Hybrid & Electric Cars: Electromagnetic Radiation Risks

Hybrid and electric cars may be cancer-causing as they emit extremely low frequency (ELF) electromagnetic fields (EMF). Recent studies of the EMF emitted by these automobiles have claimed either that they pose a cancer risk for the vehicles' occupants or that they are safe.

Unfortunately, much of the research conducted on this issue has been industry-funded by companies with vested interests on one side of the issue or the other which makes it difficult to know which studies are trustworthy.

Meanwhile, numerous peer-reviewed laboratory studies conducted over several decades have found biologic effects from limited exposures to ELF EMF. These studies suggest that the EMF guidelines established by the self-appointed, **International Commission on Non-Ionizing Radiation Protection** (ICNIRP) are inadequate to protect our health. Based upon the research, more than 250 EMF experts have signed the **International EMF Scientist Appeal** which calls on the World Health Organization to establish stronger guidelines for ELF and radio frequency EMF. Thus, even if EMF measurements comply with the ICNIRP guidelines, occupants of hybrid and electric cars may still be at increased risk for cancer and other health problems.

Given that magnetic fields have been considered **"possibly carcinogenic" in humans** by the International Agency for Research on Cancer of the World Health Organization since 2001, the precautionary principle dictates that we should design consumer products to minimize consumers’ exposure to ELF EMF. This especially applies to hybrid and electric automobiles as drivers and passengers spend considerable amounts of time in these vehicles, and health risks increase with the duration of exposure.

In January 2014, **SINTEF**, the largest independent research organization in Scandinavia, proposed manufacturing design guidelines that could reduce the magnetic fields in electric vehicles (see below). All automobile manufacturers should follow these guidelines to ensure their customers' safety.

The public should demand that governments adequately fund high-quality research on the health effects of electromagnetic fields that is independent of industry to eliminate any potential conflicts of interest. In the U.S., a major national research and education initiative could be funded with as little as a 5 cents a month fee on mobile phone subscribers.

Following are summaries and links to recent studies and news articles on this topic.

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6/18/2024 Note: The following paper was just published. Also see below a 2020 European Commission study I just added to this post, "Assessment of low frequency magnetic fields in electrified vehicles."

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Do non-ionizing radiation concerns affect people's choice between hybrid and traditional cars?

Anat Tchetchik, Sigal Kaplan, Orit Rotem-Mindali O. Do non-ionizing radiation concerns affect people's choice between hybrid and traditional cars? Transportation Research Part D: Transport and Environment, Volume 131, 2024, doi: 10.1016/j.trd.2024.104226.

Abstract

The growing market for hybrid electric vehicles (HEV) has raised concerns about the long-term impacts of non-ionizing radiation (NIR) exposure. This study is the first to address the impact of NIR on consumer choice between HEV and internal combustion engine (ICE) vehicles. We explore the hypothesis that NIR is associated with a lower probability of HEV choice in the presence of NIR information and the relative effect of NIR-health concerns versus environmental attitudes and driving norms. The data are collected from a stated choice experiment and estimated via a hybrid choice model. The results show that i NIR is associated with a lower choice probability of HEV, ii NIR-dread is associated with a higher probability of choosing ICE vehicles, while skepticism about NIR is associated with a higher probability of choosing HEV, iii prompting positively or negatively framed information about NIR discourages HEV choice compared to providing no information.

Conclusions and policy recommendations

The results show the effect of NIR-associated barriers on the choice of HEV versus ICE and highlight the following policy recommendations.

First, the massive production of EVs combined with the lack of regulatory frameworks can lead to the introduction of low-cost car models with low NIR safety standards (Trentadue et al., 2020). The European Union recommends a clear regulatory framework and international standards to promote the transition toward EVs. This study showed that NIR levels negatively affect the choice of HEV, signaling to car manufacturers and policymakers that consumers are concerned about NIR levels. Accordingly, setting NIR safety standards and maintaining low NIR levels are important goals for the transition toward autonomous, connected, electric vehicles.

Second, this study showed that while NIR dread was a discouraging factor, NIR skepticism was a strong choice motivator. Thus, perceived occurrence probability is as important as NIR risk dread. As with other health issues, prevalence across the population is an important decision-making factor that, in the absence of information, may lead to self-exemption beliefs. Scientific evidence from large-scale studies regarding both short- and long-term NIR effects and their prevalence in the population and among risk groups will enable informed decision-making, help mitigate NIR dread, and establish meaningful guidelines for in-vehicle NIR levels. With climate goals requiring the transition toward EV by 2030 and with the rapid

technological advancement of autonomous, connected, electric vehicles, establishing the prevalence of NIR short- and long-term health effects is important for the future of the industry.

Third, better information quality strengthens the relationship between the depiction of new vehicle technologies and perceived purchase value (Zhang et al., 2022). Our study showed that both positive and negative framing can lead to a lower choice probability when an NIR safety threshold is provided. In this study, the information that "Studies show that long-term exposure to NIR levels below 4 mG is safe" was associated with lower choice probabilities, similar to the case of negative framing, "Studies show that long-term exposure to NIR levels below 4 mG increases the health risks to health concerns." Policymakers and manufacturers must consider information quality in terms of accuracy, clarity, ambiguity, and potential sources of confusion and decision bias. In this study, consumers used the provided threshold of 4 mG as a decision anchor, which means that consumers in some cultural contexts seek clear, "fast and frugal" evaluation criteria without engaging in complex exposure evaluations.

Finally, the model shows that travel with children is negatively associated with HEV leasing. Nevertheless, while NIR dread is negatively associated with HEV leasing, an additional interaction effect between NIR levels and travel with children was not statistically significant. These results indicate that while NIR dread is important, there is no additional health concerns particularly associated with travel with children. Hence, the decrease in the HEV leasing propensity when traveling with children may be associated with other reasons, such as vehicle reliability or other concerns that were not investigated in the current study. Notably, previous studies found a particular concern for children's health-related to NIR from mobile phones and cellular stations. Leach and Bromwich (2018) found that two-thirds of the participants believed that mobile technology use should be restricted due to possible health risks to children's health. P¨olzl (2011) added that 30 % of the population had strong or considerable concerns regarding NIR health risks to children, and noted that adults can be motivated to adjust their behavior to protect their children. Further research is important in other regions and contexts, to understand more thoroughly the issue of HEV leasing or purchase when traveling with children.

https://www.sciencedirect.com/science/article/pii/S1361920924001834

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[Electromagnetic fields (EMF) in electric cars]

Eberhard J, Fröhlich J, Zahner M. [Electromagnetic fields (EMF) in electric cars] Elektromagnetische Felder (EMF) in Elektrofahrzeugen. Swiss Federal Office of Energy (SFOE). 2023.

My note: I would be interested in seeing an English translation of this report. The exposures reported in the following English-language summary are alarming since the ICNIRP exposure limits are far too lax and inadequate to protect our health.

Summary

More and more battery-powered electric vehicles (e-vehicles) are being put into operation to facilitate the decarbonisation of mobility. Electric, magnetic and electromagnetic fields (EMF) are generated in and around vehicles by the electrical components of the drive, through battery charging and from other diverse electronic systems used in modern vehicles. In principle, it can be stated from a technical point of view that all vehicles generate immissions of electromagnetic fields, regardless of the type of drive. In addition to the electrical parameters of the components, the design and the materials used are significant. A feature of exposure in vehicles is that passengers may be simultaneously exposed to a large number of sources of various frequencies in a very confined space for hours at a time. One is also in a volume that is (partially) shielded by the car body and window panes coated with vapour-deposited metal.

The aim of this project was to assess, through measurements on a selection of e-vehicles, whether the additional EMF immissions from the electric drive and associated components are to be judged critically as a health risk and whether further, more in-depth clarifications are necessary.

For this purpose, extensive measurements of the occurring low-frequency and high-frequency EMFs extant under real operating conditions, including the charging process, were carried out on a small selection of series-production passenger vehicles (5 e-vehicles purely electric and battery-powered, 1 diesel-motorised vehicle for comparison) from the stock vehicle market in order to be able to assess the immissions on passengers and persons staying in the vicinity of the vehicle. Since there are currently no specific regulations for EMF in e-vehicles, the field strengths of the measured EMF were classified against internationally established limit recommendations (ICNIRP). The total exhaustions of the limit values thus determined from all sources were rather low, on average in the range of up to 5% for low-frequency magnetic fields and up to approx. 10% for high-frequency EMF. Occasionally, higher peak readings of low-frequency magnetic fields up to approx. 50% of the limit values were found. In general, as is common with magnetic fields in general, these high values are often very localised. Moreover, due to the dynamic and complex situation in vehicles, they often occur only sporadically and, as far as they could be identified, are hardly directly related to the electric drive. The measurement results of the present study are consistent with other previous studies. Wireless power transfer (charging) was not investigated in this project.

As far as the results of this study can be generalised, the electric drive with energy drawn from a battery appears to be unproblematic with regard to additional EMF.

Regardless of the type of drive, attention must be paid to further technological development, especially with regard to the trend toward increasing networking and digitisation. One outstanding issue remains the insufficient EMF regulation for vehicle interiors.

Open access report in German:
https://www.aramis.admin.ch/Default?DocumentID=70257&Load=true

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Exposure to RF Electromagnetic Fields in the Connected Vehicle: Survey of Existing and Forthcoming Scenarios

G. Tognola, M. Bonato, M. Benini, S. Aerts, S. Gallucci, E. Chiaramello, S. Fiocchi, M. Parazzini, B. Masini, W. Joseph, J. Wiart, P. Ravazzani. Exposure to RF Electromagnetic Fields in the Connected Vehicle: Survey of Existing and Forthcoming Scenarios. IEEE Access. doi: 10.1109/ACCESS.2022.3170035.

Abstract

Future vehicles will be increasingly connected to enable new applications and improve safety, traffic efficiency and comfort, through the use of several wireless access technologies, ranging from vehicle-to-everything (V2X) connectivity to automotive radar sensing and Internet of Things (IoT) technologies for intra-car wireless sensor networks. These technologies span the radiofrequency (RF) range, from a few hundred MHz as in intra-car network of sensors to hundreds of GHz as in automotive radars used for in-vehicle occupant detection and advanced driver assistance systems. Vehicle occupants and road users in the vicinity of the connected vehicle are thus daily immersed in a multi-source and multi-band electromagnetic field (EMF) generated by such technologies. This paper is the first comprehensive and specific survey about EMF exposure generated by the whole ensemble of connectivity technologies in cars. For each technology we describe the main characteristics, relevant standards, the application domain, and the typical deployment in modern cars. We then extensively characterize the EMF exposure scenarios resulting from such technologies by resuming and comparing the outcomes from past studies on the exposure in the car. Results from past studies suggested that in no case EMF exposure was above the safe limits for the general population. Finally, open challenges for a more realistic characterization of the EMF exposure scenario in the connected car are discussed.

Open access paper:
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9762806&isnumber=6514899

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Complex Electromagnetic Issues Associated with the Use of Electric Vehicles in Urban Transportation

Krzysztof Gryz, Jolanta Karpowicz, Patryk Zradziński. Complex Electromagnetic Issues Associated with the Use of Electric Vehicles

in Urban Transportation. Sensors (Basel). 2022 Feb 22;22(5):1719. doi: 10.3390/s22051719.

Abstract

The electromagnetic field (EMF) in electric vehicles (EVs) affects not only drivers, but also passengers (using EVs daily) and electronic devices inside. This article summarizes the measurement methods applicable in studies of complex EMF in EVs focused on the evaluation of characteristics of such exposure to EVs users and drivers, together with the results of investigations into the static magnetic field (SMF), the extremely low-frequency magnetic field (ELF) and radiofrequency (RF) EMF related to the use of the EVs in urban transportation. The investigated EMF components comply separately with limits provided by international labor law and guidelines regarding the evaluation of human short-term exposure; however other issues need attention-electromagnetic immunity of electronic devices and long-term human exposure. The strongest EMF was found in the vicinity of direct current (DC) charging installations-SMF up to 0.2 mT and ELF magnetic field up to 100 µT- and inside the EVs-up to 30 µT close to its internal electrical equipment. Exposure to RF EMF inside the EVs (up to a few V/m) was found and recognized to be emitted from outdoor radio communications systems, together with emissions from sources used inside vehicles, such as passenger mobile communication handsets and antennas of Wi-Fi routers.

Excerpts

4.5. Health Aspects of Exposure to EMF in EVs

An EV driver’s long-lasting daily exposure to EMF, even if compliant with the exposure limits, cannot be counted to be negligible when the context of possible adverse health effects due to chronic exposure to EMF is considered. The ELF MF was classified to be a possible carcinogenic to human (2B classification) based on the epidemiologically proven elevated carcinogenic health risks in populations chronically exposed to MF exceeding 0.4 µT (attention level related to yearly averaged exposure) [38,39,40]. The level of ELF MF exposure reported in various studies focused on EMF in EVs and discussed in this article may significantly contribute to the total long-lasting exposure to drivers.

The effects of EMF exposure induced in exposed objects are frequency-dependent, but the significant majority of studies performed so far in the area of EMF safety have referred to the populations exposed to high-voltage power lines (i.e., to chronic exposure to EMF of sinusoidal power frequency), and the outcome of such observations was a base for the abovementioned 2B classification for ELF MF exceeding 0.4 μT. Because of differences in the frequency patterns of the discussed exposures (near power lines and in EVs), there needs to be very careful analysis of how far the studied health and safety outcomes from ELF EMF exposures vary in such cases, and which exposure metrics are relevant to evaluate them. Consistently, the mentioned differences in frequency characteristics of ELF EMF in EVs and EMF near regular electric power installations also need attention with respect to the exposure evaluation protocol, which in practice means that studies of the parameters of EMF exposure associated with the use of EVs require not only measurements of the RMS value (which, in practice, is usually almost equal to the RMS value of the dominant frequency component of exposure), but also attention to the higher harmonics of this exposure, the components of fundamental frequencies other than 50 Hz, the parameters of transient EMF over rapid changes in the mode of EV driving, and combined exposure including the above mentioned components.

Similar to ELF MF, RF EMF was classified by the IARC in the group of 2B carcinogenic environmental factors [41]. This component of driver EMF exposure also needs attention because of its level at least comparable to office exposure, where wireless radio communication facilities are in use and daily long-lasting exposure, potentially significantly contributing to total driver chronic exposure, combines with other components of lower frequencies (covering together exposure to: static, low frequency and radiofrequency fields).

5. Conclusions

In every urban area, there is a daily mass of passengers traveling by public transportation. Ecological and economic reasons, as well as technological development, mean that a significant percentage of the population already use EVs (trams, metro, trolleys, buses) daily, seeing as they are an increasing majority of transportation resources in various large cities. During the journeys, passengers and drivers are exposed to a specific complex EMF, with a dominant ELF component emitted by the driving systems and their supply installations, and an RF component emitted by various wireless communications systems (e.g., Wi-Fi routers located often inside vehicles, handsets of mobile communications used by passengers, and mobile communication BTS located outside vehicles). Depending on the location of the electric equipment inside the EVs, a higher exposure to EMF may affect passengers, or in some cases drivers.

Investigations into SMF, ELF and RF EMF emitted by various electrical equipment associated with the use of EV urban transportation showed that their levels, considered separately, comply with the limits provided by international labor law and guidelines aimed at protecting against the direct effects of short-term influence on humans of EMF of a particular frequency range (set up to prevent thermal load or electrical stimulation in exposed tissue) [12,13,17,20,21,22]. International guidelines and labor law do not provide rules on how to evaluate simultaneous exposure at various frequency ranges (e.g., SMF together with ELF and RF). This needs also specific attention, given that electronic devices and systems used inside EVs need to have sufficient electromagnetic immunity to ensure that their performance is not negatively affected by the impact from EMF emitted by the use of EVs.

Considering the chronic nature of exposure to EMF in EVs (in particular with respect to potential exposure to drivers when various EMF sources are located near their cabins), and the potential specific risks from exposure to EMF of complex composition in time and frequency domains, there is a need to collect research data on the complex characteristics of EMF exposure related to the use of EVs in public transportation and the associated health outcome in chronically exposed workers, as well as decreasing the level of their exposure by applying relevant preventive measures (e.g., locating indoor Wi-Fi routers, and other such electrical equipment, away from the driver's cabin) [17,23,42,43,44].

Open access paper: https://www.mdpi.com/1424-8220/22/5/1719

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Assessment of low frequency magnetic fields in electrified vehicles

European Commission, Joint Research Centre, Trentadue, G., Zanni, M., Martini, G. (2020). *Assessment of low frequency magnetic fields*

in electrified vehicles, Publications
Office. https://data.europa.eu/doi/10.2760/056116

Abstract

This report presents exploratory research into the low frequency (up to 400 kHz) magnetic fields generated by hybrid and electric vehicles under driving and charging conditions.

The study includes a literature survey and experimental work addressing the issues of: measurement protocols; instrument selection; and data processing, with the aim of contributing to standards development. When the experimental activities were planned, there were no published measurement procedures specific to the automotive sector; so different methodologies and instrumentation setups were explored.

Executive Summary

Electrification is currently considered one of the key options for decarbonisation of the road transport sector. The number of registered electric vehicles and of models offered on the market is continuously increasing.

Still, there are a number of issues that represent, or are perceived by consumers as, barriers to the purchase of an electric car. Limited range, high price, and lack of recharging infrastructure are the most important ones. Potential safety hazards related to exposure to magnetic fields during the use of electric vehicles are in some cases indicated as a reason for concern that can discourage people from choosing this technology.

The health effects of electromagnetic fields have been studied for several decades and there is no clear evidence of possible long-term effects. On the contrary, direct physiological effects are well known. Direct effects occur above certain thresholds and consist of electrostimulation of nerves at low frequencies (1 Hz to 10 MHz) and heating of body tissues at higher frequencies (100 kHz-300 GHz). Indirect effects are also known and include: initiation of electro-explosive devices, electric shocks or burns due to contact currents, projectile risk from ferromagnetic objects, interference with medical devices, etc.

Direct effects are linked to in-body quantities, not measurable in practice. For these reasons the international guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) identify specific parameters to be measured, and define the related reference levels for workers and the general public.

While existing vehicle regulations address aspects such as electromagnetic compatibility and other safety related issues, for the moment there is no specific legislation regulating electromagnetic fields (EMFs) generated by vehicles. There are a few recently published procedures that are recommended to assess EMFs in the automotive sector which differ in the level of detail of the protocol description and certain requirements.

This study was carried out with the following objectives in mind:

- To provide a clear picture of current knowledge in this field by means of a comprehensive literature survey. A summary of the main findings is available in chapter 3.2;
- To gather experimental data on low frequency magnetic fields generated by electrified vehicles of the latest generation through ad-hoc experiments carried out in the JRC's VELA laboratories (section 5);
- To support the development of a standard test procedure in anticipation of future legislation on type approval of electric vehicles (sections 6, 7).

In total, nine different electrified passenger cars, including both pure electric vehicles and hybrids, were tested in the JRC's facilities. The main focus was the assessment of the magnetic flux density (B-field), in the time and frequency domains, inside the vehicle under various operating conditions. The instrument used for the campaign follows the guidelines set in IEC standard 61786-1:2013 "Measurement of DC Magnetic, AC Magnetic and AC Electric Fields from 1 Hz to 100 kHz with Regard to Exposure of Human Beings – Part 1: Requirements for measuring instruments".

It is important to stress that when this exploratory work started, no standard for the assessment of low frequency magnetic fields inside vehicles was available. As a consequence, the protocol used changed significantly in response to the experience gained in the course of the work. Measurement locations corresponding to different parts of the human body (head, thorax and feet) were defined inside each vehicle. The vehicles were operated according to a driving cycle that included hard acceleration and braking events, as well as constant speed phases. Being a completely new activity for the JRC, solutions to a number of technical challenges were found, in particular regarding reproducibility of the driving cycle and proper data acquisition.

Results show that the highest B-field values were recorded in locations corresponding to the feet positions, during hard accelerations and regenerative braking. Acceleration and braking phases, rather than constant speed phases, were responsible for the highest peaks of current and consequently B-field; B-field values were also influenced by vehicle configuration and use during the test (air conditioning, regenerative breaking).

The study has identified some potential issues related to the requirements of the instrumentation and the test procedure that have to be further investigated and solved in view of a future regulation.

A complete characterization of the magnetic fields arising during vehicle operation would require correlation of instantaneous B – field values with the currents in the conductors within the vehicle, and with the vehicle’s speed. This task represents a significant challenge in terms of measurement instrumentation that has not yet been fully solved. Ad-hoc tools must be developed to acquire and synchronize all relevant parameters, including encrypted parameters from the vehicle's electronic control unit. Moreover, it turned out that the frequency resolution of probes appropriate for measuring human exposure to magnetic fields (i.e. probes complying with European Directive 2013/35/UE, ICNIRP 2010 and 1998 guidelines, and IEC 61786-2 -Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings – Part 2: Basic standard for measurements) might not be sufficient for accurate frequency-domain characterisation of the field. This implies that specific requirements are needed for instruments to be used for measurements of exposure to magnetic fields inside vehicles. The other issue related to the instrument used is that raw B - field values were not available during time-domain measurements, since the probe only output the percentage of the ratio between the measured field and the reference level, limiting the possibilities for post-processing. For this reason, further measurements, whose results are pending publications, were made with a second instrument in collaboration with ENEA, the Italian Agency for New Technologies, Energy and Sustainable Economic Development, with the aim to acquire instantaneous magnetic field values to quantify a hypothesised underestimation of values recorded by the instrument used previously.

Recently published measurement procedures for magnetic fields inside vehicles recommend an approach similar to that described here in terms of used instrumentation and operating conditions of the vehicle under test. However, these protocols differ in the level of detail concerning both the procedure and the requirements for the instrumentation. An effort to harmonize and better define the so far proposed standards is desirable.

In a future with massively increased production of electric vehicles and inadequate regulation, manufacturers might seek to reduce production costs by saving on protections against EMF exposure, bringing car models with lower EMF safety standards to market. To prevent this, an appropriate regulatory standard, for type approval or in-use compliance, is required. This would also provide a clear legislative framework with which market players in the automotive sector could plan their investments with less uncertainty

Open access paper: https://op.europa.eu/en/publication-detail/-/publication/d0294984-b68a-11ea-bb7a-01aa75ed71a1

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Review of Safety and Exposure Limits of Electromagnetic Fields (EMF) in Wireless Electric Vehicle Charging (WEVC) Applications

Erdem Asa, Mostak Mohammad, Omer C. Onar, Jason Pries, Veda Galigekere, Gui-Jia Su. Review of Safety and Exposure Limits of Electromagnetic Fields (EMF) in Wireless Electric Vehicle Charging (WEVC) Applications. 2020 IEEE Transportation Electrification Conference & Expo (ITEC). 23-26 June 2020**.** doi: 10.1109/ITEC48692.2020.9161597.

Abstract

This study reviews the exposure limits and safety of intermediate frequency (IF) electromagnetic field (EMF) emissions for wireless electric vehicle charging (WEVC) applications. A review of the electromagnetic field exposure limits identified in international guidelines are presented. An overview of the electromagnetic field shielding technologies is provided including recommended geometries, materials, and performances of the methods available in the literature. Available laboratory results of EMF emissions are summarized considering several wireless power transfer studies in different power levels. Possible EMF reduction techniques are discussed with shielding practices and ORNL [Oak Ridge National Laboratory] case studies. Also, living object detection (LOD) and foreign object detection (FOD) methods are reviewed from a safety aspect.

Conclusions

This study reviews and compiles the EMF emission limitations identified in international guidelines and standards including IEEE, ICNIRP, ACGIH, and SAE. EMF emissions can be substantial particularly at high-power transfer levels and misaligned conditions and should be reduced below the limits identified in the ICNIRP 2010 guidelines which are more conservative and thought to be safer. This study also provides a review of the shielding methods and presents two case studies from ORNL experiences and practices on EMF shielding. EMF exposure levels and shielding methodologies for high-power and dynamic wireless power transfer applications should be analyzed in future studies with possible standards development activities.

https://ieeexplore.ieee.org/document/9161597

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Electromagnetic Exposure Study on a Human Located inside the Car Using the Method of Auxiliary Sources

Jeladze VB, Nozadze TR, Tabatadze VA, et al. Electromagnetic Exposure Study on a Human Located inside the Car Using the

Method of Auxiliary Sources. J Communications Technology Electronics. 65(5): 457-464. May 2020.

Abstract

The article studies the effect of the electromagnetic field of wireless communications on a human inside a car in the frequency ranges of 450, 900, and 1800 MHz, corresponding to the operational range of police radios and modern mobile phones. A comparative analysis of the influence of the Earth's surface under the car is presented. The results of numerical calculations using the Method of Auxiliary Sources show the presence of resonance phenomena and a high reactive field inside the car, which leads to an undesirable increase in the level of absorbed energy in human tissues.

Conclusions

The Method of Auxiliary Sources was used to study the exposure of the electromagnetic field of a mobile phone's antenna on a human inside a car. The calculations took into account the effect of Earth's reflective surface under the car. The results showed that high-amplitude reactive fields inside the car can lead to a multiple increase in the SAR coefficient in human tissues compared to values obtained in the free space. It is recommended to reduce the duration of mobile phone calls inside a car.

https://link.springer.com/article/10.1134/S1064226920050034

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Patients with pacemakers or defibrillators do not need to worry about e-Cars: An observational study

Lennerz C, Horlbeck L, Weigand S, Grebmer C, Blazek P, Brkic A, Semmler V, Haller B, Reents T, Hessling G, Deisenhofer I, Lienkamp M, Kolb C, O'Connor M. Technol Health Care. 2019 Nov 8. doi: 10.3233/THC-191891.

Abstract

BACKGROUND: Electric cars are increasingly used for public and private transportation and represent possible sources of electromagnetic interference (EMI). Potential implications for patients

with cardiac implantable electronic devices (CIED) range from unnecessary driving restrictions to life-threatening device malfunction. This prospective, cross-sectional study was designed to assess the EMI risk of electric cars on CIED function.

METHODS: One hundred and eight consecutive patients with CIED presenting for routine follow-up between May 2014 and January 2015 were enrolled in the study. The participants were exposed to electromagnetic fields generated by the four most common electric cars (Nissan Leaf, Tesla Model S, BMW i3, VW eUp) while roller-bench test-driving at Institute of Automotive Technology, Department of Mechanical Engineering, Technical University, Munich. The primary endpoint was any abnormalities in CIED function (e.g. oversensing with pacing-inhibition, inappropriate therapy or mode-switching) while driving or charging electric cars as assessed by electrocardiographic recordings and device interrogation.

RESULTS: No change in device function or programming was seen in this cohort which is representative of contemporary CIED devices. The largest electromagnetic field detected was along the charging cable during high current charging (116.5 μT). The field strength in the cabin was lower (2.1-3.6 μT).

CONCLUSIONS: Electric cars produce electromagnetic fields; however, they did not affect CIED function or programming in our cohort. Driving and charging of electric cars is likely safe for patients with CIEDs.

Open access paper: https://content.iospress.com/articles/technology-and-health-care/thc191891

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Low Frequency Magnetic Fields Inside Cars

Pääkkönen R, Korpinen L. Low Frequency Magnetic Fields Inside Cars. Radiation Protection Dosimetry. 2019. 187(2):268-271. doi: 10.1093/rpd/ncz248.

Abstract

Magnetic fields were compared inside passenger seats of electric, petrol and hybrid cars. While driving about 5 km in an urban environment, values were recorded and compared between car types. The magnetic flux densities of the cars were less than 2.6 μT. The magnitudes of the magnetic fields of petrol cars and hybrid cars were about the same and slightly lower for electric cars. Based on our measurements, values were less than 3% of the guidelines given for the general population or people using pacemakers.

https://doi.org/10.1093/rpd/ncz248

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Long-Term Monitoring of Extremely Low Frequency Magnetic Fields in Electric Vehicles

Yang L, Lu M, Lin J, Li C, Zhang C, Lai Z, Wu T. Long-Term Monitoring of Extremely Low Frequency Magnetic Fields in Electric Vehicles. Int J Environ Res Public Health. 2019 Oct 7;16(19). pii: E3765. doi: 10.3390/ijerph16193765.

Abstract

Extremely low frequency (ELF) magnetic field (MF) exposure in electric vehicles (EVs) has raised public concern for human health. There have been many studies evaluating magnetic field values in these vehicles. However, there has been no report on the temporal variation of the magnetic field in the cabin . This is the first study on the long-term monitoring of actual MFs in EVs. In the study, we measured the magnetic flux density (B) in three shared vehicles over a period of two years. The measurements were performed at the front and rear seats during acceleration and constant-speed driving modes. We found that the B amplitudes and the spectral components could be modified by replacing the components and the hubs, while regular checks or maintenance did not influence the B values in the vehicle. This observation highlights the necessity of regularly monitoring ELF MF in EVs, especially after major repairs or accidents, to protect car users from potentially excessive ELF MF exposure. These results should be considered in updates of the measurement standards. The ELF MF effect should also be taken into consideration in relevant epidemiological studies.

Open access paper: https://www.mdpi.com/1660-4601/16/19/3765

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Effect of static magnetic field of electric vehicles on driving performance and on neuro-psychological cognitive functions

He Y, Sun W, Leung PS, Chow YT. Effect of static magnetic field of electric vehicles on driving performance and on neuro-psychological cognitive functions. Int J Environ Res Public Health. 2019 Sep 12;16(18). pii: E3382. doi: 10.3390/ijerph16183382.

Abstract

Human neuropsychological reactions and brain activities when driving electric vehicles (EVs) are considered as an issue for traffic and public safety purposes; this paper examined the effect of the static magnetic field (SMF) derived from EVs. A lane change task was adopted to evaluate the driving performance; and the driving reaction time test and the reaction time test were adopted to evaluate the variation of the neuro-psychological cognitive functions. Both the sham and the real exposure conditions were performed with a 350 μT localized SMF in this study; 17 student subjects were enrolled in this single-blind experiment. Electroencephalographs (EEGs) of the subjects were adopted and recorded during the experiment as an indicator of the brain activity for the variations of the driving performance and of the cognitive functions. Results of this study have indicated that the impact of the given SMF on both the human driving performance and the cognitive functions are not considerable; and that there is a correlation between beta sub-band of the EEGs and the human reaction time in the analysis.

Open access paper: https://www.mdpi.com/1660-4601/16/18/3382

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Possible Health Impacts of Advanced Vehicles Wireless Technologies

Judakova Z, Janousek L. Possible Health Impacts of Advanced Vehicles Wireless Technologies. Transportation Research Procedia. 40:1404-1411. 2019. https://doi.org/10.1016/j.trpro.2019.07.194

Abstract

Modern vehicles contain various security systems including vehicular networking where vehicles receive relevant traffic information using wireless communications from their peers. This wireless communication is mediated by the radiofrequency electromagnetic field. Exposure to electromagnetic fields caused by the transportation system is a cause of concern for many people. Plenty of dosimetric analysis of electromagnetic field carried out by various research groups found out the highest exposure values in the transport. How long-term effects of these fields affect the human organism and what is the mechanism of action, are questions without known answers. Several studies point to the possible association of different diseases with electromagnetic field exposure. The key to understanding the effect of the electromagnetic field on the human organism is to reveal the mechanism of action of these fields.

Open access paper: https://www.sciencedirect.com/science/article/pii/S2352146519303643?via%3Dihub

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Evaluating extremely low frequency magnetic fields in the rear seats of the electric vehicles

Lin J, Lu M, Wu T, Yang L, Wu TN. Evaluating extremely low frequency magnetic fields in the rear seats of the electric vehicles. Radiation Protection Dosimetry. 182(2):190-199. Dec 2018.

Abstract

In the electric vehicles (EVs), children can sit on a safety seat installed in the rear seats. Owing to their smaller physical dimensions, their heads, generally, are closer to the underfloor electrical systems where the magnetic field (MF) exposure is the greatest. In this study, the magnetic flux density (B) was measured in the rear seats of 10 different EVs, for different driving sessions. We used the measurement results from different heights corresponding to the locations of the heads of an adult and an infant to calculate the induced electric field (E-field) strength using anatomical human models. The results revealed that measured B fields in the rear seats were far below the reference levels by the International Commission

on Non-Ionizing Radiation Protection. Although small children may be exposed to higher MF strength, induced E-field strengths were much lower than that of adults due to their particular physical dimensions.

https://www.ncbi.nlm.nih.gov/pubmed/29584925

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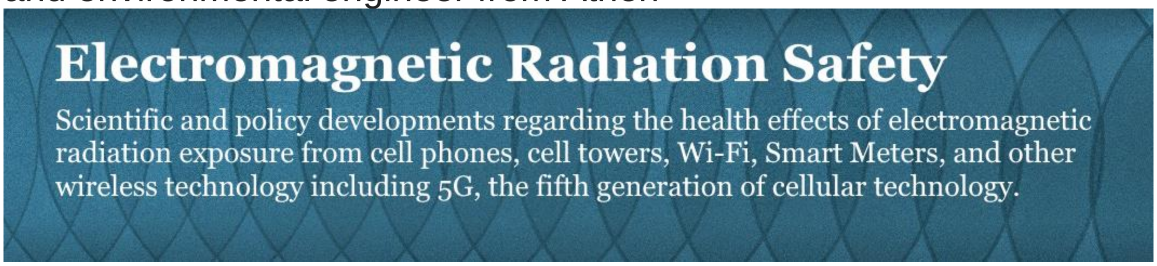
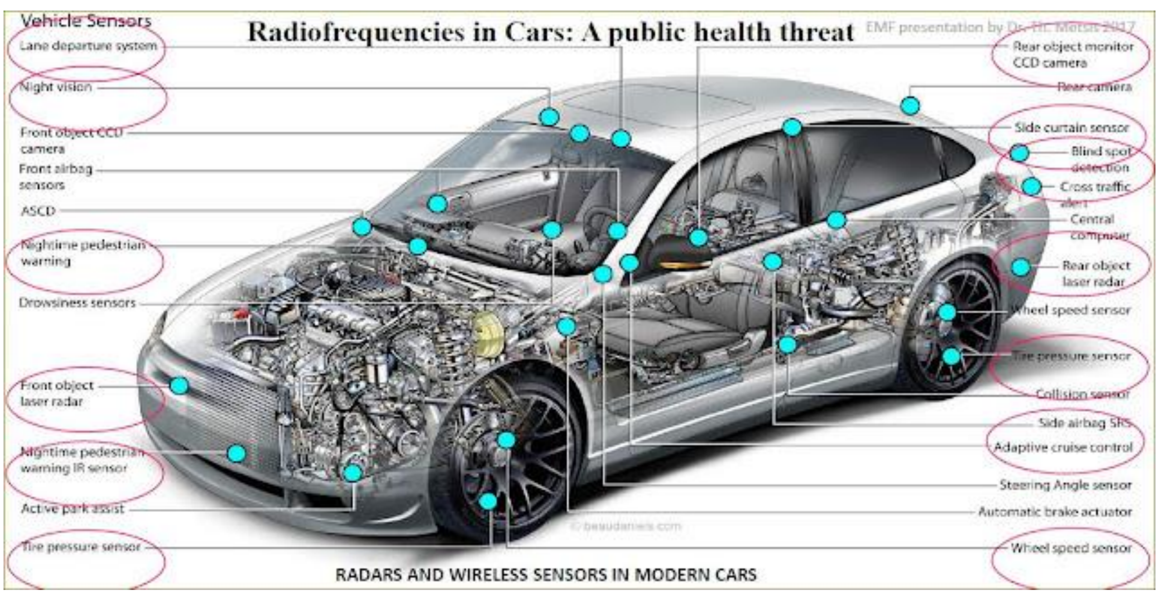
Radiofrequencies in cars: A public health threat

According to Theodore P. Metsis, Ph.D., an electrical, mechanical, and environmental engineer from Athen



s, Greece, modern conventional gas- and diesel-powered automobiles incorporate many EMF-emitting devices.
"EMFs in a car in motion with brakes applied + ABS activation may well exceed 100 mG. Adding RF radiation from blue tooth, Wi Fi, the cell phones of the passengers, the 4G antennas laid out all along the major roads plus the radars of cars already equipped with, located behind, left or right of a vehicle, the total EMF and EMR fields will exceed any limits humans can tolerate over a long period of time."

http://www.radiationdangers.com/automotive-radiation/automotive-radiation/



PDF of Dr. Metsis' graphics (2 pages): http://bit.ly/RFcarsMetsis

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Mobile Phone Antenna's EM Exposure Study on a Human Model Inside the Car

Nozadze T, Jeladze V, Tabatadze V, Petoev I, Zaidze R. Mobile phone antenna's EM exposure study on a homogeneous human model inside the car. 2018 XXIIIrd International Seminar/Workshop on Direct and Inverse Problems of Electromagnetic and Acoustic Wave Theory (DIPED). Tlibisi, Georgia. Sep 24-27, 2019.
DOI: 10.1109/DIPED.2018.8543310

Abstract

Mobile phones' radiation influence on a homogenous human model located inside a car is studied in this research. One of the novelty of proposed research is earth surface influence consideration under the car on EM field formation inside it. The inner field and its amplification by the car's walls that in some cases act like a resonator are studied. The problem was solved numerically using the Method of Auxiliary Sources. Numerical simulations were carried out at the 450, 900, 1800 [MHz] standard communication frequencies. Obtained results showed the presence of resonant phenomena inside the car.

Excerpts

On Fig. 9 are presented point SAR peak values at the considered non-resonant and resonant frequencies. As it seen, point SAR peak values for resonant frequencies are approximately 5–8 times higher than non-resonant frequencies.

Based on the analysis of the obtained results we can conclude that at some frequencies car's walls acts as the resonator and amplifies the field radiated from the mobile phones; which is cause of high point SAR values inside the human body. For the low frequency the EM field energy deeply penetrates into the human body, while for the high frequencies is mostly absorbed in the skin.

Conclusions

The mobile phone's EM exposure problem for a homogenous human model inside the car is studied using the MAS. MAS were used to simulate earth reflective surface. The obtained results, conducted with the MAS based program package, showed the presence of resonance and reactive fields inside the car, that causes high SAR in human tissues. The reason of this is that at the considered frequencies car's metallic surface acts as the resonator. So, it isn't desirable speak on phones for a long time inside the car, that can be hazardous for the cell phone users located in it.

https://ieeexplore.ieee.org/document/8543310

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Electric cars and EMI with cardiac implantable electronic devices: A cross-sectional evaluation

Lennerz C, O'Connor M, Horlbeck L, Michel J, Weigand S, Grebmer C, Blazek P, Brkic A, Semmler V, Haller B, Reents T, Hessling G, Deisenhofer I, Whittaker P, Lienkamp M, Kolb C. Letter: Electric cars and electromagnetic interference with cardiac implantable electronic devices: A cross-sectional evaluation. *Annals of Internal Medicine*. Apr 24, 2018.

No Abstract
Excerpts

Cardiac implantable electronic devices (CIEDs) are considered standard care for bradycardia, tachycardia, and heart failure. Electromagnetic interference (EMI) can disrupt normal function … Electric cars represent a potential source of EMI. However, data are insufficient to determine their safety or whether their use should be restricted in patients with CIEDs.

Objective: To assess whether electric cars cause EMI and subsequent CIED dysfunction.

Methods and Findings: We approached 150 consecutive patients with CIEDs seen in our electrophysiology clinic … 40 patients declined to participate, and 2 withdrew consent … Participants were assigned to 1 of 4 electric cars with the largest European market share…we excluded hybrid vehicles.

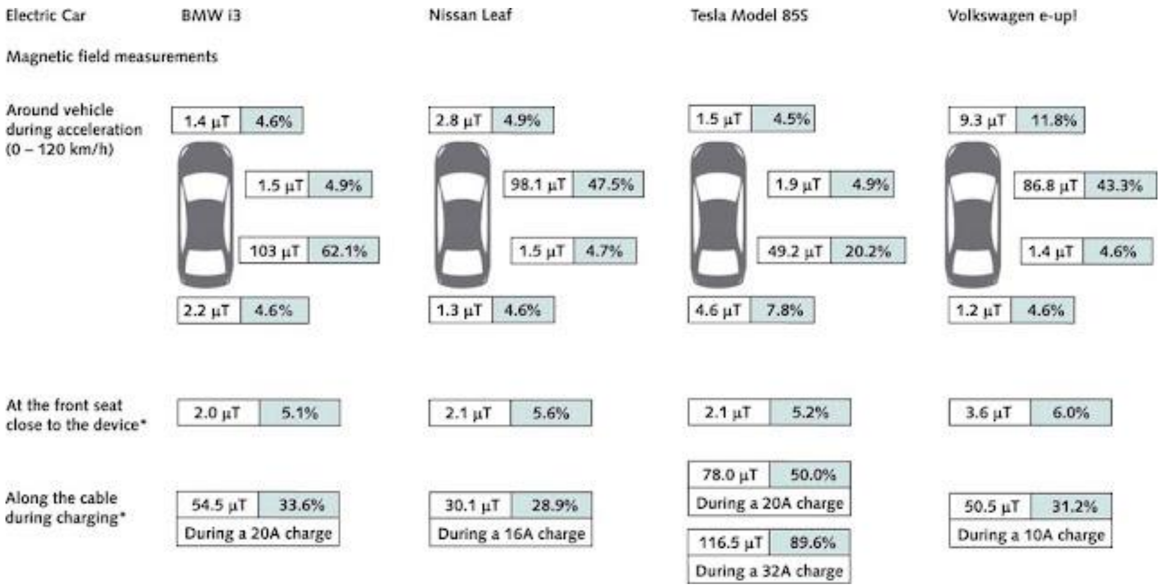
Participants sat in the front seat while cars ran on a roller test bench … Participants then charged the same car in which they had sat. Finally, investigators drove the cars on public roads.

Field strength was generally highest during charging (30.1 to 116.5 µT) and increased as the charging current increased. Exposure during charging was at least an order of magnitude greater than that measured within 5 cm of the CIED in the front seat (2.0 to 3.6 µT). Field strength did not differ between the front and back seats. Peak field strength measured outside the cars ranged between the values measured during charging and those measured within the cars during testing … Field strength measured inside the cars during road driving was similar to that measured during test bench studies.

We found no evidence of EMI with CIEDs ...The electrocardiographic recorder did observe EMI, but CIED function and programming were unaffected.

Our sample was too small to detect rare events ... Nevertheless, other evidence supports a lack of EMI with CIEDs. Magnetic fields are generated in gasoline-powered vehicles if the vehicles' steel-belted tires are magnetized (3); average fields of approximately 20 µT were reported in the back seat of 12 models, and those as high as 97 µT were reported close to the tires (4). Similar values were reported in electric trains and trams (5). The lack of anecdotal reports of CIED malfunction associated with such transportation is consistent with our findings.

Electric cars seem safe for patients with CIEDs, and restrictions do not appear to be required. However, we recommend vigilance to monitor for rare events, especially those associated with charging and proposed “supercharging” technology.



http://bit.ly/2Hs9s9Y

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Evaluating ELF magnetic fields in the rear seats of electric vehicles

Lin J, Lu M, Wu T, Yang L, Wu T. Evaluating extremely low frequency magnetic fields in the rear seats of the electric vehicles. Radiat Prot Dosimetry. 2018 Mar 23. doi: 10.1093/rpd/ncy048.

Abstract

In the electric vehicles (EVs), children can sit on a safety seat installed in the rear seats. Owing to their smaller physical dimensions, their heads, generally, are closer to the underfloor electrical systems where the magnetic field (MF) exposure is the greatest. In this study, the magnetic flux density (B) was measured in the rear seats of 10 different EVs, for different driving sessions. We used the measurement results from different heights corresponding to the locations of the heads of an adult and an infant to calculate the induced electric field (E-field) strength using anatomical human models. The results revealed that measured B fields in the rear seats were far below the reference levels by the International Commission on Non-Ionizing Radiation Protection. Although small children may be exposed to higher MF strength, induced E-field strengths were much lower than that of adults due to their particular physical dimensions.

https://www.ncbi.nlm.nih.gov/pubmed/29584925

Excerpts

Small children and infants sitting in a safety seat at the rear part of the vehicle is a common occurrence. Children have smaller physical dimensions and, thus, their heads are generally much closer to the car floor, where the MF strength has been reported to be higher due to tire magnetization and the operation of the underfloor electrical systems (6, 7). The matter of children being potentially subject to greater magnetic field exposure may be relevant as leukemia is the most common type of childhood cancer (8). In particular, Ahlbom et al. (9) and Greenland et al. (10) indicated that the exposure to 50 and 60 Hz MF exceeding 0.3–0.4 μT may result in an increased risk for childhood leukemia although a satisfactory causal relationship has not yet been reliably demonstrated. Also, it was reported that a combination of weak, steady and alternating MF could modify the radical concentration, which had the potential to lead to biologically significant changes (11).

... the *B* field values measured at location #4 (floor in from of rear seat) were the highest, followed by values from location #3 (rear seat cushion), #2 (child's head position) and #1 (adult's head position) ($p < 0.012$, $\alpha = 0.05/3 = 0.017$). There was a significant difference between the driving scenarios ($F(3, 117) = 3.72$, $p = 0.013$). The acceleration and deceleration scenarios generated higher *B* fields compared with the stationary and the 40 km/h driving scenarios ($p < 0.01$, $\alpha = 0.05/3 = 0.017$) while no difference was identified between acceleration and deceleration ($p = 0.16$).

... The results demonstrate that the induced *E*-field strength was lower for the infant model compared with that of the adult in terms of both the head and body as a whole.

The infant was reported to have higher electrical conductivity [(29)] but there was no database dedicated to the infant. Furthermore, below 1 MHz, the database was hard to be measured and the uncertainty was large [(30)]. Therefore, we would not include the issue in the study.

Although several SCs (spectral components) on higher frequencies have been observed (can spread to 1.24 kHz), the spectral analysis revealed that the SCs concentrated on bands below 1000 Hz. The EVs under test used aluminum alloy wheel rims, which have low magnetic permeability. However, the steel wire in the reinforcing belts of radial tires pick up magnetic fields from the terrestrial MF. When the tires spin, the magnetized steel wire in the reinforcing belts generates ELF MF usually below 20 Hz, that can exceed 2.0 μT at seat level in the passenger compartment [(6)]. The measurement did not identify the ELF MF by different sources because the purpose of the study was to investigate the realistic exposure scenario for the occupants. To note, degaussing the tires or using the fiberglass belted tires can eliminate this effect and provide the MF results solely introduced by the operation of the electrified system.

ICNIRP proposed guidelines to evaluate the compliance of the non-sinusoidal signal exposure[3]. The measurements rendered the maximal *B* field at the level of one-tenth to several μT, far below the reference level of the guidelines (e.g. 200 μT for 20–400 Hz). The similar non-sinusoidal MF signal magnitudes can only account for 6–10% of the reference levels according to the previous reports[32]. However, as noted in the Introduction, '… 50 and 60 Hz MF exceeding 0.3–0.4 μT may result in an increased risk for childhood leukemia'. Therefore, it is necessary to measure the MF in the EVs to limit the exposure and for the purpose of epidemiological studies.

In this study, we measured ELF MF in the rear seats of ten types of EVs. The measurements were performed for four different driving scenarios. The measurement results were analyzed to determine the worst-case scenario and those values were used for simulations. We made numerical simulations to compare the induced E-field strength due to the physical difference between children and adults using detailed anatomical models. The results support the contention that the MF in the EVs that we tested was far below the reference levels of the ICNIRP guidelines. Furthermore, our findings show that children would not be more highly exposed compared to adults when taking into consideration of their physical differences. However, the measurement results indicated that further studies should be performed to elucidate the concerns on the incidence of the childhood leukemia for infant and child occupants.

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Evaluation of electromagnetic exposure during 85 kHz wireless power transfer for electric vehicles

SangWook Park. Evaluation of Electromagnetic Exposure During 85 kHz Wireless Power Transfer for Electric Vehicles. IEEE Transactions on Magnetics. Volume: PP, Issue: 99. Sep 1, 2017. doi: 10.1109/TMAG.2017.2748498.

Abstract

The external fields in the proximity of electric vehicle (EV) wireless power transfer (WPT) systems requiring high power may exceed the limits of international safety guidelines. This

study presents dosimetric results of an 85 kHz WPT system for electric vehicles. A WPT system for charging EVs is designed and dosimetry for the system is evaluated for various exposure scenarios: a human body in front of the WPT system without shielding, with shielding, with alignment and misalignment between transmitter and receiver, and with a metal plate on the system for vehicle mimic floor pan. The minimum accessible distances in compliance are investigated for various transmitting powers. The maximum allowable transmitting power are also investigated with the limits of international safety guidelines and the dosimetric results.

http://ieeexplore.ieee.org/document/8024022/

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Electric and magnetic fields <100 KHz in electric and gasoline-powered vehicles

Tell RA, Kavet R. Electric and magnetic fields <100 KHz in electric and gasoline-powered vehicles. Radiat Prot Dosimetry. 2016 Dec;172(4):541-546.

Abstract

Measurements were conducted to investigate electric and magnetic fields (EMFs) from 120 Hz to 10 kHz and 1.2 to 100 kHz in 9 electric or hybrid vehicles and 4 gasoline vehicles, all while being driven. The range of fields in the electric vehicles enclosed the range observed in the gasoline vehicles. Mean magnetic fields ranged from nominally 0.6 to 3.5 µT for electric/hybrids depending on the measurement band compared with nominally 0.4 to 0.6 µT for gasoline vehicles. Mean values of electric fields ranged from nominally 2 to 3 V m-1 for electric/hybrid vehicles depending on the band, compared with 0.9 to 3 V m-1 for gasoline vehicles. In all cases, the fields were well within published exposure limits for the general population. The measurements were performed with Narda model EHP-50C/EHP-50D EMF analysers that revealed the presence of spurious signals in the EHP-50C unit, which were resolved with the EHP-50D model.

https://www.ncbi.nlm.nih.gov/pubmed/26769905

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Passenger exposure to magnetic fields due to the batteries of an electric vehicle

Pablo Moreno-Torres Concha; Pablo Velez; Marcos Lafoz; Jaime R. Arribas. Passenger Exposure to Magnetic Fields due to the Batteries of an Electric Vehicle. IEEE Transactions on Vehicular Technology. 65(6):4564-4571. Jun 2016.

Abstract

In electric vehicles, passengers sit very close to an electric system of significant power. The high currents achieved in these vehicles mean that the passengers could be exposed to significant magnetic fields (MFs). One of the electric devices present in the power train are the batteries. In this paper, a methodology to evaluate the MF created by these batteries is presented. First, the MF generated by a single battery is analyzed using finite-elements simulations. Results are compared with laboratory measurements, which are taken from a real battery, to validate the model. After this, the MF created by a complete battery pack is estimated, and results are discussed.

Conclusion

Passengers inside an EV could be exposed to MFs of considerable strength when compared with conventional vehicles or to other daily exposures (at home, in the office, in the street, etc.). In this paper, the MF created by the batteries of a particular electric car is evaluated from the human health point of view by means of finite-elements simulations, measurements, and a simple analytical approximation, obtaining an upper bound for the estimated MF generated by a given battery pack. These results have been compared with ICNIRP's recommendations concerning exposure limitation to low-frequency MFs, finding that the field generated by this particular battery pack should be below ICNIRP's field reference levels, and conclusions concerning the influence of the switching frequency have been drawn. Finally, some discussion regarding other field sources within the vehicle and different vehicles designs has been presented. Due to the wide variety of both available EVs and battery stacks configurations, it is recommended that each vehicle model should be individually assessed regarding MF exposure.

http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=7297855

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Magnetic field exposure assessment in electric vehicles

Vassilev A et al. Magnetic Field Exposure Assessment in Electric Vehicles. IEEE Transactions on Electromagnetic Compatibility. 57(1):35-43. Feb 2015.

Abstract

This article describes a study of magnetic field exposure in electric vehicles (EVs). The magnetic field inside eight different EVs (including battery, hybrid, plug-in hybrid, and fuel cell types) with different motor technologies (brushed direct current, permanent magnet synchronous, and induction) were measured at frequencies up to 10 MHz. Three vehicles with conventional powertrains were also investigated for comparison. The measurement protocol and the results of the measurement campaign are described, and various magnetic field sources are identified. As the measurements show a complex broadband frequency spectrum, an exposure calculation was performed using the ICNIRP "weighted peak" approach. Results for the measured EVs showed that the exposure reached 20% of the ICNIRP 2010 reference levels for general public exposure near to the battery and in the vicinity of the feet during vehicle start-up, but was less than 2% at head height for the front passenger position. Maximum exposures of the order of 10% of the ICNIRP 2010 reference levels were obtained for the cars with conventional powertrains.

http://ieeexplore.ieee.org/abstract/document/6915707/

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Characterization of ELF magnetic fields from diesel, gasoline and hybrid cars under controlled conditions

Hareuveny R, Sudan M, Halgamuge MN, Yaffe Y, Tzabari Y, Namir D, Kheifets L. Characterization of Extremely Low Frequency Magnetic Fields from Diesel, Gasoline and Hybrid Cars under Controlled Conditions. Int J Environ Res Public Health. 2015 Jan 30;12(2):1651-1666.

Abstract

This study characterizes extremely low frequency (ELF) magnetic field (MF) levels in 10 car models.

Extensive measurements were conducted in three diesel, four gasoline, and three hybrid cars, under similar controlled conditions and negligible background fields.

Averaged over all four seats under various driving scenarios the fields were lowest in diesel cars (0.02 μT), higher for gasoline (0.04-0.05 μT) and highest in hybrids (0.06-0.09 μT), but all were in-line with daily exposures from other sources. Hybrid cars had the highest mean and 95th percentile MF levels, and an especially large percentage of measurements above 0.2 μT. These parameters were

also higher for moving conditions compared to standing while idling or revving at 2500 RPM and higher still at 80 km/h compared to 40 km/h. Fields in non-hybrid cars were higher at the front seats, while in hybrid cars they were higher at the back seats, particularly the back right seat where 16%-69% of measurements were greater than 0.2 μT.

As our results do not include low frequency fields (below 30 Hz) that might be generated by tire rotation, we suggest that net currents flowing through the cars' metallic chassis may be a possible source of MF. Larger surveys in standardized and well-described settings should be conducted with different types of vehicles and with spectral analysis of fields including lower frequencies due to magnetization of tires.

Excerpts

Previous work suggests that major sources of MF in cars include the tires and electric currents [4,5]. The level of MF exposure depends on the position within the vehicle (e.g., proximity to the MF sources) and can vary with different operating conditions, as changes to engine load can induce MFs through changes in electric currents. Scientific investigations of the levels of MF in cars are sparse: only one study evaluated fields only in non-hybrid cars [6], two studies of hybrid cars have been carried out [4,7], and few studies have systematically compared exposures in both hybrid and non-hybrid cars [8,9,10,11,12], some based on a very small number of cars

In hybrid cars, the battery is generally located in the rear of the car and the engine is located in the front. Electric current flows between these two points through cables that run underneath the passenger cabin of the car. This cable is located on the left for right-hand driving cars and on the right for left-hand driving cars. Although in principle the system uses direct current (DC), current from the alternator that is not fully rectified as well as changes to the engine load, and therefore the current level, can produce MFs which are most likely in the ELF range. While most non-hybrid cars have batteries that are located in the front, batteries in some of them are located in the rear of the car, with cables running to the front of the car for the electrical appliances on the dashboard. In this study, all gasoline and diesel cars had batteries located in the front of the car.

...the percent of time above 0.2 μT was the most sensitive parameter of the exposure. Overall, the diesel cars measured in this study had the lowest MF readings (geometric mean less than 0.02 μT), while the hybrid cars had the highest MF readings (geometric mean 0.05 μT). Hybrid cars had also the most unstable results, even after excluding outliers beyond the 5th and 95th percentiles. With regard to seat position, after adjusting for the specific car model, gasoline and diesel cars produced higher average MF readings in the front seats, while hybrid cars produced the highest MF readings in the back right seat (presumably due to the location of the battery). Comparing the different operating conditions, the highest average fields were found at 80 km/h, and the differences between operating conditions were most pronounced in the back right seat in hybrid cars. Whether during typical city or highway driving, we found lowest average fields for diesel cars and highest fields for hybrid cars.

Previous works suggest that the magnetization of rotating tires is the primary source of ELF MFs in non-hybrid cars [5,15]. However, the relatively strong fields (on the order of a few μT within the car) originating from the rotating tires are typically at 5–15 Hz frequencies, which are filtered by the EMDEX II meters. ....

Overall, the average MF levels measured in the cars' seats were in the range of 0.04–0.09 μT (AM) and 0.02–0.05 μT (GM). These fields are well below the ICNIRP [17] guidelines for maximum general public exposure (which range from 200 μT for 40 Hz to 100 μT for 800 Hz), but given the complex environments in the cars, simultaneous exposure to non-sinusoidal fields at multiple frequencies must be carefully taken into account. Nevertheless, exposures in the cars are in the range of every day exposure from other sources. Moreover, given the short amount of time that most adults and children spend in cars (about 30 minutes per day based on a survey of children in Israel (unpublished data), the relative contribution of this source to the ELF exposure of the general public is small. However, these fields are in addition to other exposure sources. Our results might explain trends seen in other daily exposures: slightly higher average fields observed while travelling (GM = 0.096 μT) relative to in bed (GM = 0.052 μT) and home not in bed (GM = 0.080 μT) [1]. Similarly, the survey of children in Israel found higher exposure from transportation (GM = 0.092 μT) compared to mean daily exposures (GM = 0.059 μT). Occupationally, the GM of time-weighted average for motor vehicle drivers is 0.12 μT [18].

Open access paper: http://bit.ly/1u9lUTN

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Design guidelines to reduce the magnetic field in electric vehicles

SINTEF, Jan 6, 2014

Based on the measurements and on extensive simulation work the project arrived on the following design guidelines to, if necessary, minimize the magnetic field in electric vehicles.

Cables

- For any DC cable carrying significant amount of current, it should be made in the form of a twisted pair so that the currents in the pair always flow in the opposite directions. This will minimise its EMF emission.
- For three-phase AC cables, three wires should be twisted and made as close as possible so as to minimise its EMF emission.
- All power cables should be positioned as far away as possible from the passenger seat area, and their layout should not form a loop. If cable distance is less than 200mm away from the passenger seats, some forms of shielding should be adopted.
- A thin layer of ferromagnetic shield is recommended as this is cost-effective solution for the reduction of EMF emission as well EMI emission.
- Where possible, power cables should be laid such a way that they are separated from the passenger seat area by a steel sheet, e.g., under a steel metallic chassis, or inside a steel trunk.

Motors

- Where possible, the motor should be installed farther away from the passenger seat area, and its rotation axis should not point to the seat region.
- If weight permits, the motor housing should be made of steel, rather than aluminium, as the former has a much better shielding effect.
- If the distance of the motor and passenger seat area is less than 500mm, some forms of shielding should be employed. For example, a steel plate could be placed between the motor and the passenger seat region

- Motor housing should be electrically well connected to the vehicle metallic chassis to minimise any electrical potential.
- Inverter and motor should be mounted as close as possible to each other to minimise the cable length between the two.

Batteries

- Since batteries are distributed, the currents in the batteries and in the interconnectors may become a significant source for EMF emission, they should be place as far away as possible from the passenger seat areas. If the distance between the battery and passenger seat area is less than 200mm, steel shields should be used to separate the batteries and the seating area.
- The cables connecting battery cells should not form a loop, and where possible, the interconnectors for the positive polarity should be as close as possible to those of the negative polarity.

http://bit.ly/1qw29Tb

https://www.sintef.no/projectweb/em-safety/

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Magnetic fields in electric cars won't kill you

Jeremy Hsu, IEEE Spectrum, May 5, 2014

Summary

“The study, led by SINTEF, an independent research organization headquartered in Trondheim, Norway, measured the electromagnetic radiation—in the lab and during road tests—of seven different electric cars, one hydrogen-powered car, two gasoline-fueled cars and one diesel-fueled car. Results from all conditions showed that the exposure was less than 20 percent of the limit recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).”

“Measurements taken inside the vehicles—using a test dummy with sensors located in the head, chest and feet—showed exposure at less than 2 percent of the non-ionizing radiation limit at head-height. The highest electromagnetic field readings—still less than 20 percent of the limit—were found near the floor of the electric cars, close to the battery. Sensors picked up a burst of radiation that same level, when the cars were started."

http://bit.ly/1pUuOxB

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ELF magnetic fields in electric and gasoline-powered vehicles

Tell RA, Sias G, Smith J, Sahl J, Kavet R. ELF magnetic fields in electric and gasoline-powered vehicles. Bioelectromagnetics. 2013 Feb;34(2):156-61. doi: 10.1002/bem.21730.

Abstract

We conducted a pilot study to assess magnetic field levels in electric compared to gasoline-powered vehicles, and established a methodology that would provide valid data for further assessments. The sample consisted of 14 vehicles, all manufactured between January 2000 and April 2009; 6 were gasoline-powered vehicles and 8 were electric vehicles of various types. Of the eight models available, three were represented by a gasoline-powered vehicle and at least one electric vehicle, enabling intra-model comparisons. Vehicles were driven over a 16.3 km test route. Each vehicle was equipped with six EMDEX Lite broadband meters with a 40-1,000 Hz bandwidth programmed to sample every 4 s. Standard statistical testing was based on the fact that the autocorrelation statistic damped quickly with time. For seven electric cars, the geometric mean (GM) of all measurements (N = 18,318) was 0.095 µT with a geometric standard deviation (GSD) of 2.66, compared to 0.051 µT (N = 9,301; GSD = 2.11) for four gasoline-powered cars ($P < 0.0001$). Using the data from a previous exposure assessment of residential exposure in eight geographic regions in the United States as a basis for comparison (N = 218), the broadband magnetic fields in electric vehicles covered the same range as personal exposure levels recorded in that study. All fields measured in all vehicles were much less than the exposure limits published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE). Future studies should include larger sample sizes representative of a greater cross-section of electric-type vehicles.

https://www.ncbi.nlm.nih.gov/pubmed/22532300

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Mythbuster: EMF levels in hybrids

Consumer Reports News: August 4, 2010

Summary

“Some concern has been raised about the possible health effects of electromagnetic field radiation, known as EMF, for people who drive in hybrid cars. While all electrical devices, from table lamps to copy machines, emit EMF radiation, the fear is that hybrid cars, with their big batteries and powerful electric motors, can subject occupants to unhealthy doses. The problem is that there is no established threshold standard that says what an unhealthy dose might be, and no concrete, scientific proof that the sort of EMF produced by electric motors harms people

“We found the highest EMF levels in the Chevrolet Cobalt, a conventional non-hybrid small sedan.”

[The peak EMF readings at the driver’s feet ranged from 0.5 mG (milligauss) in the 2008 Toyota Highlander to 30 mG in the Chevrolet Cobalt. The hybrids tested at 2-4 mG. Here are some highlights from the tests. EMF readings were highest in the driver’s foot well and second-highest at the waist, much lower higher up, where human organs might be more susceptible to EMF.

“To get a sense of scale, though, note that users of personal computers are subject to EMF exposure in the range of 2 to 20 mG, electric blankets 5 to 30 mG, and a hair dryer 10 to 70 mG, according to an Australian government compilation. In this country, several states limit EMF emissions from power lines to 200 mG. However, there are no U.S. standards specifically governing EMF in cars.”

“In this series of tests, we found no evidence that hybrids expose drivers to significantly more EMF than do conventional cars. Consider this myth, busted.”

http://bit.ly/TN5q2r

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Israel preps world’s first hybrid car radiation scale

Tal Bronfer, the truth about cars, March 1, 2010

Summary

"The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) recommends a limit of 1,000 mG (milligauss) for a 24 hour exposure period. While other guidelines pose similar limits, the International Agency for Research on Cancer (IARC) deemed extended exposure to electromagnetic fields stronger than 2 mG to be a "possible cause" for cancer. Israel's Ministry of Health recommends a maximum of 4 mG."

"Last year, Israeli automotive website Walla! Cars conducted a series of tests on the previous generation Toyota Prius, Honda Insight and Honda Civic Hybrid, and recorded radiation figures of up to 100 mG during acceleration. Measurements also peaked when the batteries were either full (and in use) or empty (and being charged from the engine), while normal driving at constant speeds yielded 14 to 30 mG on the Prius, depending on the area of the cabin.

The Ministry of Environmental Protection is expected to publish the results of the study this week. The study will group hybrids sold in Israel into three different radiation groups, reports Israel's Calcalist. It's expected that the current-gen Prius will be deemed 'safe', while the Honda Insight and Civic Hybrid (as well as the prev-gen Prius) will be listed as emitting 'excessive' radiation."

http://bit.ly/1pUu7Ep

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Fear, but few facts, on hybrid risk

Jim Motavalli, New York Times, Apr 27, 2008

Summary

"... concern is not without merit; agencies including the National Institutes of Health and the National Cancer Institute acknowledge the potential hazards of long-term exposure to a strong electromagnetic field, or E.M.F., and have done studies on the association of cancer risks with living near high-voltage utility lines.

While Americans live with E.M.F.'s all around — produced by everything from cellphones to electric blankets — there is no broad agreement over what level of exposure constitutes a health hazard, and there is no federal standard that sets allowable exposure levels.

Government safety tests do not measure the strength of the fields in vehicles — though Honda and Toyota, the dominant hybrid makers, say their internal checks assure that their cars pose no added risk to occupants."

"A spokesman for Honda, Chris Martin, points to the lack of a federally mandated standard for E.M.F.'s in cars. Despite this, he said, Honda takes the matter seriously. "All our tests had results that were well below the commission's standard," Mr. Martin said, referring to the European guidelines. And he cautions about the use of hand-held test equipment. "People have a valid concern, but they're measuring radiation using the wrong devices," he said."

"Donald B. Karner, president of Electric Transportation Applications in Phoenix, who tested E.M.F. levels in battery-electric cars for the Energy Department in the 1990s, said it was hard to evaluate readings without knowing how the testing was done. He also said it was a problem to determine a danger level for low-frequency radiation, in part because dosage is determined not only by proximity to the source, but by duration of exposure. "We're exposed to radio waves from the time we're born, but there's a general belief that there's so little energy in them that they're not dangerous," he said."

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