weekly intervals. Research demonstrated that mice undergoing MFH exhibited a marked suppression of tumor growth (V = 169 +/- 94 mm(3); p < 0.05) in comparison to the control group of untreated mice. The CEM43 (cumulative number of equivalent minutes at 43 degrees C) value for these treatments were estimated for ca. 9.6 min with the specific absorption rate (SAR) level ranging from 100 to 150 W<middle dot>g(-1). Conclusions: The as-obtained results, both cytotoxic and those related to energy calculations and SAR, may contribute to the advancement of thermal therapies, concurrently indicating that the proposed magnetic fluid hyperthermia holds a great potential for further testing in the context of medical applications. https://doi.org/10.1186/s12645-024-00276-0

Numerical simulation in magnetic resonance imaging radiofrequency dosimetry,
SUBAAR C., E. GYAN, K. A. DOMPREH, J. K. AMOAKO, G. EDUSEI and A. OWUSU, *Biomedical Physics & Engineering Express* 10, no. 5 (Sep 2024),
Magnetic Resonance Imaging (MRI) employs a radiofrequency electromagnetic field to create pictures on a computer. The prospective biological consequences of exposure to radiofrequency electromagnetic fields (RF EMFs) have not yet been demonstrated, and there is not enough evidence on biological hazards to offer a definite response concerning possible RF health dangers. Therefore, it is crucial to research the health concerns in reaction to RF EMFs, considering the entire exposure in terms of patients receiving MRI. Monitoring increases in temperature in-vivo throughout MRI scan is extremely invasive and has resulted in a rise in the utilization of computational methods to estimate distributions of temperatures. The purpose of this study is to estimate the absorbed power of the brain exposed to RF in patients undergoing brain MRI scan. A three-dimensional Penne's bio-heat equation was modified to computationally analyze the temperature distributions and potential thermal effects within the brain during MRI scans in the 0.3 T to 1.5 T range (12.77 MHz to 63.87 MHz). The instantaneous temperature distributions of the in-vivo tissue in the brain temperatures measured at a time, t = 20.62 s is 0.2 degrees C and t = 30.92 s is 0.4 degrees C, while the highest temperatures recorded at 1.03 min and 2.06 min were 0.4 degrees C and 0.6 degrees C accordingly. From the temperature distributions of the in-vivo tissue in the brain temperatures measured, there is heat build-up in patients who are exposed to electromagnetic frequency ranges, and, consequently, temperature increases within patients are difficult to prevent. The study has, however, indicated that lengthier imaging duration appears to be related to increasing body temperature. https://doi.org/10.1088/2057-1976/ad6a68

Investigation of genotoxicity induced by intermediate frequency magnetic field combined with ionizing radiation: In vitro study on human fibroblast cells,
SZILÁGYI Z., B. PINTÉR, E. SZABÓ, G. KUBINYI, Y. LE DREAN and G. THURÓCZY, *Mutation Research-Genetic Toxicology and Environmental Mutagenesis* 899 (Oct 2024),
These days, exposure to electromagnetic fields has become omnipresent in modern society. Not only the extremely-low frequency and radiofrequency, but also intermediate frequency (IF) magnetic field (MF) might be absorbed in the human body resulting in an ever-growing concern about their possible health effects. Devices, such as induction cooktops, chargers, compact fluorescent lamps, touchscreens and electric vehicles emit a wide range of intermediate frequency fields. We investigated the effects of 22 kHz or 250 kHz intermediate frequency magnetic field exposure on the human skin cells. We also examined the adaptive response phenomenon; whether IF MF exposure could possibly reduce the harmful genotoxic effects of ionizing radiation. To get answers to these questions, in vitro studies were carried out on fibroblast cells to investigate the effects on oxidative stress, DNA damage and micronucleus formation. We found a decreased micronucleus formation due to the 22 kHz IF MF exposure and significantly increased oxidative

stress in fibroblast cells, which were exposed only to 250 kHz IF MF. We were unable to detect the protective or co-genotoxic effects of intermediate frequency magnetic field exposure combined with ionizing radiation, thus we found no evidence for the adaptive response phenomena. https://doi.org/10.1016/j.mrgentox.2024.503817

Electromagnetic Fields Trigger Cell Death in Glioblastoma Cells through Increasing miR-126-5p and Intracellular Ca²⁺ Levels,
TEMIZ E. and M. BOSTANCIKLIOGLU, *Cell Biochemistry and Biophysics* (2024 Jul 2024),
Electromagnetic fields create potential negative implications on biological systems, including modifications to DNA structure, nuclear condensation, cellular ion transport, and intracellular Ca2+ accumulation. To explore these effects on cancer cells, we exposed prostate, glioblastoma and cervix cancer cell lines to electromagnetic fields of wireless and assessed its anti-proliferative effects. PC3, A172, and HeLa cancer cells were cultured and exposed to electromagnetic fields for 24, 48, and 72 h. We used the MTT assay to detect cell viability and proliferation, Annexin V staining to determine apoptotic cells, and confocal microscopy to measure apoptosis-mediated intracellular calcium signals. Additionally, we performed profiling for apoptosis-related miRNAs. The results indicated that the electromagnetic field triggers apoptosis in the glioblastoma cell line A172 by increasing level of miR-129-5p, a known tumor suppressor. In contrast, the cervix cancer cell line and the prostate cancer cell line remained largely unaffected. In summary, our investigation underscores that electromagnetic fields at a 2.4 GHz frequency may adversely affect certain cancer cell lines, notably triggering apoptosis in the glioblastoma cancer cell line.
https://doi.org/10.1007/s12013-024-01449-9

Cellular and Molecular Effects of Magnetic Fields,
TOTA M., L. JONDERKO, J. WITEK, V. NOVICKIJ and J. KULBACKA, *International Journal of Molecular Sciences* 25, no. 16 (Aug 2024),
Recently, magnetic fields (MFs) have received major attention due to their potential therapeutic applications and biological effects. This review provides a comprehensive analysis of the cellular and molecular impacts of MFs, with a focus on both in vitro and in vivo studies. We investigate the mechanisms by which MFs influence cell behavior, including modifications in gene expression, protein synthesis, and cellular signaling pathways. The interaction of MFs with cellular components such as ion channels, membranes, and the cytoskeleton is analyzed, along with their effects on cellular processes like proliferation, differentiation, and apoptosis. Molecular insights are offered into how MFs modulate oxidative stress and inflammatory responses, which are pivotal in various pathological conditions. Furthermore, we explore the therapeutic potential of MFs in regenerative medicine, cancer treatment, and neurodegenerative diseases. By synthesizing current findings, this article aims to elucidate the complex bioeffects of MFs, thereby facilitating their optimized application in medical and biotechnological fields. https://doi.org/10.3390/ijms25168973

The Physiological Impact of Melatonin, Its Effect on the Course of Diseases and Their Therapy and the Effect of Magnetic Fields on Melatonin Secretion-Potential Common Pathways of Influence,
WOLDANSKA-OKONSKA M. and K. KOSZELA, *Biomolecules* 14, no. 8 (Aug 2024),
Melatonin is a relic, due to its millions-of-years-old presence in chemical reactions, found in evolutionarily diverse organisms. It has a multidirectional biological function. It controls diurnal rhythms, redox homeostasis, intestinal motor functions, mitochondrial biogenesis and fetal development and has antioxidant effects. It also has analgesic and therapeutic effects. The purpose of this paper is to describe the role of melatonin in vital processes occurring in interaction with the environment, with particular reference to various magnetic fields ubiquitous in the life of animate matter, especially radio frequency/extra low frequency (RF/ELF EMF) and static magnetic fields. The most important part of this article is to describe the potential effects of magnetic fields on

melatonin secretion and the resulting possible health effects. Melatonin in some cases positively amplifies the electromagnetic signal, intensifying health effects, such as neurogenesis, analgesic effects or lowering blood pressure. In other cases, it is a stimulus that inhibits the processes of destruction and aggravation of lesions. Sometimes, however, in contrast to the beneficial effects of electromagnetic fields in therapy, they intensify pathogenic effects, as in multiple sclerosis by intensifying the inflammatory process. https://doi.org/10.3390/biom14080929

The histological and biochemical analysis of the effects of radiofrequency radiation on testis tissue of rats and the protective effect of melatonin,
YARDIM A., B. SIRAV, A. TOMRUK, S. ORUÇ, K. DELEN, D. KUZAY, C. M. SEYMEN and G. TAKE KAPLANOGLU, *Turkish Journal of Medical Sciences* 54, no. 4 (2024),
Background/aim: Primarily due to wireless communication devices, especially mobile phones, there has been a steady rise in the intensity of nonionizing radiofrequency radiation (RFR). In recent years, increased human health problems raised concerns about whether there is a positive relationship between intense exposure to RFR and public health. The present study aims to investigate the effects of GSM-like RFR exposure on the male reproductive system and the impact of melatonin treatment (synergistic, antagonist, or additive). Materials and methods: Thirty-six male Wistar Albino rats were used and separated into six groups: i. Control; ii. Sham; iii. RFR exposure; iv. Control-melatonin; v. Sham-melatonin; vi. Melatonin + RFR exposure. Animals were exposed to 2600 MHz RFR with electric (E) field levels of 21.74 V/m for 30 min per day, 5 days per week, for 4 weeks. All testicular tissue samples were evaluated under a light microscope for hematoxylin-eosin staining. Biochemical analyses were performed by measuring malondialdehyde, total nitric oxide, glutathione, and glutathione peroxidase levels. We evaluated the combined effects of prolonged RFR exposure and melatonin treatment on ROS-mediated structural changes in testicular tissues. Results: Results showed that reactive intermediates (malondialdehyde and total nitric oxide) increased significantly with RFR exposure, while the protective effect of melatonin effectively reduced the radical levels of the tissues. Histological evaluation revealed a decrease in cell population and connective tissue elements under RFR exposure, accompanied by marked edema in the testicular tissues. Conclusion: The structural and functional effects of prolonged RFR exposure might be ROS-based. Moreover, these adverse effects might be compensated with externally treated supplements. There is a need for new extensive research.
https://doi.org/10.55730/1300-0144.5857

Méthodes

Scalar Measurements of 5G mm-Wave EMF Power in NLoS Propagation
ADDA S., V. BOTTURA, S. D'ELIA, N. PASQUINO, R. SUMAN, M. VACCARONO and IEEE (2024). IEEE International Symposium on Measurements and Networking (M and N), Rome, ITALY.
We present a methodology for on-site measurements of electromagnetic fields (EMFs) exposure of 5G base stations (BSs) operating in the millimeter-wave (mm-wave) frequency range (24.5-52.6 GHz) that extends the one introduced by the authors in previous work to mm-wave frequencies and Non-Line-of-Sight (NLoS) propagation. The impact of omnidirectional and directional antennas on measurements in the new measurement conditions is examined. This investigation marks the first instance of such a comprehensive analysis. Results indicate that measurement techniques devised for frequencies below 6 GHz under Line-of-Sight (LoS) conditions can generally be applied in the mm-wave range. However, in an NLoS scenario, it is suggested that omnidirectional antennas are employed, as directional ones require an initial evaluation to align the probe with the direction of

the strongest signal. This work has significance for standardization bodies developing methodologies to measure exposure from new-generation mobile network BSs. https://doi.org/10.1109/mn60932.2024.10615587

Measuring and simulation of magnetic field generated by high voltage overhead transmission lines,
AHSAN M., M. N. R. BAHAROM, Z. ZAINAL and I. U. KHALIL, *Results in Engineering* 23 (Sep 2024), Overhead transmission lines produce significant Magnetic Fields (MF).MF impact is crucial for Overhead Transmission lines (OTL) design because of health concerns regarding radiation effects because they can induce electrical currents within the human body. This paper presents the MF measurement results underneath OTL in two different locations and periods in Malaysia. The first site consisted of two 132 kV double-circuit transmission lines, while the second site contained a 132 kV double-circuit line and a 132 kV quadruple-circuit system. The measurements are conducted in December 2023 and February 2024. The measured MF levels are presented via graphs to facilitate the localization of zones with high-intensity MF. The study found that areas beneath the transmission lines with the highest levels of MF intensities were identified by analyzing the measured results. In the first site, for both double and quadruple circuits, the maximum RMS magnetic flux density level is 2.81 mu T, and in the second site, for double circuits is 3.5 mu T. For validation of the measurement results, MF is simulated using ANSYS Electronics based on IEEE standards, CIGRE, and other researchers. The measurement outcomes closely matched the simulated MF with very few errors for both double-circuit and quadruple-circuit measurements, as well as for two double-circuit measurements. The simulated and measured MFs were compared with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) limit in occupational and general exposure values. The study found that the measurement outcome closely matched the simulated MF under the ICNIRP limit. https://doi.org/10.1016/j.rineng.2024.102688

Electromagnetic simulation and electromagnetic safety characteristics analysis of implantable medical devices in wireless charging processes,
CHE K., P. YANG, P. LUO, J. X. YU, H. P. HOU, X. N. NIU, Y. Q. GONG and C. M. CHEN, *Journal of Computational Methods in Sciences and Engineering* 24, no. 4-5 (2024): 2357-2374,
In recent years, wireless charging technology for electric vehicles has received increasing attention. Existing research has been limited to the safety of specific body parts in the electromagnetic environment of wireless charging for electric vehicles, with insufficient consideration for the overall human body and the electromagnetic safety of implanted medical devices. In order to assess its safety in the electromagnetic environment more comprehensively, a three-dimensional electromagnetic simulation software based on the finite element method is used to construct models of the human body and implanted medical devices in the electromagnetic environment of wireless charging for electric vehicles. The study aims to investigate the impact of this electromagnetic environment on the human body and implanted medical devices. The results indicate that, except for the maximum magnetic induction of 0.47 mu T at the ankle, which exceeds the limit, the magnetic induction intensity and electric field strength in important tissue areas, especially the upper trunk of the human body, are both below the safety limits specified by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. For implanted cardiac pacemakers, the effective and peak magnetic field strengths are 13.7 A/m and 19.4 A/m, respectively, when the coil input power is 22 kW, meeting the relevant magnetic field strength requirements. The maximum temperature rise of the pacemaker is 3.2 x 10(-3 degrees)C, and there are no significant changes in the temperature of the major organs in the human body after the implantation of the pacemaker. The thermal effects of electromagnetic waves on the temperature rise caused by implanted cardiac pacemakers have minimal impact on the human body. https://doi.org/10.3233/jcm-247457

Electromagnetic Field Exposure-Aware AI Framework for Integrated Sensing and Communications-Enabled Ambient Backscatter Wireless Networks,
JAMSHED M. A., Y. A. QADRI, A. NAUMAN and H. JUNG, *Ieee Internet of Things Journal* 11, no. 18 (Sep 2024): 29252-29259,
An exponential increase in the volume of connected user proximity wireless devices (UPWDs) is spearheading a hyper-connected ecosystem, which may enable smart cities, industries, and connected healthcare. However, this increase in the number of connected UPWDs results in significant amplification in electromagnetic field (EMF) exposure among users and consequently may result in potential physiological effects. Integrated sensing and communication (ISAC)-enabled ambient backscatter communication (ABC) is a promising technology that can power low-energy sensors and facilitate communication between data sources and sinks by reusing the available resources. The power-domain nonorthogonal multiple access (PD-NOMA) has the potential to provide channel resources to an increasing number of users simultaneously while adhering to the Quality-of-Service (QoS) requirements. However, empowering PD-NOMA with machine learning (ML) can mitigate challenges in massive channel access. This work uses a k-medoid and Silhouette analysis for subcarrier allocation and optimizes power allocation to the users with optimization techniques using PD-NOMA in an ABC-enabled cellular network. The proposed system demonstrates a significant capability to reduce the aggregated uplink EMF exposure using robust and low-complexity ML techniques. The simulations show a superior performance compared to the state-of-the-art methods. https://doi.org/10.1109/jiot.2024.3394041

Monitoring the time-variability of electromagnetic exposure due to mobile radio communication emissions using narrow-bandwidths data loggers
KARPOWICZ J., S. MICLAUS and IEEE (2024). IEEE International Symposium on Measurements and Networking (M and N), Rome, ITALY.
Analyzing measurements performed by equipment, differing in sensitivity and sample recording rates, belongs to key problems in long duration monitoring of electromagnetic exposure. Parameters of descriptive statistics, Weibull distribution and Poincare maps, were applied to the relevant databases of electric field strength values recorded simultaneously in the same microenvironment (in fast train cars, with dominating exposure from travelers' terminals for mobile communication, i.e. GSM 900 and LTE 1800 up link emissions) by three types of data loggers operating at various sample recording rates. Analyzed case of exposure to uplink emissions significantly differs from down link cases in the majority of environmental studies. The combination of used analytical tools provided comprehensive parameterizing and comparing the results from various data loggers, which were found to be insignificantly different (over particular range of percentiles) when measurements were performed in the same microenvironment. It confirmed reliability of used equipment for comparative monitoring electromagnetic exposure (despite differences in sensitivity and recording rate). The study's methodology and findings provide a solid foundation for ongoing research and monitoring efforts into better understanding of electromagnetic exposure in specific microenvironments and required monitoring strategies.
https://doi.org/10.1109/mn60932.2024.10615726

RF Human Exposure Mitigation in a Fusion Radar WPT System
MEHRJOUSERESHT P., O. J. BABARINDE, D. SCHREURS and IEEE (2024). IEEE MTT-S International Microwave Biomedical Conference (IMBioC), Montreal, CANADA.
This paper presents a Fusion Radar Wireless Power Transfer (FRWPT) system, which incorporates radar technology to prevent RF human exposure during wireless powering. The system operates by using a radar to detect a person's location and then estimating the power density (PD) accordingly. If the power exceeds RF exposure limits, the WPT system's transmitted power is controlled to

prevent exposure. We propose an algorithm that dynamically modifies the WPT transmitter's output power based on the person's detected location to not only reduce the dangerous radiation but also maximize the transmitted power. Our experimental indoor measurements demonstrate the system's effectiveness in maintaining the PD below safety thresholds, regardless of varying distances and angles relative to the WPT system.
https://doi.org/10.1109/imbioc60287.2024.10590368

Safeguarding Humans From Indoor Wireless Powering via Radar Detection,
MEHRJOUSERESHT P., O. J. BABARINDE, V. VOLSKI, A. Y. SVEZHENTSEV and D. SCHREURS, *Ieee Journal of Electromagnetics Rf and Microwaves in Medicine and Biology* (2024 Aug 2024),
Ensuring the safety of electromagnetic exposure stands as an important concern in wireless power transfer (WPT) systems. This work proposes a distributed Fusion Radar WPT (FRWPT) system designed to maintain safe Electric Field Amplitude (EFA) levels at specific locations detected by the radar, primarily where an individual is present. This approach allows for higher EFA in areas without the person, thus optimizing overall power utilization within the system. Also, the radar's ability to detect a person's velocity allows for projecting the person's upcoming location to ensure safety in advance. We introduce an algorithm including power weighting factors for controlling power to not only mitigate dangerous radiation but also maximize power utilization. One significant challenge is the estimation of EFA considering multipath propagation, a common issue in indoor environments. To overcome this, we explore the indoor EFA distribution and suggest a simulation-based method for EFA estimation, taking into account the amplifying effect of the human body on EFA. Experimental results demonstrate that the system successfully maintains EFA below a predefined threshold across various human locations. Moreover, these experiments highlight the system's capability to maximize power utilization ratio (PUR), achieving a value exceeding 50%.
https://doi.org/10.1109/jerm.2024.3447469

Near Field Scatter from a Body of Revolution,
MICHAELCHUCK E. C., JR., S. G. LAMBRAKOS and W. O. COBURN, *Applied Computational Electromagnetics Society Journal* 39, no. 5 (May 2024): 376-389,
Better understanding of electromagnetic wave propagation through vegetation and forest environments can be achieved with the aid of modeling and simulation. Specifically, modeling the coherent summation of electromagnetic waves due to both single scatter and multi-scatter effects. To accurately perform simulations in lower frequency bands, S-band and below, the Body of Revolution (BOR) Method of Moments (MoM) must be extended to calculate the scattered electric and magnetic near-fields from BOR in the presence of a plane wave. The near field interactions specifically occur during the various higher order scattering harmonics, i.e. 2 nd order and greater harmonics. Additionally, the method must accurately capture scattered fields in the presence of a non-plane wave incident upon BOR. The focus of this study is modeling lossy dielectric BOR that are characteristic of vegetation and forest environments, e.g., cylinders representing tree branches. Although the formal electric and magnetic field scattering definitions are known, this report presents analytical formulations of near field scattering from BOR for this implementation of BOR-MoM. The scattered-field extensions are validated using the commercial software FEKO (c), which simulates electromagnetic-wave scattering in 3D using MoM formulation of scattered fields.
https://doi.org/10.13052/2024.Aces.J.390501

Development of Measurement Phantom for Absorbed Power Density Assessment by Human Exposure at 28 GHz Band,
NISHIHARA D., K. SASAKI, R. BAHARIN, T. NAGAOKA, O. HASHIMOTO and R. SUGA, *Ieee Journal of Electromagnetics Rf and Microwaves in Medicine and Biology* (2024 Sep 2024),

In recent years, the guidelines/standards of human exposures to electromagnetic fields have been revised and a new metric referred to as absorbed/epithelial power density (APD) is specified as the basic restriction in the frequency range from 6 to 300 GHz. In this paper, we focus on the development of low-loss phantoms that can model the electromagnetic interaction between an antenna/device and skin in the quasi-millimeter and millimeter-wave frequencies using electromagnetic simulation. The phantom will be used for APD assessment based on field measurement at 28 GHz. It was found that polyphenylene-ether (PPE), which is typically used for antenna substrates, enables the accurate assessment of APD on the skin surface regardless of the antenna type, and that it is rendered suitable as a phantom for APD assessment by optimizing the thickness of low-loss materials with respect to relative permittivity in the range from 10 to 28.5 at 28 GHz. https://doi.org/10.1109/jerm.2024.3419026

Extremely low-frequency electromagnetic fields from indoor transformers: a review of occupational and residential exposure assessment studies,
RATHEBE P. C., N. MATJUTLA, V. NDWANDWE and T. MAFA, *Cogent Engineering* 11, no. 1 (Dec 2024),
The widespread use of electrical and electronic devices in the 21st century has been attributed to human exposure to electromagnetic fields (EMFs), and potential public health threats. Amongst other electrical devices, indoor transformer stations have exposed both general public and workers to potentially high levels of extremely low-frequency electromagnetic fields (ELF-EMFs), resulting in acute and severe health implications. In this review, the health effects resulting from occupational and residential exposure to ELF-EMFs from indoor transformer stations were assessed by synthesizing evidence from published studies. Population, Exposure, Comparison and Outcome (PECO) framework was used as a guide in documenting the evidence, and Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) to select studies that match the inclusion criteria. Following the PRISMA guide, a total of 13 studies formed part of this review. Highest magnetic field (MF) exposure level found from a residential exposure assessment study was 11.60 mu T, 0.2 m above the transformer station, with the lowest at 0.1 mu T due to household electrical appliances. Occupational exposure assessment revealed the highest exposure level of 4.67 mu T in the transformer room and lowest at >0.05 mu T. Cancer was mostly prevalent in residential studies with longer exposure period (>34 years), and with non-specific exposure symptoms (3 years and 18 months exposure period) within occupational exposure studies. This review found insufficient evidence to suggest the average exposure levels of ELF EMF from indoor transformers, which could pose significant health risks. However, these findings have a noteworthy implication for environmental health and occupational safety.
https://doi.org/10.1080/23311916.2024.2399302

Enhancing Predictive Models for Assessing 5G Exposure Effects on Human Health and Cognition through Supervised Machine Learning: A Multi-Stage Feature Selection Approach,
SOFRI T., A. M. ANDREW, H. A. RAHIM, H. NISHIZAKI, L. M. KAMARUDIN, P. W. WONG and P. J. SOH, *Przeglad Elektrotechniczny* 100, no. 6 (2024): 122-128,
No prior reviews have focused on any comprehensively examine the effects of 5G exposure (700 MHz to 30 GHz) on human health and cognition using supervised Machine Learning (ML). This novel research combined the Multi -Stage Feature Selection (MSFS) and hybrid features for classification machine learning model. The approach which includes the use of MSFS, yielded better results in terms of accuracy, precision, F1-score, sensitivity, and specificity when contrasted with the approach that did not incorporate MSFS with accuracy more than 0.95 for both datasets.
https://doi.org/10.15199/48.2024.06.23

Toxicité sur les animaux

Effects of Head-Only Exposure to 900 MHz GSM Electromagnetic Fields in Rats: Changes in Neuronal Activity as Revealed by c-Fos Imaging without Concomitant Cognitive Impairments, BONTEMPI B., P. LÉVÊQUE, D. DUBREUIL, T. M. JAY and J. M. EDELINE, *Biomedicines* 12, no. 9 (Sep 2024),
Over the last two decades, animal models have been used to evaluate the physiological and cognitive effects of mobile phone exposure. Here, we used a head-only exposure system in rats to determine whether exposure to 900 MHz GSM electromagnetic fields (EMFs) induces regional changes in neuronal activation as revealed by c-Fos imaging. In a first study, rats were exposed for 2 h to brain average specific absorption rates (BASARs) ranging from 0.5 to 6 W/kg. Changes in neuronal activation were found to be dose-dependent, with significant increases in c-Fos expression occurring at BASAR of 1 W/kg in prelimbic, infralimbic, frontal, and cingulate cortices. In a second study, rats were submitted to either a spatial working memory (WM) task in a radial maze or a spatial reference memory (RM) task in an open field arena. Exposures (45 min) were conducted before each daily training session (BASARs of 1 and 3.5 W/kg). Control groups included sham-exposed and control cage animals. In both tasks, behavioral performance evolved similarly in the four groups over testing days. However, c-Fos staining was significantly reduced in cortical areas (prelimbic, infralimbic, frontal, cingulate, and visual cortices) and in the hippocampus of animals engaged in the WM task (BASARs of 1 and 3.5 W/kg). In the RM task, EMF exposure-induced decreases were limited to temporal and visual cortices (BASAR of 1 W/kg). These results demonstrate that both acute and subchronic exposures to 900 MHz EMFs can produce region-specific changes in brain activity patterns, which are, however, insufficient to induce detectable cognitive deficits in the behavioral paradigms used here.
https://doi.org/10.3390/biomedicines12091954

Short and long-term 2100 MHz radiofrequency radiation causes endoplasmic reticulum stress in rat testis,
KIRIMLIOGLU E., A. O. OFLAMAZ, E. HIDISOGLU, S. OZEN, P. YARGICOGLU and N. DEMIR, *Histochemistry and Cell Biology* 162, no. 4 (Oct 2024): 311-321,
Long-term radiofrequency radiation (RFR) exposure, which adversely affects organisms, deteriorates testicular functions. Misfolding or unfolding protein accumulation in the endoplasmic reticulum (ER) initiates an intracellular reaction known as ER stress (ERS), which activates the unfolded protein response (UPR) for proteostasis. Since both RFR exposure and ERS can cause male infertility, we hypothesized that RFR exposure causes ERS to adversely affect testicular functions in rats. To investigate role of ERS in mediating RFR effects on rat testis, we established five experimental groups in male rats: control, short-term 2100-megahertz (MHz) RFR (1-week), short-term sham (sham/1-week), long-term 2100-MHz RFR (10-week), and long-term sham (sham/10-week). ERS markers Grp78 and phosphorylated PERK (p-Perk) levels and ERS-related apoptosis markers Chop and caspase 12 were investigated by immunohistochemistry, immunoblotting, and quantitative real-time polymerase chain reaction (qPCR). Long-term RFR exposure increased Grp78, p-Perk, and Chop levels, while short-term RFR exposure elevated Chop and caspase 12 levels. Chop expression was not observed in spermatogonia and primary spermatocytes, which may protect spermatogonia and primary spermatocytes against RFR-induced ERS-mediated apoptosis, thereby allowing transmission of genetic material to next generations. While short and long-term RFR exposures trigger ERS and ERS-related apoptotic pathways, further functional analyses are needed to elucidate whether this RFR-induced apoptosis has long-term male infertility effects. Long-term radiofrequency radiation in testis triggers endoplasmic reticulum stress.Short-term radiofrequency

radiation causes apoptosis in testis.Spermatogonia and spermatocytes are not affected by short-term radiofrequency radiation. https://doi.org/10.1007/s00418-024-02308-7

Impact of Extremely Low-Frequency Electromagnetic Fields on Skeletal Muscle of Sedentary Adult Mice: A Pilot Study,
MORABITO C., N. DI SINNO, M. A. MARIGGIÒ and S. GUARNIERI, *International Journal of Molecular Sciences* 25, no. 18 (Sep 2024),
Extremely low-frequency electromagnetic fields (ELF-EMFs) are ubiquitous in industrialized environments due to the continuous use of electrical devices. Our previous studies demonstrated that ELF-EMFs affect muscle cells by modulating oxidative stress and enhancing myogenesis. This pilot study investigated these effects on the skeletal muscles of sedentary adult mice, assessing physiological responses to ELF-EMF exposure and potential modulation by antioxidant supplementation. Male C57BL/6 mice were exposed to ELF-EMFs (0.1 or 1.0 mT) for 1 h/day for up to 5 weeks and fed a standard diet without or with N-acetyl-cysteine (NAC). The results showed transient increases in muscle strength (after 2 weeks of exposure at 1.0 mT), potentially linked to muscle fiber recruitment and activation, revealed by higher PAX7 and myosin heavy chain (MyH) expression levels. After ELF-EMF exposure, oxidative status assessment revealed transient increases in the expression levels of SOD1 and catalase enzymes, in total antioxidant capacity, and in protein carbonyl levels, markers of oxidative damage. These effects were partially reduced by NAC. In conclusion, ELF-EMF exposure affects skeletal muscle physiology and NAC supplementation partially mitigates these effects, highlighting the complex interactions between ELF-EMFs and antioxidant pathways in vivo. Further investigations on ELF-EMFs as a therapeutic modality for muscle health are necessary. https://doi.org/10.3390/ijms25189857

Characterising core body temperature response of free-moving C57BL/6 mice to 1.95 GHz whole-body radiofrequency-electromagnetic fields,
SYLVESTER E., C. DENG, R. MCINTOSH, S. ISKRA, J. FRANKLAND, R. MCKENZIE and R. J. CROFT, *Bioelectromagnetics* (2024 Oct 2024),
The present study investigated the core body temperature (CBT) response of free-moving adult male and female C57BL/6 mice, during and following a 2-h exposure to 1.95 GHz RF-EMF within custom-built reverberation chambers, using temperature capsules implanted within the intraperitoneal cavity and data continuously logged and transmitted via radiotelemetry postexposure. Comparing RF-EMF exposures (WBA-SAR of 1.25, 2.5, 3.75, and 5 W/kg) to the sham-exposed condition, we identified a peak in CBT within the first 16 min of RF-EMF exposure (+0.15, +0.31, +0.24, +0.37 degrees C at 1.25, 2.5, 3.75, and 5 W/kg respectively; statistically significant at WBA-SAR >= 2.5 W/kg only), which largely dissipated for the remainder of the exposure period. Immediately before the end of exposure, only the CBT of the 5 W/kg condition was statistically differentiable from sham. Based on our findings, it is apparent that mice are able to effectively compensate for the increased thermal load at RF-EMF strengths up to 5 W/kg. In addition, the elevated CBT at the end of the exposure period in the 5 W/kg condition was statistically significantly reduced compared to the sham condition immediately after RF-EMF exposure ceased. This would indicate that measures of CBT following the end of an RF-EMF exposure period may not reflect the actual change in the CBT of mice caused by RF-EMF exposure in mice. Exposure of 1.95 GHz electromagnetic fields at 5 W/kg whole-body average specific absorption rate increases core body temperature by 0.4 degrees C. The increased thermal energy at 3.75 W/kg is effectively managed by thermoregulation (max increase = 0.24 degrees C). An extended habituation period prior to RF-EMF exposure is necessary to account for the large effect of handling on mice core body temperature. https://doi.org/10.1002/bem.22527

Rat brain and testicular tissue effects of radiofrequency radiation exposure: Histopathological, DNA damage of brain and qRT-PCR analysis,
YAVAS M. C., A. KILITCI, E. ÇELIK, K. YEGIN, B. SIRAV and S. VAROL, *International Journal of Radiation Research* 22, no. 3 (Jul 2024): 529-536,
Background: : The Background: We evaluate the effects of radiofrequency electromagnetic field (RF-EMF) on rat brain and testicular tissue using histopathology, comet assay, and real-time quantitative PCR techniques. Materials and Methods: Two equal groups of fourteen rats one for sham-control and the other for exposure (n = seven) were created. For a duration of 14 days, the exposure group (2100 MHz, testicular tissue SAR values of 163 mW/kg for 10 g, brain tissue SAR values of 292 mW/ kg on average) was subjected to five hours of exposure per day. Evaluations were conducted on tissue gene expression levels, histopathology, and DNA damage to brain tissue. Results: The histological examination of brain tissue from the exposed group revealed vascular alterations and significant edema ($p < 0.05$). It was determined that RF radiation-induced much more cellular damage in the exposed group (18.26% tail DNA) than in the control group (4.06% tail DNA). Signs of deterioration in spermatogenic cells in the testicular tissue of the exposed group also changed significantly ($p < 0.05$). The Bax and bcl-2 genes showed a significant difference ($p < 0.05$) in the mRNA level data, whereas the p53 genes showed no significant change ($p > 0.05$). Conclusion: These findings suggest that it may cause some histopathological and cellular damage in brain and testis tissue. https://doi.org/10.61186/ijrr.22.3.529

Actualité, société et mesures de prévention

Radiation information, protection and awareness of healthcare professionals in terms of occupational health and safety: a two-center survey study,
ÇETIN M. E., M. M. AKBAS, N. BAYRAM, M. CANDEMIR and S. ARAS, *Journal of Radiological Protection* 44, no. 4 (Dec 2024),
The objective of this study was to assess the level of knowledge, protection and awareness of radiation among healthcare professionals. A total of 413 healthcare professionals from two major training and research hospitals in Istanbul took part in the study. The sample consisted of 26.6% physicians and 73.4% other healthcare professionals. There was considerable variation in the knowledge of radiation content in imaging techniques, with correct response rates of 89.3% for Computed Tomography, 80.1% for digital x-ray, and 52.8% for Magnetic Resonance Imaging. While 69.5% of respondents provided correct answers to questions regarding radiation protection principles, 64.4% demonstrated a lack of sufficient knowledge in this area. It is noteworthy that 48.4% of respondents incorrectly identified the medical imaging technique to which the public is most exposed. It was concluded that further training on radiation-related issues should be provided at the university level and through in-service training for healthcare professionals.
https://doi.org/10.1088/1361-6498/ad8204

Virtual reality for training on measuring human exposure to electromagnetic fields around cellular base stations,
CUIÑAS I., I. GONZÁLEZ-ALONSO, I. EXPÓSITO, M. GARCÍA-SÁNCHEZ and P. TORIO, *Computer Applications in Engineering Education* (2024 Sep 2024),
Assessing of human exposure to electromagnetic field is one of the tasks of a telecommunication engineer. This activity has significant social interest, as the measured levels must comply with health safety limits. It is also an appealing area for students as it integrates concepts related to radiofrequency, antennas, and propagation, both theoretically and practically. We offer our

students practical activities for measuring field levels, using test and measurement equipment. Additionally, we have developed a virtual reality tool to enhance our students' skills in this area, which is presented in this paper. We compare the learning outcomes of two separate groups of students to validate the performance of this new tool. The first group attended a lesson with theoretical content and then performed outdoor measurements. The second group had the added virtual reality experience before using the test equipment. Quantitative results show an improvement in the assimilation of the concepts, and qualitative feedback from the users confirms the effectiveness of this approach. https://doi.org/10.1002/cae.22798

Construction of heterojunction MXene/RGO/CoFe-LDH for electromagnetic wave absorption, DING G. X., C. F. SUN, M. Y. WANG, Y. X. HU, G. J. CHENG and J. LIU, *Materials Research Bulletin* 181 (Jan 2025),
The 2D nanomaterial has been widely used in the field of electromagnetic wave absorption because of its high specific surface area and special electrical properties. In this work, three 2D materials were integrated to form a unique ternary composite with Ti3C2Tx MXene as the substrate, RGO as the intercalator with additional components, and CoFe-LDH loaded on the MXene/RGO surface. The interfacial and dipole polarizations were notably enhanced due to the abundant formation of heterogeneous interfaces between the three 2D materials and their corresponding abundant functional groups and defects, and the space between the 2D lamellae enabled multiple reflections of electromagnetic waves. Compared with pure MXene, the MXene/RGO/CoFe-LDH composites exhibited excellent electromagnetic wave absorption performance due to the synergy of multiple loss mechanisms, resulting in the best reflection loss value of -58.9 dB at 13.12 GHz.
https://doi.org/10.1016/j.materresbull.2024.113121

Exploring edible bird nest's potential in mitigating Wi-Fi's impact on male reproductive health, MALUIN S. M., F. H. F. JAFFAR, K. OSMAN, A. F. ZULKEFLI, M. F. M. ROS and S. F. IBRAHIM, *Reproductive Medicine and Biology* 23, no. 1 (Jan 2024),
Purpose: This study aimed to evaluate the protective effects of edible bird nest (EBN) against the detrimental impact of Wi-Fi on male reproductive health. Specifically, it examines whether EBN can mitigate Wi-Fi-induced changes in male reproductive hor-mones, estrogen receptors (ER), spermatogenesis, and sperm parameters.Methods: Thirty-six adult male rats were divided into six groups (n= 6): Control, Control EBN, Control E2, Wi-Fi, Wi-Fi+EBN, and Wi-Fi+E2. Control EBN and Wi- Fi+EBN groups received 250 mg/kg/day EBN, while Control E2 and Wi- Fi+E2 groups received 12 mu g/kg/day E2 for 10 days. Wi- Fi exposure and EBN supplementation lasted eight weeks. Assessments included organ weight, hormone levels (FSH, LH, testosterone, and E2), ER alpha/ER beta mRNA and protein expression, spermatogenic mark-ers (c-KIT and SCF), and sperm quality.Results: Wi-Fi exposure led to decreased FSH, testosterone, ER alpha mRNA, and sperm quality (concentration, motility, and viability). EBN supplementation restored serum FSH and testosterone levels, increased serum LH levels, and the testosterone/E2 ratio, and normalized mRNA ER alpha expression. Additionally, EBN increased sperm con-centration in Wi-Fi-exposed rats without affecting motility or viability.Conclusions: EBN plays a crucial role in regulating male reproductive hormones and spermatogenesis, leading to improved sperm concentration. This could notably ben-efit men experiencing oligospermia due to excessive Wi-Fi exposure
https://doi.org/10.1002/rmb2.12606

The EU Directive on Electromagnetic Fields-Practical Experience of Field Measurements, MILD K. H., *Applied Sciences-Basel* 14, no. 16 (Aug 2024),
The EU directive on exposure to electromagnetic fields was published in 2004, but due to some problems it was not introduced in the EU countries before 2016. However, still today, many companies are not aware of the legislation and have not taken measures to comply. This could

perhaps be due to some of the practical problems they are facing in trying to comply. Here, we address some of these problems, such as showing compliance with the action levels for non-sinusoidal extremely low-frequency magnetic fields, time-averaging for the initial start-up current of handheld machines and time-averaging of radiofrequency fields when measuring plastic welding machines, including the uncertainty in the measurements. Finally, we discuss some of the problem concerning workers with special needs. https://doi.org/10.3390/app14167064

Effects of website-based risk communication of radio-frequency electromagnetic fields on general public,
YAMAGUCHI-SEKINO S., K. KAMEGAI, M. IKUYO, M. TAKI, T. ONISHI and S. WATANABE, *Frontiers in Public Health* 12 (Sep 2024),
Background Radio-frequency electromagnetic fields (RF-EMFs) are utilized in communications and appliances and are indispensable in daily life. However, some people have concerns about the adverse health effects of RF-EMFs; therefore, effective risk communication (RC) is needed in this field.Objective In this study, we investigate public attitudes towards RF-EMFs and examine the impact of RC via a website on these attitudes and objective knowledge.Methods Three web surveys were conducted over 10 weeks with the same participants. The questionnaires were conducted at three different time points with 5-week intervals: baseline survey (T1), RC evaluation survey (T2), and follow-up survey (T3). Participants of T2 were randomly recruited from among those of T1, and participants of T3 were randomly selected from among the T2 respondents. Approximately half of the respondents in each of T2 and T3 were assigned to the control group. Twelve items regarding attitudes toward RF-EMFs and objective knowledge were evaluated in all surveys (T1-T3). After removing low-engagement data, the number of valid answers was 782 in T3. Differences between T1 and T2 (Sub T1-T2) and T1 and T3 (Sub T1-T3) were analyzed. Participant selection was randomized and the authors were blind to this selection until analysis.Results Four clusters were identified: Cluster 1 (Non-anxious, 25.0%), Cluster 2 (Anxious, 16.0%), Cluster 3 (Low-interest, 40.5%), and Cluster 4 (High-interest, 18.5%). A decrease in subjective RF-EMF exposure levels was noted in Cluster 2 immediately after website viewing. Temporary increases and decreases in health concerns about RF-EMF usage activities were observed in Clusters 1 and 2, respectively, immediately after viewing. Clusters 1 and 3 showed a temporal decrease in needs for RF-EMF usage activities at T2 but it returned to the baseline level 5 weeks later. Cluster 4 was less responsive to the risk communication. Subanalysis stratified by gender and age showed fluctuations in responses, especially in Clusters 1 and 2.Conclusion We demonstrate the effectiveness of RF-EMF risk communication via websites, particularly for Cluster 2. The results of this study showed that offering objective and comprehensible information through a website can significantly reduce concerns and perceived risks related to RF-EMFs. https://doi.org/10.3389/fpubh.2024.1438986