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Possible Health Impacts of Advanced Vehicles Wireless Technologies

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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.

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Keywords: Intelligent Transportation System, wireless communications, electromagnetic field, helth impact, IPR, exposure of EMF;

1. Introduction

According to the report published by WHO approximately 1.35 million people die each year as a result of road traffic crashes WHO (2018). Consequently, modern cars contain various security systems including vehicular networking. Vehicular networking is an emerging concept for Intelligent Transportation System (ITS) to enhance

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passenger comfort, traffic efficiency, safety of passengers and so on, by forwarding upcoming traffic information in a timely manner. Vehicle-to-Vehicle (V2V) communication, Vehicular Ad-Hoc Network (VANET), vehicle-to-infrastructure (V2I) connectivity based on Wi-Fi, GPS, Dedicated Short Range Communication (DSRC) are the key part in the ITS framework 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 (EMF) caused by the transportation system is a cause of concern for many people. Throughout the history of Earth's development (nearly 4 billion years), living organisms have been exposed to very low intensities of this type of radiation and therefore have not developed sufficient protection against electromagnetic radiation. Radio (very high frequency, micro, and millimeter waves) and infrared electromagnetic waves are used in this system for the information transfer. But vehicular networking is not only one sources of radiation in vehicles. Another sources are many sensors used in modern vehicles, which generate low or high-frequency radiation, Fig.1. Although these systems help to protect people's lives, they might threaten their health. The massive use of wireless technologies increases electromagnetic smog. The long-term effects of electromagnetic fields cause various health problems not only to people with electromagnetic hypersensitivity (EHS). For the determined of impact of electromagnetic fields impact on human health, it is needed to know values of EM quantities. The quantities can be verified by dosimetric analysis and simulations.

2. Sources of Radiation in Vehicles

Today's cars typically have more than 50 electronic control units, Fig. 1. Almost all new cars on the market today contain at least some wireless inputs to these computers. It works with large volumes of vehicle driving history, including information technologies - navigation systems, telematics, emergency assistance systems, and remote control locks to ensure greater driver safety. Security magazine (2015)

Electronic dashboard is the basic source of high-frequency radiation in cars. Radio frequencies are used in a number of applications: electronic security system, ad-hoc vehicle network, dedicated short-range communication, GPRS / GSM / GPS localization systems, Bluetooth, Wi - Fi and other vehicle control systems.

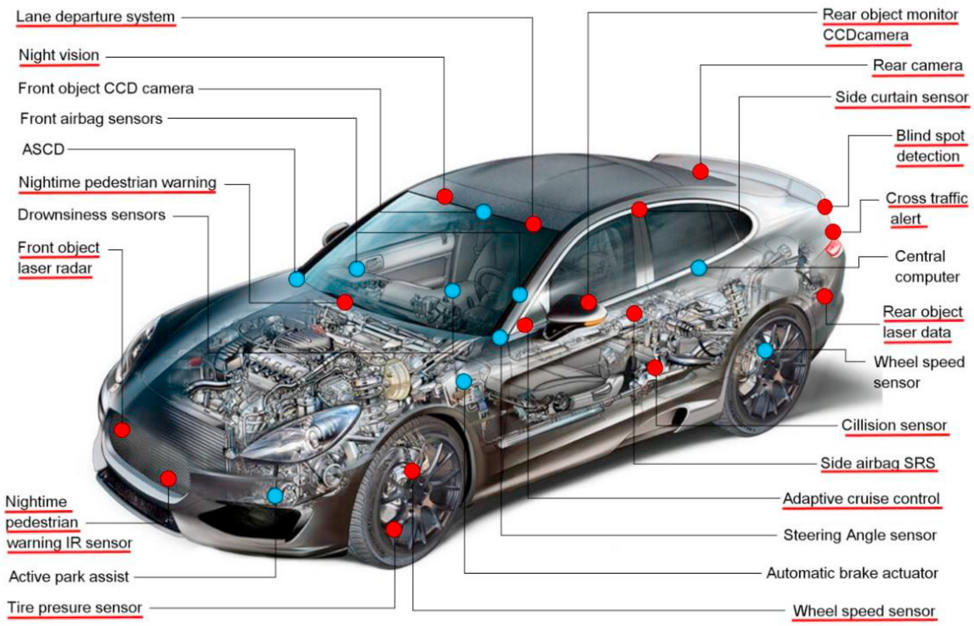

Fig. 1. Radar and wireless sensors in car

The most commonly implemented technologies using electromagnetic fields are described in the following paragraphs.

VANET is a technology that uses moving cars as nodes in a mesh to create a mobile network. VANET (part of ITS) turns every participating car into a wireless router or node, allowing cars approximately 100 to 300 meters of each other to connect and, in turn, create a network with a wide range. As cars fall out of the signal range and drop out of the network, other cars can join in, connecting vehicles to one another so that a mobile internet is created. It is estimated that the first systems that will integrate this technology are police and fire vehicles to communicate with each other for safety purposes. VANETs can use any wireless networking technology as their basis. The most prominent are short range radio technologies like WLAN (2.4 GHz or 5 GHz, use IEEE 802.11), either standard Wi - Fi (2.4 GHz, use IEEE 802.11p) or ZigBee (2.4 – 2.4835 GHz, reach 75 m, use IEEE 802.15.4). In addition, cellular technologies or LTE (3.9 GHz) and WiMAX (3.5 GHz or 10.5 GHz, use IEEE 802.16) can be used for VANETs. The latest technology for this wireless networking is visible light communication - infrared transmission and reception. Commission decision (2008); Gallagher et al. (2006)

DSRC operates on the 5.8 GHz frequency band, is a wireless communication technology designed to allow automobiles in ITS to communicate with other automobiles or infrastructure technology. It receives very little interference (100 m), even in extreme weather conditions, because of the short range that it spans. The technology has a high transfer rate and a small delay. DSRC technology can be used in either a V2V or V2I format, and communicates using transponders known as on-board units (OBUs) or roadside units (RSUs).

Remote locking is very frequently used in modern cars. Most of the remote control of the vehicle locks operate at 300 to 400 MHz radio frequencies. In some countries, this band is relatively often used for the TETRA / TETRAPOL security telecommunication system.

GPRS / GSM / GPS localization systems regularly transmit pulsed radio signals using the GSM mobile network (900-1800 MHz). This way of communication is also used by eCall. The on-board eCall is an emergency system comprising an on-board device and means for generating, managing and executing an eCall call transmission that is activated either by automatic onboard sensors or manually (SOS button) and which, through a public mobile wireless communication network, a data set and using 112 to create an audiobook between persons in a vehicle and the eCall emergency call center. The eCall system is located in the black box at the engine compartment which is least susceptible to damage during an accident. The black box contains a GPS and GMS module (contains the SIM card) and communicates with the car's control unit. This system is obligatory in the EU for all cars manufactured from April 2018. Regulation (EU) 2015/758 of the European parliament and of the council (2015)

Bluetooth operates at ISM (frequency band for industrial, scientific and medical purposes, free of licensing charge) band of 2.4 GHz. For transmission uses the FHSS method, for one second make 1600 jumps between 79 frequencies with a 1 MHz distance for one second. This mechanism is intended to increase the interference immunity to the same frequency. Several power levels (1 mW, 10 mW, 100 mW) are defined with which communication is possible up to 100 m.

Another problem may pose electric vehicles. In electric vehicles passengers sit very close to an electric system of significant power, usually for a considerable amount of time. The relatively high currents used in these systems and the short distances between the power devices and the passengers mean that the latter could be exposed to relevant magnetic fields. This involve that it becomes requirement to evaluate the electromagnetic environment in the interior of these vehicles before placing them in the market. Moreno-Torres et al. (2016)

Other major source of radiation that does not come directly from the vehicle but is very often used in vehicles is the cell phone. It transmits pulsed radio signals using the GSM mobile network (900-1800 MHz). Using mobile phone in partially closed environments of transportation vehicles, there are special situations for several reasons: the metallic structures produce large reflections, the structure itself is large compared to the wavelength, but the near field effects must be considered and the reflective surfaces are mostly curved. For whole body deposition, when the phone is far from the user, usage a cell phone inside a vehicle produces an increase of SAR values over the whole body. The vehicle structure is responsible for large relative changes in SAR. Anzaldi et al. (2007)

3. EMF Values in Various Microenvironments

Electricity is used substantially and sources of electric and magnetic fields are, unavoidably, everywhere. The transportation system is a source of these fields, to which a large proportion of the population is exposed. In this part of the contribution the dosimetric analysis of EMF carried out by various research groups are summarized.

In work Aguirre et al. (2015), the dosimetric analysis of the indoor of a car has been achieved by estimating electric field values for ZigBee, GSM and UMTS frequencies. On one hand, measured values have been obtained using a dosimeter and using a Radio Frequency Spectrum Analyzer and on the other hand theoretical values have been obtained by simulating a car model with an in house developed 3D RL method. Higher electric field levels have been observed using ZigBee compared with UMTS or GSM. In all cases, the systems comply with field levels found in the recommendations proposed by ICNIRP. The maximum electric field value obtained in the simulations is 31.89 V/m, at GSM 900 MHz when transmitting 2 W. The value is much higher than the measurements presented in this work, but it is still below the ICNIRP level (40.84 V/m). Although it is worth noting that if the situation changes (e.g. the car is in a remote place where the mobile phone needs to transmit high power), the measured values will be higher.

Eeftens et al. (2018) collected simultaneous real-time personal measurements of RF-EMF over 24 to 72 h in 294 parent-child pairs from Denmark, the Netherlands, Slovenia, Switzerland, and Spain. The devices measured the power flux density (mW/m2) in 16 different frequency bands every 4 seconds. Exposure during activities where most of the time is spent (home, school and work) was relatively low whereas exposure during travel and outside activities was higher. The figure describe means of personal mean exposure to broadcast, DECT, downlink, uplink, and Wi-Fi per activity for children and parents. The total number of participants whose measurements contributed to each summary is shown, as well as the total number of measurement hours. Bars are not shown where fewer than 5 participants provided data or where the total number of hours measured was lower than 5. The highest exposure values can be seen in the transport, Fig. 2.

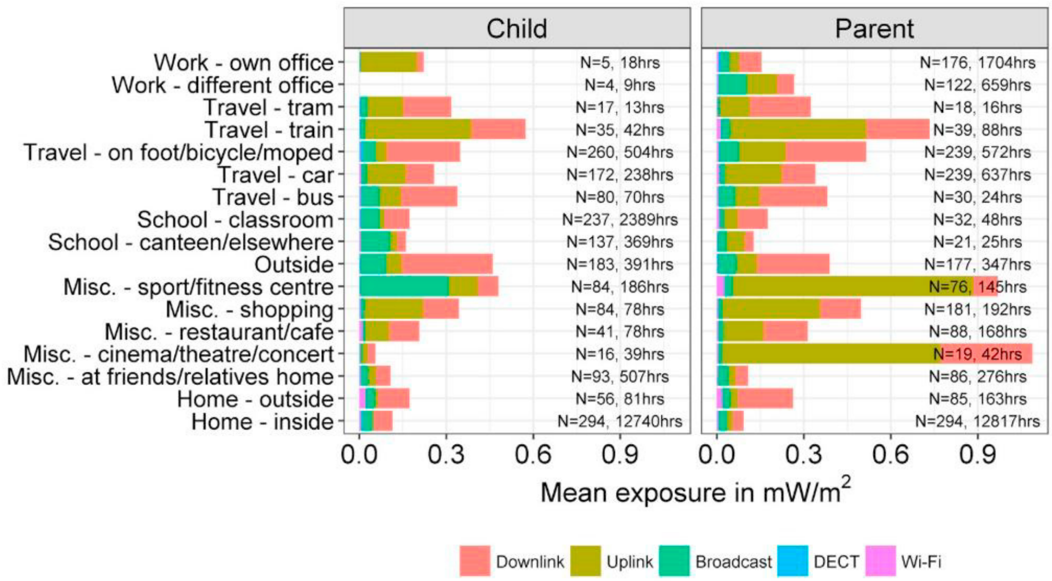

Fig. 2. Means of personal mean exposure, Eeftens et al. (2018)

Roser et al. (2017) in their work describe personal RF-EMF exposure of Swiss adolescents and evaluate exposure relevant factors. Personal exposure was measured using a portable RF-EMF measurement device (ExpoM-RF) measuring 13 frequency bands ranging from 470 to 3600 MHz. The participants carried the device for three consecutive days and kept a time activity diary. In total, 90 adolescents aged 13 to 17 years participated in the study conducted between May 2013 and April 2014, Fig. 3. The maximum exposure of EMF was in transportation: car, bus, train. For 38 (42.2%) participants they had measurements on workdays and on weekend days available. For those, mean RF-EMF measurements were slightly higher on weekend days compared to workdays (57.3 vs. 51.0 μW/m^2).

Measurements outside European countries were carried out by Choi et al. (2018). They monitored 50 child-adult pairs, living in Seoul, Cheonan, and Ulsan, South Korea. RF-EMF measurements were performed between September and December 2016, using a portable exposure meter tailored to capture 14 Korean radiofrequency bands ranging from 87.5 to 5875 MHz. The participants wear the device for 48 h and kept a time activity diary using a smartphone application in flight mode. To enhance accuracy of the exposure assessment, the body shadowing effect was compensated during the statistical analysis with the measured RF-EMF exposure. The compensation was transferred using the hybrid model that represents the decrease of the exposure level due to the body shadowing effect. The arithmetic (geometric) means of the total power density were 174.9 (36.6) μW/m^2 for all participants, 226.9 (44.6) for fathers, 245.4 (44.8) for mothers, and 116.2 (30.1) for children. By compensating for the body shadowing effect, the total RF-EMF exposure increased marginally, approximately 1.4 times. Among the three regions, total RF-EMF exposure was highest in Seoul, and among the activities, it was highest in the metro, followed by foot/bicycle, bus/car, and outside. Total RF-EMF exposure levels in Korea were higher than those reported in European countries.

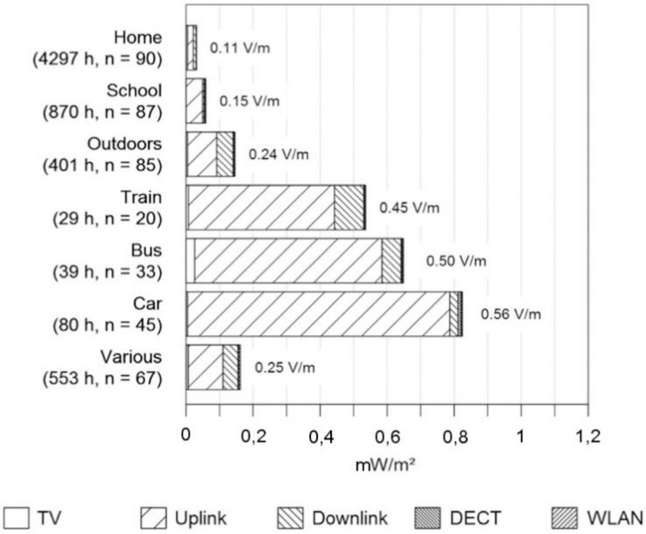

Fig. 3. Mean RF-EMF measurements from different sources at different locations, Roser et al. (2017)

The aim of the study Sagar et al. (2018) was to quantify RF-EMF exposure applying a tested protocol of RF-EMF exposure measurements using portable devices with a high sampling rate in 94 microenvironments and 18 public transport vehicles of Switzerland (15), Ethiopia (18), Nepal (12), South Africa (17), Australia (24) and the United States of America (8). The measurements were taken either by walking with a backpack with the devices at the height of the head and a distance of 20–30 cm from the body, or driving a car with the devices mounted on its roof, which was 170 – 180 cm above the ground. The measurements were taken for about 30 min while walking and about 15 – 20 min while driving in each microenvironment, with a sampling rate of once every 4 seconds (ExpoM-RF) and 5 seconds (EME Spy 201). The highest RF-EMF exposure levels across public transportation were measured in auto rickshaw (Lalitpur, Nepal), taxi (Lalitpur, Nepal) and in train (Zurich, Switzerland), Fig. 4.

In work Sagar et al. (2016) using the ExpoM-RF devices mounted on a backpack, they have conducted RF - EMF measurements by walking through 51 different outdoor microenvironments from 20 different municipalities in Switzerland: 5 different city centers, 5 central residential areas, 5 non-central residential areas, 15 rural residential areas, 15 rural centers and 6 industrial areas. Measurements in public transport (buses, trains, trams) were collected when traveling between the areas. Measurements were conducted between 25th March and 11th July 2014. The maximum exposure values were again in transport and in city center, Fig. 5.

Presented research shows that humans are in modern world unavoidably exposed to considerable values of EMF. The highest values of the EMF power flux were measured in transport means. It should be noted that all the measured values are below limits given by the International commission on non-ionizing radiation protection (2010). However, those limits are adjusted only based on the known thermal effects of EMF exposure. Those associated with the non-thermal phenomena are uncovered. Therefore, one should be aware that long-term exposure even to low level EMFs can lead to various health problems.

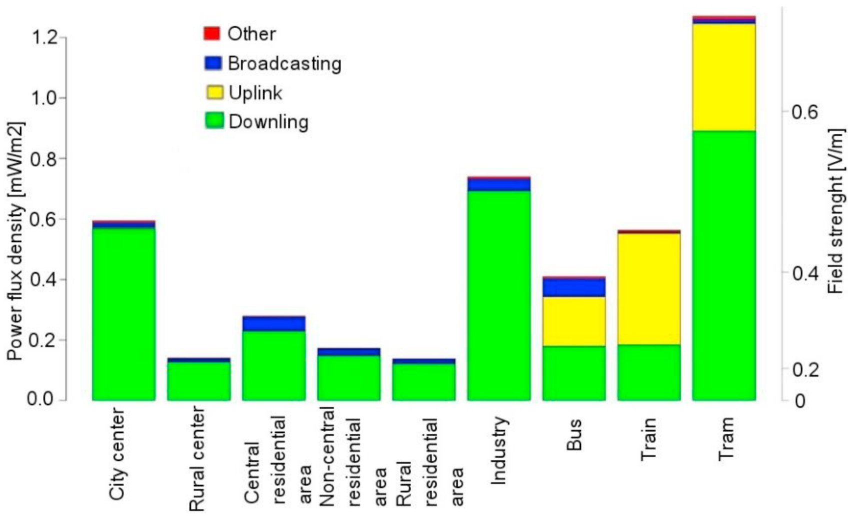

Fig. 4. Mean RF-EMF exposure levels across public transportation. Sagar et al. (2018)

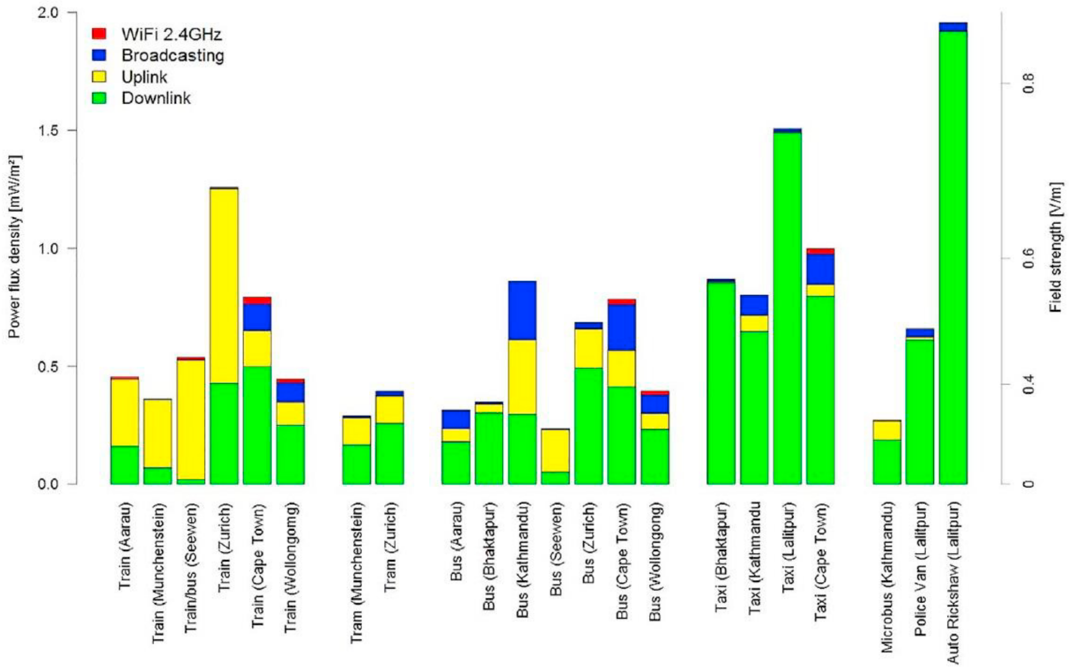

Fig. 5. Mean RF-EMF exposure per type of microenvironment, Sagar et al. (2016)

4. Possible Health Impact

Electromagnetic fields are packets of energy that have no mass. They fluctuate in frequency and wavelength. At the high end of the electromagnetic spectrum there are cosmic and X-rays that have enough energy to involve ionization, and therefore are known as ionizing EMFs. Going below in frequency range there are ultraviolet, visible light and infrared EMFs. Excessive exposure to ultraviolet EMFs introduces clear danger to human health, but life on earth would not be possible without visible light and infrared EMFs. Below these forms of EMF are those used for communications (radiofrequency or RF-EMFs, 30 kHz-300 GHz) and those generated by electricity (extremely low-frequency or ELF-EMFs, 3 Hz-3 kHz). These EMFs do not have sufficient energy to directly cause ionization, and are therefore known as non-ionizing radiation. RF-EMFs at sufficient intensity cause tissue heating.

Exposing frequency EMP greater than ~ 100 kHz can cause considerable energy absorption and increased temperature. In general, EMP exposure creates unequal energy storage in the body. Physical magnitude used to describe the absorption of electromagnetic field by living tissue is a specific absorption rate (SAR). SAR should be minimized so that blood flow and other body heat distribution mechanisms can dissipate this heat. Thermal effects are associated with energy absorption, which causes an increase in the body temperature, with a significant increase in temperature being detected at the earliest after six minutes of exposure. In published data, the effects of heat are most often reported as damage to the inner ear, clouding of the eye lens and damage to the cornea as a result of eye warming.

The current subject of the investigation is human health effects secondary to exposures to non-ionizing EMFs at low intensities that do not cause measureable heating. Thermal hazards are associated with acute exposures and are thought to be characterized by thresholds, below which they are not present. However, many studies have suggested that RF exposure at lower than thermal levels may have biological effects, but they have either not been consistently replicated or else their significance for human health cannot be adequately assessed using information currently available. Exposure to low frequency and radiofrequency electromagnetic fields at low intensities poses a significant health hazard. There is strong proof that excessive exposure to mobile phone-frequencies over long periods of time enhance the risk of brain cancer both in humans and animals. Other possible consequences of exposure to EMFs are: negative effects on male and female reproduction, risk for glioma, meningioma and acoustic neuroma, risk of leukemia among children (living near to very high intensity radio transmission towers), breast cancer, ipsilateral parotid tumors. There are other diseases or physiologic alterations which have been reported to be associated with exposure to non-thermal EMFs in humans and in animals: Alzheimer disease, increase neuropsychiatric and behavioral disorders, trigger cardiac rhythm alteration and peripheral arterial pressure instability, induce changes in immune system function and alter salivary and thyroid function, cognitive and neurobehavioral problems in children, idiopathic environmental intolerance. There is increasing evidence the exposures can result in neurobehavioral decrements and that some individuals develop a syndrome of EHS or microwave illness. While the symptoms are non-specific, new biochemical indicators and imaging techniques allow diagnosis that excludes the symptoms as being only psychosomatic.

Many organizations have dismissed the strong evidence for harm from ELF and RF-EMFs by arguing that we do not know the mechanism whereby such low energetic EMFs might cause cancer and other diseases. It is known that low-intensity ELF- and RF-EMFs generate reactive oxygen species (ROS), alter calcium metabolism and change gene expression through epigenetic mechanism, any of which may result in development of cancer and/or other diseases or physiological changes. Weak magnetic and electromagnetic fields affect physiological processes in living organisms. The most accepted model characterizing the mechanism of electromagnetic field action on cellular structures is the ionic parametric resonance (IPR) model Belpomme (2018). The theory of IPR describes the action of a magnetic field generated by the superposition of a static and time-variable magnetic field that are parallel to each other (a combined magnetic field). This field is involved in parametric resonance ion Ca^{+2} bound to specific protein locations (e.g. calmodulin, protein kinase) on cells membranes and affects the balance of the chemical reaction:

$$protein + Ca^{+2} \leftrightarrow protein(Ca^{+2})$$

These bound ions are responsible for ion channel opening and/or closing and thus for control of ion influx and efflux through the cell membrane, which leads to membrane voltage changes and specific proliferative response. Basically, the theory assumes that parallel combination of static and time-varying EMF could affect the bound ions and therefore the proliferative behavior of the cell. Lednev (1991); Radil and Barabáš (2012)

5. Conclusion

This article was focused on sources of electromagnetic fields in vehicles and in various microenvironments of ordinary life. The number of electromagnetic sources inside passenger vehicles is growing rapidly. Therefore, it is important to pay attention to research about possible health risks of those fields. Drivers and passengers spend considerable amounts of time in these vehicles, and health risks might increase with the duration of exposure.

Scientific research into possible health effects has been lagging comparing to the rapid advances in the applications of RF fields in our working and living environment. This delay has been increasing doubts among the general public and workforce. There are still many unresolved health issues that need to be addressed as a matter of urgency. Technological advancement is constantly growing and there is a need for continued research on this issue. It becomes requirement to evaluate the electromagnetic environment in the interior of vehicles before placing them in the market and before their daily application.

Future work will be focused on evaluating of impacts of various electromagnetic field variables on living cells proliferation according to the theory of the Ion Parametric Resonance. Especially, low frequency area would be covered as this is still unexplored range having very high intensities especially due to widening of electro-mobility.

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